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Re: Conditional Approval of Supplemental Source Control Containment/Recovery Measures East Street Area 2, General Electric Company, Pittsfield, Massachusetts DEP Site No. 1-0146, USEPA Area 4

Dear Messrs. Olson, Tagliaferro, and Weinberg:

I. INTRODUCTION

The General Electric Company (GE) has received the United States Environmental Protection Agency's (USEPA's) February 11, 1999 conditional approval letter concerning GE's *Proposal for Supplemental Source Control Containment/Recovery Measures* (Supplemental Source Control Proposal, Blasland, Bouck & Lee, Inc, January 1999). In that letter, the USEPA provided several comments, questions and requests for additional information concerning the January 1999 proposal. This letter provides GE's responses to those items in a format that is generally consistent with the topics identified in the USEPA's conditional approval letter. Where necessary, additional, more detailed information is provided as attachments to this letter.

II. PERFORMANCE STANDARDS AND REVISED MONITORING PROCEDURES

In its February 11, 1999 conditional approval letter, the USEPA requested that GE propose Performance Standards and revised monitoring procedures pertaining to the proposed containment/recovery measures. The USEPA stated that the Performance Standards for the proposed containment barrier should fulfill the objectives of achieving no discharge of LNAPL or residual LNAPL to the Housatonic River, no sheens on the River, no bank seeps, and no measurable LNAPL in the perimeter monitoring wells located outside the proposed sheetpiling. The USEPA also stated that the revised monitoring procedures to determine compliance with the Performance Standards should include a number of specified procedures.

In response to the USEPA's letter, GE proposes the Performance Standards listed below for the containment barrier to achieve the objectives identified by the USEPA. It should be noted that, although the objectives specified by the USEPA were not specifically identified as Performance Standards in the Supplemental

Source Control Proposal, they were considered as design criteria for the proposed containment barrier. The Performance Standards proposed by GE for the sheetpile barrier are as follows (with the activities designed to achieve each standard presented in parentheses):

1. Prevention, to the extent practical, of detectable discharges of LNAPL to the Housatonic River in the area of the proposed containment barrier (to be accomplished by the continued operation of the ongoing active LNAPL recovery systems and the installation of supplemental control measures -- i.e., a sheetpile containment barrier);

2. Prevention, to the extent practical, of bank seeps, as well as sheens to the Housatonic River in this area resulting from either bank seeps or residual LNAPL in soils/sediments located on the riverside of the proposed containment barrier (to be accomplished through the removal of soils/sediments along the river's edge that may contain historic residual LNAPL); and

3. Prevention of any measurable LNAPL migration around the ends of the containment barrier (to be accomplished by the continued operation of the ongoing active LNAPL recovery systems and the installation of additional perimeter monitoring wells).

GE proposes the following measurement and monitoring activities to demonstrate that the proposed Performance Standards listed above have been achieved:

1. Install two monitoring wells at the east and west ends of the proposed containment barrier, respectively, to detect any potential LNAPL migration around the ends of the barrier (refer to Figure 1);

2. Conduct weekly monitoring activities at the two wells proposed above to collect water level information and assess whether any LNAPL is present;

3. Conduct weekly visual inspections of the Housatonic River in the area of the sheetpile, as well as the bank area located between the sheetpile and Housatonic River, to assess the potential presence of bank seeps or sheens on the Housatonic River; and

4. Incorporate the monitoring activities in Items 2 and 3 above, as well as monitoring of relevant source control investigation monitoring wells, into the comprehensive monitoring program described in Section 3.4 of the Supplemental Source Control Proposal. This monitoring plan will begin following installation of the proposed monitoring wells and sheetpile barrier. However, the Performance

Standards will not become effective until after completion of the activities outlined in the *Removal Action Work Plan - Upper ½-Mile Reach of the Housatonic River* (½-Mile Removal Action Work Plan). This groundwater monitoring will be incorporated into the ongoing riverbank monitoring program, which includes wells 53, 54, 64X-N, 64X-S, 64X-W, RW-1 (X), RW-2 (X), PZ-1S, PZ-2S, PZ-4S, PZ-5S, PZ-6S, RB-1, WP-1 through WP-6, and WP-13. If any of these wells are damaged/destroyed by the work activities in this area, they will be replaced. Additionally, GE proposes to add weekly monitoring for potential LNAPL at wells E2SC-13, 14, and 16, which were recently installed as part of the source control investigation.

As noted above, the Performance Standards will not become effective until the proposed riverbank/sediment excavations outlined in the ½-Mile Removal Action Work Plan have been completed. If, after that time, the Performance Standards are not met, GE will propose corrective measures and implement such measures upon USEPA approval.

III. DESCRIPTION OF SUPPLEMENTAL LNAPL CONTROL MEASURES

In its February 11, 1999 conditional approval letter, the USEPA approved the proposed containment barrier subject to several conditions, and requested clarification of several calculations used in designing the proposed sheetpile. Additionally, USEPA requested clarification of the maximum excavation depth of bank soils located between the sheetpile and river. GE's responses to these requests are presented below.

Since the Supplemental Source Control Proposal was provided to the USEPA, GE has further evaluated the technical design of the proposed containment barrier and has conducted additional soil and sediment investigations in the vicinity of the proposed barrier. Based on these activities, the following information is provided:

1) The analytical data collected during the additional bank soil and near-bank sediment sampling efforts recently conducted (as proposed in GE's January 29, 1999 *Proposal for Further Investigation Pursuant to Supplemental Source Control Containment/Recovery Measures*) indicate that excavation of bank soils to a maximum depth corresponding to elevation 967.5 feet will likely achieve the Performance Standards presented above in Section II. These investigations included the installation of eight riverbank soil borings along the area between the river and the proposed containment barrier. Samples were collected in 1-foot intervals to depths of 7 to 8 feet below the surface. These samples were submitted for laboratory analysis of PCBs and Total Petroleum Hydrocarbons (TPH). Additionally, field screening tests were performed consisting of soil screening with a photoionization detector (PID),

shake testing, and visual observations. Select samples were also submitted to the laboratory for analysis using the Toxicity Characteristic Leaching Procedure (TCLP), to support disposal decisions for soil which may need to be removed along the base of the bank prior to sheetpile installation. The locations of these borings are illustrated on Figure 2. The results of the analyses are presented collectively in Tables 1 and 2 and on Figure 3. Additionally, sediment sampling was performed at locations adjacent to these boring locations (plus one additional location). These samples were collected from depths ranging up to 4 feet. However, at the majority of the locations, samples could not be collected below a depth of 1 foot because of sampling refusal. These samples were screened in the field and submitted for laboratory analysis as described above for the riverbank soil samples (except for TCLP analysis). The results of these analyses are also presented in Table 1, and the locations are illustrated on Figure 2.

The results of these supplemental investigations indicate that the concentrations of PCBs and TPH in riverbank soils are generally highest in the elevation range associated with the typical groundwater table (971 to 972 feet). PCBs and TPH concentrations below 967.5 feet are at low concentrations or non-detectable. Field screening evaluation by shake testing and visual observation of the soil samples from these borings produced inconclusive results. In many instances, the visual observations and shake tests do not correlate well with the TPH and PCB analytical results. Furthermore, staining/sheens were indicated on a number of soil cores along the eastern section of the proposed containment barrier (i.e., sample locations SL0028, SL0404, and SL0007) in areas where bank seeps or separate phase LNAPL have not been observed. Some of the sheens and staining in this area may be associated with coal gas manufacturing by-products, since cinders have been observed along the riverbank and in borings located in this area. Polycyclic aromatic hydrocarbons (PAHs) have also been detected in previously collected soil samples in this vicinity (e.g., boring E2SC-16 and riverbank soil sample SL0009-T05).

Based primarily on the PCB and TPH analytical results, it appears that a maximum excavation depth to an elevation 967.5 feet may be warranted for the majority of the bank adjacent to the riverside of the proposed containment barrier. However, in the area of sediment sample SL0404, excavation to a depth of 2.5 feet is proposed in the ½ -Mile Removal Action Work Plan. The recent sediment sampling at this location indicates that the river bed surface topography to be at an elevation of 969.3 feet. Removal of 2.5 feet of sediment in this area would require excavation to an elevation of approximately 966.5 feet.

As explained below in the responses to the other USEPA technical questions, excavation to these elevations (966.5 feet in the area of sample location SL0404 and 967.5 for the remaining areas) can be completed and would be supported by the proposed sheetpile wall. If site conditions arise that cause the current design of the sheetpile to be less than sufficient to allow excavation, GE will augment the design (through tiebacks, bracing or other controls) to ensure that excavation activities may take place to the necessary depths. The actual limits and depths of excavation of bank soils and sediments in this area will be evaluated and presented in the next phase of design-documentation related to the ½-Mile Removal Action Work Plan.

2) The containment barrier design calculations submitted in the Supplemental Source Control Proposal have been reviewed and revised considering the USEPA comments regarding the interface friction between the silty sand and the sheet piling. The results of this review/revision are presented below in summary form, and the revised calculations are included in Attachment 1.

After reviewing the EPA's comments, our technical consultant, Blasland, Bouck & Lee, Inc. (BBL), believes that an average N value of 10, corresponding to an angle of internal friction (ϕ) of 30°, is a conservative value for design since the results of the Standard Penetration Test (SPT) for fine sands below the water table may, in general, not be representative of the actual material. According to Peck, Hanson and Thornburn (1974)[1]:

> "By far the most common error in connection with the standard penetration test in sand or silt occurs, however, when drilling is being done below the water table. If the water level in the drill hole is allowed to drop below groundwater level, as may easily occur, for instance, when the drill rods are removed rapidly, an upward hydraulic gradient is created in the sand beneath the drill hole. Consequently, the sand may become quick and its relative density may be greatly reduced. The N-value will accordingly be much lower than that corresponding to the relative density of the undisturbed sand."

In the opinion of our technical consultant, BBL, the lower N values for boring E2SC-03I (referenced by USEPA) reflect this phenomenon and are not considered to be representative of the actual in situ conditions. Since this effect tends to be less for medium to coarse sands, the N values for the other borings were not affected as much. Therefore, based on this information and the results in other borings, BBL considers a friction angle of 30° to be a conservative strength estimate for the material.

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[1] Peck, R. B., W. E. Hanson, and T. H. Thornburn (1974) *Foundation Engineering.* John Wiley & Sons, Inc. New York, New York pp. 514.

The USEPA also expressed a concern about the higher N values in boring E2SC-03I. The elevation where the higher N-values were encountered are at, or above, the elevation at which driving will commence. If shallow debris is encountered that could cause damage to the sheetpile, it will have to be removed as part of pre-driving operations.

3) The containment barrier design calculations have been re-evaluated to consider the other USEPA comments, the recently collected bank soil/sediment data, removal depths proposed in the ½ -Mile Removal Action Work Plan, and changes in horizontal placement of the containment barrier to allow for a 1:1 slope as part of final restoration activities. The revised calculations are presented in Attachment 1. Figure 1 illustrates the revised layout of the proposed containment barrier, and a discussion of the 1:1 slope evaluation is presented in Section VI.

