REPORT

GROUNDWATER INVESTIGATION REPORT

FORMER BARKSDALE FACILITY
BARKSDALE, WISCONSIN

(VOLUME 1 OF 2)

Prepared for

E.I. DuPont De Nemours and Company, Inc.
Wilmington, Delaware

March 1999

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D4BA7191.99

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This report documents subsurface sampling and other actions undertaken to further define the extent of 2,4- and 2,6-DNT originally detected at low concentrations in the Bretting Well located near the eastern border of the former Barksdale Works.

Investigative and remedial objectives agreed to during the May 28, 1998 meeting between the Wisconsin Department of Natural Resources and DuPont Company, Inc. are basis for this investigation and are summarized below:

1. Characterize soil and groundwater in the vicinity of the Bretting Well and former Barksdale Works water supply line for the presence of 2,4 - and 2,6- dinitrotoluene.
2. Evaluate groundwater quality downgradient of the former manufacturing areas.
3. Determine groundwater flow direction both horizontally and vertically in the Chequamegon Sandstone across the Facility.
4. Eliminate potential manmade subsurface contaminant migration pathways.

A Groundwater Investigation Workplan (GI Workplan) was submitted to WDNR in July 1998 which detailed actions to be undertaken to achieve these objectives. The actions presented in the GI Workplan were:

1. Completion of a Geoprobe® soil and groundwater investigation in the vicinity of the Bretting Well and former Barksdale Works water supply line.
2. Installation and sampling of four bedrock (Chequamegon Sandstone) monitoring wells located downgradient of the former manufacturing areas.
3. Installation and testing of six nested piezometer pairs across the site to determine vertical hydraulic gradients and hydraulic conductivities within the Chequamegon Sandstone.
4. Abandonment of two unused water supply wells north of the Bretting residence.
5. Draining and plugging of the main water supply lines from Chequamegon Bay to the former facility.

Additional activities, not included in the GI Workplan, were undertaken based on conditions encountered during the field work. These activities included:

1. Installation of a fifth bedrock monitoring well located between Boyd Creek and the Bretting well (CX-533).
2. Placement of staff gages in Boyd Creek to better define the hydraulic relationship between the creek and groundwater.

The results of sampling activities and analytical testing are:

1. Boyd Creek is a losing stream in the western portion of the site and is a gaining stream in the lower reaches.
2. Surface water samples from Boyd Creek contained low but detectable concentrations of dinitrotolune isomers. None of the surface water detections exceed ecological risk based standards which is consistent with the Boyd Creek investigation conducted by Exponent in August 1998 for DuPont (Exponent 1998)

3. Nitroaromatic compounds in the parts per billion range were detected at MW-03, MW-02, and the Bretting Well. No nitroaromatic compounds were detected in monitoring wells MW-01, MW-04, MW-05 or the other water supply wells tested. The nitroaromatic compounds appear to occur in groundwater in a limited and discrete area.

Based on these results the following actions are recommended:

1. Monitor water levels at Boyd Creek and the on-site monitoring wells and piezometers on a quarterly basis for one year to verify that the hydraulic relationship identified is seasonally consistent.
2. Continue operation of the current treatment system at the Bretting well
3. Continue a sampling and analysis program of the onsite monitoring wells, the Bretting well and the private wells IW883 and IW711.

Groundwater samples collected by the Wisconsin Department of Natural Resources (WDNR) in June 1997 from a drinking water well located within the boundary of the former Barksdale Works at the Bretting residence (CX533) showed detectable levels of 2,4-DNT and 2,6-DNT. A carbon treatment system was installed on the Bretting well in the fall of 1997. DuPont also provided WDNR with a Site Conditions Report (DERS, 1997), which summarized decommissioning and decontamination activities at the former Barksdale works. The WDNR and E.I. DuPont de Nemours and Company, Inc. (DuPont) as described below deemed additional sampling appropriate.

A July 1998 Groundwater Investigation Work Plan (GI Workplan) was prepared in accordance with Wisconsin Administrative Code (WAC) Chapter NR 716 to addresses the investigative and remedial objectives agreed to during the May 28, 1998 meeting between the WDNR and DuPont.

This Groundwater Investigation Report (GIR) documents investigation undertaken to further refine the understanding of the extent of low level detections of 2,4- and 2,6-DNT in the Bretting Well and to refine the hydrogeologic model in the vicinity of the Barksdale Works. The scope of the work conducted is described in Section 4.1.

The GIR was prepared in accordance with NR-716.15 based on information obtained during field activities conducted between September 14 and December 11, 1998. The GIR summarizes the well installation, well abandonment, permeability testing and groundwater sampling actions; presents and evaluates the results of subsequent sample analyses; and makes recommendations for further sampling activities.

2.1 SITE LOCATION

Site Location: Former DuPont Barksdale Works
Highway 13, Barksdale, WI
All of sections 23 and 24 and
the north half of sections 25 and 26 T28N R5W
Bayfield County (WDNR County Code 4)

Project Manager: DuPont Corporate Remediation Group
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2.2 OVERVIEW OF SITE HISTORICAL OPERATIONS

DuPont operated the former Barksdale Works from 1905 to 1971. While active, the facility primarily produced dynamite, nitroglycerin (NG) and trinitrotoluene (TNT) for the U.S. Military and the mining industry. Other products associated with the explosives industry were produced at the Barksdale Works in smaller quantities including trinitroxylene (TNX), trivelene, nitramon, soda amatol, and nitramex. Intermediate and supplemental materials produced included sulfuric acid (oil of vitriol), nitric acid and sellite. Figure 3 shows the reported locations of historical production areas.

Nitroglycerin (NG), gelatin and dynamite production was conducted in the flood plain along Boyd Creek near the center of the property. These production areas operated throughout most of the history of the Barksdale Works. In 1946, a flood destroyed the gelatin portion of the dynamite production area on the south side of the creek, after which the operations were conducted only on the north bank of the creek.

During World War I, the plant operated about ten TNT and five TNX production lines located in the north central and north west portions of the property. During WWII, two TNT lines were operated in the northwest portion of the property adjacent to Boyd Creek. The use of these lines was significantly reduced after the war.

Between 1971 and 1986 the plant was dismantled and the grounds became overgrown by prairie and forest vegetation, The property was purchased by Bretting Manufacturing in 1986. Since 1986 the property has been used as a game preserve and residence.

The reader is referred to Appendix F of the Site Conditions Report for further details of the production history of the facility (DERS 1997).

2.3 HISTORY OF SITE INVESTIGATION ACTIVITIES

Between 1943 and 1996, nine documented site sampling/assessment actions were undertaken. The majority of these activities were related to plant decommissioning actions and WDNR concerns regarding subsequent surface conditions at the property. The reader is referred to Appendix A of the Site Conditions Report for details of these sampling and assessment activities. Focused groundwater sampling was conducted by WDNR in the spring of 1997. At the time, trace levels of nitroaromatics were detected in CX533.

In order to understand historic and current site conditions DuPont conducted a Site Conditions Assessment in 1997 consisting of a site reconnaissance, operator interviews, historical facility document review, geologic literature search, and an additional round of ground water sampling from supply wells in use at the game preserve, the Bretting residence and the neighboring residential properties.

The 1997 assessment found:

- The Bretting well (CX 533) contained low levels of 2,4-DNT and 2,6-DNT. The six other wells tested did not contain detectable levels of nitroaromatic compounds.
- Conventional and accepted protocols were used in decommissioning the production and storage areas (no areas with explosive hazards are believed to currently exist on the grounds).
- The water pipeline formerly employed by the Barksdale Works may have acted as a possible source of groundwater impacts to the Bretting well.

The 1997 assessment recommended:

- Installing and maintaining carbon treatment at the Bretting well.
- Routinely monitoring the Bretting well.
- Routinely monitoring residential wells to the north and south of the Bretting well.
- Closing the unused wells in disrepair immediately north of the Bretting well.
- Closing the water pipeline formerly employed by the Barksdale Works.

In May 1998, DuPont and WDNR met and defined several activities to further define conditions at the former Barksdale Works. The groundwater investigation and remedial activities agreed upon are summarized below and form the basis for this GIR.

- Characterize soil and groundwater in the vicinity of the Bretting Well and former Barksdale Works water supply line for the presence of 2,4 - and 2,6- DNT.
- Evaluate groundwater quality downgradient of the former manufacturing areas.
- Determine groundwater flow direction both horizontally and vertically in the Chequamegon Sandstone across the Facility.
- Properly abandon the unused wells
- Properly close the water pipeline leading from the site to the bay.

The investigation was augmented during field implementation to include assessment of the hydraulic relationship between groundwater and Boyd Creek

Additionally, DuPont volunteered to investigate surface water and sediment quality in Boyd Creek and two of its unnamed intermittent tributaries. The objective of this investigation was to determine if nitroaromatic compounds are migrating off-site at concentrations of ecological concern. The results of that investigation are provided in a separate report (Exponent, 1999).

This section presents a summary of the environmental setting of the Facility as understood after the 1997 Site Conditions Assessment. Specific findings of the 1998 GI are presented in Sections 5 through 7. A significant portion of the setting information presented in this section has been excerpted from the Site Conditions Report (DuPont, 1997). The reader is refered to that report for the sources of the information presented here.

3.1 REGIONAL CONDITIONS

3.1.1 SurficialConditions

Topography

The former Barksdale Works is located adjacent to Chequamegon Bay (Lake Superior) about 6 miles south of Washburn, Wisconsin. The topography is fairly rugged to the north and west of the site. However, approximately one mile south, the terrain levels out into a wide, flat, marshy, wetlands area where the Whittlesey and Fish Creeks drain into Chequamegon Bay (see Figure 1).

Surface *Wafers*

Regionally, surface water drains toward Lake Superior. Water from Lake Superior is utilized as a water supply for municipal, industrial, rural, domestic and stock supplies. It is also used for recreational purposes and is suitable for fish and wildlife habitat.

Surface Soils

Surface soils in the vicinity of the facility are depicted as Hibbing, Rudyard and Pickford silty clay loams; Hiawatha loamy sand and Hibbing, Rudyard, Pickford and Ontonagon silty clay loam; and Superior loams.

3.1.2 Geology

The former Barksdale Works is located in the Southern Province of the Canadian Shield. There are two main geological units of interest in the area of the former Barksdale Works, Pleistocene-aged glacial sediments of the Miller Creek Formation and the underlying Chequamegon Sandstone, a Precambrian-aged rock.

*Precambrian Rock - Chequamegon **Sandstone***

The Lake Superior Basin is believed to have formed as a result of geologic activity during Precambrian time along a major continental rift zone. The volcanics, intrusives, and interflow sedimentary units of Keweenawen age, which formed during the basin's development, crop out extensively in the Lake Superior region. The rocks of the late Keweenawen Supergroup can be subdivided, with decreasing age, into the interflow sedimentary rocks, the Or-onto Group and the Bayfield Group. The latest member of the Bayfield Group is the Chequamegon Sandstone, which underlies the former Barksdale Works. The Chequamegon sandstone is locally known as the Lake Superior sandstone.

The Bayfield Group is thought to be over 4,100 feet thick (1,250 meters) in Wisconsin. Paleocurrents evidence indicates a dominant direction of sediment transport towards the center of the basin (northeast of the site in west central Lake Superior) compatible with fluvial deposition. In addition, other aspects such as fining upward sequences and argillaceous units indicate deposition by meandering streams. Compositionally, the Bayfield Group consists primarily of quartz and feldspar. The Chequamegon Sandstones consist of predominantly red feldspathic to arkosic sandstone and siltstone with locally abundant intercalated layers of shale and conglomerate. The conglomerate clasts are predominantly quartz and quartzite. The estimated thickness of the Chequamegon Sandstone in the area of the former Barksdale Works is at least 500 feet based on outcrop data.

Pleistocene ***Sediments - Miller*** *Creek* **formation**

The Pleistocene deposits of the Superior region of Wisconsin include the Copper Falls Formation, the Miller Creek Formation, and postglacial sediments. The area of the former Barksdale Works lies in the Superior lowland region. The Pleistocene sediments in this area are of the Miller Creek Formation, which consists primarily of clayey silty till. The Miller Creek Formation can be further divided into the Hanson Creek Member and the Douglas Creek Member. The Douglas Creek Member overlies the Hanson Creek Member.

The Hanson Creek Member is described as unlaminated till, and usually contains between 45 and 75 percent clay, 20 and 45 percent silt, 3 and 20 percent sand and a few percent or less of pebbles, cobbles, and boulders. The color is commonly a dull reddish-brown to dark reddish-brown. The Hanson Creek Member is calcareous with the silt and clay fractions containing approximately 10 percent carbonates.

The till of the Douglas Member is similar to the Hanson Creek Member but tends to contain more clay. The Douglas till typically contains between 45 and 85 percent clay; 10 and 40 percent silt; 3 and 20 percent sand; and a few percent or less of pebbles, cobbles, and boulders. The surficial till may have been modified further by lake wave action or may have flowed somewhat in its water-logged state. In the Barksdale area, the Douglas member is a glaciolacustrine deposit of Glacial Lake Post-Duluth.

It is reported the glacial till reaches a thickness of greater than 400 feet in the central portion of Bayfield County.

3.1.3 Hydrogeology

The main aquifer in the area is the Precambrian Chequamegon Sandstone, a red arkosic sandstone, which is estimated to be 500 feet thick in the Barksdale area. Overlying the Precambrian sandstone is Pleistocene glacial till and/or reworked Pleistocene till (Douglas Member).

Groundwater from the Chequamegon Sandstone discharges to Lake Superior. Average hydraulic conductivities based on regional modeling are approximately 15 to 20 feet/day, which is average for a silty to clean sand.

The surficial glacial till, according to published information, is the probable main recharge for the aquifer. The main recharge area is located in the central portion of the Bayfield Peninsula, west of the site.

3.1.4 Climatology

The Lake Superior region averages 3 1 inches of precipitation a year with 20 to 35 percent of the precipitation in the form of snowfall. Bayfield County averages 27 inches of rainfall per year and 53 inches of snowfall per year. The average range in temperatures for spring, summer, fall, and winter are 39° to 45°F, 65° to 71°F, 42° to 47°F, and 18° to 23°F, respectively. In general, wind direction in the Ashland area is from the southwest during the spring and fall, from the northeast in the winter, and variable the during the rest of the year.

3.2 SITE CONDITIONS

3.2.1 Suficial Conditions

Topography

The surface elevation at the facility ranges fi-om 793 feet mean sea level (MSL) in the northwestern comer of the property to 602 feet MSL at the Lake Superior shoreline.

In general the ground surface contours of the site parallel the shoreline of Lake Superior. Ground within 1 mile of the northwest property corner is relatively flat with slopes ranging from 0.007 to 0.014 ft/ft. Within 1 mile of the Lake the average slope becomes slightly steeper ranging from 0.021 to 0.024 ft/ft.

Four major erosional features (stream valleys) cross the site from northwest to southeast. These valleys cross Highway 13 at about 2000 to 2500 ft intervals.

The largest of these valleys lies along the course of Boyd Creek which runs from near the center of the west property line to a point on Lake Superior about 1700 ft southwest of the Bretting residence. The meandering Boyd Creek valley varies from 100 to 1000 A in width and has banks ranging from 15 to 50 ft high with slopes of 0.1 to 0.15 ft/ft. In the wider portions of the valley a flood plain is present which typically lies about 2 to 3 ft above the stream bed. The other stream valleys are similar in structure but smaller in scale.

Surface Wafers

Boyd Creek is the only one of the four creeks that drain the site which maintains flow through out the year. The others are intermittent streams and their flow is a function of precipitation amounts. Boyd Creek is approximately 1.7 miles in length and flows to the western boundary of the Chequamegon Bay of Lake Superior. The elevation of the Boyd Creek streambed decreases from approximately 740 feet along the western boundary to about 602 feet where it enters Chequamegon Bay (an approximate stream gradient of 80 feet/mile).

Surface Soils

Much of the natural surficial soil at the site can be categorized as clay or silt. Some areas have been altered by erosion exposing underlying strata particularly along the course of Boyd Creek. Some of the exposed layers include clayey glacial till, silty sands and weathered bedrock outcrops.

In the north central portion of the site (the TNT, TNX and acid production areas) surface soils appear to have been disturbed by extensive grading or excavation. Soils exposed at the surface in many of these developed areas are sand and gravel fill.

In addition, numerous roads and railroad beds exist throughout the site. These beds contain gravel and cinders (from the facility power plant). The rail beds in some areas have been observed to be up to 4 feet thick.

3.2.2 Geology and Hydrogeology

Several poorly logged water supply wells have been installed on and adjacent to the site. The logs for these wells, when available, showed geology typically in agreement with published regional studies. Groundwater was reportedly encountered at approximately 80 feet bgs to the west of the site. At the eastern boundary of the site, groundwater was encountered only a few feet bgs. Some wells along the lake are free flowing. Based on these well logs and shoreline observations, the thickness of the Pleistocene sediments at the former Barksdale Works is believed to range from approximately 200 feet in the northwest to nonexistent in some locations along the shoreline of Chequamegon Bay. The logs show the Chequamegon Sandstone to be variable, describing color changes from red to white within the sandstone and discontinues shale layers which indicate a high degree of variability over short distances.

For a detailed discussion of the subsurface conditions encountered during the GI the reader is directed to Section 6.

4.1 INVESTIGATION SCOPE

The work conducted in the fall of 1998 consisted of the following components:

- Preparation of a topographic base map using photogrametric methods.
- Installation of four staff gages in Boyd Creek to assess the hydraulic relationship between the creek and groundwater.
- Field screening of surficial soils and investigative wastes for nitroaromatic compounds.
- Installation and sampling of five bedrock (Chequamegon Sandstone) monitoring wells located downgradient of the former manufacturing areas to determine the quality of groundwater between the manufacturing areas and the Bretting well.
- Installation of six nested piezometer pairs across the site to determine vertical hydraulic gradients and flow directions within the Chequamegon Sandstone.
- Sampling and analysis of five groundwater monitoring wells and three water supply wells.
- Completion of a soil and groundwater investigation in the vicinity of the Bretting Well and former Barksdale Works watermain using Geoprobe® / Rotosonic® methods. This investigation consisted of two parts: sampling along the water main near the well to determine whether the watermain was acting as a pathway for DNT migration; and sampling perpendicular to the watermain near the security perimeter of the former manufacturing areas west of Highway 13 to determine the lateral extent of impacts.

