Appendix C

C3 Waterloo Barrier Installation Report

Remedial Action Report

Former Gulf States Creosoting Site
Hattiesburg, Mississippi

WATERLOO BARRIER® SYSTEM INSTALLATION REPORT

Pine Street & Gordon's Creek
Hattiesburg, Mississippi

Prepared for:

Kerr McGee Chemical, LLC
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January 2004

January 2, 2004

Kerr-McGee Chemical, LLC
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P.O. Box 25861
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Attn: Mr. Keith Watson

Re: Waterloo Barrier® QA/QC Report – Pine Street & Gordon's Creek Site, Hattiesburg, Mississippi

Dear Mr. Watson:

The enclosed report provides detailed records of the sheet pile, helical tieback and sealant installation for the Waterloo Barrier® System, installed between May 19th, 2003 and July 25th, 2003 at the Pine Street & Gordon's Creek Site.

The data and information enclosed in this report is confidential. The information is intended for the sole use of the individual or entity named above. 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.

Regards,
C3 ENVIRONMENTAL LIMITED

Albie Moffat, B.A.Sc.
Project Manager

EXECUTIVE SUMMARY

This report provides details of the installation of a Waterloo Barrier® cut-off wall during the period of May 19th, 2003 through July 25th, 2003 at the Pine Street & Gordon's Creek Site in Hattiesburg, Mississippi.

C3 Environmental Limited was contracted by Kerr McGee Chemical, LLC to provide Quality Assurance/Quality Control services during the installation of the barrier wall. In addition, C3 Environmental Limited was responsible for the installation of the helical tiebacks, and the joint sealing for the barrier wall.

The cut-off wall was installed along the north side of Gordon's Creek with two wing walls extending from each end of the creek stretch of wall to the south, perpendicular to the creek. The WEZ95 profile of Waterloo Barrier® sheet piling was installed, along with a tieback system consisting of a waler and several Chance® Helical Tie-backs, to provide the cut-off wall with additional lateral support.

A pre-packaged silica fume modified, cementitious grout (WBS-301) was used to seal the joints of the Waterloo Barrier® cut-off wall. Detailed records were collected for each sheet pile installed, each joint grouted, and each helical tieback installed.

The area of the installed Waterloo Barrier® sheet piling was approximately 21,073 square feet. Approximately 9,501 linear feet of sealable cavity were grouted, as documented in the project records.

A total of 22 helical tiebacks were installed along the creek stretch of the cut-off wall to various depths and at various locations, as documented in the project records and indicated on the cut-off wall profile drawings.

Based upon the results of C3 Environmental's Quality Assurance/Quality Control inspection, the Waterloo Barrier® installation generally conformed to the procedures and specifications necessary to provide a low permeability groundwater barrier. 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 cut-off wall which was developed at the University of Waterloo under the direction of Professor John Cherry.

The main difference between Waterloo Barrier® sheet piles and conventional sheet piles is that a sealable cavity is produced at the joints when the Waterloo Barrier® sheets are rolled. The sheet piling is available in a 7.5 mm (0.295 inch) thickness (WZ75) and a 9.5 mm (0.375 inch) thickness (WEZ95) and has been rolled in lengths up to 22.8 metres (75 feet). The patented section produced by this rolling method provides a cavity that is inspected to confirm the integrity of the joints after driving, and a controlled leak path that is sealed with a grouting compound. In addition, there are various grout designs that may be used on a site specific basis.

2. PROJECT OVERVIEW

The Pine Street & Gordon's Creek Site in Hattiesburg, Mississippi is currently owned by Kerr McGee Chemical, LLC (KMC). In conjunction with Shows, Dearman & Waits, Inc. (SDW), a consulting engineering firm based in Hattiesburg, KMC developed a remedial plan to address creosote contamination present in the soil and groundwater at the Site. As part of the remedial plan, a Waterloo Barrier® cut-off wall was installed to intercept contamination migrating from the boundaries of the Site. Helical tiebacks were also installed to provide the cut-off wall with additional lateral support. The cut-off wall and helical tiebacks were installed during the period of May 19th, 2003 through July 25th, 2003.

C3 Environmental Limited (C3) was hired by KMC to monitor the barrier system installation, install the helical tiebacks, and seal the joints of the cut-off wall. In order to complete the installation of the barrier system successfully, C3 implemented a Quality Assurance/Quality Control (QA/QC) program for the installation of the sheet piles and the joint sealant. The three programs are summarized in the following sections.