As a result of the re-evaluation of the design calculations, it has been determined that the previous design depth for the bottom of the containment barrier (i.e., 20 feet) should generally be extended 5 feet (for an overall depth of 25) to provide a reasonable degree of safety. Additionally, in a limited area adjacent to the proposed 2.5 foot removal area near sediment sample location SL0404, the sheetpile should extend 3 feet deeper (to a depth of 28 feet). The factor of safety for the permanent condition, i.e., after the sheeting is installed and the ½ -Mile Removal Action activities are completed, is greater than 2.0. For the temporary condition, i.e., when sediments/banksoils are excavated to maximum depths corresponding to elevations of 966.5 to 967.5 feet, the factor of safety is at least 1.25. Figure 4 illustrates a revised containment barrier profile.

IV. EROSION CONTROL MEASURES

As part of its February 11, 1999 conditional approval letter, the USEPA requested the implementation of various erosion control measures in the vicinity of the proposed sheetpile containment barrier. These measures will be performed during installation of the sheetpile barrier and will continue until the area is fully restored upon completion of the ½-Mile Removal Action activities.

Consistent with the USEPA's comments, GE proposes that erosion control matting, geotextiles, and/or straw mulch be used as appropriate to temporarily protect disturbed soils from erosion. GE will install erosion control matting and/or geotextile on exposed soils at the toe of the bank to be able to withstand river flow velocities of at least 10 feet/sec. The existing absorbent booms along the riverbank will also be extended and maintained. GE will inspect the erosion control measures and booms every working day during construction and weekly during the interim period between completion of the sheetpile containment barrier and completion of the work outlined in the ½-Mile Removal Action Work Plan.

V. SHEETPILE TOP PROTECTION

As part of its February 11, 1999 conditional approval letter, the USEPA requested protection of the sheetpile joints until they are grouted to prevent introduction of debris into the joints. GE concurs with this comment, and will implement measures to protect the joints such as installation of end caps or utilization of high strength tape sealants.

VI. SITE RESTORATION

As part of its February 11, 1999 conditional approval letter, the USEPA had several comments concerning site restoration activities. Specifically, these comments can be summarized as follows:

1) USEPA requested consideration by GE of the installation of a "heavy-duty woven geotextile or geogrid" beneath the proposed riprap.

2) USEPA requested the addition of two notes on Sheet 4 in Appendix D (summarized as):

> "The top of the sheetpile wall will be covered with riprap at the completion of the work."
>
> "The riprap toe protection will be well graded, composed of angular stones and will be smooth and uniform in appearance. Oversize stones will be rejected, as well as riprap which contains an objectionable amount of fines."

3) USEPA requested the inclusion into the ½ -Mile Removal Action Work Plan of mitigation measures for the permanent loss of bank habitat and stream cover resulting from the proposed bank soil removal.

GE responds to these three items as follows:

1) During the site restoration, GE will implement the USEPA suggestion concerning the installation of either a heavy-duty woven geotextile or geogrid beneath the riprap.

2) GE will incorporate notes to Sheet 4 similar to those suggested by USEPA. A revised Sheet 4 is presented in Attachment 2.

3) Section 9.2 of the ½-Mile Removal Action Work Plan includes mitigation measures pertaining to restoration of areas where bank excavations will occur. The riprap backfill planned as part of the proposed sheetpile containment barrier will not result in significant loss of bank or river bed habitats. Riprap will be utilized in an approximate 5- to 6-foot wide strip along the toe of the bank. It will be placed on a slope extending from approximately the top of the sheeting to the edge of the river. The work planned in this area will result only in a temporary absence of bank habitat. GE will evaluate the need for additional restoration activities along this narrow rip-rap strip in the final ½-Mile Removal Action Work Plan.

In addition to responding to the USEPA's above-listed comments relating to site restoration, and as mentioned in Section III above, GE's technical consultant, BBL, has evaluated restoration conditions associated with a 1:1 slope along the riverside of the proposed sheetpile wall. Specifically, the evaluation was conducted to ascertain: 1) the location of the sheetpile wall necessary to result in an approximate 1:1 slope between the top of the wall (i.e., elevation of 977 feet) and the edge of the Housatonic River (i.e., assumed at an average elevation of 972 feet); and 2) the potential change in flood storage volume resulting from the proposed activities, incorporating the re-alignment of the sheetpile to achieve a 1:1 slope.

Figure 1 depicts the proposed re-alignment of the sheetpile wall necessary to fulfill the criteria in Item 1 in the preceding paragraph. This re-alignment was generated by assuming that bank soil removal could extend horizontally to the edge of the river. Placement of a 1:1 slope will require a width of 5.0 feet between the sheetpiling and the river edge to avoid encroachment on the river channel. This guideline results in the sheetpiling re-alignment shown on Figure 1. Note that, in certain areas, the sheetpile top elevation 977 feet is now below existing grade (generally near upstream wing wall). Hence, the height of the sheetpile top in these areas will be adjusted to allow for the re-alignment on Figure 1.

Figures 5 and 6 present two illustrative cross sections of the proposed sheetpile and bank restoration. Figure 1 also depicts these cross section locations along the sheetpile. The cross sections represent approximate typical sections for calculating changes of flood storage capacity (discussed below) due to the removal of bank soil associated with sheetpile installation and restoration of the lower portion of the bank with rip-rap at a 1:1 slope.

Several assumptions have been made in assessing the changes in flood storage capacity due to this project: 1) both existing soil and riprap backfill were assumed to have similar porosities; 2) permeability differences between soil and riprap were ignored; 3) riprap will constitute the entire fill volume (i.e., a triangular solid with a length of 388 feet, height of 5.0 feet, and base of 5.0 feet); and 4) the assessment of the change in flood storage capacity ignores changes that may result from work in the first ½ -mile of the Housatonic River stream bed.

If it is assumed that the porosities and permeabilities of the existing soil and riprap backfill are both similar and inconsequential, assessing the change in flood storage capacity is reduced to a comparison of material present prior to, and following, removal and restoration operations.

The volume of the existing soil located between the sheetpile wall and the river is estimated at 116 cy. The volume of the riprap backfill is 205 cy. The resultant change in flood storage capacity is a loss of approximately 89 cy.

Figures 5 and 6 depict two cross sections typical of the changes in grade at locations along the proposed sheetpile wall. Changes in flood storage per total volume, per foot of elevation, are also presented in tabulated format for each cross section.

Preliminary flood storage capacity calculations related to site restoration at the Building 68 Area located just downstream, indicates a reserve volume of flood storage capacity from that project which is generally of the same order of magnitude needed for the 1:1 slope re-alignment for the proposed sheetpile wall. The results of the preliminary Building 68 Area flood storage capacity calculations were presented in the Notice of Intent for General Electric Company, Newell Street Parking Lot Pump Station, dated December 17, 1998 (Newell Street NOI). In that document, it was indicated that a reserve flood capacity of 74 cy existed as a result of the Building 68 Area activities. It was further explained that approximately 19 cy of the 74 cy were needed to compensate for the Newell Street Parking Lot Pump Station. This would result in a net reserve capacity of approximately 55 cy. However, the preliminary calculations performed for the Building 68 Area were based on estimates made utilizing riverbank topography which was only partially surveyed. Final survey data has been recently obtained which indicates that the actual reserve flood storage capacity will be greater than the preliminary calculation of 74 cy. BBL is currently in the process of incorporating this new data and revising the calculations. When the sheetpile wall is installed, GE will provide a final evaluation of the resulting change in flood storage capacity. If the increase of material along the sheetpile barrier cannot be offset by the reserve capacity from the Building 68 Area, GE will propose a means to offset this increase.

In addition to these analyses, we are including as Attachment 3 an evaluation of the potential impacts of the proposed project on areas subject to the Massachusetts Wetlands Protection Act (310 CMR 10.00), together with a description of the proposed temporary mitigation (e.g., erosion control) measures and permanent site restoration measures designed to mitigate or minimize such impacts. Although approval from the Pittsfield Conservation Commission is not necessary to implement this project (since the project is an onsite removal action under the Comprehensive Environmental Response, Compensation, and Liability Act), this Attachment is provided to address the substantive requirements of the Massachusetts Wetlands Protection Act.

VII. FURTHER EVALUATION OF DNAPL

As part of its February 11, 1999 conditional approval letter, the USEPA requested that GE conduct additional DNAPL characterization activities south of the Housatonic River in the vicinity of the proposed containment barrier. Specifically, the USEPA suggested the drilling of three soil borings (rather than the proposed single boring) along the southern bank to evaluate the potential presence of DNAPL and determine the top of till elevation.

In response, GE proposes to install three soil borings along the south bank of the Housatonic River at the locations shown on Figure 1. These borings will be installed and sampled in a manner consistent with the previous source control investigation borings installed at the East Street Area 2 site. These borings have been located in a potential "trough" area in the till surface as indicated by the geophysical data presented in the Source Control Report.

The USEPA also requested in the conditional approval letter that GE include in the forthcoming *DNAPL Recovery Evaluation and Report* performance standards and measurement methods concerning DNAPL in the East Street Area 2 site. GE will do so, and anticipates submission of that report within approximately six weeks of completing the three new borings at the Hibbard Playground. (It should be noted that GE has not yet received access from the City of Pittsfield to install these borings.)

VIII. WEST HEADWALL

As part of its February 11, 1999 conditional approval letter, the USEPA presented several comments concerning the proposed configuration of the sheetpile wall in the vicinity of the west headwall as presented on Sheet 5 of Appendix D of the Supplemental Source Control Proposal. In general, these comments relate to the integration of the sheetpile wall with the headwall without resulting in permanently exposed sheetpiles along this portion of the river.

In response to these comments, the alignment of the sheetpile wall in the vicinity of the west headwall has been modified to address the USEPA's comments. The modified connection details are shown on Figure 1 and in Attachment 4. Specifically, the sheetpile wall alignment has been changed such that it will extend out flush with the front face of the west headwall, with the use of "L" sections on either side of the headwall. To accomplish this, longer sheets will be used in this area so that the driving hammer will not be obstructed by the existing headwall. The sheets will then be cut flush with the top of the headwall once they have been driven to the desired depth. A new concrete headwall will be constructed on the face of the sheetpile such that the sheetpile will not be exposed. Geotextile and riprap will be placed at the excavated toe of the bank slope as a measure of erosion protection until such time that final excavation and restoration activities are conducted as part of the ½-Mile Removal Action Work Plan activities.

IX. FURTHER INVESTIGATIONS PURSUANT TO SUPPLEMENTAL SOURCE CONTROL CONTAINMENT/RECOVERY MEASURES

The USEPA's February 11, 1999 conditional approval letter presented several conditions to be applied to the work proposed by GE in a letter dated January 29, 1999. GE's January 29, 1999 letter proposed additional bank soil and sediment sampling activities in the area of the sheetpile wall at East Street Area 2 in order to obtain additional descriptive and analytical data of the riverbank and near-bank soils and sediments.