4.2 TOPOGRAPHIC MAP PREPARATION

Between October 19 and 24, 1998, land surveyors from Enviroscience of Eden Prairie MN, used global positioning system (GPS) equipment to determine North American Vertical Datum of 1988 (NAVD 88) elevations and Wisconsin State Plane North Zone coordinates of surficial site features including: land survey system section and subsection corners; Lake Superior shoreline and Boyd Creek centerline reference points; and riser and ground points at all newly installed monitoring wells, boreholes and piezometers. They also recorded the locations of watermain closure points and stream sediment sampling locations.

On November 12 1998, KBM Aerometrics conducted a fly-over of the site during which aerial photographs were taken.

On November 19 and 20, 1998, Enviroscience returned to the site and surveyed staff gage elevations and locations and established reference monuments adjacent to each staff gage for use in restoring the markers in cases of future flood damage.

The photographs and the field elevations were combined by KBM using stereoscopic analysis to generate a site base map with 2 ft topographic contours. A copy of the map (showing only 10 ft contours for increased readability) is included as Figure 2.

4.3 STAFF GAGE INSTALLATION

Four staff gages were installed along the course of Boyd Creek at the locations depicted on Figure 2. The gages (3.3 ft steel plates graduated in 0.01 ft intervals and affixed to 6 ft long steel fence posts) were driven into the stream bed at accessible points along the creek. Gage locations were chosen adjacent to sediment sampling location SB-1, about 300 ft downstream of sediment sampling location SB-3, about 200 ft upstream of sediment sampling location SB-6, and at the point at which Boyd Creek enters the former Barksdale Works grounds. After installation, the NAVD 88 elevation of the 0.0 mark on each gage was surveyed using GPS methods.

4.4 FIELD SCREENING FOR NITROAROMATIC COMPOUNDS

Prior to drilling, field personnel employed a Erez Forensic Technology Exospray test kit to screen surficial soil at each borehole location for the presence of nitroaromatic compounds. Additional screening was conducted at depth if the location were near the water line, or if particularly permeable or unusually colored layers were encountered (see Table 1).

Exospray kits consist of three chemical sprays which are applied successively to test paper that has been wiped with soil or sediment suspected of containing nitroaromatic compounds.

The first spray will react with TNT and TNB to produce a brownish violet color. The second spray reacts with dynamite, nitrocellulose or nitroglycerin to produce a pink color. The third spray reacts with nitrate containing compounds to produce a violet color. Color changes are virtually concurrent with spray application.

Doped verification papers are provided to check the reliability of the sprays, these were used prior to each day of testing. The verification papers always produced the desired results on each day the test was used.

The second spray is said to also react to certain cellulose based laquers. Also, unreacted sprayed papers reportedly become pink after prolonged exposure to air. This latter reaction was observed, usually occurring about 10 minutes or more after spraying was completed.

4.5 BOREHOLE DRILLING

Four of the monitoring well boreholes, three of the proposed Geoprobe® boring locations and all twelve piezometer boreholes were installed using Rotosonic® methods as described in GI Workplan SOP No. 2. Well MW-05 was installed using an all-terrain hollow stem auger rig to access marshy area. Drilling locations are shown on Figure 3.

The boreholes for each monitoring well and piezometer were logged as described in SOP No. 5 (see Appendix A). Ten to twenty ft long coring strokes were used to collect continuous soil samples whenever possible. Bag samples, representative of the major geologic layers encountered in the borehole, were collected during the drilling and stored in the Bretting's maintenance shed.

Monitoring wells were typically advanced to about the depths indicated in the GI Workplan. Piezometer borehole depths varied based on field conditions. At each piezometer nest, the borehole for the deep piezometer was drilled first. Drilling continued until samples indicated that the borehole extended at least 55 ft into bedrock at which point the deep piezometer was installed. Once the deep piezometer was set, the drill rig was moved 5 to 15 A away and the shallow borehole was drilled (without sampling) to a depth 40 ft above the top of the deep piezometer's screen. Table 6 presents a summary of well construction information including the borehole depths.

4.5.1 Drilling Observations

The sampling process consisted of spinning a 4-inch inside diameter (6" outside diameter) by 10, 20 or 30 ft long hollow steel core barrel into the formation at up to 300 rpm under up to 14,000 pounds of down pressure. A variable frequency vibration was induced in the drill rods by the drive head to shatter and liquefy the geologic formations. Variously configured toothed shoes were added to the barrel mouth to aid in cutting the formations. The rods were advanced dry or with a drilling fluids (water or bentonite drilling mud) introduced down the interior of the rod column.

Full core barrels were brought to the surface and vibrated to extrude the samples into 4-inch diameter plastic bags. The bags were then collected in an area near the rig for logging and analytical sampling.

Dry core Rotosonic® sampling was used in all unsaturated formations. Dry drilling progressed at about 1 to 2 ft per minute and material from about 95 to 100% of the interval cored was typically recovered in the sample barrel.

Once the drill column advanced below the groundwater surface, the driller filled the rods with potable water to equalize hydrostatic pressures inside and outside the sample barrel. Several attempts at drilling without the water in the rods were made during the initial day of sampling, but no sample was recovered from these dry core runs.

In saturated friable bedrock formations, the rate of advance of the drill column was on the order of 2 ft per minute and material from about 75 to 80% of the interval cored was typically recovered.

In saturated competent bedrock formations, the rate of advance of dry drill column was on the order of 0.5 to 1 .O ft per minute and material from about 45 to 50% of the interval cored was typically recovered.

When a potable water wash was added to the competent bedrock drilling process, the rate of advance increased to 5 ft per minute but recovery dropped to 5 to 10%.

4.5.2 Drilling Problems

Occasionally the drilling rate dropped in more competent bedrock layers or when boulders were encountered in the till formations. Once progress dropped below one foot per half-hour the driller typically requested to employ a potable water flush through the rods while drilling. This increased the drilling rate but caused a loss of loose material from the samples. Five different sample retainer configurations were tried to retain sample during wash-drilling but each was destroyed by the sandstone. Initially, the use of wash-drilling was held to a minimum and dry advance was employed to maximize sample recovery, however during periods of dry rod advance through the sandstone, the drill rod assembly experienced substantial resistance to spinning. This caused excessive wear on the Teflon bushings in the drive assembly which was visible as a snow like discharge from the drivehead. On three occasions excessive wear of these bushings caused the assemblies to fail, once with substantial associated damage to the stainless steel assembly housing. Each time the drive head failed, the drilling firm provided a replacement assembly which was installed at the drill site. Each replacement operation resulted in 6 to 8 hours of down-time during on-site repair and several hours of down-time waiting for delivery of the new assembly. Rather than face repeated delays and substantial repair costs, the wash drilling process was used at all locations after October 2, 1998. The associated poor bedrock recovery was accepted as unavoidable.

As an alternative to Rotosonic® core sampling, spilt spoons were tried at depths where sample recovery was particularly important (e.g. at suspected bedrock layer changes or in the proposed screened intervals). However, the spoons and cutting shoes were typically damaged in the process and the samples were not much more informative than the cores retrieved. After destroying 6 spoons, this procedure was abandoned.

The vibrations of the drill rods caused fracturing and massive disturbance of the structure of the friable bedrock samples which made identification of bed alignment, fractures or cavities impossible. As a possible solution, the driller attempted to operate at a reduced vibratory frequency but this resulted in very slow progress. The extended time spent turning the drill rods at each location using this process caused excessive wear to the drill rod cutting head. Numerous cutting tooth configurations were tried, but after several heads were ruined, the drill crew determined that this problem could not be resolved without switching to a different drilling methodology.

The fracturing and vibration of the friable bedrock created stone fragments which migrated toward the rod column and became compacted as the sampling progressed. Since the core barrel had a slightly larger diameter than the extension rods, this compaction often locked the core barrel in place preventing retrieval. To avoid this, the driller employed outer casing whenever he suspected that the borehole might collapse. At three locations (PZ-04D, PZ-05D and PZ-06D) the transition between unconsolidated and friable stone formation was masked by a layer of cobbles and boulders. The driller did not extend the casing after coring through these boulders and the core barrel became locked in the sandstone formation. At PZ-04D and PZ-05D the driller was able to reverse the barrel into the existing casing after several hours of back spinning. At PZ-06D, the barrel could not be recovered and the driller was forced to employ a 7-inch diameter overdrill casing to free the barrel at a depth of 170 ft bgs (resulting in two days of down-time).

Occasionally sampled soil would lodge in the core barrel either due to cohesion or fictional interlocking of gravel fragments. In these situations, vibrating the barrel alone was not sufficient to extrude the sample. The driller would then pump water into the upper end of the barrel while vibrating until the sample was pushed out. Several times this resulted in the sample shooting out of the barrel in a rush of water. The drilling assistant typically lost his grip on the sample bag in these case and no recognizable sample could be collected.

When dry drilling in bedrock, the core barrel became hot, often reaching 250 to 300 degrees Fahrenheit. Although the driller hosed the barrel exterior with cold water to cool it, the sample in these cases often retained enough heat to melt the sample bag and was dropped before it could be logged or sampled.

4.6 MONITORING WELL AND PIEZOMETER INSTALLATION

Five bedrock monitoring wells and six pairs of piezometers were installed at the locations depicted in Figure 3.

The monitoring wells and piezometers were installed in accordance with the requirements of Wisconsin Administrative Code Chapter NR 141, and in accordance with the procedures outlined in GI Workplan SOP No. 10. Table 6 provides a summary of monitoring well construction dimensions. All wells were constructed using 2-inch ID Schedule 80 PVC riser. The wells and piezometers each have a 5 foot section of 20 slot factory cut slotted screen. A lockable, steel, protective casing was utilized to minimize the potential for damage and vandalism to the wells and piezometers. WDNR Well Construction Forms are included in Appendix B.

Development was conducted at least 12 hours after well or piezometer installation to allow the cement bentonite grout time to set. Development consisted of surging with a block and bailing until visible sand was removed (usually 30 to 90 minutes), then pumping with a submersible pump until the water became clear or ten well volumes had been removed. Submersible pneumatic bladder pumps were installed in each monitoring well after development.

4.7 GROUNDWATER SAMPLING

The GI Workplan scheduled sampling of: nine Geoprobe® locations; four new monitoring wells; the Bretting well (and treatment system ports); residential supply wells IW709, IW7 11 and IW884; and non-residential supply wells IW882 and IW883. Subsequent additions to the GI scope added MW-05 and four surface water samples at the staff gage locations. Because of problems in the field the following locations could not be sampled in December 1998: Geoprobe® locations GP-01, GP-02, GP-03 and GP-09 (because the borings terminated above the groundwater surface); Geoprobe® locations GP-05 and GP-07 (because these locations were not drilled); IW883 (because of electrical failures at the pump) and IW884 (because the owner of this residential well was apparently out of town on an extended basis and had shut off their outside taps).

Groundwater sampling in the Geoprobe® probe holes and monitoring wells utilized dedicated downhole equipment and followed the protocols described in the WDNR's September 1996 *Groundwater Sampling Field Manual* and the September 1996 *Groundwater Sampling Desk Reference* with modifications indicated in the appropriate GI Workplan SOPs.

Groundwater samples from the Geoprobe® probe holes were collected during drilling from the boring terminus at GP04, GP-06 and GP-08. Groundwater was not present within the borehole depth at the other GP locations. Groundwater samples were collected using a peristaltic pump and dedicated Tygon® tubing after at least two water column volumes had been purged from the probe hole. Groundwater samples were immediately field filtered through an in-line, disposable 0.45 micron filter attached to the Tygon tubing. The probe holes were abandoned according to NR-112 following sample collection.

Groundwater samples were collected from the five monitoring wells on December 4, 1998. Dedicated bladder pumps were used to purge the monitoring wells. The pumping rate was adjusted so that a stable water level was maintained throughout the purging process. Purge flow rates were typically on the order of 0.5 to 0.75 liters per minute. Field parameters (temperature, pH, specific conductance and dissolved oxygen) were monitored (using a flow through cell) and recorded at 2 minute intervals during purging. Purging was continued until the field parameters stabilized (three consecutive sets of field readings fell within 10 percent of each other). Sampling was begun immediately after purging. Prior to sample collection, the flow through cell was removed and the flow rate dialed down to 0.5 liters per minute or less. Groundwater sample containers for the analyses described in the GI Workplan were filled directly from the tubing attached to the dedicated pump in each well. Samples for dissolved iron, magnesium, calcium, potassium and sodium, were field filtered through an in-line, disposable 0.45 micron filter attached to the pump tubing. All sample labeling, handling and shipping was completed as described in GI Workplan SOP No. 9. A description of the laboratory analyses is included in Section 6.2 and laboratory data sheets are included in Appendix D.

Groundwater samples were collected from three of the five planned drinking water wells on December 3 and 4, 1998. Taps were run for 5 minutes to clear the piping and well riser of stagnant water. Field parameters (temperature, pH, specific conductance and dissolved oxygen) were recorded at the end of purging. Sampling was begun immediately after purging. Groundwater sample containers for the analyses described in the GI Workplan were filled directly from the tap. Samples for dissolved iron, magnesium, calcium, potassium and sodium, were collected in unused disposable transfer jars then field filtered within 5 minutes by passing them through an in-line, disposable 0.45 micron filter attached to the tubing of a portable centrifugal pump. All sample labeling, handling and shipping was completed as described in GI Workplan SOP No. 9. A description of the laboratory analyses is included in Section 6.2 and laboratory data sheets are included in Appendix D.

4.8 HYDRAULIC CONDUCTIVITY TESTING

Single well permeability tests (slug tests) were performed at each of the newly installed monitoring wells and piezometers to estimate values of hydraulic conductivity. Both falling and rising head slug tests were performed utilizing a Solonist 3 100 datalogger / transducer probe. At locations without dedicated pumps, a 5 ft long by 1.66 inch outside diameter slug was used to displace the water surface. At the five pump-equipped monitoring wells, a smaller (40 inch long by 1.0 in outside diameter) slug, was employed to allow testing with the pump in place (i.e. without altering the initial steady state condition of the well by removing the pump).

At each location, the static water level was measured then the probe was hung on a cable at 6 or 10 ft below the water surface (deeper with the larger slug) and the water level was allowed to equilibrate. After the probe was secured, the slug was dropped into the water column to about 1 ft above the probe. The transducer recorded water levels at one second intervals until the water dropped back to within 0.1 ft of the original level. The slug was then removed and the levels recorded as the water recovered to within 0.1 ft of the initial depth. After each well, the probe was downloaded to a PC and the data was checked to verify proper probe function. At two locations, the recovery test was thrown off when the slug caught on the probe cable during removal. These tests were rerun. Plots of the raw data from the probe for each location is included in Appendix E.

The data were analyzed according to the Bouwer-Rice Method using BRSLUG software (Jones 1995). In calculation of the hydraulic conductivities a confining layer was assumed to exist 100 ft below the bottom of each well. The results of the analyses are presented in Table 4 and software data set-up sheets are included in Appendix E.

4.9 DIRECT PUSH SOIL AND GROUNDWATER SAMPLING

Geoprobe® direct-push techniques were initially used for probe holes and collection of soil and shallow groundwater samples in the vicinity of the Bretting Well and along the course of the former water supply line (see section 5.2 for information on the configuration of the watermain). Direct push techniques were initially chosen for this investigation rather than Rotosonic® or auger boring methods since they allow more rapid sampling, do not disturb as much ground surface, require less clearing of vegetation and produce less waste soil.

Direct-push probes were advanced on September 15, 1998 at one location in the Bretting lawn between the residence's supply well and the pipeline (GP-01) and at two locations along the alignment of the watermain (GP-02 and GP-03). Soil at each of these borings was sampled and logged from the ground surface to the depth of the base of the pipeline (7.5 to 8 ft bgs). Surficial soils and soils at the pipeline depth were screened for nitroaromatic compounds (see section 6.1.2 and Table 1). After logging, soils from the pipeline depth were immediately transferred from the sample liner to glass jars provided by the analytical laboratory. These jars were chilled and shipped to the laboratory by overnight delivery service for analysis of nitroaromatic compound content (see section 6.1.3 and Table 2).

GP-01 through GP-03 probes met refusal at approximately six to twelve inches below the top of the Chequamegon Sandstone. Since the groundwater surface in these areas lies below the top of the sandstone, the direct push technique did not allow collection of groundwater samples at these locations.

A fourth direct push probe (GP-09) was located within the fenced grounds adjacent to the west side of Highway 13 about 450 ft north of the pipeline on September 16, 1998. The direct push sampler advanced to about 10 ft bgs where it became wedged within the sandstone. Because the sampler did not reach the water table, no water sample was collected. As at the other direct push locations, soil was screened for nitroaromatic compounds at the ground surface, but since the pipeline was not present in this area no soil screening or soil analytical samples were scheduled at depth. During the extraction process, the Geoprobe® samples were damaged and the direct push method had to be abandoned in favor of use of the Rotosonic® rig.

Borings GP-04, GP-06 and GP-08 were advanced with the Rotosonic® rig on September 22, 1998. Completion of GP-09 to the groundwater surface with the Rotosonic® rig was not possible because of the steep slope of the ground at this location. Although these locations were not sampled with the Geoprobe®, the GP designations used in the workplan were maintained to be consistent with the GI Worlcplan maps. Soil at each of these borings was sampled and logged from the ground surface to 20 ft bgs (about 1 to 3 ft below the depth of groundwater). Surficial soils were screened for nitroaromatic compounds (see section 6.1.2 and Table 1). Groundwater samples were collected directly from the drill rods using a peristaltic pump (see section 6.2.2 and Table 5). The heavy sediment load suspended in the water column after drilling was removed from these samples via filtering with a 0.45 micron inline filters. In addition, at GP-06, soils from the pipeline depth were collected in glass jars provided by the analytical laboratory. These jars were chilled and shipped to the laboratory by overnight delivery service for analysis of nitroaromatic compound content (see section 6.1.3 and Table 2).