SDW hired Michael Pisani & Associates, Inc. (MPA), an environmental management and engineering company to assist with soil and groundwater testing, and general co-ordination and project management through the duration of the project. KMC hired U.S. Environmental Services, LLC (USES) to undertake all construction activities on the Site. USES then subcontracted the majority of the work to Taylor Construction (Taylor), a contractor based in Hattiesburg, and retained a project supervisor on site to oversee the work performed by Taylor. Taylor subcontracted the pile driving to Magco, Inc. (Magco), a local pile driving company.

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 and vertical alignment of each sheet pile;
- Inspection of the sealable cavities by flushing/probing of each joint to confirm that there were no obstructions and that the sheet piles were 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 the physical characteristics of the sealant; and,
- Documentation of the grouting times and volumes of sealant installed for each sheet pile joint.

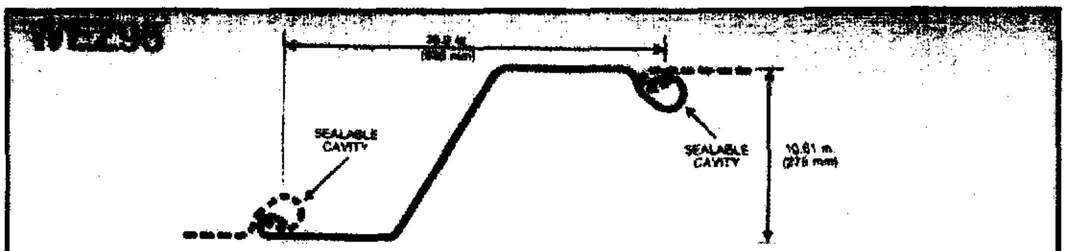
Appendices C through H contain the QA/QC project records for each stage of the sheet pile and sealant installations.

3. Waterloo Barrier® Sheet Pile Specifications

The steel sheet piling used to construct the cut-off wall at the Site was the Waterloo Barrier® WEZ95 profile. A typical cross-section and general section properties of this type of sheet pile are shown in Figure 3.1.

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

A key procedure in ensuring proper installation of the WEZ95 sheet piles is the attachment of a driving shoe (or foot plate) at the base of every enlarged joint as shown in Figure 3.2. The driving shoe minimizes the entry of debris through the base of the joint during sheet pile installation.



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 3.1: WEZ95 Cross-Section

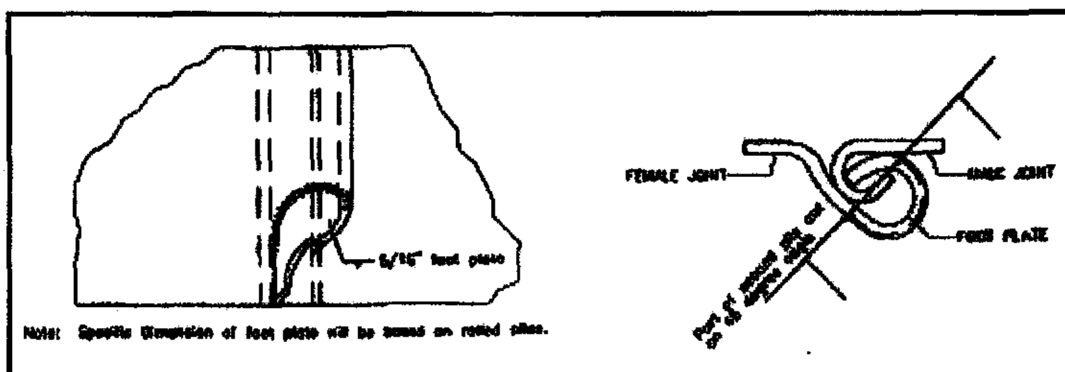


Figure 3.2: Foot Plate Cross-Section

4. Sealant Material

A pre-packaged silica fume modified, cementitious grout (WBS-301) was used to seal the joints of the Waterloo Barrier® sheet piles. WBS-301 grout 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 thoroughly mix the material. Table 4.1 contains general mixing data for the WBS-301 sealant. Refer to Appendix H for the WBS-301 technical data sheet. Random samples were taken to ensure that proper gel and set times for the sealant were achieved.