The USEPA's conditions are summarized as follows:

1) GE will survey each sampling location in the horizontal and vertical planes;

2) GE will collect samples from each location to the limits of the approved sampling equipment (i.e. refusal);

3) All samples collected will be analyzed for PCBs and TPH;

4) Shake tests will be performed on all samples;

5) Efforts will be made to collect bank samples to elevation 967;

6) Sampling intervals for bank locations will begin at the water table or at two feet below grade, whichever horizon is encountered first; and

7) Samples will be analyzed within 5 days of receipt by the laboratory.

GE conducted these sampling efforts on February 8, 9 and 10, 1999 (with USEPA Contractor oversight) in accordance with the conditions listed above. The data obtained during this sampling effort have been used to support discussions presented in Section III above, as further summarized in Tables 1 and 2 and on Figure 3. It should be noted (as indicated above in Section III) that sediment sampling refusal occurred at a depth of 1 foot at the majority of the sampling locations.

X. REVISED SCHEDULE

In their conditional approval letter, the USEPA requested a revised construction schedule. This schedule is presented in Figure 7, GE will contact USEPA shortly to discuss the timing of the proposed sheetpile installation relative to implementation of the work activities proposed in the ½-Mile Removal Action Work Plan.

If you have any questions on this information, feel free to contact me at (413) 494-3952.

Yours truly,

John D. Ciampa
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Housatonic River Initiative
Public Information Repositories ECL I-P-IV(A)(1)* & (2)

(* with tables, figures, and attachments)

Tables

TABLE 1

GENERAL ELECTRIC COMPANY - PITTSFIELD, MASSACHUSETTS
SOURCE CONTROL MEASURES FOR EAST STREET AREA 2 / USEPA AREA 4

SUMMARY OF SEDIMENT AND RIVERBANK SOIL DATA - FEBRUARY 1999

Sample Identification	Depth	Elevation Interval (Feet AMSL)	Date Collected	Analytical Results (ppm)		Field Observations/Testing		
				Total PCBs	TPH	PID Reading (Instrument Units)	Stain / Sheen Observed on Soil Core	Shake Test Results
Riverbank Soil								
SL0007-BNK(0-1')	0-1'	974.7 - 973.7	02/10/99	N/A	N/A	8.3	no	negative
SL0007-BNK(1-2')	1-2'	973.7 - 972.7	02/10/99	N/A	N/A	10.2	no	negative
SL0007-BNK(2-3')	2-3'	972.7 - 971.7	02/10/99	26.6	450	40.2	yes	trace oily residue
SL0007-BNK(3-4')	3-4'	971.7 - 970.7	02/10/99	0.301	240	23.7	yes	trace oily residue
SL0007-BNK(4-5')	4-5'	970.7 - 969.7	02/10/99	ND (0.057)	600	35.5	yes	oily residue
SL0007-BNK(5-6')	5-6'	969.7 - 968.7	02/10/99	ND (0.064)	560	41.5	yes	oily residue
SL0007-BNK(6-7')	6-7'	968.7 - 967.7	02/10/99	ND (0.062)	700	35.7	yes	oily residue, trace sheen
SL0007-BNK(7-8')	7-8'	967.7 - 966.7	02/10/99	0.118	260	21.3	yes	trace oily residue
SL0404-BNK(0-1')	0-1'	976.6 - 975.6	02/10/99	N/A	N/A	4.3	no	negative
SL0404-BNK(1-2')	1-2'	975.6 - 974.6	02/10/99	N/A	N/A	7.6	no	negative
SL0404-BNK(2-3')	2-3'	974.6 - 973.6	02/10/99	3.51	ND (100)	4.6	no	negative
SL0404-BNK(3-4')	3-4'	973.6 - 972.6	02/10/99	20	140	5.6	no	negative
SL0404-BNK(4-5')	4-5'	972.6 - 971.6	02/10/99	187	730	12.5	yes (4.8-5.0' only)	trace oily residue
SL0404-BNK(5-6')	5-6'	971.6 - 970.6	02/10/99	725	2,900	18.3	yes	sheen
SL0404-BNK(6-7')	6-7'	970.6 - 969.6	02/10/99	84.6	4,100	27.3	yes	sheen
SL0404-BNK(7-8')	7-8'	969.6 - 968.6	02/10/99	57.7	610	29.8	yes (7-7.8' only)	oily residue
SL0028-BNK(0-1')	0-1'	973.5 - 972.5	02/10/99	N/A	N/A	9.7	no	negative
SL0028-BNK(1-2')	1-2'	972.5 - 971.5	02/10/99	1.59 [4.91]	ND(120) [ND(100)]	8.1	no	negative
SL0028-BNK(2-3')	2-3'	971.5 - 970.5	02/10/99	5.61	180	7.3	no	trace oil
SL0028-BNK(3-4')	3-4'	970.5 - 969.5	02/10/99	23.5	2,000	28.6	no	oily residue
SL0028-BNK(4-5')	4-5'	969.5 - 968.5	02/10/99	7.82	1,600	41.2	yes	oily residue
SL0028-BNK(5-6')	5-6'	968.5 - 967.5	02/10/99	59.2	1,800	81.7	yes	oily residue
SL0028-BNK(6-7')	6-7'	967.5 - 966.5	02/10/99	4.26	100	25	yes (6-6.5' only)	trace oil
SL0028-BNK(7-8')	7-8'	966.5 - 965.5	02/10/99	0.401	ND (100)	17	no	negative
SL0401-BNK(0-1')	0-1'	974.9 - 973.9	02/08/99	1.91	ND (110)	3.7	no	negative
SL0401-BNK(1-2')	1-2'	973.9 - 972.9	02/09/99	37.4	2,700	9.2	no	negative
SL0401-BNK(2-3')	2-3'	972.9 - 971.9	02/09/99	94.6	4,200	17.6	no	negative
SL0401-BNK(3-4')	3-4'	971.9 - 970.9	02/09/99	21.8	1,600	24	no	oily residue
SL0401-BNK(4-5')	4-5'	970.9 - 969.9	02/09/99	39.9 [13.1]	3,100 [970]	34.7	yes	oily residue
SL0401-BNK(5-6')	5-6'	969.9 - 968.9	02/09/99	20	910	27	yes	sheen
SL0401-BNK(6-7')	6-7'	968.9 - 967.9	02/09/99	1.19	ND (100)	19.7	yes	oily residue
SL0401-BNK(7-8')	7-8'	967.9 - 966.9	02/09/99	0.392	ND (100)	11.2	no	negative

See notes on page 3.

TABLE 1

GENERAL ELECTRIC COMPANY - PITTSFIELD, MASSACHUSETTS
SOURCE CONTROL MEASURES FOR EAST STREET AREA 2 / USEPA AREA 4

SUMMARY OF SEDIMENT AND RIVERBANK SOIL DATA - FEBRUARY 1999

Sample Identification	Depth	Elevation Interval (Feet AMSL)	Date Collected	Analytical Results (ppm)		Field Observations/Testing		
				Total PCBs	TPH	PID Reading (Instrument Units)	Stain / Sheen Observed on Soil Core	Shake Test Results
Riverbank Soil (cont.)								
SL0041-BNK(0-1')	0-1'	973.2 - 972.2	02/09/99	N/A	N/A	24.7	no	negative
SL0041-BNK(1-2')	1-2'	972.2 - 971.2	02/09/99	477	46,000	38.0	yes	negative
SL0041-BNK(2-3')	2-3'	971.2 - 970.2	02/09/99	53.5	5,700	31.8	yes	oily residue
SL0041-BNK(3-4')	3-4'	970.2 - 969.2	02/09/99	157	3,100	30.4	yes	sheen
SL0041-BNK(4-5')	4-5'	969.2 - 968.2	02/09/99	16.1	430	29.9	yes	oily residue
SL0041-BNK(5-6')	5-6'	968.2 - 967.2	02/09/99	0.773	ND (100)	18.6	yes	oily residue
SL0041-BNK(6-7')	6-7'	967.2 - 966.2	02/09/99	0.272	ND (100)	10.7	yes	oily residue
SL0041-BNK(7-8')	7-8'	966.2 - 965.2	02/09/99	ND (0.052)	ND (100)	8.5	yes (7-7.8' only)	trace sheen
SL0398-BNK(0-1')	0-1'	974.9 - 973.9	02/09/99	N/A	N/A	6.9	no	negative
SL0398-BNK(1-2')	1-2'	973.9 - 972.9	02/09/99	N/A	N/A	4.6	no	negative
SL0398-BNK(2-3')	2-3'	972.9 - 971.9	02/09/99	386	4,300	4.0	no	negative
SL0398-BNK(3-4')	3-4'	971.9 - 970.9	02/09/99	88.3	3,400	32.0	yes	trace oily residue
SL0398-BNK(4-5')	4-5'	970.9 - 969.9	02/09/99	20.9	1,800	38.7	yes	trace sheen
SL0398-BNK(5-6')	5-6'	969.9 - 968.9	02/09/99	12.5	900	36.3	yes	trace sheen
SL0398-BNK(6-7')	6-7'	968.9 - 967.9	02/09/99	2.06	170	22.4	yes (6-6.5' only)	trace oily residue
SL0398-BNK(7-8')	7-8'	967.9 - 966.9	02/09/99	0.715	ND (100)	9.7	no	negative
SL0031-BNK(0-1')	0-1'	973.1 - 972.1	02/09/99	N/A	N/A	6.5	no	negative
SL0031-BNK(1-2')	1-2'	972.1 - 971.1	02/09/99	N/A	N/A	8.0	no	negative
SL0031-BNK(2-3')	2-3'	971.1 - 970.1	02/09/99	189	8,900	31.0	yes (2-2.5' only)	negative
SL0031-BNK(3-4')	3-4'	970.1 - 969.1	02/09/99	8.72	580	27.7	no	trace oily residue
SL0031-BNK(4-5')	4-5'	969.1 - 968.1	02/09/99	0.199	ND (100)	14.0	no	negative
SL0031-BNK(5-6')	5-6'	968.1 - 967.1	02/09/99	0.145	ND (100)	9.9	no	negative
SL0031-BNK(6-7')	6-7'	967.1 - 966.1	02/09/99	0.171	ND (100)	9.0	no	trace sheen
SL0031-BNK(7-8')	7-8'	966.1 - 965.1	02/09/99	0.064	ND (100)	8.2	no	negative
SL0395-BNK(0-1')	0-1'	975.8 - 974.8	02/09/99	N/A	N/A	11.8	no	negative
SL0395-BNK(1-2')	1-2'	974.8 - 973.8	02/09/99	N/A	N/A	6.2	no	negative
SL0395-BNK(2-3')	2-3'	973.8 - 972.8	02/09/99	8	130	6.2	no	negative
SL0395-BNK(3-4')	3-4'	972.8 - 971.8	02/09/99	599	47,000	18.7	no	negative
SL0395-BNK(4-5')	4-5'	971.8 - 970.8	02/09/99	232	19,000	32.3	yes (4.9-5.0' only)	negative
SL0395-BNK(5-6')	5-6'	970.8 - 969.8	02/09/99	19.5 [21.4]	1,200 [1,600]	21.9	yes (5.0-5.1' only)	trace oil
SL0395-BNK(6-7')	6-7'	969.8 - 968.8	02/09/99	2.15	200	20.1	no	negative
SL0395-BNK(7-8')	7-8'	968.8 - 967.8	02/09/99	2.96	230	17.8	no	negative

See notes on page 3.