Once sampled, the Geoprobe® location probe holes were backfilled with granular bentonite. WDNR Borehole Abandonment Forms are included in Appendix C. Because of the extra cost and access requirements of the Rotosonic® rig, borings GP-05 and GP-07 were not advanced.

Two remedial activities were undertaken during this field event:

- Abandonment of the two unused water supply wells.
- Abandonment of an unused water supply pipeline from Lake Superior to the facility.

These actions are discussed below.

5.1 POTABLE WELL ABANDONMENT

Two water supply wells had previously been installed on grounds now owned by the Brettings and occasionally used by the local Boy Scout council (See Figure 3). The wells were topped by 4-inch diameter steel casing which had apparently been drilled into the local bedrock to depths of about 40 feet below the ground surface (bgs). The well boreholes extended to 95 ft bgs in the western well, identified by WDNR as IW707, and to 62 ft bgs in the eastern well to which no WDNR identification number had been assigned. These wells were no longer being used and per Wisconsin code required appropriate closure.

These wells were abandoned per the requirements of WAC Section NR-141 on October 14, 1998. Details of the abandonment procedures are outlined in GI Workplan SOP 7 and WAC Section NR-141. WDNR Borehole Abandonment Forms are included in Appendix C. The abandonment procedures were as follows:

- The pump and piping were removed from the western well (none was present in the eastern well). The pump was a Baker Manufacturing, Monitor model, hand operated piston pump. Piping was 45 ft of 1.5-inch OD galvanized steel pipe. A filter box attached to the pipe intake could not be removed and was pushed with drill rods to about 93 ft bgs, probably resting on the bottom of the well.
- The west well was filled with cement-bentonite grout to the top of the riser. Grout was pumped to the well bottom using steel tremie pipe and allowed to flow until water was displaced and grout ran from the well top. The east well was filled with 8 bags of dry chip bentonite.
- The ground around both risers was excavated down about 36 inches. The steel risers were cut off with a welding torch at 30 inches below ground. The holes at the well heads were filled with soil and raked to match the adjacent ground.
- Well abandonment forms were completed and submitted to WDNR on November 11, 1998.

5.2 WATER SUPPLY LINE ABANDONMENT

The former Barksdale Works required a large volume of water for manufacturing processes. According to available records, during the 1910's two cast iron water supply lines were installed to provide water from Lake Superior to the plant. Both of these water lines originate at the former Pump House and pass through the current Bretting residence property in close proximity to well CX533.

The purpose of the water pipeline investigation and closure plan was to gather necessary information to determine if infiltrating water or groundwater was being conveyed by or along the existing abandoned water system pipes and to close the pipelines to eliminate the possibility of future water movement. DuPont elected to voluntarily investigate the condition of the pipeline at three (3) locations.

The water pipeline investigation and closure was conducted from August 25 through September 16, 1998. This involved exposing the pipelines and performing the following activities at each closure location:

- Determine the pipeline trench condition (bedding, backfill and evidence of groundwater).
- Determine the external condition of the pipes (pipe material, joint type and overall integrity).
- Determine the internal condition of the pipes (presence of water, condition of the pipe).
- Containerize and manage pipeline water in accordance with the site waste management plan.
- Close the pipes (see section 5.2.2)

5.2.1 Pipeline Investigation

The three locations investigated are depicted on Figure 3. Two (2) locations were selected to determine whether water was leaving the former manufacturing areas (West of Route 13). A third location, in the vicinity of the former Pump House, was investigated to ascertain the condition of the pipes in the immediate vicinity of the Bretting well.

A total of seven samples (three soil samples, a soil duplicate and three water samples) were collected and submitted to an off-site laboratory for analysis using Method 8321. The results of these analyses are presented in Tables 2 and 7. No nitroaromatic compounds were detected in the water and soil samples collected. A photographic log of the investigation and closure activities in included in Appendix F.

During excavation at the three locations, soil removed was screened using an Exospray™ kit. There were no detections in the screened soils at any of the locations.

A description of the investigation at the three areas follows:

Closure Area 1

This location, in the vicinity of the former Booster Pump House, was selected to define possible sources of flow from the North branch or West branch of the system. The trench was excavated in the vicinity of the pipes to the bottom of bedding material, at approximately six feet below ground surface (bgs). The bedding and backfill material present in the trench appeared to be low permeability native red clay. No groundwater was encountered at Closure Area 1.

Both pipelines were located within approximately twenty feet of each other and found to be in good general condition. The pipes were 8-inch cast iron with bell and spigot joints. To determine if water was present in the pipes, each exposed pipe was wet-tapped. There was no water present in the West branch pipeline. A minimal amount of water, with an approximate flow rate of one liter per hour, was encountered in the North branch pipeline.

Closure Area 2

This location, in the vicinity of the perimeter of the manufacturing area, was selected to determine if flow off the site was occurring at the North branch or West branch pipes. The trench was excavated in the vicinity of the pipes to the bottom of bedding material, at approximately seven feet bgs. The bedding and backfill material present in the trench appeared to be low permeability native red clay. No groundwater was encountered at Closure Area 2.

Only one of the pipelines could be located in this area. It could not be determined whether the lone pipe was part of the North branch or West branch. The pipe was found to be in good general condition. This pipe was 8-inch cast iron with bell and spigot joints. There was no water present in this pipe.

Closure **Area 3**

This location, at the former Pump House near the Bretting Residence and well CX533, was investigated to ascertain the condition of the pipes or possible conveyance of water in this area. The trench was excavated in the vicinity of the pipes to the bottom of bedding material, at approximately six feet bgs. The backfill material present in the trench appeared to be low permeability native red clay. Both pipes were found to have been set on the Chequamegon sandstone. No groundwater was encountered at Closure Area 3.

Both pipelines were located within approximately twenty feet of each other and found to be in good general condition. The pipes were 8-inch cast iron with bell and spigot joints. Each exposed pipe was wet-tapped and found to contain water. Approximately 3000 gallons of water was removed from the West branch pipeline and approximately 2000 gallons from the North branch pipeline.

5.2.2 Pipeline Closure

Closure of the exposed water pipelines and trench at each of the three pipeline locations consisted of the following steps:

- Each pipe was cut and approximately a 24-inch length of pipe was removed.
- Each end of the pipe was then plugged with pipe plugs (push-on joint, restrained plug type)-
- Concrete thrust blocks were placed in the void between each pipe end.

The excavations were immediately backfilled to existing grade with low permeability native red clay material.

6.1 SOIL RESULTS

6.1.1 Geology

The boring logs and associated lithology for the 17 boreholes advanced during the GI are presented in Appendix B. This information was used in conjunction with available historical data to form cross sections. Cross section locations are presented in Figure 4 and the cross sections are included as Figures 5 through 12.

Glacial Deposits

Two distinct unconsolidated glacial deposits are present: surficial clay and a silty-clayey sandy till. In general, the glacial materials were thickest at the northern and western edges of the site where the observed depth to bedrock range from 167 to 229 ft. The thickness of glacial deposits decreased to the east and only a 6 to 7 ft layer of clay was found above the bedrock at the Bretting residence. Total thickness of observed glacial deposits is summarized in Figure 13. The glacial materials observed during the GI are described below:

- **Surficial Clay (Miller Creek Formation - Douglas Member):** Red, soft to dense, low- to moderately-plastic, silty-clay with 5 to 10 % gravel was typically found as the surficial lithology throughout the site. This red clay was formed by the reworking of glacial till by lake actions (REF). In most places the clay was 4 to 8 ft thick. Exceptions were at PZ-03 where the clay was 40 ft thick and at PZ-05 where the clay was missing (probably due to grading for road construction). The clay was sampled via Shelby tubes and flexible wall permeability tests indicated hydraulic conductivities on the order of 10^{-8} cm/sec. However, shallow fracture networks have been reported in shallow clayey glacial deposits with reported hydraulic conductivity values ranging from 10^{-6} to 10^{-4} cm/sec (Frederica, 1990). In the western portion of the site the clay contacts underlying till materials. In the central and eastern portions of the site the clay overlies red sandstone bedrock.
- **Till (Miller Creek Formation):** In all but the northeast quarter of the site a silty to clayey till containing occasional lenses of sand and gravel was encountered. This till was typically grayish to dark brown in color and contained occasional rounded igneous gravel and cobbles throughout. On average this formation contained 30 to 40 % silt, 20 to 30 % clay, 25 to 45% sand and 5 to 12 % gravel or cobbles. These materials were often distributed in gradational beds. At the PZ-03, PZ-04 and PZ-06 locations the till exhibited a regular layered grading of grain size, typically shifting from silt or clay (90% silt and clay with 10% gravel or cobbles) to a silty-gravely sand (40 % silt and clay, 45 % sand and 5% gravel or cobbles) over about a 1 to 4 ft change in depth. At PZ-02 the gradational beds were often thicker with several sand & gravel layers of over 10 ft in thickness encountered. At PZ-05, the beds were thinner (typically 2 to 8 inches) and there was no gradation between layers. No till material was encountered between MW-03 and the lakeshore. In that area red sandstone was present directly below the surficial clay.

Bedrock

Bedrock consisting of Chequamegon Sandstone was encountered at all locations sampled. Up to three layers of sandstone were observed: a highly friable red and white layered sandstone, a less friable red and white layered sandstone and a competent purple and white mottled sandstone.

- **Red & White Layered Sandstone (Chequamagon Sandstone): Highly Friable to Friable Sandstone:** In the northern and central portions of the site a highly friable sandstone was encountered from about 5 ft bgs to 40 ft bgs. This material is a fine to medium grained sand with varying silt and clay content containing red, reddish brown, orange-brown and white colored layers about 6 to 36 inches in thickness. Layers in contact with the surficial clay often contained 10 to 25 percent clay and exhibited some cohesion while lower layers were typically non-plastic silty or clean sands. This friable sandstone, where present, was underlain by less friable sandstone bedrock.
  The less friable sandstone bedrock was encountered throughout the full area investigated at depths of 5 to 229 ft bgs. The less friable sandstone bedrock was 30 to 70 ft thick and distinguished by red, white, orange and brown horizontal layers several inches to several feet thick. The sandstone was typically fine to medium grained with the coarser grains associated with the lighter colored layers. The disturbed condition of samples retrieved fi-om the sandstone by the Rotosonic® drill rig made the presence of fractures in this layer difficult to identify. The broken samples also made differentiation between competent sandstone and friable sandstone problematic.
- **Purple & White Mottled Sandstone:** This unit was encountered below the red and white layered sandstone at four of the monitoring wells and three of the piezometer locations. The purple sandstone was encountered near 200 ft bgs in PZ-02, PZ-04 and PZ-06 and at 50 to 90 ft bgs in MW-01, MW-02, MW-04 and MW-05. A fine grained purple sand matrix with medium grained white sand spots or streaks distinguished this sandstone. Dark red to violet fissile claystone and fat siltstone and claystone lenses were observed in most of the cores retrieved. The lenses retrieved varied in thickness from 0.1 to 1 .O inch. Samples retrieved only represented 10 to 20 percent of the interval sampled and larger lenses or coarser grained material may have been present in the lost segments. Rough drilling and occasional rounded igneous cobbles were typically encountered just prior to drilling into the purple sandstone layer. The base of the purple sandstone was not encountered.

Cross sections completed through the site (Figures 4 through 12) indicate a general east-southeast dip of the bedrock surface with bedrock being encountered at a depth of around 100 to 200 feet below ground surface. To the east and northeast of the PZ-06 piezometers a sudden rise in the bedrock surface is encountered and the depth to bedrock decreases to generally less than 20 feet.

6.1.2 Field Screening Results

Fifty-one soil samples were field screened using the Exospray kits described in Section 4.2. The screening results are tabulated in Table 1. The only location at which nitroaromatic compounds were detected was a wet gray colored gravely soil layer at about 29 ft bgs in the MW-03 borehole. The kit result, a faint pink color, indicates the presence of a compound in the dynamite / nitroglycerin / nitrocellulose group at less than one ppm concentrations.

6.1.3 Laboratory Analytical Results

Soil analytical samples were collected at watermain Geoprobe® locations GP-01, GP-02, GP-03 and GP-06 and at the water-main closure excavations at the pipeline depth (see Section 5.2). None of the soil samples contained detectable nitroaromatic concentrations.

6.2 GROUNDWATER RESULTS

6.2.1 Hydrologeology

Groundwafer Elevations

Groundwater elevations from December 1998 are presented in Table 3. Figure 14 is a contour map depicting the upper groundwater surface (glacial till and red and white Chequamegon Sandstone aquifers) which was created using the groundwater elevations in Table 4. Groundwater flow through the site is influenced chiefly by the topography. As shown on the map, groundwater flow and discharge is generally to the east-southeast from topographic high (the western portion of the site) to topographic low (Lake Superior). In the southeastern portion of the site, from approximately the former dynamite production area to the Bay, the upper portion of the groundwater table discharges to Boyd Creek.

*Horizontal/Vertical Hydraulic **Gradients***

Based on the December 1998 groundwater contours (Figure 14) the horizontal hydraulic gradient for the shallow bedrock aquifer ranges from 0.01 in the north eastern portion of the site to 0.02 ft/ft in the west central portion of the site. The average horizontal hydraulic gradient is 0.016 ft/ft.

Two of the three upland well clusters (PZ-04 at the west of the site and PZ-02 at the north of the site) had an upward hydraulic gradient in December 1998. PZ-04 had an upward gradient of 0.008 ft/ft while PZ-02 had an upward gradient of 0.406 ft/ft. The other upland piezometer nest, PZ-03 had a downward vertical gradient of 0.021 ft/ft.

The well clusters near the stream valley all exhibited downward gradients: PZ-01 (0.006 ft/ft), PZ-05 (0.099 ft/ft) and PZ-06 (0.012 ft/ft).

***Groundwater** Flow Velocity*

A summary of slug test results is presented in Table 4. Appendix E contains supporting data.

The groundwater flow velocity was calculated for the red and white layered sandstone (upper Chequamegon Sandstone) using the median hydraulic conductivity value of 1.54×10^{-3} cm/s, a horizontal gradient of 0.016, and a bedrock assumed porosity of 0.2.

Average linear groundwater velocity can be estimated by rearranging Darcy's Law as follows: V=(Ki/ne); where V = groundwater velocity, K = hydraulic conductivity, i = hydraulic gradient, and ne = effective porosity.

This velocity is a minimum value because the estimated hydraulic conductivity value assumes 100% well efficiency. Assuming that the monitoring wells have a range of efficiency from 60% to 100%, the range of average linear groundwater velocity expected in the upper Chequamegon Sandstone is from 0.35 to 0.58 per day or from 130 to 220 feet per year.

Surface *Wafer Elevations*

Lake Superior elevation data were not measured directly during this GI, but two shoreline survey targets placed just above the waterline (targets 106 and 113) were located at an elevation of about 602 ft msl.

Stream depths observed during the GI field activities ranged from 1 to 3 inches in gravel shoals to over four feet at several beaver ponds. In early December of 1998 Boyd Creek was observed to be flowing 2 inches deep through the culvert under Ondassagon Road at the western boundary of the site. The water in the creek was moving at an estimated velocity of about 7 ft/sec (based on debris movement) which indicates an estimetedc flow of 3 to 5 cfs. The flow at the bridge where Boyd Creek passes' under Highway 13 was divided amongst several small sub-channels and the flow rate was therefore was not easily estimated. The other streams, at the culverts where they cross highway 13, were dry throughout the period of the GI.

Correlation of stream gage elevations with groundwater results at nearby wells show that Boyd Creek is a neutral to losing stream in the western reaches and a gaining stream in the eastern reach between the dynamite grounds and the bay.

Stream Reach	Well No. / Groundwater Elevation	Staff Gage No. / Surface water Elevation	Estimated Relation at Gage derived from Groundwater Contour Map
Western	PZ-04S 1698.07	SB-06 / 699.23	Even
East Central	PZ-05S 1643.98	SB-03 1626.43	stream 16 ft below
Eastern	MW-02S / 623.97	SB-011605.78	stream 17 ft below

Correlation of the groundwater contours (Figure 14) with the stream levels also indicates that Boyd Creek is receiving groundwater in the eastern reaches and losing surface water to groundwater in the western reaches.

6.2.2 Laboratory Analytical Results

Groundwater analytical tests run and the results obtained are shown on Table 5. Analyses were run for the constituents of nitroaromatic and ammonium based products. The main findings are summarized below:

- Nitroaromatic compounds were detected at four groundwater and three surface water locations.
- Elevated nitrate concentrations were detected at two groundwater locations.
- Elevated sulfate concentrations were detected at four groundwater locations and ♦·□ surface water locations.

The nitroaromatic compounds detected in groundwater samples included: 1,3-dinitrobenzene, 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT), 2-amino-dinitrotoluene, 4-amino-dinitrotoluene and 4-nitrotoluene. The total nitroaromatic groundwater detections were; MW-03-14.85 ug/L, MW-02 8.25 ug/L and the Bretting Well (CX533) - 2.81 ug/L. The inferred extent of these impacts based on concentrations and flow directions is shown on Figure 15.

The nitroaromatic compounds detected in surface water samples included: 1,3-dinitrobenzene, 2,4,6-trinitrotoluene, 2,4-dinitrotoluene, 2,6-dinitrotoluene, 2-amino-dinitrotoluene, 4-amino-dinitrotoluene and 4-nitrotoluene. The total nitroaromatic surface water detections were; SG-03 - 5.71 ug/L, SG-Ol- 4.64 ug/L, and SG-08 - 2.50 ug/L.

Elevated nitrate concentrations were detected at MW-02 - 44 mg/L. Nitrate gronndwater concentrations at the other locations tested ranged from less than 0.05 to 1 .O mg/L.

