WATERLOO BARRIER® SYSTEM INSTALLATION REPORT

BAY SHORE FORMER MGP SITE AND ASSOCIATED OFF-SITE AREA OPERABLE UNIT No.1 Bay Shore, Suffolk County, New York

Prepared for:

National Grid
175 East Old County Road
Hicksville, New York 11801

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August 2008

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August 15th, 2008

National Grid
175 East Old County Road
Hicksville, New York 11801

Attention: Mr. William Ryan, Project Manager

Re: Waterloo Barrier® QA/QC Report - Bay Shore Former MGP Site and Associated Off-site Area Operable Unit No.1 (OU-1) Bay Shore, Suffolk County, New York

Dear Mr. Ryan:

The enclosed report provides detailed records of the sheet pile and sealant installation for the Waterloo Barrier® System at the site named above. The installation of five (5) bentonite-filled drilled shafts utilized to close the gap in the Waterloo Barrier® subsurface containment barrier wall is also documented. This system was installed between May 3rd, 2007 and May 9th, 2008.

The data and information enclosed in this report is confidential. The information is intended for the sole use of National Grid and the New York State Department of Environmental Conservation. Any disclosure, copying or use of the contents of this report is expressly prohibited without the written consent of C3 Environmental Limited.

If, upon review of this report, any questions arise regarding the content or work completed, please contact the undersigned at your earliest convenience.

Yours truly,
C3 ENVIRONMENTAL LIMITED

Jeff Clark, P.Eng.
Project Manager

EXECUTIVE SUMMARY

This report provides details of the installation of a Waterloo Barrier® subsurface containment barrier wall between May 3rd, 2007 and May 9th, 2008 at the Bay Shore former MGP site and associated off-site area operable unit no.1 (OU-1) Bay Shore, Suffolk County, New York.

C3 Environmental Limited (hereafter referred to as C3) was contracted by National Grid (hereafter referred to as KeySpan) to perform the General Contracting for the installation of a subsurface containment barrier at the Bay Shore former MGP site. C3 as a licensed Waterloo Barrier® installer was also to complete the Quality Assurance/Quality Control (QA/QC) inspection of the installation of the barrier wall at the site and complete the joint sealing for the barrier wall. JD Posillico (hereafter referred to as JDP) was contracted by C3 to conduct pile driving and drilled shaft installations for the barrier wall.

The barrier wall was installed on the site using the WEZ95 profile of Waterloo Barrier® sheet piling following layout as planned by Paulus, Sokolowski and Sartor (hereafter referred to as PS&S) and five (5) bentonite [Holeplug®]-filled drilled shafts.

The pre-packaged silica fume-modified, cement based grout, WBS-301, was used to seal the joints of the Waterloo Barrier® wall. Detailed records were collected for each sheet pile installed and each joint grouted. Permeability testing of the WBS-301 grout is ongoing and will be forwarded, when completed, as an attachment for the report.

The area of the installed Waterloo Barrier® sheet piling was approximately 46,783 square feet. Approximately 21,569 lineal feet of sealable cavity were grouted, as indicated in the project records.

Based upon the results of C3's QA/QC inspection, the Waterloo Barrier® and drilled shaft installations generally conformed to the procedures and specifications necessary to provide a low permeability groundwater barrier meeting the design parameters of 1×10^{-5} cm/sec. A Statement of Certification for the installation is provided in Appendix A.

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1. WATERLOO BARRIER® SYSTEM DEVELOPMENT

The Waterloo Barrier® is a low hydraulic conductivity groundwater containment system, which was developed by the Centre for Groundwater Research at the University of Waterloo, under the direction of Professor John Cherry. This patented system is composed of the following two basic elements:

- Custom rolled steel sheet piling incorporating a sealable cavity at the joint, and
- Site specific grouts used for sealing the Waterloo Barrier® joints.