TABLE 1

GENERAL ELECTRIC COMPANY - PITTSFIELD, MASSACHUSETTS
SOURCE CONTROL MEASURES FOR EAST STREET AREA 2 / USEPA AREA 4

SUMMARY OF SEDIMENT AND RIVERBANK SOIL DATA - FEBRUARY 1999

Sample Identification	Depth	Elevation Interval (Feet AMSL)	Date Collected	Analytical Results (ppm)		Field Observations/Testing		
				Total PCBs	TPH	PID Reading (Instrument Units)	Stain / Sheen Observed on Soil Core	Shake Test Results
River Sediment								
SL0007-SED(0-1')	0-1'	971.1 - 970.1	02/08/99	51.1	800	14.4	yes	negative
SL0404-SED(0-1')	0-1'	969.3 - 968.3	02/08/99	42.8	280	17.2	yes	trace sheen
SL0404-SED(1-2')	1-2'	968.3 - 967.3	02/08/99	52.8	450	42.6	yes	sheen
SL0028-SED(0-1')	0-1'	971.8 - 970.8	02/08/99	3.12	160	10.5	no	negative
SL0401-SED(0-1')	0-1'	970.9 - 969.9	02/08/99	165	11,000	25.5	yes	trace sheen
SL0398-SED(0-1')	0-1'	970.8 - 969.8	02/08/99	30.1	1,800	20.0	yes	sheen
SL0031-SED(0-1')	0-1'	971.0 - 970.0	02/08/99	46.2 [49.6]	2,300 [2,200]	33.3	no	negative
SL0395-SED(0-1')	0-1'	971.0 - 970.0	02/08/99	8.51	460	25.6	no	negative
SL0395-SED(1-2')	1-2'	970.0 - 969.0	02/08/99	ND (0.056)	ND (100)	17.7	no	negative
SL0395-SED(2-3')	2-3'	969.0 - 968.0	02/08/99	0.091	ND (100)	17.1	no	negative
SL0395-SED(3-4')	3-4'	968.0 - 967.0	02/08/99	ND (0.058)	ND (100)	16.8	no	negative
SL0041-SED(0-1')	0-1'	971.3 - 970.3	02/08/99	58.7	2,700	28.3	yes	trace sheen
SL0044-SED(0-1')	0-1'	971.1 - 970.1	02/08/99	ND (0.056)	ND (100)	12.6	no	negative

Notes:

1. Samples were collected and field tested by Blasland, Bouck & Lee, Inc.
   Field analyses consisted of photoionization detector (PID) screening, shake testing, and sample description.
2. Water shake tests were performed on all samples.
3. Samples submitted to Northeast Analytical, Inc., for analysis of PCBs by EPA Method 8082 and Total Petroleum Hydrocarbons (TPH) by EPA Method 418.1.
4. ppm: dry weight parts per million.
5. Duplicate sample results shown in brackets [ ].
6. ND: not detected (Practical Quantitation Limit shown in parantheses).
7. N/A: not analyzed.
8. Feet AMSL: Feet above mean sea level.

TABLE 2

GENERAL ELECTRIC COMPANY - PITTSFIELD, MASSACHUSETTS
SOURCE CONTROL MEASURES FOR EAST STREET AREA 2 / USEPA AREA 4

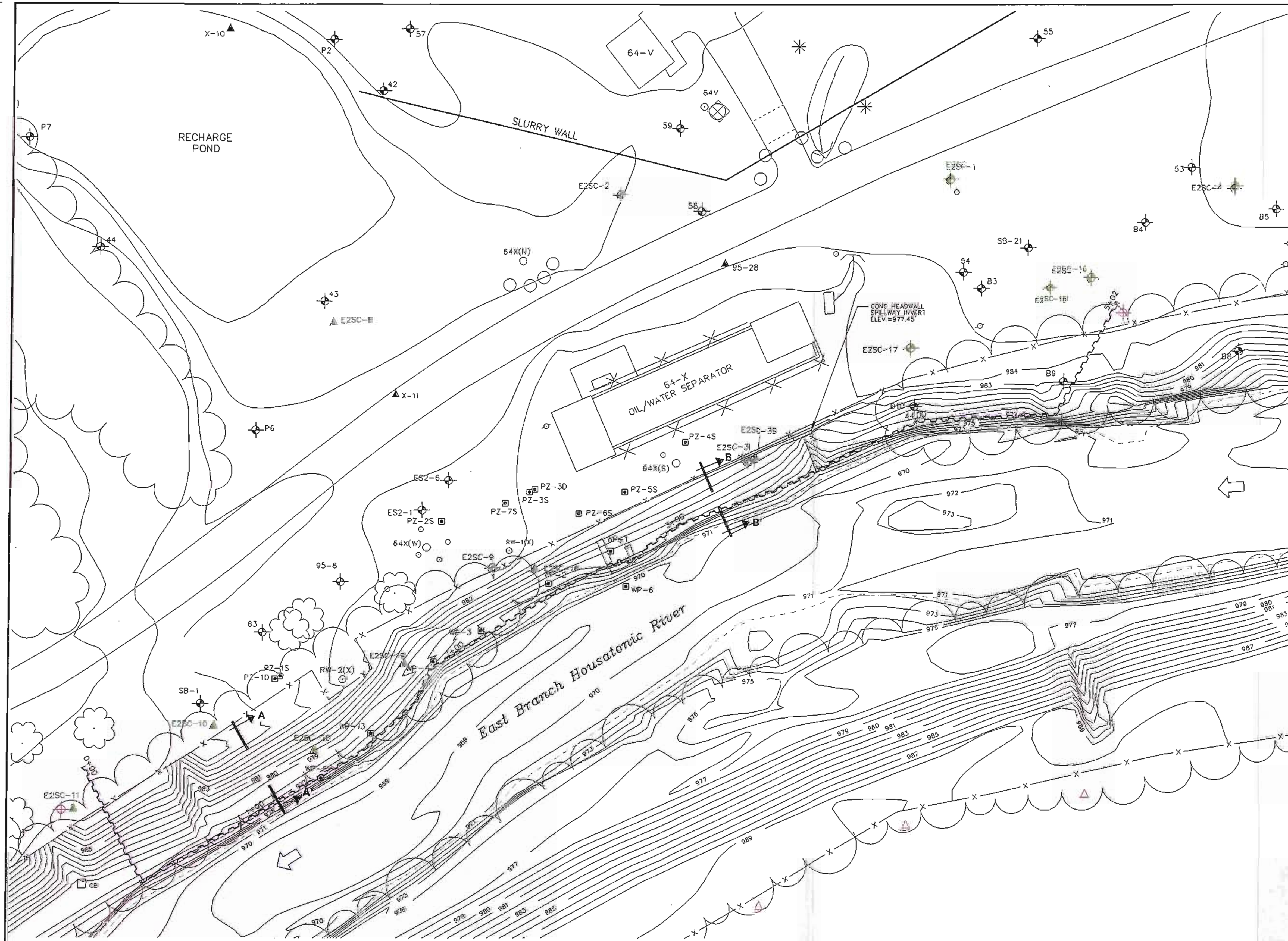
SUMMARY OF RIVERBANK SOIL TCLP DATA - FEBRUARY 1999

Sample I.D.:	SL0007-BNK(1-2')	SL0028-BNK(0-1')	SL0041-BNK(0-1')	SL0395-BNK(1-2')
Date:	02/10/99	02/10/99	02/09/99	02/09/99
Depth:	1-2'	0-1'	0-1'	1-2'
Elevation:	973.7 - 972.7	973.5 - 972.5	973.2 - 972.2	974.8 - 973.8
VOLATILES				
Chlorobenzene	ND (0.005)	ND (0.005)	0.0133	ND (0.005)
SEMI-VOLATILES	None Detected			
PESTICIDES	None Detected			
HERBICIDES	None Detected			
METALS				
Barium	0.78	0.64	0.69	0.34
Lead	0.18	ND (0.18)	ND (0.18)	ND (0.18)

Notes:

1. Samples were collected by Blasland, Bouck & Lee, Inc.
2. Samples were submitted to Northeast Analytical, Inc., for analyses by the following EPA Methods:
   - VOLATILES: EPA Method 8260B-TCLP
   - SEMI-VOLATILES: EPA Method 8270C - TCLP
   - PESTICIDES: EPA Method 8081
   - HERBICIDES: EPA Method 8151A
   - METALS: EPA Method 6010B (7471A for mercury)
3. Results are presented in parts per million (ppm). Only constituents detected in at least one sample are presented.
4. ND: not detected (Practical Quantitation Limit shown in parantheses, when applicable).
5. Elevations presented in feet above mean sea level.

Figures



LEGEND:

- EXISTING INDEX ELEVATION CONTOUR
- 980 — EXISTING INTERMEDIATE ELEVATION CONTOUR
- TYPICAL WATER LINE
- DECIDUOUS TREE
- CONIFEROUS TREE
- MANHOLE
- CHAIN LINK FENCE
- POLE (NON-UTILITY)
- POLE (OVERHEAD UTILITY)
- ES2-1 PREVIOUSLY INSTALLED MONITORING WELL
- 64X(W) PREVIOUSLY INSTALLED OIL RECOVERY CAISSON
- RW-1(X) PREVIOUSLY INSTALLED PUMPING WELL
- X-11 PREVIOUSLY INSTALLED SOIL BORING
- PZ-4S PREVIOUSLY INSTALLED PIEZOMETER
- E2SC-1 1998 MONITORING WELLS
- E2SC-5 1998 SOIL BORINGS
- LOCATION OF REVISED PROPOSED CONTAINMENT BARRIER
- PROPOSED MONITORING WELL
- PROPOSED SOIL BORING
- A A' APPROXIMATE CROSS SECTION LOCATION

NOTES:

1. BASE MAP PROVIDED BY LOCKWOOD MAPPING, INC. PREPARED FROM 1990 AERIAL PHOTOGRAPHY. RIVERBANK AND RIVER BED TOPOGRAPHIC INFORMATION PROVIDED BY BBL FROM OCTOBER 12-23, 1998 FIELD SURVEY.
2. COORDINATE GRID BASED ON 1927 STATE PLANE COORDINATES.
3. ELEVATION DATUM REFERENCED TO NGVD 1929.
4. CONTOUR INTERVAL IN THE RIVER AND ON RIVERBANK = 1 FOOT CONTOUR. INTERVAL OUTSIDE RIVERBANK AREA = 2 FEET.
5. ALL MONITORING WELL, BORING, PUMPING WELL, CAISSON, FENCE, MANHOLE, AND TREE LOCATIONS ARE APPROXIMATE.
6. PROFILE OF SHEETPILE WALL ALIGNMENT, INCLUDING SHEETPIPE LENGTHS AND CUTOFF ELEVATIONS, SHOWN ON DRAWING 4.