Sulfate was detected at relatively elevated concentrations at MW-02 - 52 mg/L, MW-03 - 50 mg/L, the Bretting Well (CX533) - 27 mg/L and at MW-04 - 23 mg/L Sulfate groundwater concentrations at the other locations tested ranged from 3.4 to 7.5 mg/L

For the compounds detected by analytical testing, Wisconsin Administrative Code Section NR140 Groundwater Quality Enforcement Standards (ES) / Preventive Action Limits (PAL) exist only for 2,4-DNT (0.05 ug/L ES /0.005 ug/L PAL), 2,6-DNT (0.05 ug/L ES /0.005 ug/L PAL), and nitrate (10 mg/L ES /2 mg/L PAL). Public welfare based nuisance thresholds also exist for sulfate (250/125 mg/L).

Since the ES for 2,4-DNT and 2,6-DNT set by state code are below analytical method detection limits, exceedences exist at all three groundwater sampling points where these compounds were detected. The nitrate concentrations detected exceeded the ES only at MW-02. The sulfate concentrations detected, although elevated in some areas, are all an order of magnitude below state standards.

The DNT concentrations decrease from MW-03 to CX533 in a distribution which is consistent with the direction of groundwater flow. The nitrate concentrations at MW-02 and the Bretting Well indicate a gradient of impacts somewhat more easterly than the general topographically controlled direction of groundwater flow and may be locally effected by groundwater flow into and along Boyd Creek.

6.2.3 Geotechnical Results

Also shown on Table 5 are the results of conventional geochemical analytical tests run on groundwater and surface water samples. Tests run for geochemical purposes included major cations (calcium, iron, magnesium, potassium and sodium), major anions (carbonate, bicarbonate, bromide, chloride, fluoride and sulfide) and indicator parameters (alkalinity, pH, conductivity, temperature, turbidity, total organic carbon, total suspended solids and total dissolved solids).

The results of these tests were plotted on a trilinear diagram (Appendix G) to determine the provenance of the samples. Ion balance calculations where used to estimate carbonate/bicarbonate concentrations for locations were these analyses were not run (see appendix G). The plots indicated that all of the water samples are from a Ca/Mg type aquifer and seven of the locations (the groundwater samples) are related based on carbonate/bicarbonate content. Water samples at staff gages SB-01 and SB-03 are very similar to each other and are related to the groundwater samples but have significantly higher sulfate content than the other samples.

Sampling locations SB-06 and SB-08 have water that is from a different source than the other samples with lower dissolved concentrations and more prevalent chloride/sulfate ions rather than the carbonate/bicarbonate species which dominated the other samples. The difference is most marked at B8.

7.1 SURFACE WATER

None of the surface water detections exceed ecological risk based standards.

Comparison of surface water and groundwater levels indicates that Boyd Creek is a gaining stream in the eastern reaches. Analysis of geochemical data supports this conclusion since the composition of the creek water in the identified gaining portion of the stream is reportedly more comparable to the composition of the groundwater samples than the composition of the upstream surface waters. Since water from the stream does not discharge to the aquifer, the surface water does not represent a threat to groundwater.

Based on these conditions, no further investigation is recommended for Boyd Creek. Continued water level monitoring on a quarterly basis for one year is recommended to verify that the hydraulic relationship identified is seasonally consistent.

7.2 GROUNDWATER

Nitroaromatic compounds detected in groundwater are at very low concentrations (the highest detection was 0.012 mg/L in MW-03). The distribution of nitroaromatic compounds in groundwater does not appear to be widespread.

The DNT compounds appear to originate somewhere north-northwest of MW-03, possibly in the former World War I TNT or TNX production areas. It is unlikely that a source remains at or near the surface given the photo- and bio-degradation rates of these compounds in aerobic settings. Since there is no major erosion occurring or excavation planned, the WWI area is not likely to present a direct contact hazard to site users or wildlife.

Based on these conditions, the only pathway of concern for the observed impacts is ingestion of groundwater from wells east of the former Barksdale Works. To address this pathway continued operation of the current treatment system at the Bretting well is recommended.

To verify that the nitroaromatic compound concentrations observed are stable, continued monitoring of the wells sampled in December 1998 is also recommended.

1. Investigation of E.I.du Pont de Nemours Company's Explosives Plant at Barksdale, Bayfield County, Wisconsin, Wisconsin Department of Natural Resources (WDNR), Jan. 1982

2. Former Du Pont Dynamite Facility, Public Health Consultation Report, Wisconsin Department of Public Health (WDPH), Dec. 1995

3. Sampling And Analysis Plan, Former Barksdale Works, Barksdale, Wisconsin, DERS Project No. 7 19 1, Du Pont Corporate Remediation Group & Du Pont Environmental Remediation Services, Oct 1997

4. Site Conditions Report, Former Barksdale Works, Washburn, Wisconsin, DERS Project No. 7191, Du Pont Corporate Remediation Group & Du Pont Environmental Remediation Services, Dec. 1997

5. Groundwater Investigation Work Plan, Woodward-Clyde Consultants, July 1998

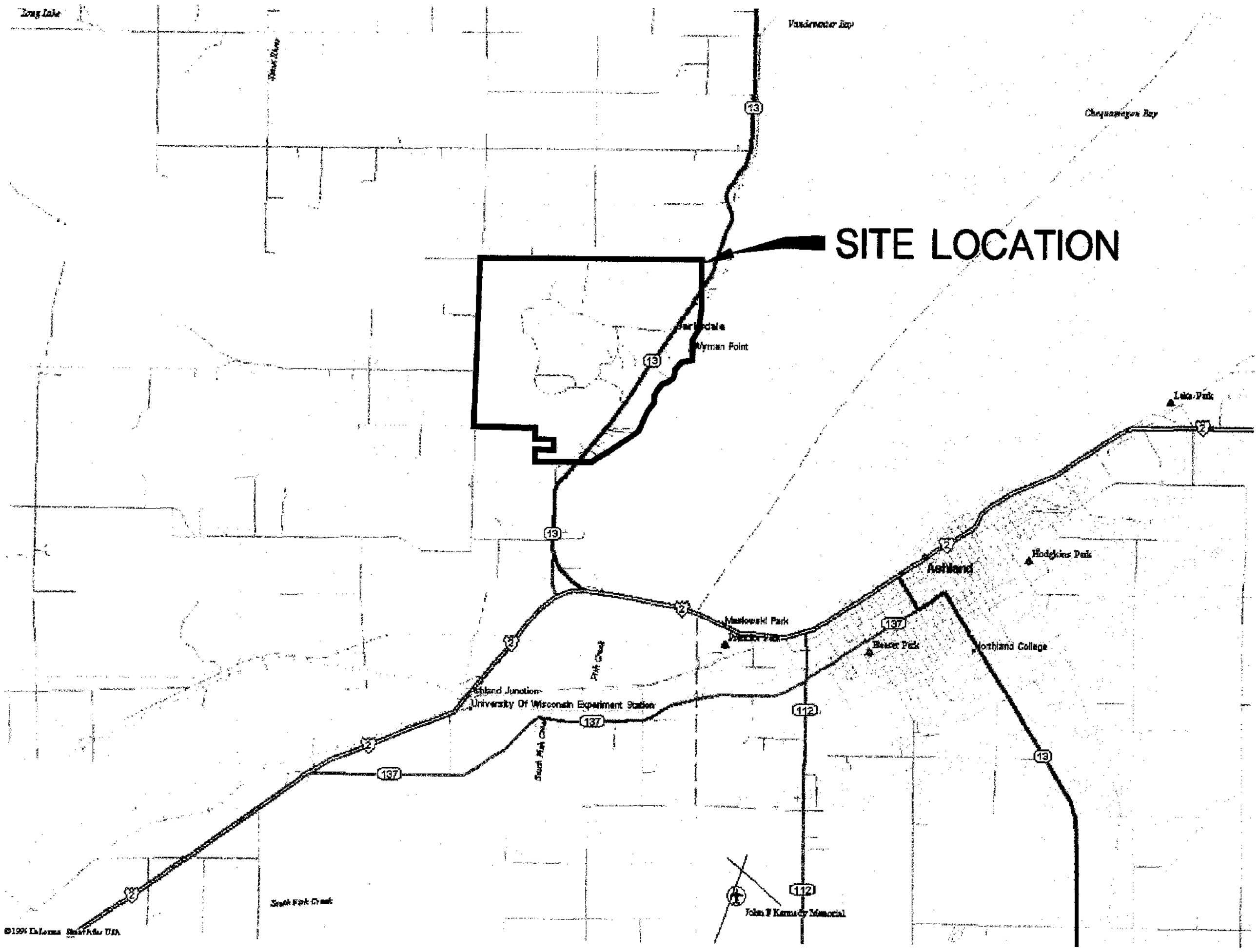
6. Results of the 1998 Sediment and Surface Water Investigation at the Former Barksdale Works, Barksdale, Wisconsin. Exponent, 1999.

7. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Bouwer, H and R.C. Rice; 1976. Water Resources Research vol. 12, no. 3 pp 423-428.

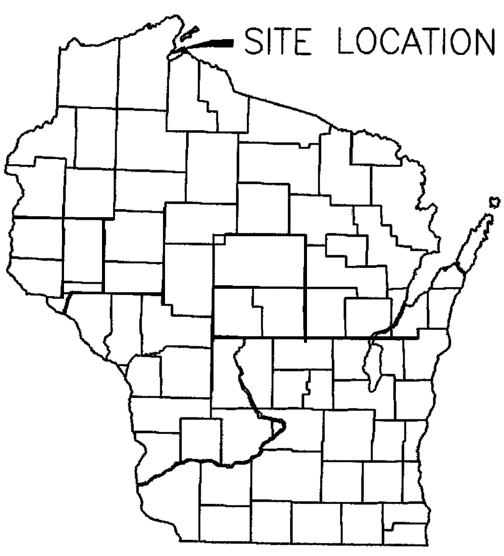
8. The Bouwer and Rice Slug Test, an Update; Bouwer, H.; 1989; Ground Water vol. 27, pp 304-309.

9. BRSLUG A Bouwer - Rice Slug Test Program for Windows; Jones, Ladon; 1995; Iowa State University.

10. Saturated hydraulic conductivity of clayey tills and the role of fractures. Fredericia, J. 1990 Nordic Hydrology. v. 21, pp. 119-132



SITE LOCATION



VICINITY MAP

N

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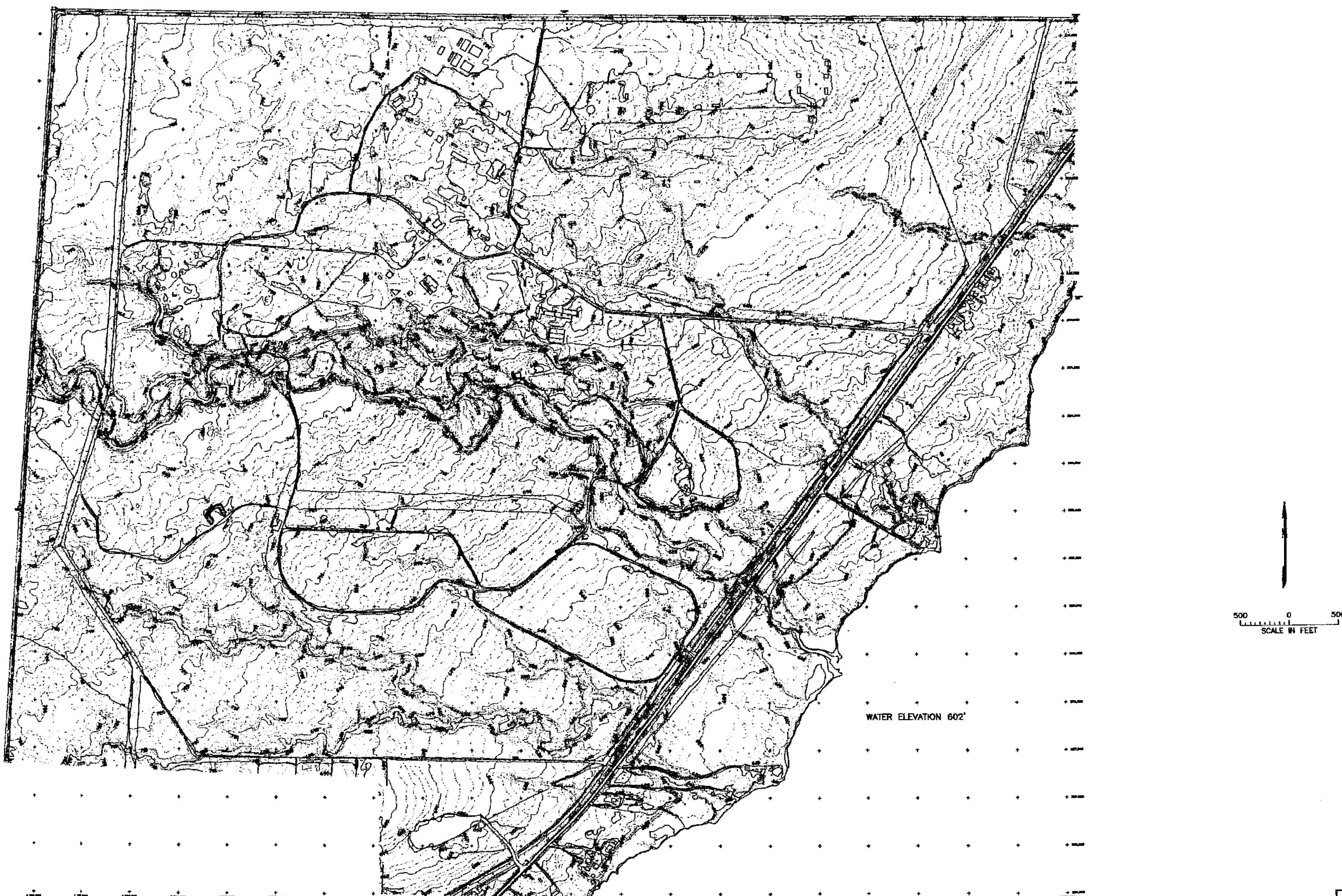
ENGINEERS, GEOLOGISTS, AND ENVIRONMENTAL SCIENTISTS

SITE LOCATION MAP
FORMER BARKSDALE WORKS

R N BY: SWH	DATE: MAR. 1999	PROJECT NO. 44D4BA7191	FIG. NO. 1
H K ' D BY: TF	DATE: MAR. 1999		



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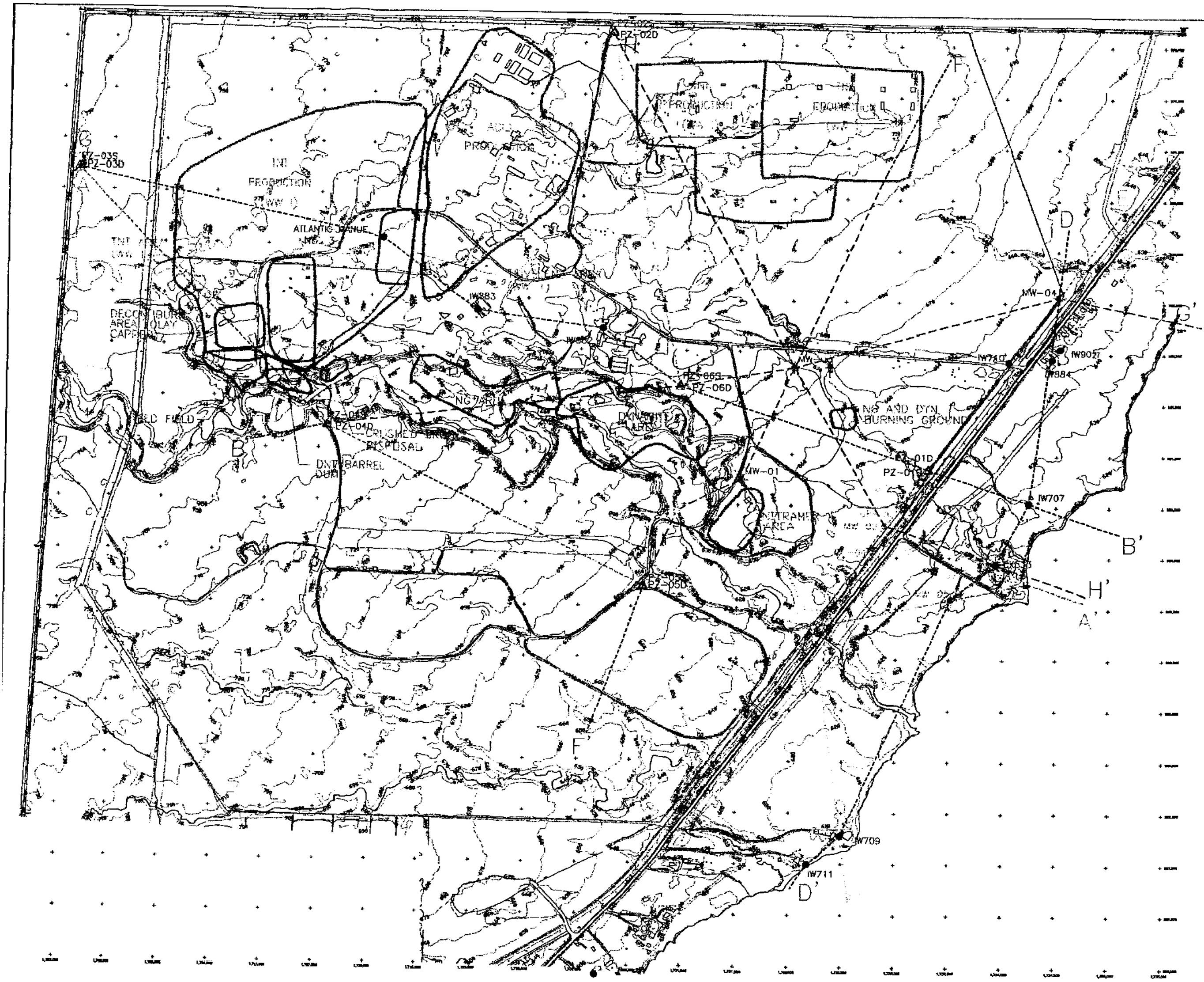
FORMER BARKSDALE WORKS
BARKSDALE, WISCONSIN
SITE LOCATION MAP

DWN BY: SWH	DATE: APR. 1999	PROJECT NO. 44D4BA7191	FIG. NO. 2
CHK'D BY:	DATE:		