The Waterloo Barrier® piling used at the Bay Shore OU-1 project was the WEZ95 profile, cold-rolled to produce a sealable cavity at the joints. The sheet piling is 9.5 mm (0.375 inch) thick and has been rolled to a length of 80 feet. The patented section produced by this rolling method has the following advantages:

- It provides a cavity that can be inspected and can be used to confirm the integrity of the sheets and joints after driving, and
- It provides a controlled leak path that can be sealed with various grouting compounds.

2. PROJECT OVERVIEW

The Waterloo Barrier® subsurface containment barrier wall was installed between May 3rd, 2007 and May 9th, 2008 at the Bay Shore Former MGP Site, located in Bay Shore, New York.

The Waterloo Barrier® subsurface containment barrier wall was constructed from 292 pieces of WEZ95 sheet piling and five (5) bentonite-filled drilled shafts. The sheet piles were installed to depths ranging from 46.8 to 65.4 feet below msl, as indicated in the project records and sheet pile driving logs. Rollform Group of Cambridge, Ontario, manufactured all of the necessary sheet piles.

C3 was responsible for the barrier system installation, including the joint sealing and drilled shaft installation. In order to complete the installation of the barrier system successfully, C3 implemented a QA/QC program for the installation of the sheet piling, joint sealant and drilled shaft installation. The three programs are summarized in the following sections.

2.1 Sheet Pile QA/QC

The QA/QC program for the sheet pile installation included the following items:

- Visual inspection of the WEZ95 sheet piles prior to installation;
- Monitoring of sheet pile driving, including documentation of driving times for each pile and/or pile pair, and documentation of the vertical alignment of each sheet pile;
- Inspection of the sealable cavities by flushing/probing of each joint to confirm that it was free of obstructions and installed to the required depth, and
- Surveying the final elevation of the top of each sheet pile.

2.2 Joint Sealant QA/QC

The QA/QC program for the joint sealant installation included the following items:

- Flushing of loose material from the sealable cavities of the WEZ95 sheet piles;
- Monitoring of the sealant mixing;
- Random sampling of the sealant during installation to confirm its physical characteristics, and
- Documentation of the grouting times and volumes for each sheet pile joint.

Appendices B through H contain the QA project records for each stage of the sheet pile and sealant installation.

2.3 Drilled Shaft QA/QC

The QA/QC program for the drilled shaft installation included the following items:

- Installation of segmented 1m diameter double walled steel liner;
- Monitoring of the verticality of the liner;
- Confirmation of the excavated depth of the drilled shaft, and
- Monitoring the installation of the Holeplug® material and the removal of the liner.

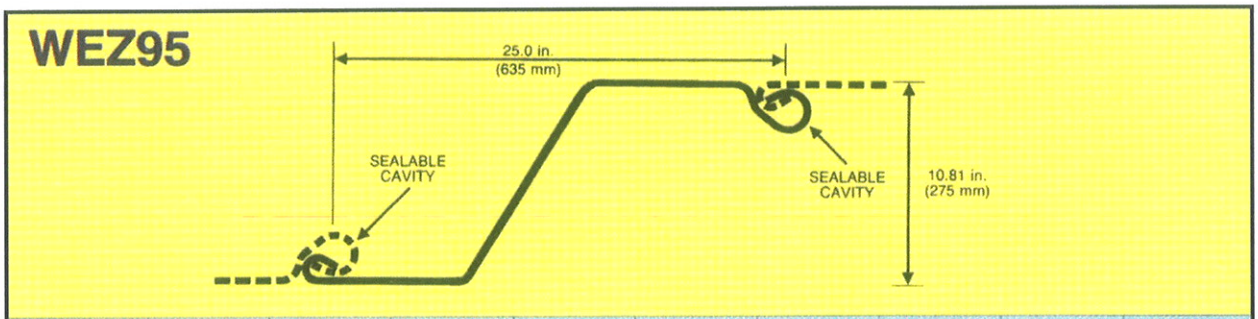
3. WATERLOO BARRIER® SHEET PILE SPECIFICATIONS

The steel sheet piling used to construct the barrier wall at the Bay Shore OU-1 site was the WEZ95 profile of the Waterloo Barrier®. A typical cross-section and general section properties of these sheet piles are shown in Figure 1.