20' 0 20' 40'
SCALE (FEET)

GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS

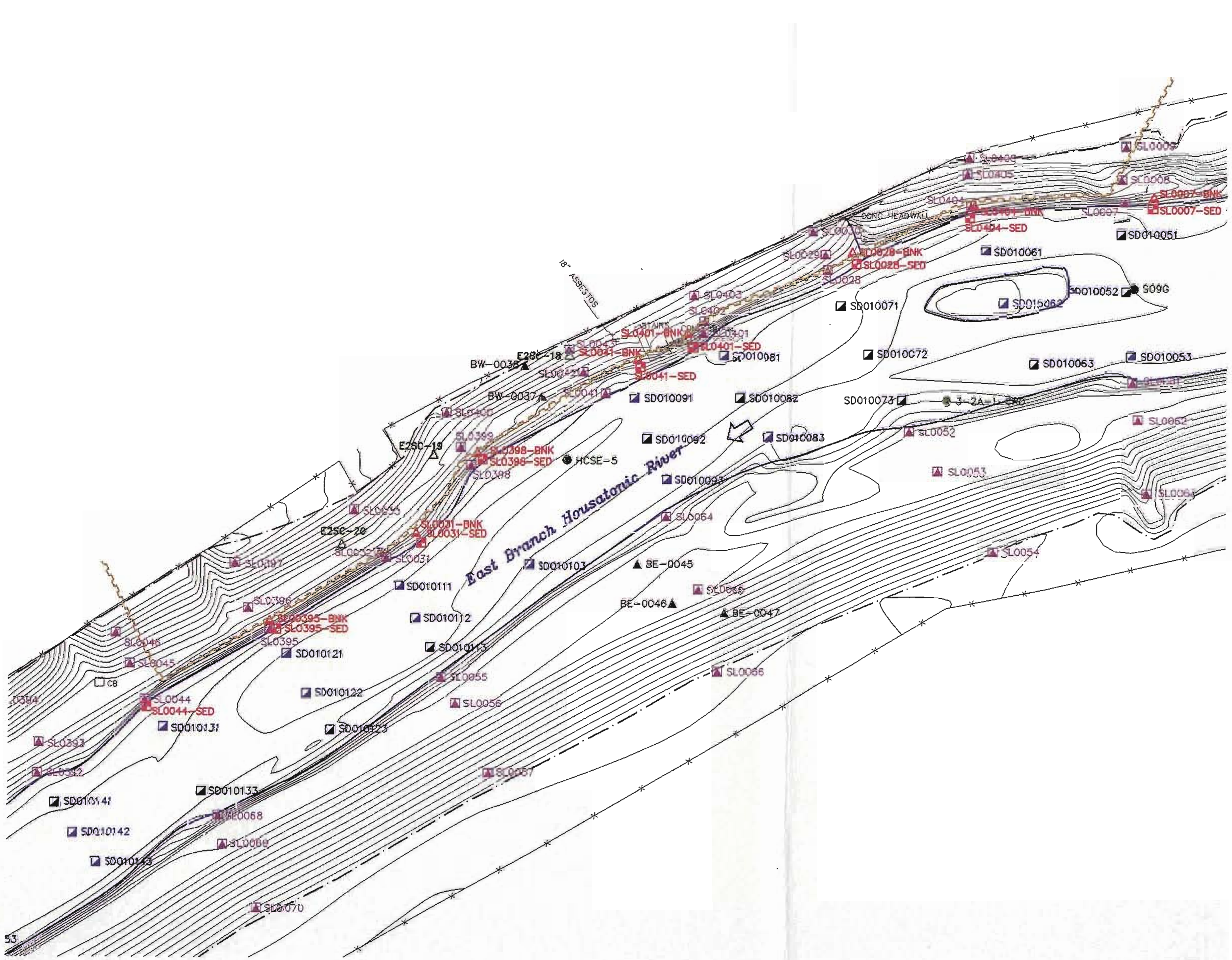
EAST STREET AREA 2 SUPPLEMENTAL SOURCE CONTROL MEASURES

CONTAINMENT BARRIER PLAN

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 1

X: 20140X03, 20140X05
L: ON=*, OFF=*REF
P: STD/PCP-DL
3/1/99 SYR-54-RJM GMS AK
20140005\20140B18.DWG



LEGEND:

- SUPPLEMENTAL BANK SAMPLE LOCATION 2/99
- SUPPLEMENTAL SEDIMENT SAMPLE LOCATION 2/99
- EPA SEDIMENT SAMPLE LOCATION
- OTHER SEDIMENT SAMPLE LOCATION
- EPA BANK SAMPLE LOCATION
- OTHER BANK SAMPLE LOCATION
- 1998 TPH SOIL BORING LOCATION
- LOCATION OF REVISED PROPOSED CONTAINMENT BARRIER

NOTES:

1. BASE MAP PROVIDED BY LOCKWOOD MAPPING, INC. PREPARED FROM 1990 AERIAL PHOTOGRAPHY. RIVERBANK AND RIVER BED TOPOGRAPHIC INFORMATION PROVIDED BY BBL FROM OCTOBER 12-23, 1998 FIELD SURVEY.
2. COORDINATE GRID BASED ON 1927 STATE PLANE COORDINATES.
3. ELEVATION DATUM REFERENCED TO NGVD 1929.
4. CONTOUR INTERVAL IN THE RIVER AND ON RIVERBANK = 1 FOOT CONTOUR. INTERVAL OUTSIDE RIVERBANK AREA = 2 FEET.
5. ALL MONITORING WELL, BORING, PUMPING WELL, CAISSON, FENCE, MANHOLE, AND TREE LOCATIONS ARE APPROXIMATE.
6. PROFILE OF SHEETPILE WALL ALIGNMENT, INCLUDING SHEETPIPE LENGTHS AND CUTOFF ELEVATIONS, SHOWN ON DRAWING 4.

0 40' 80'

GRAPHIC SCALE

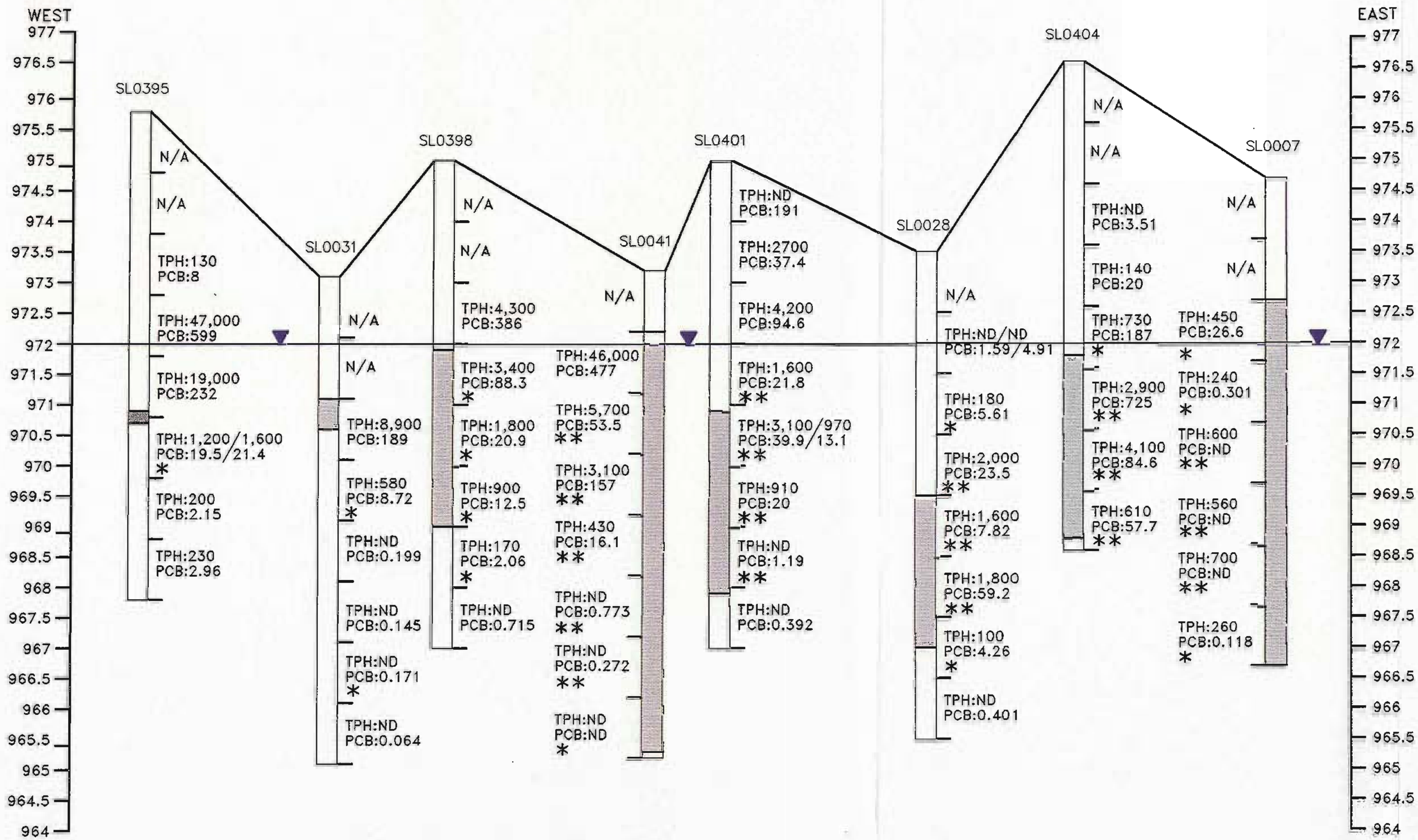
GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
EAST STREET AREA 2 SUPPLEMENTAL SOURCE CONTROL MEASURES

SUPPLEMENTAL SAMPLING LOCATIONS - FEBRUARY 1999

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 2

X: NONE
L: ON =* OFF=*REF*,SURV*
P: STD-PCP/BL
02/25/99 SYR-54-NES AK
20140B08/20140B19.DWG



LEGEND:

SL0007	BORING DESIGNATION
TPH:ND PCB:ND	SOIL SAMPLE INTERVAL: TOTAL PETROLEUM HYDROCARBON (TPH) AND TOTAL POLYCHLORINATED BIPHENYL (PCB) CONCENTRATIONS IN DRY WEIGHT PARTS PER MILLION
ND	NOT DETECTED
ND/ND	DUPLICATE SAMPLE RESULTS
N/A	NOT ANALYZED
(shaded box)	STAINING/SHEEN OBSERVED ON SOIL CORE
*	TRACE OIL/SHEEN OBSERVED DURING SOIL-WATER SHAKE TEST
**	OIL RESIDUE/SHEEN OBSERVED DURING SOIL-WATER SHAKE TEST
(triangle)	APPROXIMATE WATER TABLE ELEVATION DURING SAMPLING EFFORT: 972 FEET AMSL