Table 4.1: WBS-301 Mixing Data

Description	Requirements
Colloidal Mixer	1400 – 1700 RPM mixing speed
Mixing Time	2 – 3 minutes
Viscosity	95 – 120 flow cone seconds
Gel Time	1 ½ - 2 hours @ 20°C (68°F)
Set Time	6 – 8 hours
Cure Time	28 days

5. Sheet Pile Installation Equipment

The Waterloo Barrier WEZ95 sheet piles were installed by Magco, using the following equipment:

- Terex HC80 – 80 tonne crane;
- Man lift;
- Kobelco SK210LC excavator;
- John Deere 544C front end loader;
- HPSI 300 vibratory hammer; and,
- Welding and cutting equipment.

Some of the equipment used to install the sheet piling is shown in Photos 5.1 and 5.2.

Photo 5.1: Vibratory Hammer

Photo 5.2: Pile Driving Equipment - General Setup

6. Sealant Installation Equipment

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

- Colloidal mixer with Lister-Petter diesel engine;
- Air-driven grout holding/agitator tanks;
- Portable diesel 185 CFM air compressor;
- Air-driven Moyno 3L4 progressive cavity pump;
- Volumetric measuring equipment;
- Grout lines and pressure control valves; and,
- John Deere 544C front end loader.

Photo 6.1 shows some of the grouting equipment used for this project.

Photo 6.1: Grouting Equipment

7. Waterloo Barrier® Installation Procedures

Magco began the sheet piling installation by driving Sheet # 1 (refer to Drawing 1 in Appendix B) to approximately mid-depth. Sheets were then threaded onto the previous, partially driven pile in sequence using the crane and the man lift. Once three or four sheets were threaded, they were driven to approximately mid-depth using the vibratory hammer. The partially driven sheets were driven to the final depth in sequence following an inspection to ensure adequate verticality. Sheets were driven such that the male joint was leading. The purpose of this procedure was to ensure that the enlarged interlock (female joint) with the affixed foot plate, would be driven onto the smaller interlock (male joint), minimizing the entry of debris in the cavity. With some exceptions (noted in the drive logs in Appendix D) this procedure was followed for the entire project. Photos 7.1 and 7.2 show the sheet pile threading and driving operations.