The Waterloo Barrier® WEZ95 sheet piles are patented sections with enlarged female joints that allow the installation of a site-specific sealant material to seal the barrier wall.

A key procedure in ensuring proper installation of the WEZ95 sheet piles is the attachment of a foot plate at the base of every enlarged female joint. The foot plate minimizes the entry of debris through the base of the joint during sheet pile installation.

Foot plates were installed at Rollform Group's shop in Cambridge, Ontario, under the supervision of C3. The installation of the foot plates was completed in accordance with project specifications.



SECTION	THICKNESS in (mm)	HEIGHT in (mm)	NOMINAL WIDTH in (mm)	SECTION AREA in² (cm²)	WEIGHT lbs/lin. ft. (kg/lin. m	WEIGHT lbs/ft² (kg/m²)	MOMENT OF INERTIA in⁴/wall ft. (cm⁴/wall m)	RADIUS OF GYRATION in (mm)	SECTION MODULUS in³/wall ft. (cm³/wall m)
WEZ95	.375 (9.50)	10.81 (275)	25.0 (635)	14.9 (96.2)	50.5 (75.2)	24.3 (119)	134 (18300)	4.33 (110)	24.9 (1340)

Figure 1: WEZ95 Cross-Section

4. SEALANT MATERIAL

A pre-packaged silica fume modified cement based grout, WBS-301, was used to seal the joints of the Waterloo Barrier® sheet piles. WBS-301 consists of a blend of fly ash, silica fume, cement and chemical admixtures which forms a stable and impermeable grout.

4.1 Sealant Mixing Data

Due to the properties of the sealant, a colloidal mixer was required to develop the necessary shear force to mix the materials properly. Table 1 contains general mixing data for the WBS-301 sealant. The Technical Data Sheet for WBS-301 sealant is contained in Appendix I.

Random samples were taken and visually inspected to ensure that the mix was consistent and that proper gel and set times were achieved by the sealant.

Table 1: WBS-301 Mixing Data

DESCRIPTION	REQUIREMENTS
Colloidal mixer:	1400-1700 RPM mixing speed
Mixing time:	2 - 4 minutes
WBS-301 viscosity:	95 - 120 Flow Cone seconds
WBS-301 gel time:	1.5 - 2 hours @ 20 C (68°F)
WBS-301 set time:	6 - 8 hours
WBS-301 cure time:	28 days

5. INSTALLATION EQUIPMENT

5.1 Sheet Pile Installation Equipment

JDP, located in Farmingdale, New York, installed the WEZ95 sheet piles. The equipment used was as follows:

- 140t Truck Crane;
- APE 250 Vibratory Hammer and diesel power unit;
- Man-lift;
- Excavator, and
- Welding and cutting equipment.

Some of the equipment used to install the sheet piling is shown in Photos 1 and 2.

5.2 Drilled Shaft Installation Equipment

The equipment used to install the drilled shafts was:

- Delmag RH-28;
- Man-lift, and
- Excavator.

Some of the equipment used to install the sheet piling is shown in Photos 3.

Photo 1: Pile Driving Equipment

Photo 2: Vibratory Hammer

Photo 3: Delmag RH28 Drill Rig

6. JOINT SEALANT INSTALLATION EQUIPMENT

The sealant installation was completed by C3 using the following equipment:

Mixing Equipment

- Colloidal Mixer with diesel engine, and
- Grout Holding/Agitator Tanks.

Grouting Equipment

- Moyno Progressive Cavity Pump, and
- Grout Lines and Pressure Control Valves.