0 2' 4'
VERTICAL GRAPHIC SCALE

0 30' 60'
HORIZONTAL GRAPHIC SCALE

L: ON=*; OFF=*REF
P: STD/PCP-BL
2/25/99 SYR-54-RJM AK
20140052\20140V01.DWG

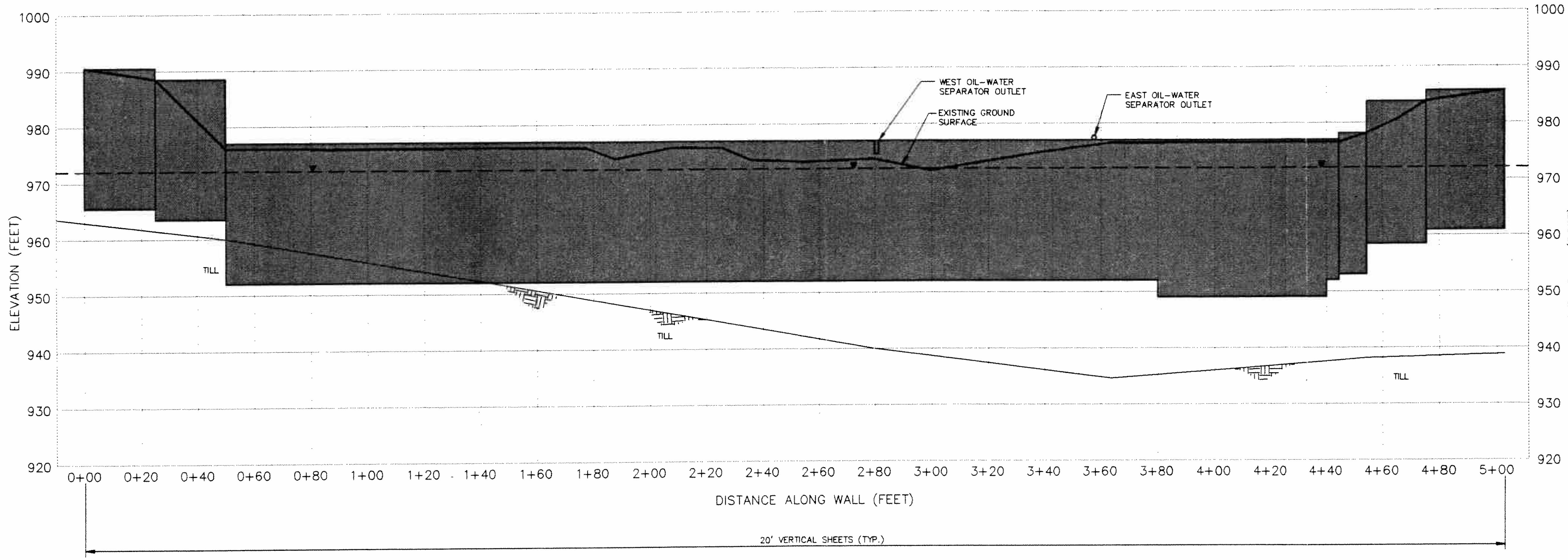
GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS

EAST STREET AREA 2 SUPPLEMENTAL SOURCE CONTROL MEASURES

GENERALIZED CROSS-SECTIONAL SUMMARY OF RIVERBANK SOIL DATA-FEBRUARY 1999

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 3



LEGEND:

CP10 SHEET PILE ALIGNMENT CONTROL POINT

TYPICAL RIVER SURFACE WATER ELEVATION

VERTICAL EXTENT OF PROPOSED CONTAINMENT BARRIER

20' 0 20' 40' HORIZONTAL SCALE (FEET)

10' 0 10' 20' VERTICAL SCALE (FEET)

NOTE:

1. TOP OF TILL TAKEN FROM SECTION A-A' OF FIGURE 3 IN SOURCE CONTROL PROPOSAL.
2. ALL THE DIMENSIONS AND ELEVATIONS ARE APPROXIMATE. FIELD CONDITIONS MAY VARY.
3. CUTOFF SHEETING AT APPROXIMATELY GROUND SURFACE AT STATIONS 0+00 TO 0+50 AND STATIONS 4+30 TO 4+85.

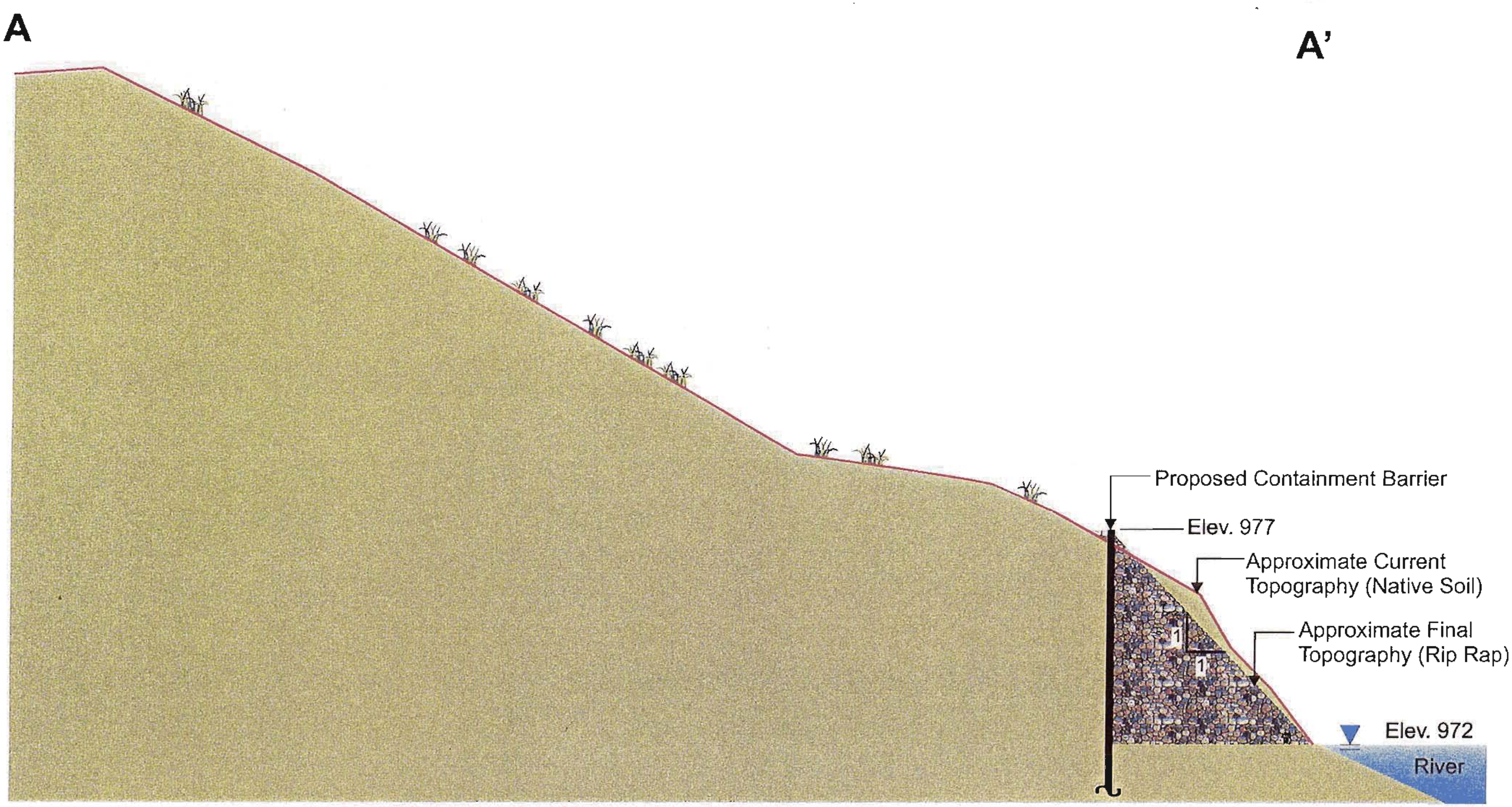
GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
EAST STREET AREA 2 SUPPLEMENTAL SOURCE CONTROL MEASURES

CONTAINMENT BARRIER PROFILE

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 4

L: ON=*, OFF=REF
P: STD-PCP/DL
3/1/99 SYR-54-AK GMS AK
20140005/20140V05.DWG



Approximate Changes in Flood Storage at A- A'

	ELEVATION INTERVAL				
	972 - 973	973 - 974	974 - 975	975 - 976	976 - 977
Current Flood Storage/ Total Volume (sf)	1.66 / 4.73	1.33 / 3.8	0.97 / 2.77	0.74 / 2.11	0.20 / 0.58
Final Flood Storage/ Total Volume (sf)	1.59 / 4.53	1.24 / 3.53	0.85 / 2.42	0.50 / 1.43	0.27 / 0.78
Change Flood Storage	0.13	0.18	0.23	0.44	-0.13
Total Change in Flood Storage at A-A'	+0.85 (sf), +0.09 (sy) (Addition of Void Space Available at Section)				

Approximate Scale 1" = 4'

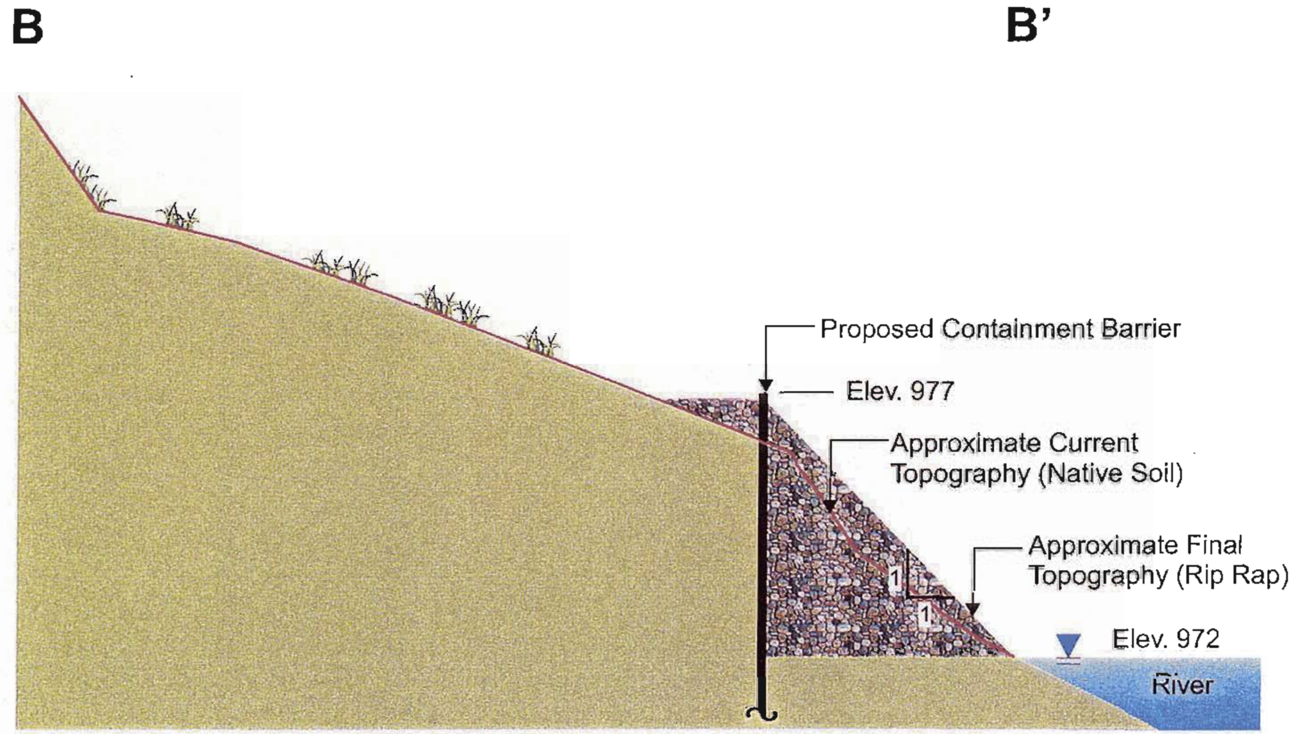
GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
EAST STREET AREA 2
SUPPLEMENTAL SOURCE CONTROL MEASURES