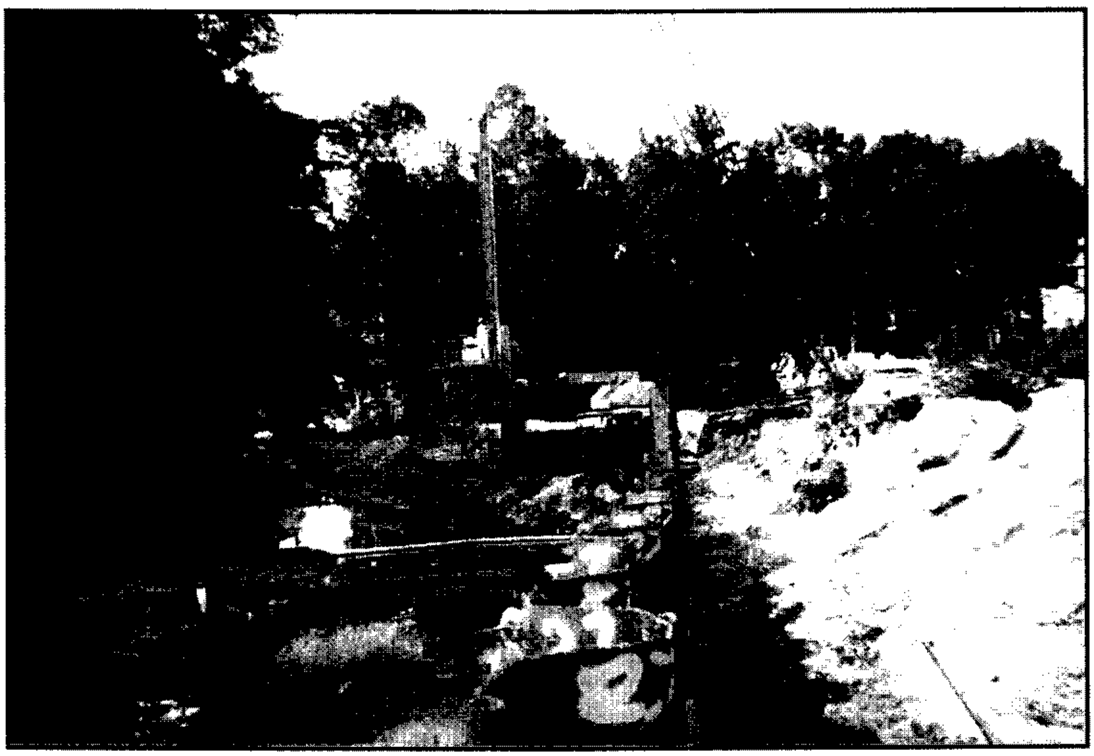


Photo 7.1: Sheet Pile Threading

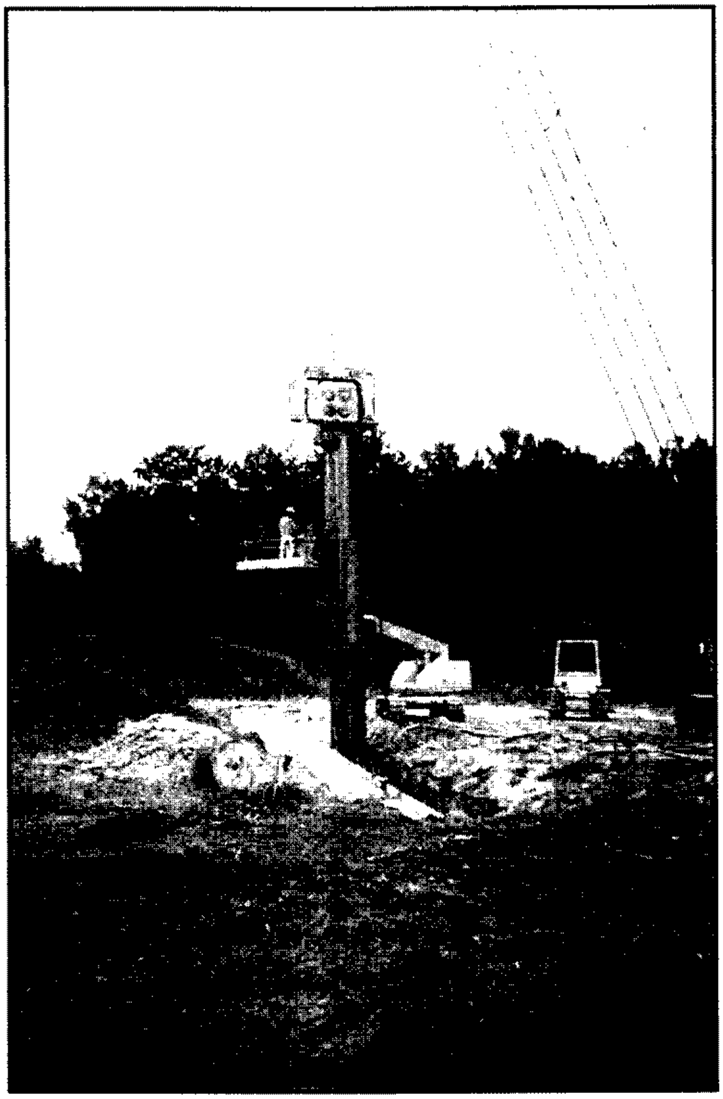


Photo 7.2: Sheet Pile Driving

7.1. Sheet Pile Installation Inspection Procedures

The sheet pile quality assurance 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 items were visually inspected and recorded:

1) **Pile Thickness** - To verify the thickness of the sheet piling.

2) **Linearity Inspection** - To ensure that the piles had not been bent or bowed during transportation to the site.

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

4) **Sheet Pile Length** - Each sheet pile was measured to confirm the specified length.

5) **Pile Marking** - One to five-foot graduations were marked on the sheet piles to assist in the recording of driving logs during pile installation.

6) **Foot Plate Inspection** - A visual inspection of each foot plate was conducted to ensure proper installation of the foot plate prior to driving.

Refer to Appendix C for the Visual Inspection Summary.

7.1.2. Monitoring of Sheet Pile Driving

Records were collected for each of the sheet piles as they were installed. A C3 Quality Assurance Engineer/Technician was 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 purposes.

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. Refer to Appendix C for the Sheet Pile Drive Logs.

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

4) **Sheet Pile Alignment** - 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 7.1 for axis definition.

5) **Elevation** - The elevation of the top of the wall was surveyed, at each sheet pile, and the elevation of the bottom of the wall was calculated using the final length of each sheet pile, taking into account any sheets that were cut at the top as a result of being driven to refusal. Refer to Appendix H for the Sheet Pile Elevations.