7. WATERLOO BARRIER® INSTALLATION PROCEDURES

JDP installed the sheet piling by threading each sheet onto the previously driven pile. Sheets were driven such that the male joint was leading in the direction of pile installation. The purpose of this procedure was to ensure that the enlarged joint (female joint) with the foot plate was driven onto the smaller interlock (male joint), thus minimizing the entry of debris into the cavity. This procedure was generally followed for the entire project.

7.1 Sheet Pile Installation Inspection Procedures

The sheet pile Quality Assurance/Quality Control inspection was performed in three stages: visual inspection, pile driving monitoring, and sealable cavity inspection.

7.1.1 Visual Inspection

A visual survey of the Waterloo Barrier® sheet piles was conducted by C3. The following is a brief outline of the inspection points:

1) Surface Condition - the surface of the piles were inspected for defects and/or deformations prior to installation.

2) Sheet Pile Length - each sheet pile was measured to confirm the specified length.

3) Pile Marking - five-foot graduations were marked on the sheet piles to assist in the collection of driving logs during pile installation.

7.1.2 Monitoring of Sheet Pile Driving

Records were collected for each of the sheet piles as they were installed. A C3 QA/QC Engineer/Technician was present on-site during the entire driving process. The following is a brief description of the documented inspection items:

1) Sheet Pile Identification - each sheet pile was numbered for reference purpose

2) Driving Records - driving records were collected on a laptop computer for each sheet pile installed in the Waterloo Barrier® System. These records documented the driving rates and any notes regarding the installation. The Sheet Pile Driving Logs can be found in Appendix D.

3) Driving Depth - the installed depth of the top of each sheet pile was measured and documented.

4) Sheet Pile Alignment – during and after the installation of the sheet piles, the alignment of each pile was recorded using a digital inclinometer. The alignment was measured in two directions, or axes. Refer to Appendix E for the Sheet Pile Driving Summary. See Figure 2 for axes definition.

5) Elevation - the elevation of the top of the wall was surveyed at each sheet pile by C3. The elevation of the bottom of the wall could then be calculated using the final length of each sheet pile, taking into account any cut-off length. Refer to Appendix B Drawings for a vertical profile of the installed Waterloo Barrier® and Appendix H for a table of the surveyed and calculated elevations.