CONCEPTUAL CROSS-SECTION A-A'

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE **5**

02/99 SYR-D54-DJH
20140005/20140g06.CDR



Approximate Changes in Flood Storage at B- B'

	ELEVATION INTERVAL				
	972 - 973	973 - 974	974 - 975	975 - 976	976 - 977
Current Flood Storage/ Total Volume (sf)	1.39 / 3.97	0.89 / 2.54	0.50 / 1.43	0.20 / 0.58	0.04 / 0.12
Final Flood Storage/ Total Volume (sf)	1.61 / 4.59	1.16 / 3.32	0.76 / 2.17	0.38 / 1.08	0.58 / 1.66
Change Flood Storage	-0.40	-0.51	-0.48	-0.33	-1.00
Total Change in Flood Storage at B-B'	-2.72 (sf), - 0.30 (sy) (Loss of Void Space Available at Section)				

Approximate Scale 1" = 4'

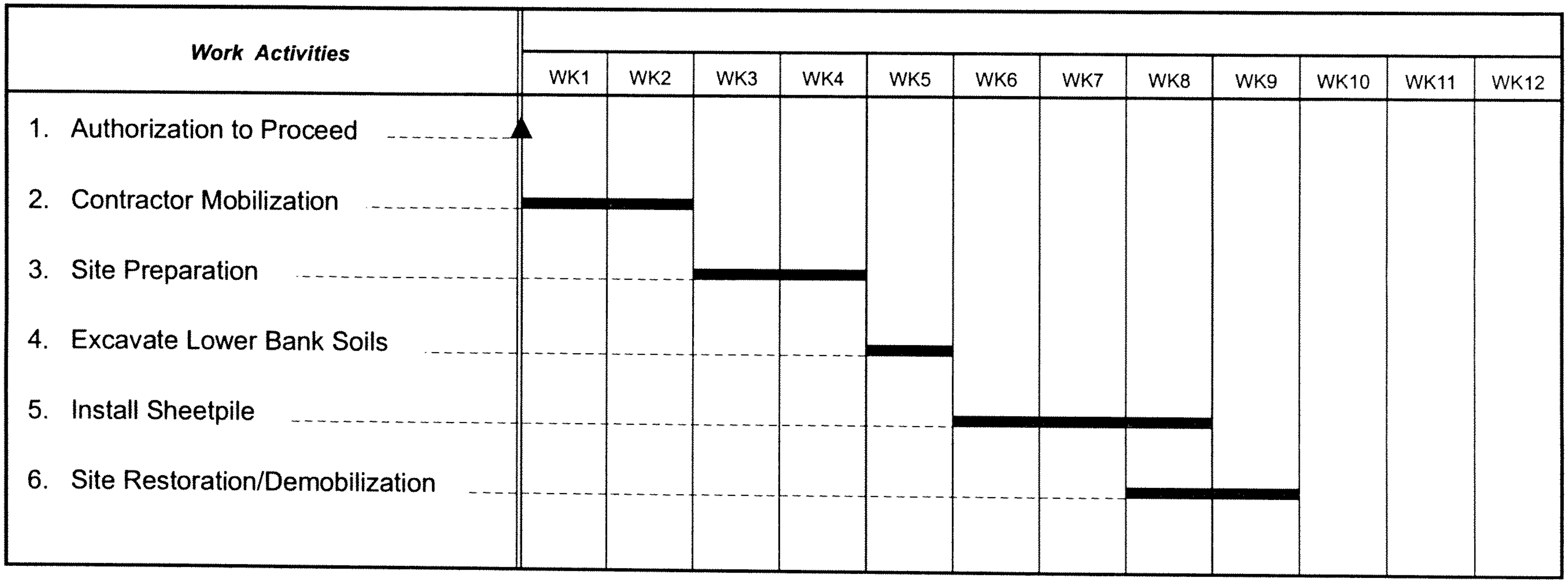
GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
EAST STREET AREA 2
SUPPLEMENTAL SOURCE CONTROL MEASURES

CONCEPTUAL CROSS-SECTION B-B'

BBL BLASLAND, BOUCK & LEE, INC. *engineers & scientists*

FIGURE 6

02/99 SYR-D54-DJH
20140005/20140g07.CDR



GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS
EAST STREET AREA 2
SUPPLEMENTAL PARKING LOT SOURCE CONTROL MEASURES

REVISED IMPLEMENTATION SCHEDULE - EAST STREET AREA 2 LNAPL CONTAINMENT BARRIER

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 7

03/99 SYR-D54-DJH
20140005/20140J05.cdr

Attachment 1

Revised Design Calculations for Proposed Containment Barrier

TASK:

To calculate the required embedment depth, maximum moment, and section modulus for a sheetpile wall supporting a slope of 2H:1V with soil excavated temporarily to 967.5 feet in front of the wall. The elevation of the top of the wall is 977 feet.

REFERENCES:

1. NAVFAC DM-7, March 1971.

2. Das, B. M. (1990) Principles of Foundation Engineering, 2nd Edition, PWS-Kent Publishing Company.

ASSUMPTIONS:

Soil unit weight = γ = 125 pcf
Buoyant soil unit weight = γ' = 62.6 pcf
Exposed height of sheetpile = 9.5 feet

CALCULATIONS:

The following calculation method is outlined in Ref. 2 (Sheets 13 through 20).

(1) Determine net pressure diagram:

(a) Calculate K_a and K_p
Using Table 1 from Ref. 1 (Sheet 21), wall friction angle $\delta = 14°$,

For K_p, $\phi = 30°$, $\beta = 0°$, $\delta = -14°$

Using Figure 6 on Sheet 22, for $\beta/\phi = 0°/30° = 0$, and $\delta/\phi = -14°/30° = -0.47$,

$K_p = R(K_p \text{ for } \delta/\phi = -1) = [(7/10)(0.746 - 0.686) + 0.686]x(6.5) = 0.728 \times 6.5 = 4.73$

$K_p = 4.73$

For K_a, $\phi = 30°$, $\beta = \tan^{-1}(1/2) = 26.6°$, $\delta = 14°$,

Since Figure 6 does not provide values for $\delta \neq \phi$, use general equation on Sheet 23 instead (with $\theta = 0$).

$K_a = \cos^2\phi \,/\, \{ \cos\delta[\, 1 + ((\sin(\phi+\delta)\sin(\phi-\beta)/(\cos\delta\cos(-\beta)))^{0.5}]^2\}$
$= \cos^2(30)/\, \{ \cos(14)[\, 1 + ((\sin(30+14)\sin(30\text{-}26.6)/(\cos(14)\cos(-26.6)))^{0.5}]^2\}$
$= 0.75/\, \{ 0.9703[\, 1 + (0.6947 \times 0.0591/(0.9703 \times 0.8942))^{0.5}]^2\}$

$K_a = 0.52$

(b) Calculate pressures and forces acting on wall.

All of the following calculations are based on the information provided on Sheets 6 and 13 through 20.

(i) Calculate active pressure on wall at EL 967.5 ft:

$p_1 = \gamma L_1 K_a = p_2$

$p_1 = 617.5$ psf

(ii) Determine location of zero net pressure as distance below excavation elevation (967.5 ft):

$$L_3 = \frac{p_2}{\gamma'(K_p - K_a)}$$

$L_3 = 2.34$ ft

(iii) Calculate magnitude and location of active force acting on wall, P.

$P = 0.5p_1L_1 + 0.5p_1L_3$

P = 3656 lb

$\sum M_E$ to determine location:

$Pz_1 = 1/2p_1L_1(L_3 + L_1/3) + 1/2p_1L_3(2/3L_3)$

$z_1 = 4.73$ ft

(iv) Formulate equations for pressures acting at the bottom of the sheetpile wall:

$p_3 = L_4(K_p - K_a)\gamma'$ (1)
$p_4 = \gamma L_1K_p + \gamma' L_3(K_p - K_a) + \gamma' L_4(K_p - K_a) = p_5 + \gamma' L_4(K_p - K_a)$ (2)
where $p_5 = \gamma L_1K_p + \gamma' L_3(K_p - K_a)$

$p_5 = 6234$ psf

(c) Satisfy principles of statics.

$\sum F_H = 0$
$P - 0.5p_3L_4 + 0.5(p_3 + p_4)L_5 = 0$ (3)

Solving Eq. 3 for L_5:

$$L_5 = \frac{p_3 L_4 - 2P}{p_3 + p_4} \tag{4}$$

$\sum M_B = 0$

$$P(L_4+z_1)-(1/2)L_4p_3(L_4/3)+(1/2)L_5(p_3+p_4)(L_5/3) = 0 \tag{5}$$

Combining Eqs. 1, 2, 4, and 5 and simplifying yields:

$$L_4^4+A_1L_4^3-A_2L_4^2-A_3L_4-A_4 = 0 \tag{6}$$

where

$$A_1 = \frac{p_5}{\gamma'(K_p-K_a)} \qquad A_2 = \frac{8P}{\gamma'(K_p-K_a)}$$

$$A_3 = \frac{6P[2z_1\gamma'(K_p-K_a)+p_5]}{(\gamma')^2(K_p-K_a)^2} \qquad A_4 = \frac{P(6z_1p_5+4P)}{(\gamma')^2(K_p-K_a)^2}$$

$A_1 = 23.65$; $A_2 = 110.98$; $A_3 = 2756$; $A_4 = 10082$

By trial and error:

L_4	Equation	
12	2466	
11.5	-2997	
11.8	188	OK

L_4=11.8 ft

Using Eqs. 1, 2, and 4 :

p_3 = 3110 psf
p_4 = 9343 psf

L_5 =2.4 ft

(d) Determine required embedment depth.