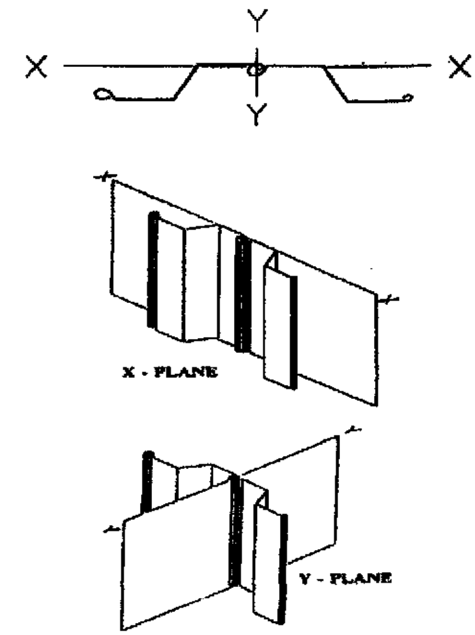


Figure 7.1: Waterloo Barrier® Sheet Pile Axes

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. Potable water delivered under pressure was used to flush soil and debris out of each joint. Primary joint flushing was completed to ensure that a sound sealable cavity was maintained during installation and that the sealable cavity was free of obstructions for the full length of the sheet. Refer to Appendix F for the Sealable Cavity Inspection Summary. Photo 7.3 shows the flushing of a sealable joint.

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 pertinent comments.

2) **Condition of Sealable Cavity** - Any unusual conditions encountered during the inspection of the sealable cavities were recorded. Unusual conditions that may be encountered include: damage to the top of joint due to driving, debris at the base of the sealable cavity and obstructions or restrictions in the sealable cavity.

3) **Inspection Report** - Deficiencies were reported and addressed prior to the initiation of joint sealing.

Photo 7.3: Primary Flushing

7.2. Barrier Penetrations

Along the river section of the wall, penetrations of the barrier were required to make concessions for a storm sewer, a sanitary sewer and numerous tiebacks.

7.2.1. Storm Sewer

A circular penetration in the wall was installed to allow a new storm sewer to pass through the barrier. The penetration was installed to accommodate a 1200 mm (48") concrete storm sewer running beneath Pine Street, through the site and into Gordon's Creek. The penetration passed through Sheets # 193, # 194 and # 195 (near the middle of the creek stretch). In order to ensure that the pipe penetration was watertight, it was sealed by means of a continuous weld along the circumference on both sides of the wall (see Photo 7.4). The pipe penetration passed through two joints (# 194 and # 195). The affected joints were welded continuously below and above the pipe penetration (see Photo 7.5). This was achieved by welding a 1-inch wide flat bar across each joint on both sides of the wall for the full length of the joint. In addition, the space around the footplate was welded 100 percent to seal the bottom of the wall.

Photo 7.4: Continuous Weld Around the Penetration

After the penetration was welded in place, the new concrete storm sewer was affixed to the penetration with a mastic adhesive and the penetration was secured to the storm sewer by tightening two bolts as shown in Photo 7.6. In addition, a concrete slab was poured beneath the connection to provide additional support.