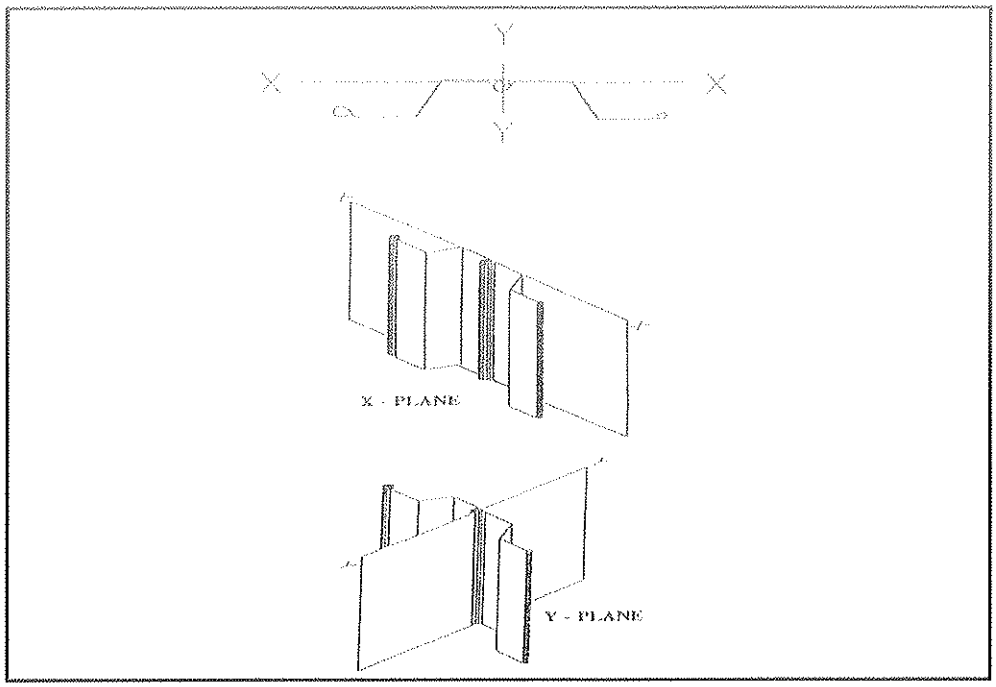


Figure 2: Waterloo Barrier® Sheet Pile Axes

7.1.3 Sealable Cavity Inspection

Inspection of the sealable cavities was the final stage of the Sheet Pile Installation QA/QC Program. Joint flushing equipment was used to inspect the integrity of each of the WEZ95 sealable cavities. The first time a joint was flushed was referred to as primary flushing. Primary flushing is shown in Photo 4. Potable water delivered under pressure was used to flush out each joint until clean. Primary joint flushing was completed to determine if:

- The sheet piles were installed so that a sound sealable cavity existed, and
- The sealable cavity was free of obstructions for the full length.

The Sealable Cavity Inspection Summary can be found in Appendix F. The following is a description of the documented inspection items.

1) Depth Measurement - the depth of penetration of the inspection probe was recorded for each joint, along with any of the inspector's comments.

2) Condition of Sealable Cavity - any unusual conditions encountered during the inspection of the sealable cavities was recorded. Documented conditions included the following:

   - Damage to the top of joint (due to driving);
   - Debris present at the base of the sealable cavity; and
   - Obstructions/restrictions present in the sealable cavity.

Inspection Report - deficiencies were reported and addressed prior to the initiation of joint sealing.

Photo 4: Primary Flushing

8. JOINT SEALANT INSTALLATION PROCEDURES

8.1 Sealant Mixing

The following is a description of the sealant mixing:

1) Water Metering - approximately 132 litres of clean, potable water was added to the mixer.

2) Sealant Addition - the sealant material was provided in pre-measured, 30 kg (66lbs) bags and twelve bags were slowly added to the mixer to allow for a consistent mix.

3) Mixing Time - upon addition of the sealant, mixing was carried out for a minimum of 2 minutes and 30 seconds

4) Material Inspection - random samples were visually inspected to ensure that the mixed sealant was consistent, and met gelling and curing requirements.

8.2 Sealant Installation (Joint Grouting)

The following is a brief description of the sealant installation:

1) Secondary Joint Flushing - secondary flushing was completed just prior to the sealant installation. Potable water delivered under pressure was used to clean and remove any loose material from the installed sealable cavities. The flushing was conducted until the return water was relatively free of debris.

2) Sealant Mixing - sealant was mixed thoroughly as described previously.

3) Initial Volume Measurement - time was measured on how long it took to fill a one (1) gallon pail of sealant prior to the start of installation of grout each day

4) Sealant Installation - the grout line was inserted to the base of the clean joint and the sealant was tremied into the cavity. This stage was referred to as primary grouting. Photo 5 shows the primary grouting stage.

Photo 5: Typical Primary Grouting

5) Sampling - random samples were taken from the end of the grout line and visually inspected to ensure the quality of the mix.

6) Grout Line Withdrawal - once the sealant was observed to be flowing out the top of the sealable cavity or after a specified pumping time was reached, the installation line was slowly withdrawn.

7) Joint Grouting - steps 1 - 6 were repeated for each joint to be sealed.

8) Secondary Grouting - typically, sealant loss occurred in the surrounding porous media prior to the sealant setting. The drop-down depth for each sheet pile joint was recorded, then used to estimate the volume required to seal the remainder of the joint. Each joint was then topped up with freshly-mixed grout. This step was repeated as necessary until each joint was full.

Records of Sealant Installation operations can be found in Appendix G.