LEGEND

MW-01	MONITORING WELL
△ PZ-01S	PIEZOMETER
	STREAM GAUGE
● IW707	GROUNDWATER WELLS
	GEO-PROBE

N

500 0 500
SCALE IN FEET

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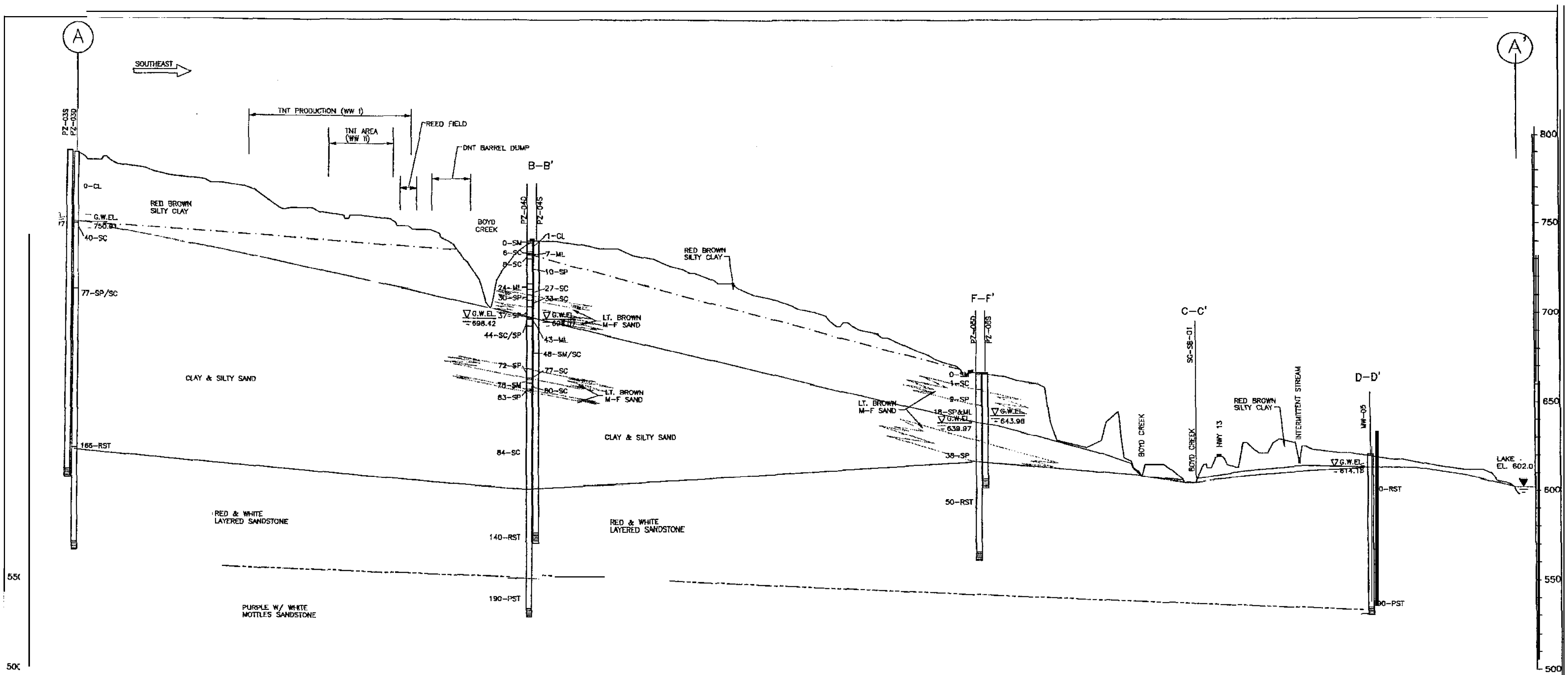
FORMER BARKSDALE WORKS BARKSDALE, WISCONSIN

CROSS SECTION LOCATIONS PLAN
GROUNDWATER INVESTIGATION

REVISION
PROJECT 44D48A7191
DRAWING 4
FIGURE OF



USCS SYMBOL DEFINITIONS

CL = CLAY
SC = CLAYEY SAND
SP/SC = POORLY SORTED CLAYEY SAND
ML = SILT
SM = SILTY SAND
SP = SAND
SM/SC = SILTY CLAYEY SAND
40-SP — UNIFIED SOIL CLASSIFICATION SYMBOL (USCS)
— DEPTH LAYER BEGINS BELOW GROUND SURFACE

CROSS SECTION A-A'

SCALE: VERT. 1" = 25'
SCALE: HORZ. 1" = 350'

LEGEND

BGS BELOW GROUND SURFACE
RED BROWN SILTY CLAY (MILLER CREEK FORMATION)
CLAY & SILTY SAND (MILLER CREEK FORMATION)
RST - RED & WHITE LAYERED SANDSTONE (CHEQUAMEGON SANDSTONE)
PST - PURPLE W/ WHITE MOTTLES SANDSTONE (CHEQUAMEGON SANDSTONE)
GW GROUNDWATER
G.W.EL. 505.87 = GROUNDWATER ELEVATIONS (12/2/98)
— ROAD

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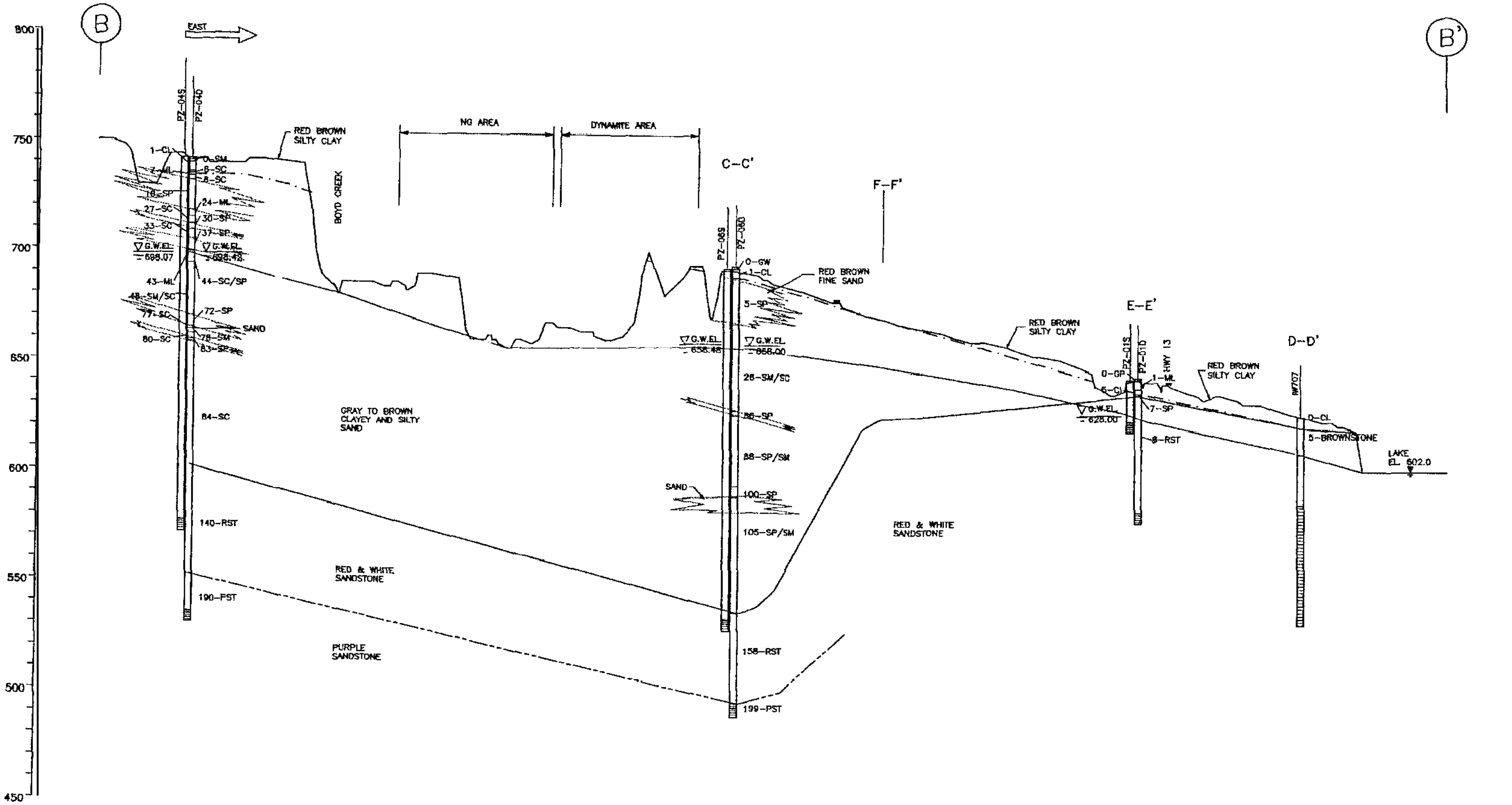
FORMER BARKSDALE WORKS — BARKSDALE, WISCONSIN

GEOLOGIC CROSS SECTION A-A'
GROUNDWATER INVESTIGATION

REVISION
PROJECT 4404BA7191
DRAWING
FIGURE 5 OF



USCS SYMBOL DEFINITIONS

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SM/SC = SILTY CLAYEY SAND
40-SP — UNIFIED SOIL CLASSIFICATION SYMBOL (USCS)
— DEPTH LAYER BEGINS BELOW GROUND SURFACE

CROSS SECTION B-B'

SCALE: VERT. 1" = 25'
SCALE: HORZ. 1" = 350'

LEGEND

BGS BELOW GROUND SURFACE
— — — RED BROWN SILTY CLAY (MILLER CREEK FORMATION)
— · — · — CLAY & SILTY SAND (MILLER CREEK FORMATION)
——— RST – RED & WHITE LAYERED SANDSTONE (CHEQUAMEGON SANDSTONE)
— - - — PST – PURPLE W/ WHITE MOTTLES SANDSTONE (CHEQUAMEGON SANDSTONE)
═══ GW GROUNDWATER
▽G.W.EL. 505.87 = GROUNDWATER ELEVATIONS (12/2/98)
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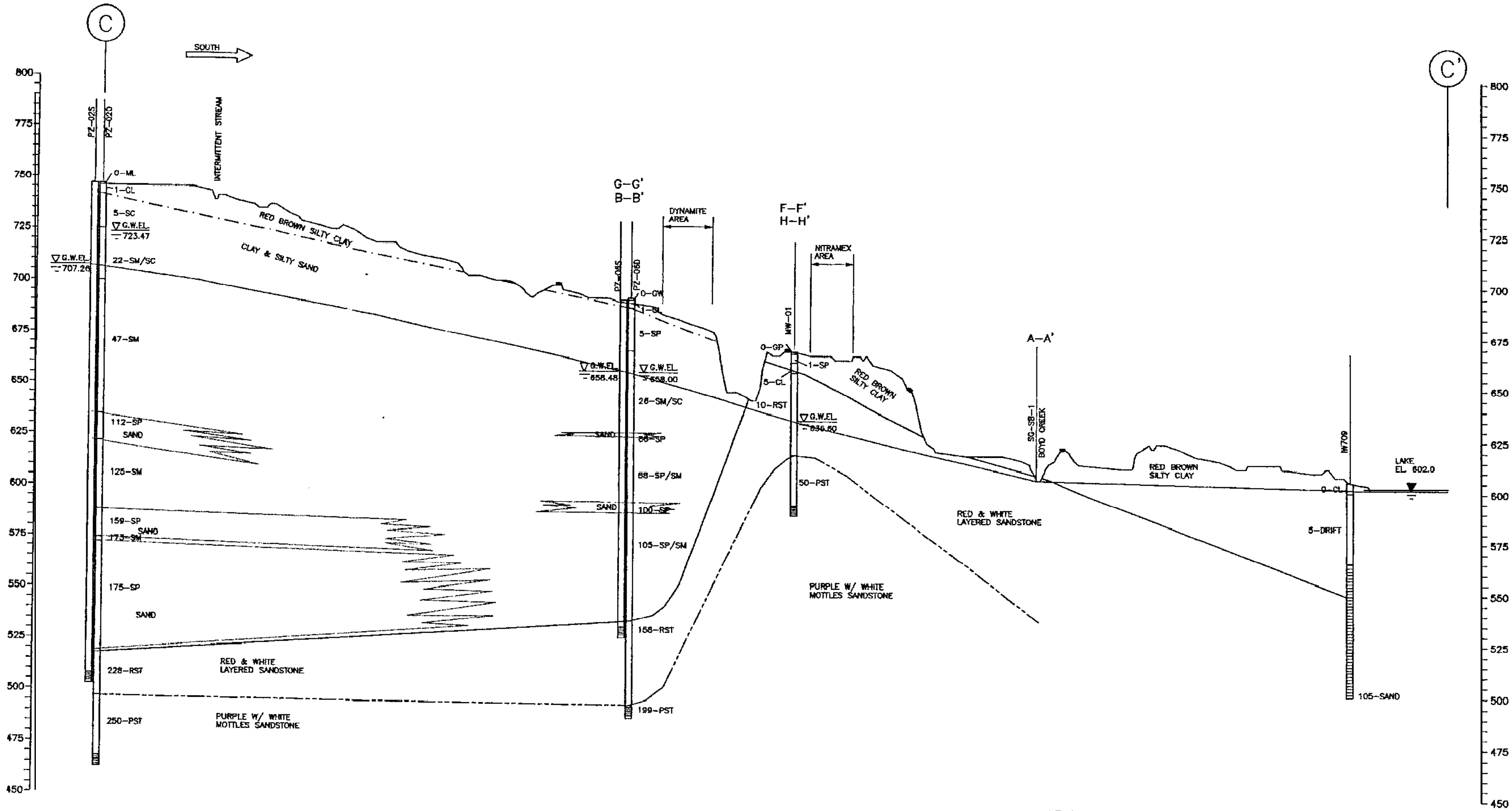
FORMER BARKSDALE WORKS — BARKSDALE, WISCONSIN

GEOLOGIC CROSS SECTION B-B'
GROUNDWATER INVESTIGATION

REVISION
PROJECT 44D4BA7191
DRAWING 6
SHEET OF



USCS SYMBOL DEFINITIONS

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SP/SC = POORLY SORTED CLAYEY SAND
ML = SILT
SM = SILTY SAND
SP = SAND
SM/SC = SILTY CLAYEY SAND

40-SP — UNIFIED SOIL CLASSIFICATION SYMBOL (USCS); DEPTH LAYER BEGINS BELOW GROUND SURFACE

CROSS SECTION C-C'

SCALE: VERT. 1" = 25'
SCALE: HORZ. 1" = 350'

LEGEND

BGS BELOW GROUND SURFACE

- RED BROWN SILTY CLAY (MILLER CREEK FORMATION)
- CLAY & SILTY SAND (MILLER CREEK FORMATION)
- RST – RED & WHITE LAYERED SANDSTONE (CHEQUAMEGON SANDSTONE)
- PST – PURPLE W/ WHITE MOTTLES SANDSTONE (CHEQUAMEGON SANDSTONE)
- GW GROUNDWATER
- G.W.EL. 505.87 = GROUNDWATER ELEVATIONS (12/2/98)
- ROAD

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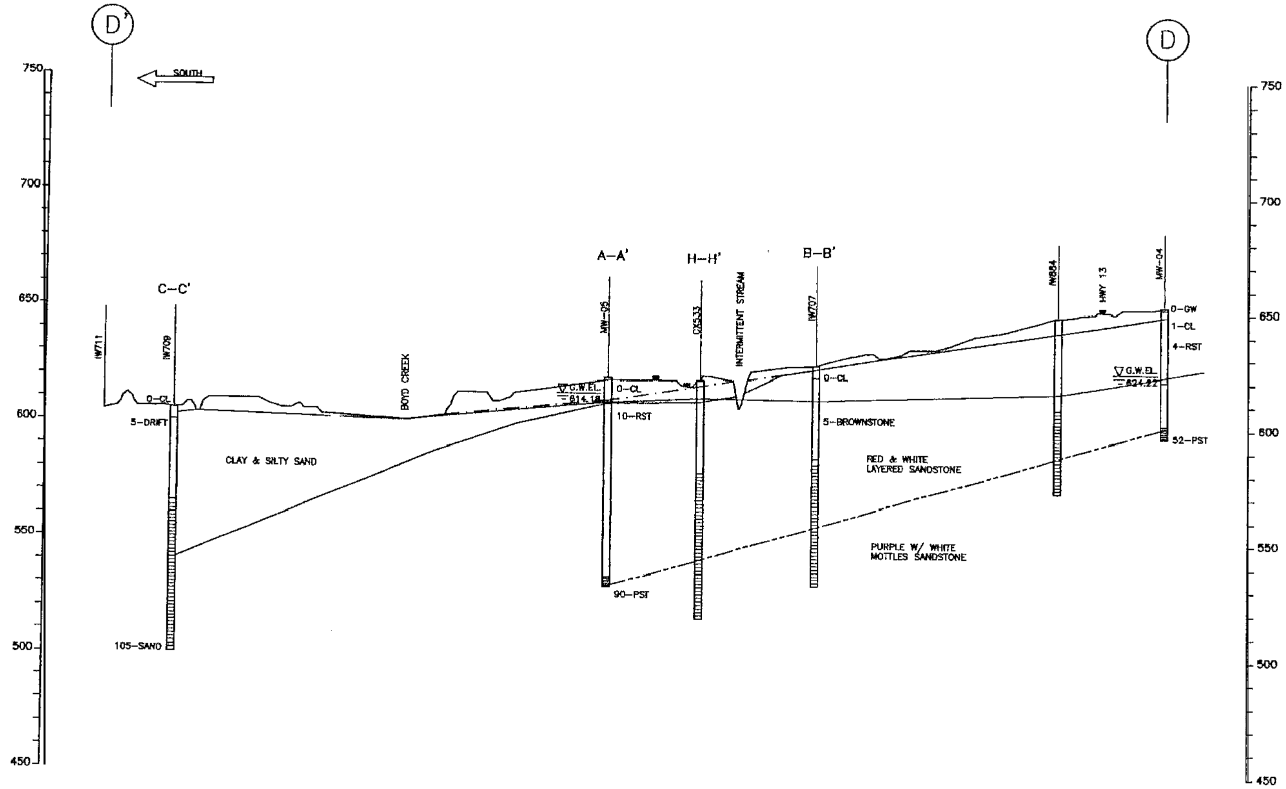
FORMER BARKSDALE WORKS BARKSDALE, WISCONSIN