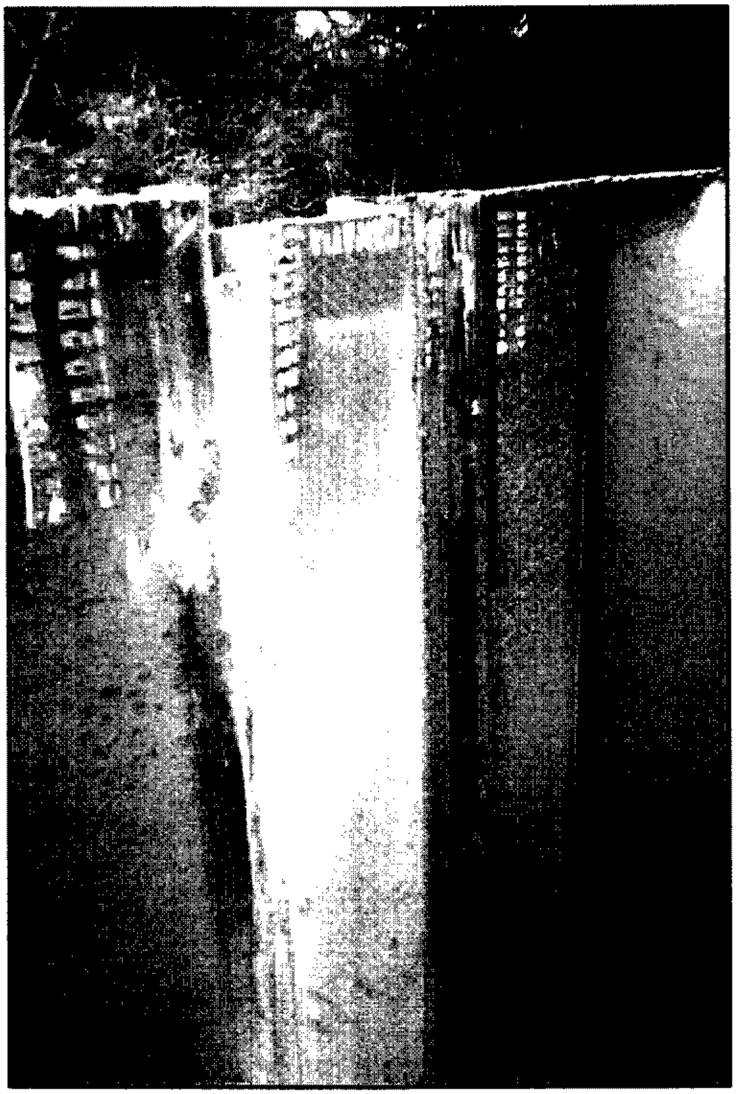


Photo 7.5: Continuous Weld Along Affected Joints

7.2.2. Sanitary Sewer

A circular penetration in the wall was installed to allow an existing sanitary sewer to pass through the barrier. The penetration was installed to accommodate a 200 mm (8") steel sanitary sewer passing through Sheet # 214 (near the middle of the creek stretch). In order to ensure that the pipe penetration was watertight, it was sealed by means of a continuous weld along the circumference on both sides of the wall (see Photo 7.7). The penetration was then attached to the existing sanitary sewer by using two splice sections, one on each side of the cut-off wall (see Photo 7.8).

Photo 7.6: Storm Sewer/Penetration Connection

Photo 7.7: Continuous Weld along Pipe Penetration

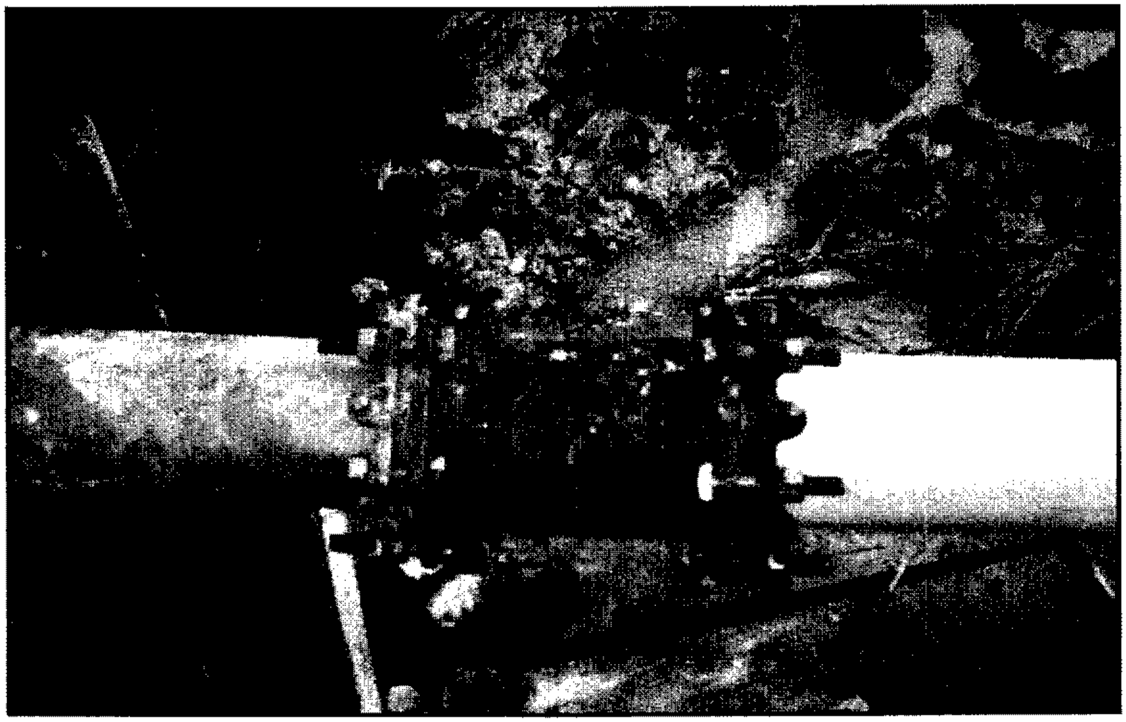


Photo 7.8: Sanitary Sewer Splice

7.2.3. Tieback Installation

Along the bank of the river, sheets were secured by a tieback system. The tieback system consisted of Chance® helical tiebacks connected to sections of waler affixed to the cut-off wall.