9. SEALANT QUANTITIES

Figure 3 illustrates a cross-section of the sealable cavity of the Waterloo Barrier® sheet pile section. The typical cross-sectional area of this section on the WEZ95 profile is approximately 1.25 x 10^{-2} square feet. Based on this, the minimum theoretical volume of sealant required for various joint lengths is given in Table 2.

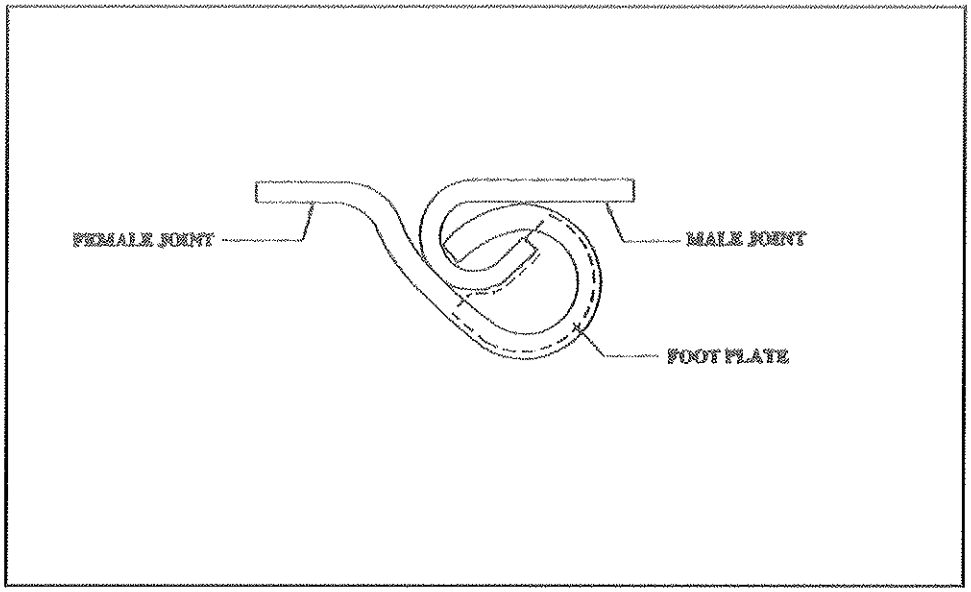


Figure 3: Waterloo Barrier® Sealable Cavity Cross-Section

Table 2: Theoretical Volume Related to Joint Length

JOINT LENGTH (ft.)	THEORETICAL VOLUME (cu. ft.)
68	0.850
74	0.925
75	0.938
80	1.000
82.5	1.031

Some of the factors affecting the actual volume of grout required to seal the joint cavities were as follows:

- Highly porous material adjacent to the sheet pile interlock;
- Contact area of the interlocking joint;
- Joint length exposed above the native soil to air or water;
- The presence of subsurface voids adjacent to the interlocking joints;
- Consolidation of the native materials during sheet installation;
- Preferential flow paths along the sheet piling to adjacent sealable cavities, and
- The effect of extensive flushing to remove obstructions and/or debris in the sealable cavity.

As indicated in the sealant installation logs, the actual grout volumes used were greater than the theoretical amount. A secondary grouting process was required in some instances to seal the top of the joint cavities.

10. WATERLOO BARRIER® PROJECT RECORDS

The following appendices contain data collected during the sheet pile and sealant installation phases of the project. Information provided is as follows:

APPENDIX B:	DRAWINGS
APPENDIX C:	VISUAL INSPECTION SUMMARY
APPENDIX D:	SHEET PILE DRIVING LOGS
APPENDIX E:	SHEET PILE DRIVING SUMMARY
APPENDIX F:	SEALABLE CAVITY INSPECTION SUMMARY
APPENDIX G:	SEALANT INSTALLATION LOGS
APPENDIX H:	SHEET PILE ELEVATIONS
APPENDIX I:	WBS-301 TECHNICAL DATA SHEET
APPENDIX J:	HOLEPLUG® TECHNICAL DATA SHEET
APPENDIX K:	IDP-433 TECHNICAL DATA SHEET

11. WINDOWED SHEETS

In order to avoid mounding behind the subsurface containment barrier and to allow the natural flow of groundwater to continue the wall segment, running parallel to Union Boulevard, was installed with "windows" cut in the sheets. These windows are illustrated in Appendix B. The original design of these sheets was modified to extend the web reinforcement to within three (3) feet of the bottom of the sheet pile to improve the driving characteristics of the sheets.