GEOLOGIC CROSS SECTION C-C'
GROUNDWATER INVESTIGATION

REVISION
PROJECT 44D4BA7191
DRAWING 7
FIGURE OF



USCS SYMBOL DEFINITIONS

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ML = SILT
SM = SILTY SAND
SP = SAND
SM/SC = SILTY CLAYEY SAND
40–SP — UNIFIED SOIL CLASSIFICATION SYMBOL (USCS)
— DEPTH LAYER BEGINS BELOW GROUND SURFACE

CROSS SECTION D–D'

SCALE: VERT. 1" = 25'
SCALE: HORZ. 1" = 350'

LEGEND

BGS BELOW GROUND SURFACE
— — — — RED BROWN SILTY CLAY (MILLER CREEK FORMATION)
— · — · — CLAY & SILTY SAND (MILLER CREEK FORMATION)
———— RST – RED & WHITE LAYERED SANDSTONE (CHEQUAMEGON SANDSTONE)
— - — - — PST – PURPLE W/ WHITE MOTTLES SANDSTONE (CHEQUAMEGON SANDSTONE)
———— GW GROUNDWATER
▽ G.W.EL. 505.87 = GROUNDWATER ELEVATIONS (12/2/98)
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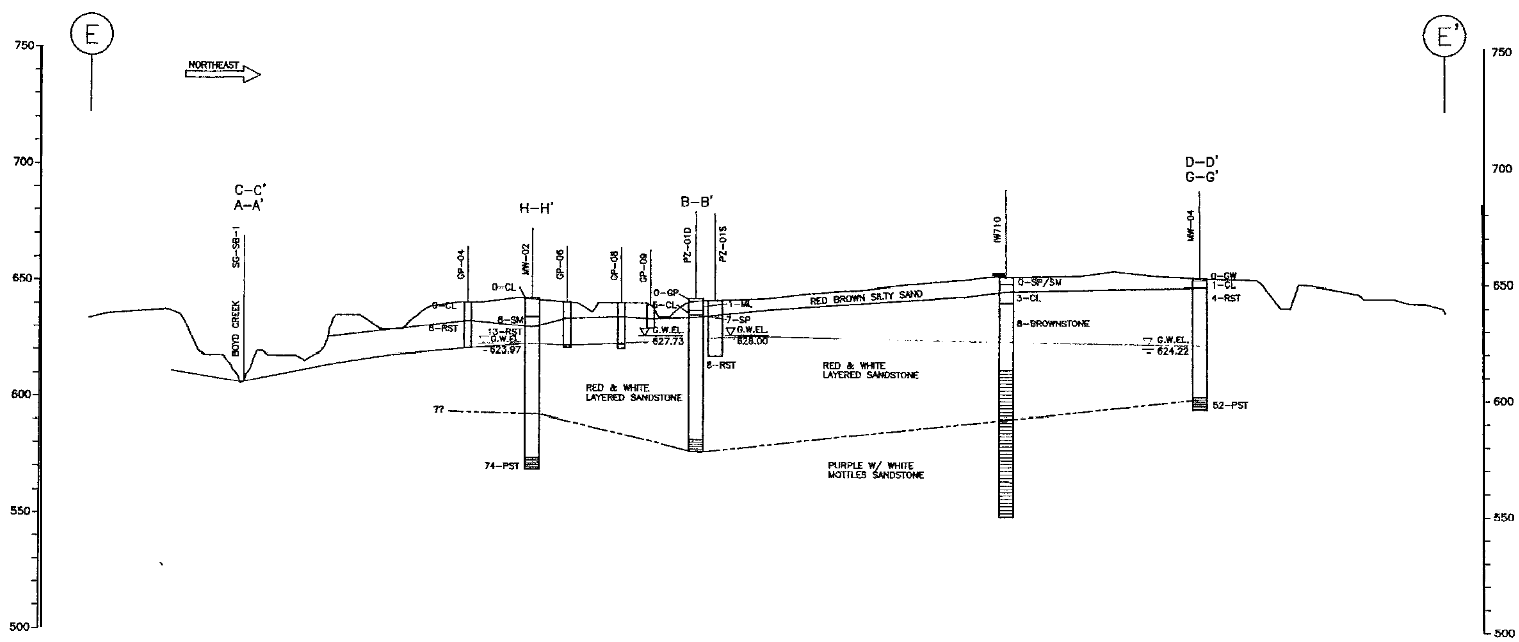
FORMER BARKSDALE WORKS BARKSDALE, WISCONSIN

GEOLOGIC CROSS SECTION D–D'
GROUNDWATER INVESTIGATION

REVISION △
PROJECT 44D4BA7191
DRAWING 8
SHEET OF



CROSS SECTION E-E'

SCALE: VERT. 1" = 25
SCALE: HORZ. 1" = 250

USCS SYMBOL DEFINITIONS

CL = CLAY
SC = CLAYEY SAND
SP/SC = POORLY SORTED CLAYEY SAND
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SM/SC = SILTY CLAYEY SAND
40-SP — UNIFIED SOIL CLASSIFICATION SYMBOL (USCS)
— DEPTH LAYER BEGINS BELOW GROUND SURFACE

LEGEND

BGS BELOW GROUND SURFACE
RED BROWN SILTY CLAY (MILLER CREEK FORMATION)
CLAY & SILTY SAND (MILLER CREEK FORMATION)
RST – RED & WHITE LAYERED SANDSTONE (CHEQUAMEGON SANDSTONE)
PST – PURPLE W/ WHITE MOTTLES SANDSTONE (CHEQUAMEGON SANDSTONE)
GW GROUNDWATER
G.W.EL. 505.87 = GROUNDWATER ELEVATIONS (12/2/98)
= ROAD

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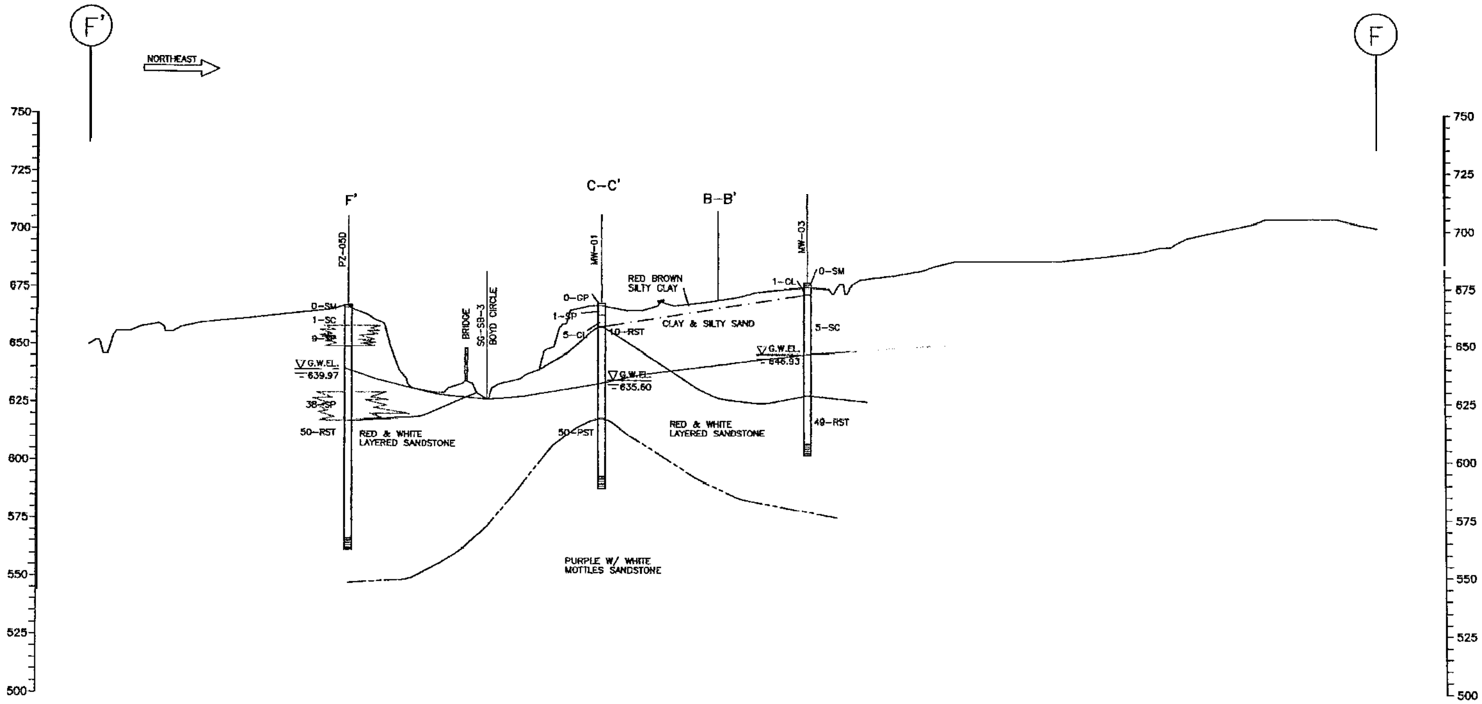
FORMER BARKSDALE WORKS — BARKSDALE, WISCONSIN

GEOLOGIC CROSS SECTION E–E'
GROUNDWATER INVESTIGATION

REVISION
PROJECT 44D4BA7191
DRAWING
FIGURE 9 OF



CROSS SECTION F-F'

SCALE: VERT. 1" = 25'
SCALE: HORZ. 1" = 350'

USCS SYMBOL DEFINITIONS

CL = CLAY
SC = CLAYEY SAND
SP/SC = POORLY SORTED CLAYEY SAND
ML = SILT
SM = SILTY SAND
SP = SAND
SM/SC = SILTY CLAYEY SAND

40-SP — UNIFIED SOIL CLASSIFICATION SYMBOL (USCS)
40 — DEPTH LAYER BEGINS BELOW GROUND SURFACE

LEGEND

BGS BELOW GROUND SURFACE
— — — — RED BROWN SILTY CLAY (MILLER CREEK FORMATION)
—— · —— · —— CLAY & SILTY SAND (MILLER CREEK FORMATION)
———— RST - RED & WHITE LAYERED SANDSTONE (CHEQUAMEGON SANDSTONE)
—— - - —— - - —— PST - PURPLE W/ WHITE MOTTLES SANDSTONE (CHEQUAMEGON SANDSTONE)
———— GW GROUNDWATER
▽ G.W.EL. 505.87 = GROUNDWATER ELEVATIONS (12/2/98)
— ROAD

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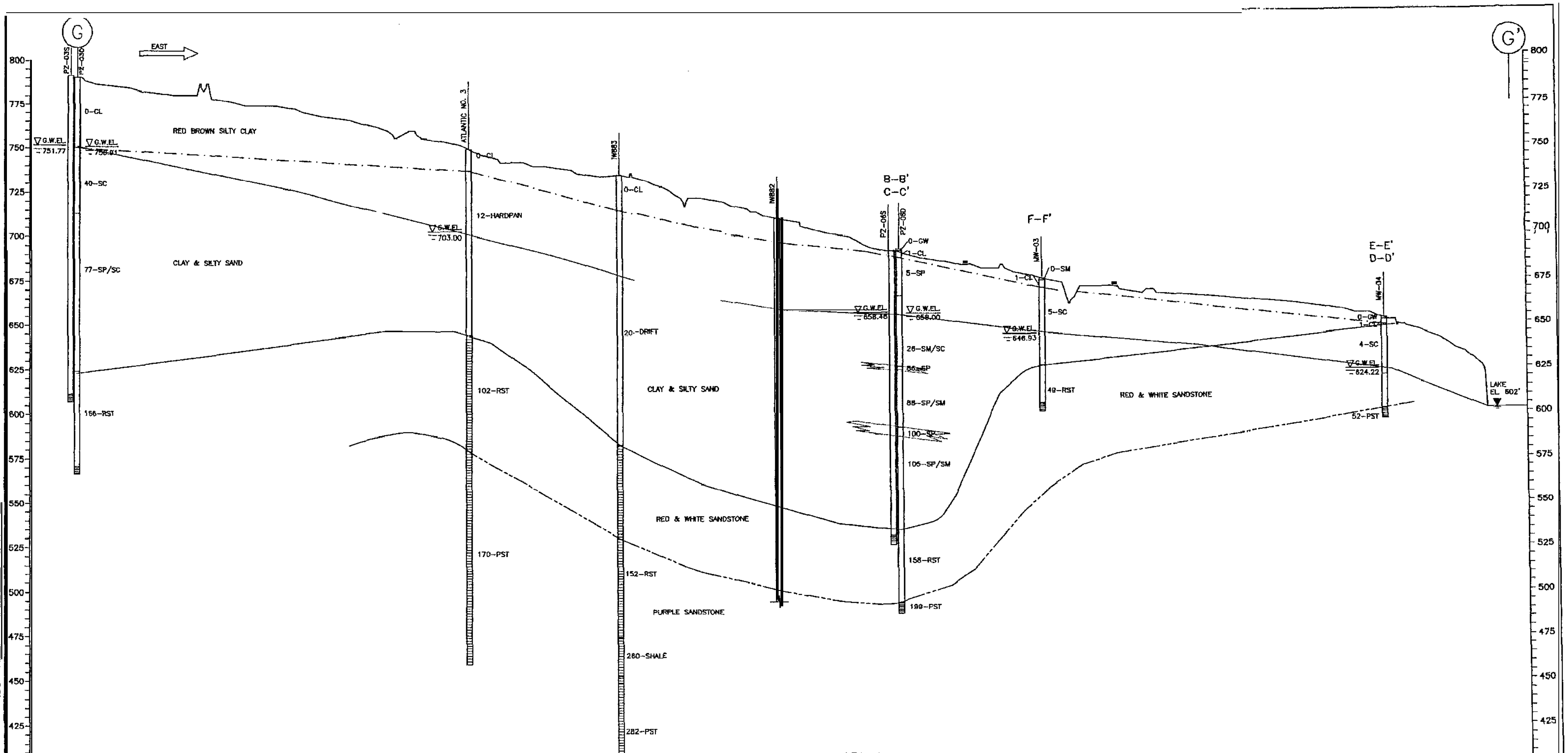
FORMER BARKSDALE WORKS BARKSDALE, WISCONSIN

GEOLOGIC CROSS SECTION F-F'
GROUNDWATER INVESTIGATION

REVISION
PROJECT 44D4BA7191
DRAWING
10
FIGURE OF



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ML = SILT
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SP = SAND
SM/SC = SILTY CLAYEY SAND
40-SP — UNIFIED SOIL CLASSIFICATION SYMBOL (USCS)
— DEPTH LAYER BEGINS BELOW GROUND SURFACE

CROSS SECTION G-G'

SCALE: VERT. 1" = 25'
SCALE: HORZ. 1" = 350'

LEGEND

BGS BELOW GROUND SURFACE
RED BROWN SILTY CLAY (MILLER CREEK FORMATION)
CLAY & SILTY SAND (MILLER CREEK FORMATION)
RST - RED & WHITE LAYERED SANDSTONE (CHEQUAMEGON SANDSTONE)
PST - PURPLE W/ WHITE MOTTLES SANDSTONE (CHEQUAMEGON SANDSTONE)
GW GROUNDWATER
G.W.EL. 505.87 = GROUNDWATER ELEVATIONS (12/2/98)
ROAD

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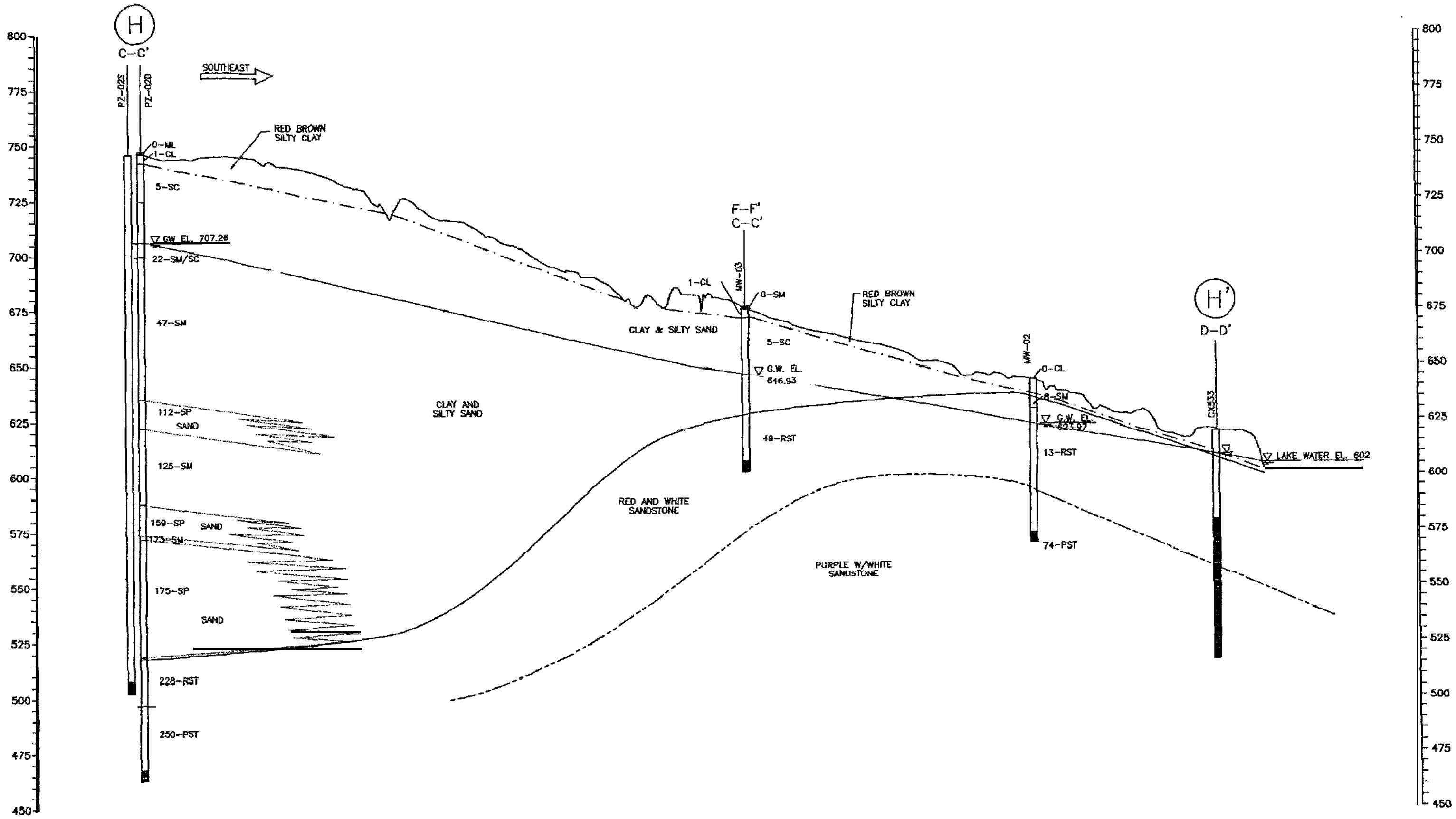
FORMER BARKSDALE WORKS BARKSDALE, WISCONSIN