The Chance® helical tiebacks were installed with a Hubbell 12,000 ft/lb installation motor attachment and a DPI (differential pressure indicator). A total of 22 tiebacks were installed along the creek stretch of wall, one tieback at each end of a waler section. C3 hired Engineering Testing Services to witness a load test to determine the torque required during installation to ensure that the required load would be sustained by the tieback. The load test was performed on May 27, 2003 under the supervision of Jerry Buckett of Engineering Testing Services. The a torque of 1350 psi was required during the installation of the tiebacks. Table 7.1 is a summary of the torques achieved during the installation of each tieback and the installation depth (refer to Appendix I for more detailed information regarding the installation of the tiebacks). Photo 7.9 shows a typical tieback installation. Once the tiebacks were installed, holes were cut in the cut-off wall at each tieback location and threaded extension arms were placed through the wall and fastened to the tiebacks.
A total of 11 walers were installed along the creek stretch of cut-off wall. The walers were S12 X 35 I-beams measuring 40' in length and were welded to the wall as shown on the profile view in

Drawing 2 (Appendix B). At each tieback penetration (i.e. one at both ends of each waler) a piece of 8 X 8 L angle iron was welded to the wall and the waler, with a hole cut to accommodate the threaded extension arm. In addition, the angle iron was welded at both ends to form a sealable box to prevent a potential pathway for contaminants (see Photo 7.10). Two small holes were cut in the top of the angle iron to allow for the sealing of the box. A 4" X 6" X 1" thick bearing plate was placed over each of the treaded extension arms and a nut was fastened to secure the tieback to the waler (see Photo 7.11).

Table 7.1: Helical Tieback Installation Summary

Tieback Number	Tieback Location	Depth Installed (ft.)	Torque Achieved (p.s.i.)
1	STA 1+61	61	1350
2	STA 1+82	54	1350
3	STA 2+02	44	1300
4	STA 2+23	54	1325
5	STA 2+44	54	1350
6	STA 2+65	30	1300
7	STA 2+86	30	1300
8	STA 3+07	30	1300
9	STA 3+28	75	1350
10	STA 3+49	37	1350
11	STA 3+69	37	1325
12	STA 3+90	37	1300
13	STA 4+11	37	1350
14	STA 4+32	37	1350
15	STA 4+47	37	1350
16	STA 4+68	47	1300
17	STA 4+82	47	1350
18	STA 5+03	61	1500
19	STA 5+24	47	1300
20	STA 5+45	47	1300
21	STA 5+66	40	1350
22	STA 5+87	40	1375

Photo 7.9: Typical Tieback Installation

Photo 7.10: Angle Iron at Extension Arm Penetration

Photo 7.11: Extension Arm Secured to Angle Iron

8. SEALANT INSTALLATION PROCEDURES

8.1. Sealant Mixing

The following is a description of the sealant mixing:

1) **Water Metering** - Approximately 15 to 19 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 two bags were slowly added to the mixer to allow for a uniform mix.

3) **Mixing Time** – Sealant was mixed for a minimum of 2 minutes.

4) **Material Testing** - Random samples were taken to ensure that the mixed sealant met the specified gelling and curing requirements.

9. Sealant Installation (Joint Grouting)

The following is a 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 free of debris.

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

3) **Initial Volume Measurement** - The sealant level in the holding (agitator) tank of the grout plant was measured and recorded prior to the start of installation of grout in each joint.

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 also referred to as primary grouting.

5) **Sampling** - Random samples were taken from the end of the grout line 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 once 2.5 to 3 times the theoretical grout volume of the sheet pile joint was pumped into the sealable cavity, the installation line was slowly withdrawn.

7) **Final Volume Measurement** - Once the grout line was removed from the joint the sealant level in the holding tank was measured and recorded.

8) **Joint Grouting** - Steps 1 - 7 were repeated for each joint to be sealed.