12. DRILLED SHAFT INSTALLATION

The installation sequence of the barrier was changed from the original sequence in order to provide the necessary time to redesign and retrofit the windowed sheets and to expedite the overall completion of the project. This required a non-sheet pile seal between sheet numbers 134 and 140 as illustrated in Appendix B.

An alternative method to provide this seal was proposed by C3. This involved progressively advancing a one (1) metre (39.3 inches) diameter segmented liner and augering out the enclosed soils to a depth of approximately 87 feet from the ground surface (approximately 60 feet below msl). The depth corresponds to a depth of three (3) feet below the bottom elevation of the adjacent sheet piles, as directed by the NYSDEC . The removed soils were containerized and removed from site for disposal. Once the drilled shaft was complete it was filled with Holeplug® (See Appendix J) by gravity feeding material contained in 3,000 lb super sacs through the water column inside the excavated liner. Holeplug® is a bentonite material with very high solids content and a very low hydraulic conductivity (1.5×10^{-9} cm/sec) and the liner was removed. This procedure was repeated until the entire shaft was filled with Holeplug® (minimum depth of eight (8) feet below ground surface) and the liner was completely removed.

The entire array of drilled shafts was laid out in an overlapping echelon pattern in the direction of the inclination of the windowed sheets. The overlap was necessary in order to ensure a seal between individual shafts and to account for any deviation (± 1° allowed) in the verticality of the shafts.

The last drilled shaft installation utilized a chemical additive IDP-433. This material was added to the water column to retard the rate of hydration of the Holeplug® which reduced the adhesion between the bentonite and liner to assist in the liner removal. Its material data sheet can be found in APPENDIX K.

Once the five (5) shafts were completed the remaining sheet piles were installed. The last sheet pile of each wall (#134 and #140) "keyed" into the Holeplug® drilled shaft array. This provided the required seal.

The orientation of shaft installation relative to the sheet pile wall is illustrated in the Appendix B.

Table 3: Drilled Shaft Detailed Records

Drilled Shaft	Verticality		Final Depth (ft. below msl)
	Parallel	Perpendicular	
A	89.9	89.8	60.0
B	89.7	90.0	60.0
C	90.0	89.8	65.0
D	89.9	89.9	60.0
E	89.8	90.0	60.0

13. DISCUSSION

Approximately 46,783 square feet of Waterloo Barrier® WEZ95 sheet piling were installed to a depth of between 46.8 to 65.4 feet below msl, as indicated in the project records (Appendices B - H).

Approximately 21,569 lineal feet of Waterloo Barrier® joint was sealed with a modified cement-based grout (WBS-301). On average, the actual volume of grout used was approximately 1.5 times greater than the theoretical volume for the reasons described in Section 9. A permeability test of the WBS-301 grout is being completed and when the results are available they will be forwarded as a letter appendix for this report. Refer to Appendix B for the project as-built drawings. The total number of sheet piles in the barrier was 292.

The Waterloo Barrier® was installed in general accordance with drawings and specifications as prepared by PS&S.

Five (5) benonite-filled overlapping drilled shafts were also installed to join the two Waterloo Barrier® wall segments. The installed depth of the drilled shafts ranged from 60.0 to 65.0 feet below msl.

Based upon the results of C3's QA/QC inspection, the Waterloo Barrier® installation generally conformed to the procedures and specifications, in accordance with Waterloo Barrier Inc., necessary to provide a low permeability groundwater barrier.