GEOLOGIC CROSS SECTION G-G'
GROUNDWATER INVESTIGATION

REVISION
PROJECT 44D4BA7191
DRAWING 11
FIGURE OF



CROSS SECTION H-H'

SCALE: VERT. 1" = 25'
SCALE: HORZ. 1" = 350'

USCS SYMBOL DEFINITIONS

CL = CLAY
SC = CLAYEY SAND
SP/SC = POORLY SORTED CLAYEY SAND
ML = SILT
SM = SILTY SAND
SP = SAND
SM/SC = SILTY CLAYEY SAND

40-SP — UNIFIED SOIL CLASSIFICATION SYMBOL (USCS)
— DEPTH LAYER BEGINS BELOW GROUND SURFACE

LEGEND

BGS BELOW GROUND SURFACE
— — — — RED BROWN SILTY CLAY (MILLER CREEK FORMATION)
— · — · — CLAY & SILTY SAND (MILLER CREEK FORMATION)
———— RST ~ RED & WHITE LAYERED SANDSTONE (CHEQUAMEGON SANDSTONE)
- - - - - PST ~ PURPLE W/ WHITE MOTTLES SANDSTONE (CHEQUAMEGON SANDSTONE)
———— GW GROUNDWATER
▽ G.W.EL. 505.87 = GROUNDWATER ELEVATIONS (12/2/98)
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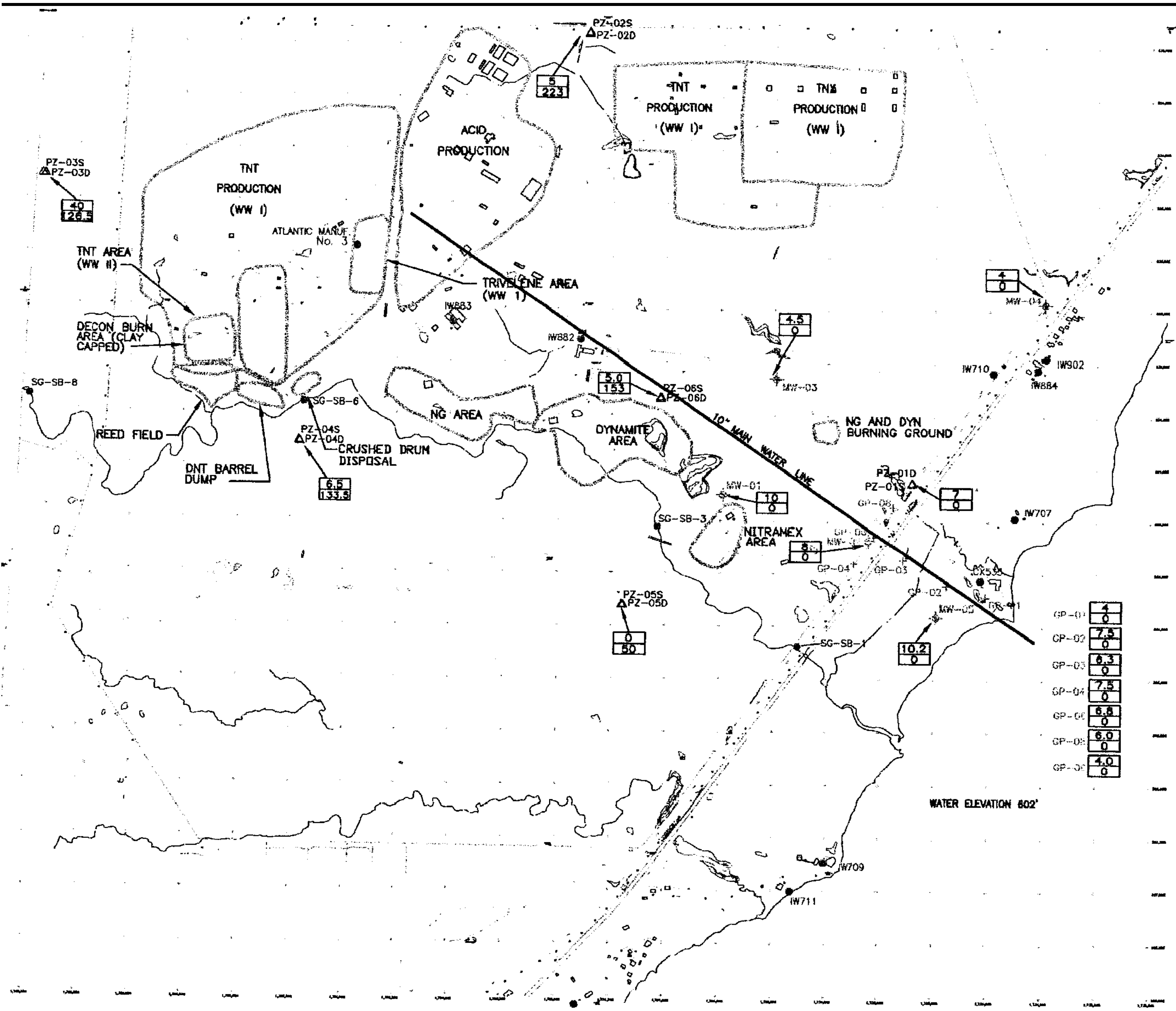
DATE	4/30/99

FORMER BARKSDALE WORKS — BARKSDALE, WISCONSIN

GEOLOGIC CROSS SECTION H-H'
GROUNDWATER INVESTIGATION

REVISION	△
PROJECT	44D4BA7191
DRAWING	12
FIGURE	OF



LEGEND

- MW-01 MONITORING WELL
- PZ-01S PIEZOMETER
- SG-SB-3 STREAM GAUGE – SEDIMENT SAMPLING POINT
- IW707 GROUNDWATER WELLS
- GP-02 GEO-PROBE

N — CLAY THICKNESS (FT) (GLACIAL LAKE DEPOSITS)
N — SILTY CLAYEY SAND THICKNESS (FT) (GLACIAL TILL DEPOSITS)

1000 0 1000
SCALE IN FEET

NOTES:
1. RED AND WHITE BANDED CHEQUAMEGON SANDSTONE PRESENT BELOW GLACIAL DEPOSITS.
2. TOTAL THICKNESS OF GLACIAL DEPOSITS EQUALS CLAY THICKNESS + SILTY CLAYEY SAND THICKNESS i.e.

40 / 126.5 = 166.5 FEET OF GLACIAL DEPOSITS

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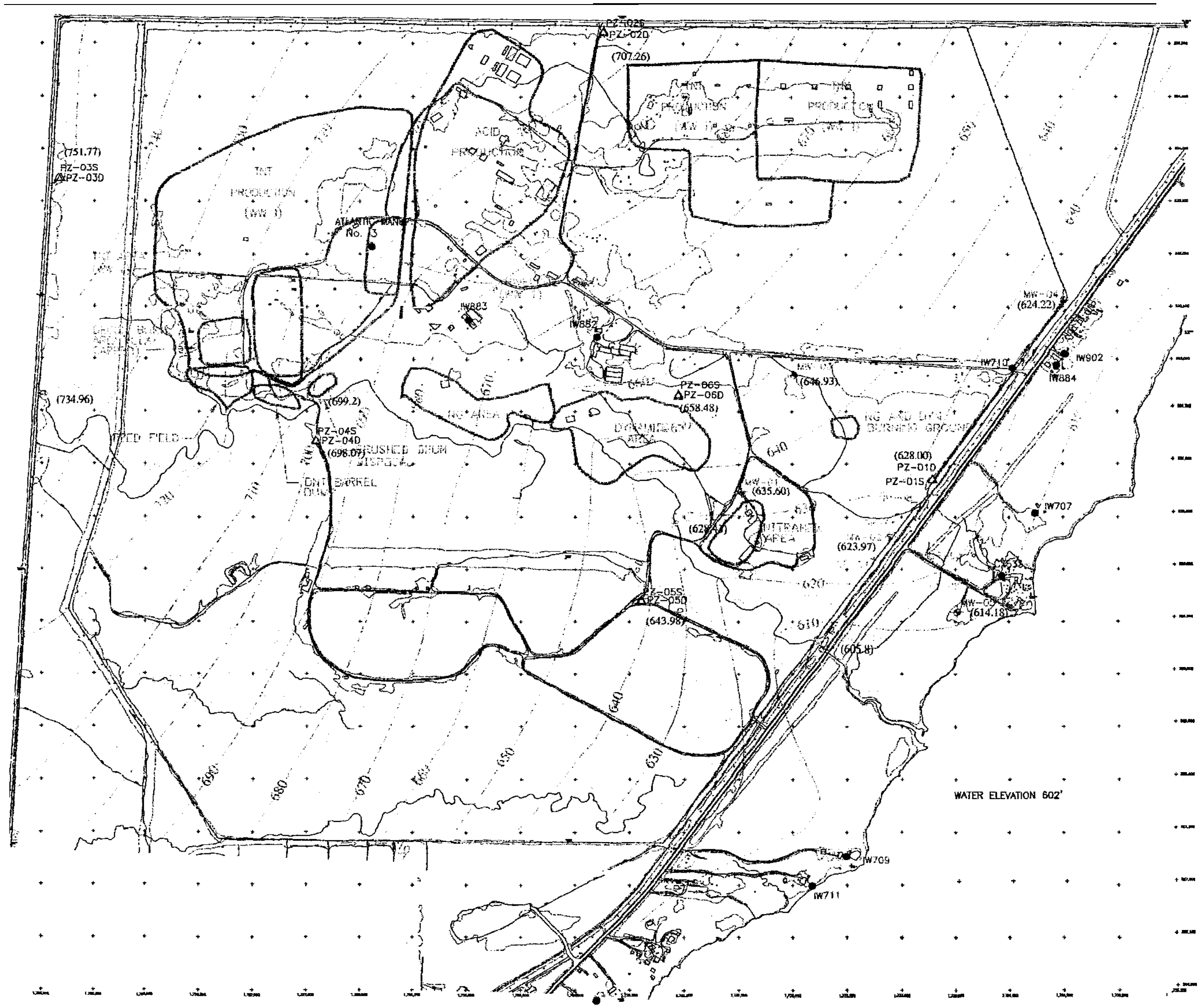
FORMER BARKSDALE WORKS
BARKSDALE, WISCONSIN
TOTAL THICKNESS OF GLACIAL DEPOSITS

DRN BY: SWH	DATE: APR. 1999	PROJECT NO. 44D4BA7191	FIG. NO. 13
CHK'D BY:	DATE:		

.DWG



LEGEND

- MW-01 — MONITORING WELL
- △ PZ-01S — PIEZOMETER
- STREAM GAUGE – SEDIMENT SAMPLING POINT
- ● IW707 — GROUNDWATER WELLS
- GEO-PROBE
- 610 — 10 FOOT GROUNDWATER CONTOURS
- 610 — INFERRED GROUNDWATER CONTOURS

N

500 0 500
SCALE IN FEET

NOTE:
ALL HISTORICAL MUNITIONS PRODUCTION AREAS HAVE BEEN REMOVED.

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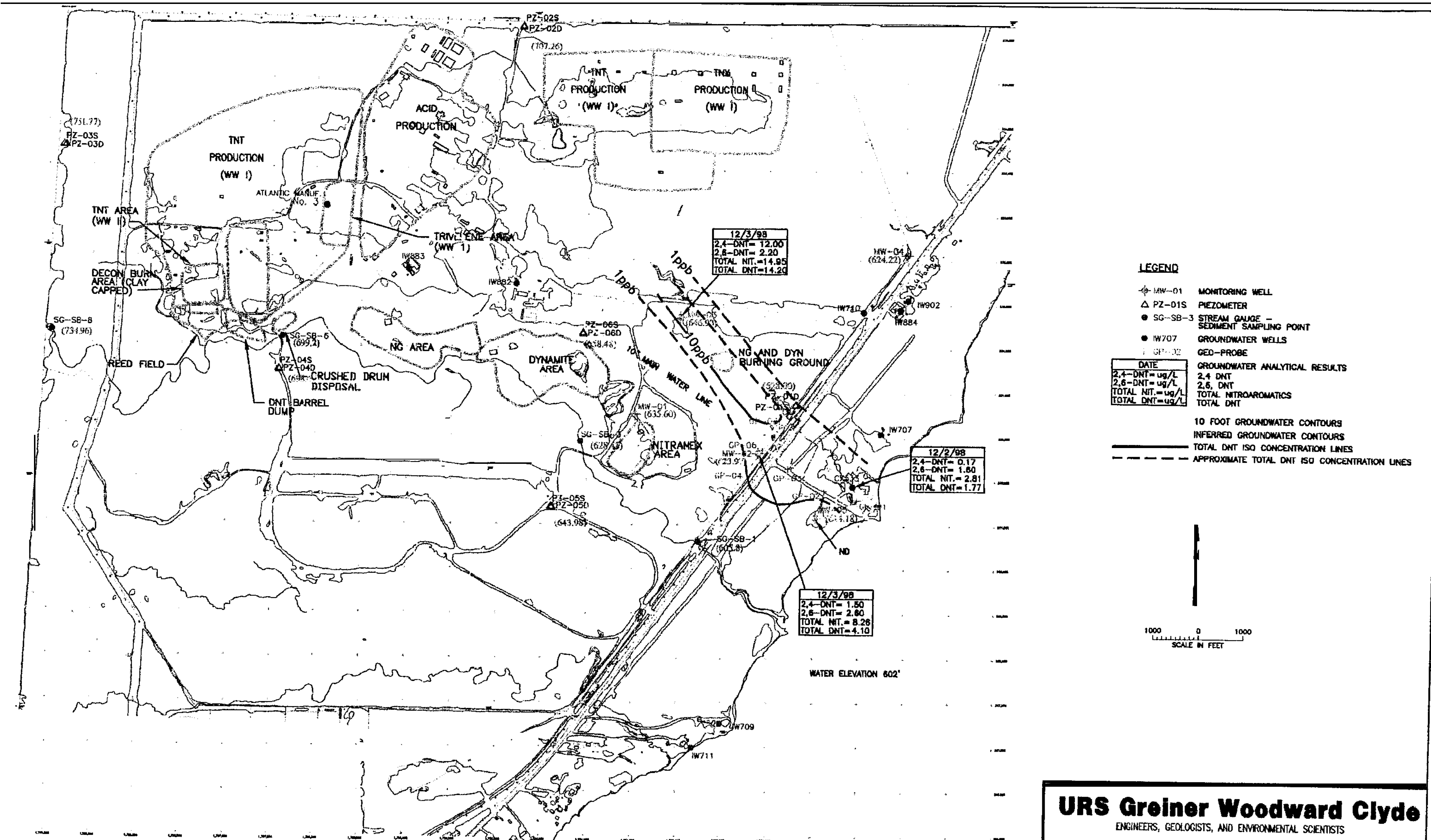
FORMER BARKSDALE WORKS — BARKSDALE, WISCONSIN

GROUNDWATER ELEVATION CONTOURS
DECEMBER 2, 1998

REVISION △
PROJECT 44DA8A7191
DRAWING
FIGURE 14 OF



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FORMER BARKSDALE WORKS
BARKSDALE, WISCONSIN
EXTENT OF IMPACTS IN GROUNDWATER

DRN BY: SWH	DATE: APR. 1999	PROJECT NO. 44D4BA7191	FIG. NO. 15
CHK'D BY:	DATE:		

91-13.DWG

Table 1
Soil Field Screening Results
1998 Groundwater Investigation
Former Barksdale Works, Barksdale, Wisconsin
WC-D Project D4BA7191

Location	Northing	Easting	Surface Result			Other Depths		
units	ft	ft		(ft bgs/result)	(ft bgs/result)	(ft bgs/result)	(ft bgs/result)	(ft bgs/result)
MW-01	530749.5	1731525.5	N.D.	3 / ND	6 / ND	10 / ND		
MW-02	530315.0	1732892.0	N.D.	8 / ND				
MW-03	531848.0	1732017.2	N.D.	29 / weak dynamite or NG				
MW-04	532563.4	1734516.5	N.D.					
Mw-05	529591 .1	1733519.3	N.D.					
PZ-01 s	530852.0	1733294.3	N.D.					
PZ-02S	535116.1	1730269.0	N.D.					
PZ-03S	533713.7	1725150.3	N.D.					
PZ-04S	531223.2	1727579.6	N.D.					
PZ-05S	529690.9	1730605.5	N.D.					
PZ-06S	531659.9	1730951.7	N.D.	8 / ND				
PZ-OID	530856.9	1733297.8	N.D.					
PZ-02D	535101.7	1730264.8	N.D.					
PZ-03D	53371 1.7	1725172.2	N.D.	4 / ND	13 / ND	40 / ND	77 / ND	179 / ND
PZ-04D	531215.3	1727584.7	N.D.					
PZ-05D	529689.0	1730616.4	N.D.					
PZ-06D	531643.8	1730950.5	N.D.	8 / ND				
GP-01	529780.0	1733978.0	N.D.	7.5 / ND				
GP-02	529890.0	1733616.0	N.D.	7.5 / ND				
GP-03	530131.0	1733215.0	N.D.	8 / ND				
GP-04	530095.0	1732755.0	N.D.					
GP-06	530357.0	1732939.0	N.D.	8 / ND				
GP-08	530637.0	1733121.0	N.D.					
GP-09	530702.0	1733210.0	N.D.	4 / ND	7 / ND			
Water Line	529732.4	1733948.1	N.D.	3 / ND	6 / ND			
Water Line	531603.6	1730962.9	N.D.	4 / ND	7 / ND			
Water Line	530347.9	1732835.8	N.D.	3 / ND	6 / ND			