9) **Secondary Grouting** - Typically, sealant loss occurred in the surrounding porous media or water in the river 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. In joints showing significant drop-down, particularly along the river, a low-permeability fabric grout sock was inserted into the cavity. This helped slow the flow of grout out of the cavity, reducing the time and quantity of material used.

Refer to Appendix G for the Sealant Installation log.

10. Sealant Quantities

The cross-section of the sealable cavity of the Waterloo Barrier® WEZ95 sheet pile is shown in Figure 10.1. The typical cross-sectional area of the joint is approximately 1.23×10^{-2} square feet. Based on this area, the minimum theoretical volume of sealant required for the various lengths of sheet piles used on this project are shown in Table 10.1.

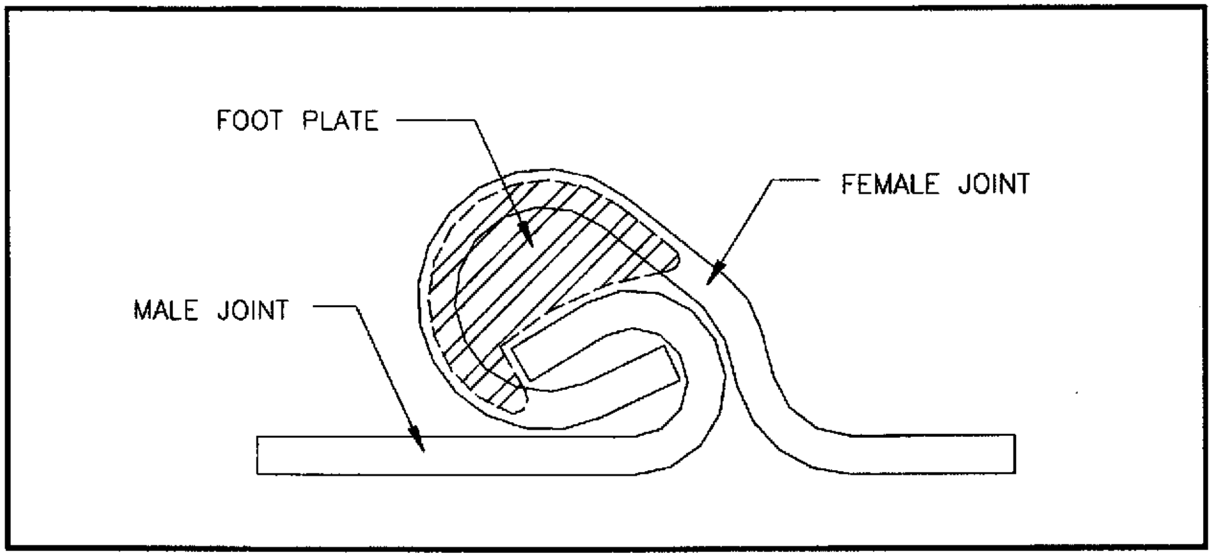


Figure 10.1: Waterloo Barrier® Sealable Cavity Cross-Section

Table 10.1: Theoretical Sealant Volumes	
Sheet Pile Length (ft)	**Theoretical Volume of Sealant (ft^3)**
26	0.32
27	0.33
28	0.34
29	0.36
30	0.37

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 most instances to seal the top of the joint cavities.

11. Conclusions

Approximately 21,073 square feet of Waterloo Barrier® WEZ95 sheet piling was installed to varying depths as indicated in the project records (Appendices B - H).

Approximately 9,501 linear feet of Waterloo Barrier® joint was sealed with a modified cementitious grout (WBS-301). On average, the actual volume of grout used was approximately 2.0 times greater than the theoretical volume for the reasons described in Section 9.

Some changes in the locations of various sheets occurred as a result of sheet pile delivery co-ordination. To prevent delay in the progress of the project, some sheets were substituted towards the west end of the creek stretch of wall and on the east wing of the wall under the direction of MPA (refer to Drawing 2 in Appendix B). This alteration in the original design had no significant impact on the design depths of the sheet piles since it was agreed upon by SDW and MPA at the beginning of the project that the majority of the sheets would be driven an additional foot beyond the originally specified depths. The additional sheets that were shipped were installed at the end of the east wing wall, which brought the project total to 366 sheets instead of 363 sheets, as specified in the original plans.

Based upon the results of C3 Environmental'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.

The Waterloo Barrier® was also installed in general accordance with drawings and specifications prepared by Shows, Dearman & Waits, Inc., with only minor variations relating to pile depth and horizontal alignment.