Table 2
Soil Analytical Results
1998 Groundwater Investigation
Former Barksdale Works, Barksdale, Wisconsin
WC-D Project D4BA7191

Nitroaromatics and Nitroamines (ug/kg)	BAR-S-GP01 (6-7.5)	BAR-S-GP02 (6-7.5)	BAR-S-GP03 (6-8.0)	BAR-S-GP06 (6-8)	BAR-S-CA01 (6-6.8)	BAR-S-CA02 (7-7.5)	BAR-S-CA03 (6-6.5)
Date Sampled	9/15/98	9/15/98	9/15/98	9/22/98	8/26/98	9/8/98	9/15/98
HMX	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
1,3,5-TNB	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
RDX	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
1,3-DNB	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
2,4,6-TNT	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Tetryl	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Nitrobenzene	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
Nitroglycerin	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
2,4-DNT	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
2-Am-DNT	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
2,6-DNT	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
4-Am-DNT	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
2-&4-NT	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
PETN	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
3-NT	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25

Table 3
Groundwater and Surface Water Elevations
1998 Groundwater Investigation
Former Barksdale Works, Barksdale, Wisconsin
WC-D Project D4BA7191

Location	Northing	Easting	Riser Top	Date	Depth to Water	Water Elevation
Units	ft	ft	ft msl		ft	ft msl
MW-01	530749.5	1731525.5	670.56	12/2/98	34.96	635.60
MW-02	530315.0	1732892.0	646.13	12/2/98	22.16	623.97
MW-03	531848.0	1732017.2	679.65	12/2/98	32.72	646.93
MW-04	532563.4	1734516.5	654.67	12/2/98	30.45	624.22
MW-05	529591.1	1733519.3	623.02	12/2/98	8.84	614.18
PZ-01S	530852.0	1733294.3	645.55	12/2/98	17.55	628.00
PZ-02s	535116.1	1730269.0	749.57	12/2/98	42.31	707.26
PZ-03S	533713.7	1725150.3	792.69	12/2/98	40.92	751.77
PZ-04s	531223.2	1727579.6	743.81	12/2/98	45.74	698.07
PZ-05S	529690.9	1730605.5	670.21	12/2/98	26.23	643.98
PZ-06S	531659.9	1730951.7	695.32	12/2/98	36.84	658.48
PZ-01D	530856.9	1733297.8	645.54	12/2/98	17.81	627.73
Pi!-02D	535101.7	1730264.8	749.41	12/2/98	25.94	723.47
PZ-03D	533711.7	1725172.2	792.26	12/2/98	41.35	750.91
PZ-MD	531215.3	1727584.7	744.02	12/2/98	45.6	698.42
PZ-05D	529689.0	1730616.4	670.20	12/2/98	30.23	639.97
PZ-06D	531643.8	1730950.5	696.05	12/2/98	38.05	658.00
GP-01	529780.0	1733978.0	na	9/22/98	na	dry
GP-02	529890.0	1733616.0	na	9/22/98	na	dry
GP-03	530131.0	1733215.0	na	9/22/98	na	dry
GP-04	530095.0	1732755.0	na	9/22/98	na	623.00
GP-06	530357.0	1732939.0	na	9/22/98	na	624.20
GP-08	530637.0	1733121.0	na	9/22/98	na	625.00
GP-09	530702.0	1733210.0	na	9/22/98	na	dry
SG-SB-1	529308.9	1732228.1	605.38	11/12/98	0.4	605.78
SG-SB-3	530442.3	1730927.4	627.25	11/12/98	1.18	628.43
SG-SB6	531593.7	1727621.2	698.48	11/12/98	0.75	699.23
SG-SB-8	531639.7	1725033.8	734.81	11/12/98	0.15	734.96

'Riser Top Elevation" at staff gages is the "0.0" mark elevation.

Table 4a
Well and Piezometer Hydraulic Conductivity Results
1998 Groundwater Investigation
Former Barksdale Works, Barksdale, Wisconsin
WC-D Project D4BA7191

Location	Northing	Easting	GW Elevation	Elev of Screen Centerline	Geologic Layer at Screen	Falling K	Rising K	Ave. K
Units	ft	ft	ft msl	ft msl		ft/sec	ft/sec	cm/sec
MW-01	530750	1731526	635.60	591.16	purple sandstone	9.75E-04	5.88E-04	7.82E-04
MW-02	530315	1732892	623.97	572.78	red & purple sandstones	6.22E-04	2.89E-04	4.55E-04
MW-03	531848	1732017	646.93	605.80	red sandstone	1.02E-03	5.43E-04	7.80E-04
MW-04	532563	1734517	624.22	598.84	red & purple sandstones	3.14E-04	1.22E-03	7.65E-04
MW-05	529591	1733519	614.18	532.97	red & purple sandstones	6.61 E-04	3.57E-04	5.09E-04
PZ-01s	530852	1733294	628.00	622.02	till & red sandstone	3.04E-03	1.02E-03	2.03E-03
PZ-02s	535116	1730269	707.26	505.87	red sandstone	1.88E-04	6.25E-04	4.06E-04
PZ-03s	533714	1725150	751.77	609.46	red sandstone	6.83E-04	1.22E-03	9.49E-04
PZ-04s	531223	1727580	698.07	574.01	red sandstone	3.47E-04	6.86E-04	5.17E-04
PZ-05s	529691	1730606	643.98	605.73	red sandstone	6.98E-04	2.07E-03	1.38E-03
PZ-06S	531660	1730952	658.48	530.04	red sandstone	2.82E-03	1.13E-03	1.98E-03
PZ-01 D	530857	1733298	627.73	580.20	red sandstone	7.35E-04	1.61 E-03	1.17E-03
PZ-02D	535102	1730265	723.47	466.01	purple sandstone	2.12E-03	2.87E-03	2.49E-03
PZ-03D	533712	1725172	750.91	569.18	red sandstone	1.91 E-03	1.61 E-03	1.76E-03
PZ-MD	531215	1727585	698.42	533.05	purple sandstone	3.90E-04	2.35E-03	1.37E-03
PZ-05D	529689	1730616	639.97	565.23	red sandstone	1.46E-03	7.65E-04	1.11E-03
PZ-06D	531644	1730951	658.00	490.75	purple sandstone	4.75E-03	5.06E-03	4.91 E-03

Table 4b
Formation Hydraulic Conductivity Results
1998 Groundwater Investigation
Former Barksdale Works, Barksdale, Wisconsin
WC-D Project D4BA7191

Lithology in Well Screen	Number of Wells	Number of Data Points *	Median Hydraulic Conductivity (cm/sec) *	Range of Hydraulic Conductivity Values (cm/sec) *
Till & Red Sandstone (1,2)	1	2	0.0011	7.35E-04 to 1.61 E-03
Red Sandstone (2)	9	18	0.0018	3.90E-04 to 5.06E-03
Red & Purple Sandstones (2,3)	3	6	0.0006	2.89E-04 to 1.22E-03
Purple Sandstone (3)	4	8	0.0009	1.88E-04 to 2.82E-03

Notes:

* Hydraulic conductivity values for both the slug-in and slug-out methods were utilized in these calculations
1) Glacial Till consist of silty, clayey sand.
2) The Red Sandstone consist of red and white layered sandstone of the Chequamagon Sandstone.
3) The Purple Sandstone consist of purple and white mottled sandstone of the Chequamagon Sandstone.

Table 5
Groundwater Analytical Results
1998 Groundwater Investigation
Former Barksdale Works, Barksdale, Wisconsin
WC-D Project D4BA7191

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ES	PAL	Sample Date	12/2/98	12/2/98	12/2/98	12/2/98	12/2/98	12/2/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3/98	12/3
		Water Depth (ft TOR)							34.96		22.16		32.72		30.45		8.84									
		Field pH (SU)							8.60		8.30		7.40		6.90		8.50									
		Field Conductivity (mS/cm)							0.20		0.76		0.40		0.33		0.30									
		Field Temp (C)							10.20		10.10		11.80		10.30		15.00									
		Turbidity (NTU)							19.00		2.00		14.00		5.00		502.00									
		Nitroaromatics and Nitramines (ug/L)																								
		HMX	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26	
		1,3,5-TNB	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26	
		RDX	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26	
		1,3-DNB	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		0.02		< 0.26		< 0.26		0.05		0.08		< 0.26		< 0.26	
		2,4,6-TNT	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		0.20		0.09		< 0.26		0.24	
		Tetryl	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26	
		Nitrobenzene	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26	
		Nitroglycerin	< 0.50		< 0.50		< 0.50		< 0.50		< 0.50		< 0.50		< 0.50		< 0.50		< 0.50		< 0.50		< 0.50		< 0.50	
0.05	0.005	2,4-DNT	0.17		< 0.26		<0.26		< 0.26		1.50		12.00		< 0.26		< 0.26		0.90		1.20		< 0.26		0.20	
		2-Am-DNT	0.48		< 0.26		< 0.26		< 0.26		2.00		0.24		< 0.26		< 0.26		0.79		0.87		< 0.26		0.51	
0.05	0.005	2,6-DNT	1.60		< 0.26		< 0.26		< 0.26		2.60		2.20		< 0.26		< 0.26		1.30		1.70		< 0.26		0.32	
		4-Am-DNT	0.56		< 0.26		< 0.26		< 0.26		2.00		0.24		< 0.26		< 0.26		1.40		1.60		< 0.26		1.10	
		2-&4-NT	< 0.26		< 0.26		< 0.26		< 0.26		0.16		0.25		< 0.26		< 0.26		< 0.26		0.17		< 0.26		< 0.26	
		PETN	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26	
		3-NT	< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26		< 0.26	
		Total Nitroaromatics	2.81		0.00		0.41		0.00		8.26		14.95		0.00		0.00		4.64		5.71		0.00		2.50	
		Total DNT	1.77		0.00		0.00		0.00		4.10		14.20		0.00		0.00		2.20		2.90		0.00		0.63	
		[illegible]																								
		Calcium	39600	41700			15500	15900	18400		107000		40000		40300		18300		23600		24900		10900		8100	
300	150	Iron	<100	<100	130	<100	1300	1200	2100	<100	300	<100	3800	<100	200	<100	14000	<100	2600	450	3300	890	4400	660	4200	55
		Magnesium	15500	16900			< 5000	5300	7300		44100		37800		10700		7000		11400		12700		< 5000		< 5000	
		Potassium	< 5000	< 5000			< 5000	< 5000	< 5000		< 5000		5200		< 5000		7900		< 5000		< 5000		< 5000		< 5000	
		Sodium	8100	8400			5300	5200	< 5000		23500		16200		5600		< 5000		< 5000		< 5000		< 5000		< 5000	
		[illegible]																								
		Alkalinity, Total (as CaCO3)	142000				71800																			
		Alkalinity, Bicarb. (as CaCO3)	142000				71800																			
		Alkalinity, Carb. (as CaCO3)	< 5000				< 5000																			
		Ammonia	< 100				< 100																			
		Bromide	< 500				< 500		< 500		< 500		< 500		< 500		< 500		< 500		< 500		< 500		< 500	
250000	125000	Chloride	1200				5200		4100		4800		4800		1500		5900		6800		7500		6600		5600	
4000	800	Fluoride	< 1000				790		< 500		< 500		< 500		< 500		600		< 500		< 500		< 500		< 500	
10000	2000	Nitrate	1900		< 50		53		71		44800		59		170		< 50		36		32		64		61	
1000	200	Nitrite	< 50		< 50		< 50		< 50		78		< 50		< 50		< 50		< 50		< 50		< 50		< 50	
		Nitrogen, Total Kjeldahl	< 500				< 500																			
		Organic Carbon, Total	< 1000		< 1000		< 1000																			
		Solids, Total Dissolved	228000		117000		73000																			
		Solids, Total Suspended	< 5000		< 5000		< 5000																			
250000	125000	Sulfate	28700		4000		3000		3400		91500		49500		22800		3400		35900		42800		8700		7600	
		Sulfide, Total	< 50		< 50		< 50																			

Table 6
Monitoring Well & Piezometer Construction Summary
1998 Groundwater Investigation
Former Barksdale Works, Barksdale, Wisconsin
WC-D Project D4BA7191

Location	Northing (State Coord) ft	Easting (State Coord) ft	Drilling started	Installation finished	Development finished	Riser Elev ft msl	Ground Surface Elev ft msl	Well Screen Top ft msl	Screen Well Bottom ft msl	Filter Sand Top ft msl	Fine Sand Top ft msl	Bentonite Seal Top ft msl	Dec 1998 GW Elev. ft msl
MW-01	530749.5	1731525.5	24-Sep-98	24-Sep-98	16-Oct-98	670.66	668.76	593.66	586.86	595.76	596.76	668.76	635.60
MW-02	530315.0	1732892.0	13-Oct-98	14-Oct-98	15-Oct-98	646.13	644.31	575.28	568.46	576.81	577.81	644.31	623.97
MW-03	531848.0	1732017.2	28-Sep-98	29-Sep-98	16-Oct-98	679.65	678.13	608.30	601.78	610.13	611.33	678.13	646.93
MW-04	532563.4	1734516.5	28-Sep-98	28-Sep-98	13-Oct-98	654.67	652.83	601.34	594.50	604.83	606.33	652.83	624.22
MW-05	529591.1	1733519.3	19-Oct-98	22-Oct-98	21-Oct-98	623.02	621.07	535.47	528.52	536.07	537.07	546.07	614.18
PZ-01S	530852.0	1733294.3	23-Sep-98	23-Sep-98	13-Oct-98	645.55	643.38	624.52	617.35	625.88	628.38	643.38	628.00
PZ-02s	535116.1	1730269.0	20-Oct-98	22-Oct-98	23-Oct-98	749.57	747.65	508.37	501.45	514.65	515.85	527.65	707.26
PZ-03s	533713.7	1725150.3	21-Oct-98	23-Oct-98	30-Oct-98	792.69	790.69	611.96	604.96	613.69	614.69	620.69	751.77
PZ-04s	531223.2	1727579.6	05-Oct-98	06-Oct-98	14-Oct-98	743.81	741.96	576.51	569.66	578.96	579.96	586.96	698.07
PZ-05S	529690.9	1730605.5	30-Sep-98	30-Sep-98	15-Oct-98	670.21	668.21	608.23	601.23	610.21	611.71	620.21	643.98
PZ-06S	531659.9	1730951.7	12-Oct-98	19-Oct-98	20-Oct-98	695.32	692.97	532.54	525.19	528.97	529.47	540.97	658.48
PZ-01 D	530856.9	1733297.8	22-Sep-98	23-Sep-98	13-Oct-98	645.54	643.66	582.70	575.82	585.66	586.66	592.66	627.73
PZ-02D	535101.7	1730264.8	14-Oct-98	22-Oct-98	22-Oct-98	749.41	747.46	468.51	461.56	474.46	475.96	487.46	723.47
PZ-03D	533711.7	1725172.2	15-Sep-98	24-Sep-98	21 -Ott-98	792.26	790.31	571.68	564.73	574.01	575.81	581.21	750.91
PZ-04D	531215.3	1727584.7	30-Sep-98	05-Oct-98	14-Oct-98	744.02	742.32	535.55	528.85	539.32	540.82	552.32	698.42
PZ-05D	529689.0	1730616.4	29-Sep-98	30-Sep-98	15-Oct-98	670.20	668.38	567.73	560.91	570.38	571.88	578.38	639.97
PZ-06D	531643.8	1730950.5	06-Oct-98	12-Oct-98	20-Oct-98	696.05	693.55	493.25	485.75	495.55	497.05	507.05	658.00

Note: All wells are constructed of schedule 80 PVC with 5 ft long 0.02 inch factory cut slotted screens.

Table 7
Water System Pipeline Water Analytical Results
1998 Groundwater Investigation
Former Barksdale Works, Barksdale, Wisconsin
WC-D Project D4BA7191

W.A.C. NR-140			BAR-W-CA01	BAR-W-CA03a	BAR-W-CA03b
ES	PAL	Sample Date	8/26/98	9/15/98	9/15/98
		HMX	< 0.26	< 0.26	< 0.26
		1,3,5-TNB	< 0.26	< 0.26	< 0.26
		RDX	< 0.26	< 0.26	< 0.26
		1,3-DNB	< 0.26	< 0.26	< 0.26
		2,4,6-TNT	< 0.26	< 0.26	< 0.26
		Tetryl	< 0.26	< 0.26	< 0.26
		Nitrobenzene	< 0.26	< 0.26	< 0.26
		Nitroglycerin	< 0.50	< 0.50	< 0.50
0.05	0.005	2,4-DNT	< 0.26	< 0.26	< 0.26
		2-Am-DNT	< 0.26	< 0.26	< 0.26
0.05	0.005	2,6-DNT	< 0.26	< 0.28	< 0.26
		4-Am-DNT	< 0.28	< 0.26	< 0.26
		2-&4-NT	< 0.26	< 0.28	< 0.26
		PETN	< 0.26	< 0.26	< 0.26
		3-NT	< 0.26	< 0.26	< 0.26
		Total Nitroaromatics	0.00	0.00	0.00
		Total DNT	0.00	0.00	0.00