$D = L_3 + L_4$
$D = 2.34+11.8=14.14$ ft

Increase D by 10 percent (F.S.=1.25 for temporary construction condition) → **D = 15.6 ft**

(2) Calculate the maximum bending moment.
(a) Determine location of maximum moment as distance from Point E (see Sheets 6 and 13 through 20 for clarification):

$$z' = \sqrt{\frac{2P}{(K_p - K_a)\gamma'}}$$

z' = 5.27 ft

(b) Calculate maximum bending moment:

$M_{max} = P(z_1+z')-[0.5\gamma'(z')^2(K_p-K_a)](1/3)z'$

M_{max} = 30127 lb-ft/ft

M_{max} = 361,525 lb-in/ft

(3) Calculate required section modulus:

$$S = \frac{M_{max}}{f_b}$$

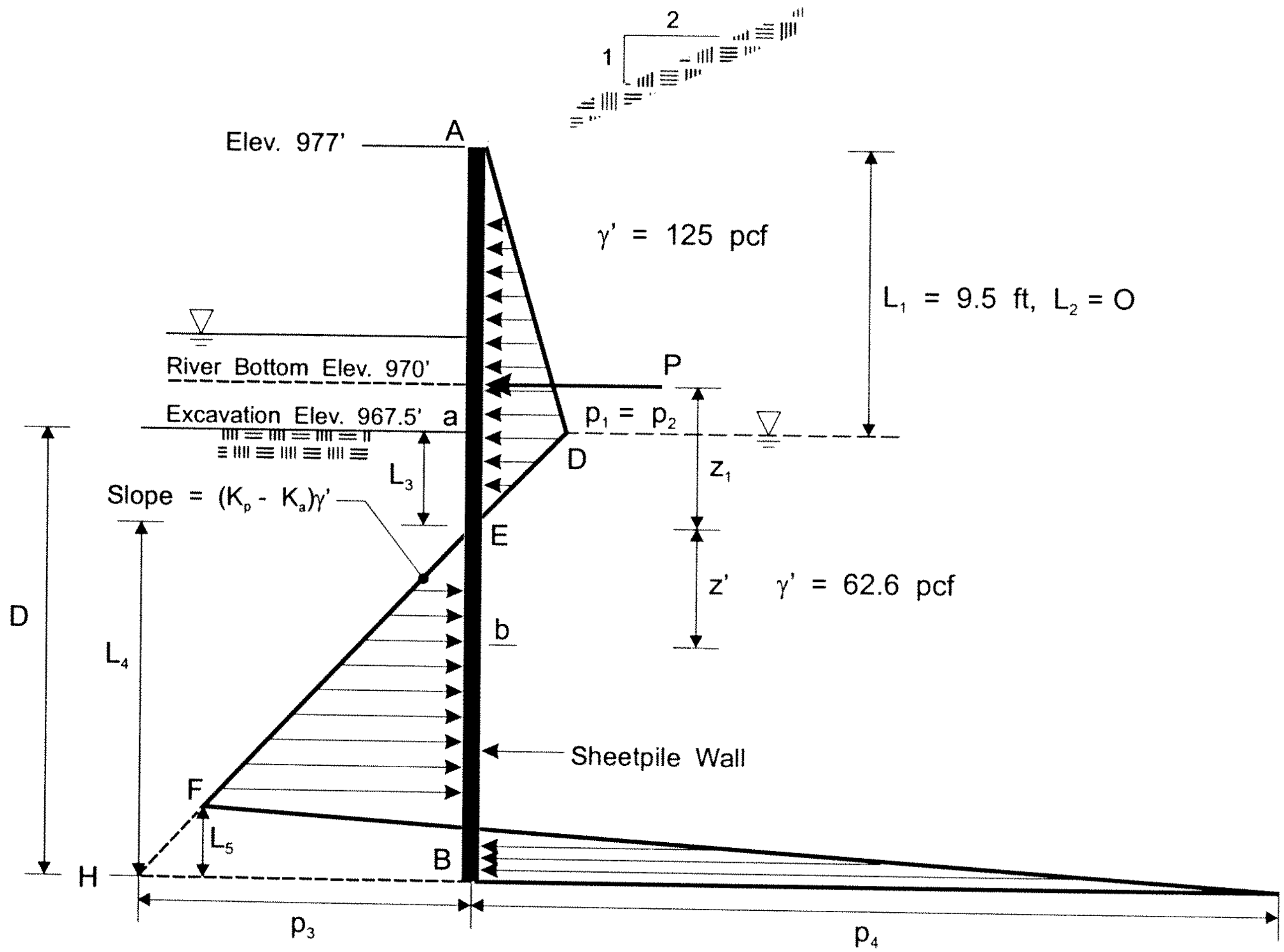
where f_b = 25 ksi for allowable stress on σ_y = 36 ksi steel.

S=14.5 in^3

The section modulus, S, is less than 15.9 in^3 for WZ-75, therefore OK.

CONCLUSIONS

For an exposed wall height of 9.5 feet with a 2H:1V slope of soil above sheetpile, the required embedment depth is 15.6 feet for a factor of safety of 1.25 under temporary construction conditions. Rounded to the nearest foot, a 25-foot long sheetpile is required. The section modulus of a WZ-75 sheetpile is acceptable.



NET PRESSURE DIAGRAM - TEMPORARY CASE

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TASK:

To calculate the required embedment depth, maximum moment, and required section modulus for a sheetpile wall supporting a slope of 2H:1V. The elevation of the top of the wall is 977 feet and the river bottom elevation adjacent to the wall is about 970 feet. The presence of rip-rap or other materials against the wall above the river bottom is ignored to be conservative.

REFERENCES:

1. NAVFAC DM-7, March 1971.

2. Das, B. M. (1990) Principles of Foundation Engineering, 2nd Edition, PWS-Kent Publishing Company.

ASSUMPTIONS:

Soil unit weight = γ = 125 pcf
Buoyant soil unit weight = γ' = 62.6 pcf
Exposed height of sheetpile = 7.0 feet

CALCULATIONS:

The following calculation method is outlined in Ref. 2 (Sheets 13 through 20).

(1) Determine net pressure diagram:

(a) Calculate K_a and K_p
Using Table 1 from Ref. 1 (Sheet 21), wall friction angle δ= 14°,

For K_p, ϕ = 30°, β = 0°, δ= -14°

Using Figure 6 on Sheet 22, for β/ϕ = 0°/30° = 0, and δ/ϕ = -14°/30° = -0.47,

$K_p = R(K_p \text{ for } \delta/\phi = -1) = [(7/10)(0.746 - 0.686) + 0.686]x(6.5) = 0.728 \times 6.5 = 4.73$

K_p = 4.73

For K_a, ϕ = 30°, $\beta = \tan^{-1}(1/2)$ = 26.6°, δ= 14°,

Since Figure 6 does not provide values for $\delta \neq \phi$, use general equation on Sheet 23 instead (with θ= 0).

$K_a = \cos^2\phi / \{ \cos \delta[1 + ((\sin (\phi + \delta) \sin (\phi - \beta)/ (\cos \delta \cos (-\beta)))^{0.5}]^2\}$
$= \cos^2(30)/ \{ \cos (14)[1 + ((\sin (30 + 14) \sin (30\text{-}26.6)/ (\cos (14) \cos (-26.6)))^{0.5}]^2\}$
$= 0.75/ \{ 0.9703[1 + (0.6947 \times 0.0591/ (0.9703 \times 0.8942))^{0.5}]^2\}$
K_a = 0.52

(b) Calculate pressures and forces acting on wall.

All of the following calculations are based on the information provided on Sheets 12 and 13 through 20.

(i) Calculate active pressure on wall at EL 970 ft:

$p_1 = \gamma L_1 K_a = p_2$

$\underline{\mathbf{p_1 = 455\ psf}}$

(ii) Determine location of zero net pressure as distance below river bottom elevation (970 ft):

$$L_3 = \frac{p_2}{\gamma'(K_p - K_a)}$$

$\underline{\mathbf{L_3 = 1.73\ ft}}$

(iii) Calculate magnitude and location of active force acting on wall, P.

$P = 0.5p_1L_1 + 0.5p_1L_3$

$\underline{\mathbf{P = 1986\ lb}}$

$\sum M_E$ to determine location:

$Pz_1 = 1/2p_1L_1(L_3+L_1/3)+1/2p_1L_3(2/3L_3)$

$\underline{\mathbf{z_1 = 3.49\ ft}}$

(iv) Formulate equations for pressures acting at the bottom of the sheetpile wall:

$p_3 = L_4(K_p - K_a)\gamma'$ (1)
$p_4 = \gamma L_1 K_p + \gamma' L_3(K_p - K_a) + \gamma' L_4(K_p - K_a) = p_5 + \gamma' L_4(K_p - K_a)$ (2)
where $p_5 = \gamma L_1 K_p + \gamma' L_3(K_p - K_a)$

$\underline{\mathbf{p_5 = 4595\ psf}}$

(c) Satisfy principles of statics.

$\sum F_H = 0$
$P - 0.5p_3L_4 + 0.5(p_3+p_4)L_5 = 0$ (3)

Solving Eq. 3 for L_5:

$$L_5 = \frac{p_3 L_4 - 2P}{p_3 + p_4} \qquad (4)$$

$\sum M_B = 0$

$$P(L_4+z_1)-(1/2)L_4p_3(L_4/3)+(1/2)L_5(p_3+p_4)(L_5/3)=0 \qquad (5)$$

Combining Eqs. 1, 2, 4, and 5 and simplifying yields:

$$L_4^4+A_1L_4^3-A_2L_4^2-A_3L_4-A_4 = 0 \qquad (6)$$

where

$$A_1 = \frac{p_5}{\gamma'(K_p-K_a)} \qquad A_2 = \frac{8P}{\gamma'(K_p-K_a)}$$

$$A_3 = \frac{6P[2z_1\gamma'(K_p-K_a)+p_5]}{(\gamma')^2(K_p-K_a)^2} \qquad A_4 = \frac{P(6z_1p_5+4P)}{(\gamma')^2(K_p-K_a)^2}$$

A_1 = 17.44; A_2 = 60.29; A_3 = 1104; A_4 = 2978

By trial and error:

L_4	Equation	
9	1477	
8.5	-787	
8.7	67	**OK**

L_4 = 8.7 ft

Using Eqs. 1, 2, and 4 :

p_3 = 2293 psf
p_4 = 6888 psf

L_5 = 1.74 ft

(d) Determine required embedment depth.

$D = L_3 + L_4$
$D = 1.73 + 8.7 = 10.4$ ft

Increase D by 20 percent (F.S. = 1.50 for long term case) → **D = 12.5 ft**

(2) Calculate the maximum bending moment.
(a) Determine location of maximum moment as distance from Point E (see Sheets 12 and 13 through 20 for clarification):

$$z' = \sqrt{\frac{2P}{(K_p - K_a)\gamma'}}$$

z' = 3.88 ft

(b) Calculate maximum bending moment:

$M_{max} = P(z_1 + z') - [0.5\gamma'(z')^2(K_p - K_a)](1/3)z'$

M_{max} = 12071 lb-ft/ft

M_{max} = 144,854 lb-in/ft

(3) Calculate required section modulus:

$$S = \frac{M_{max}}{f_b}$$

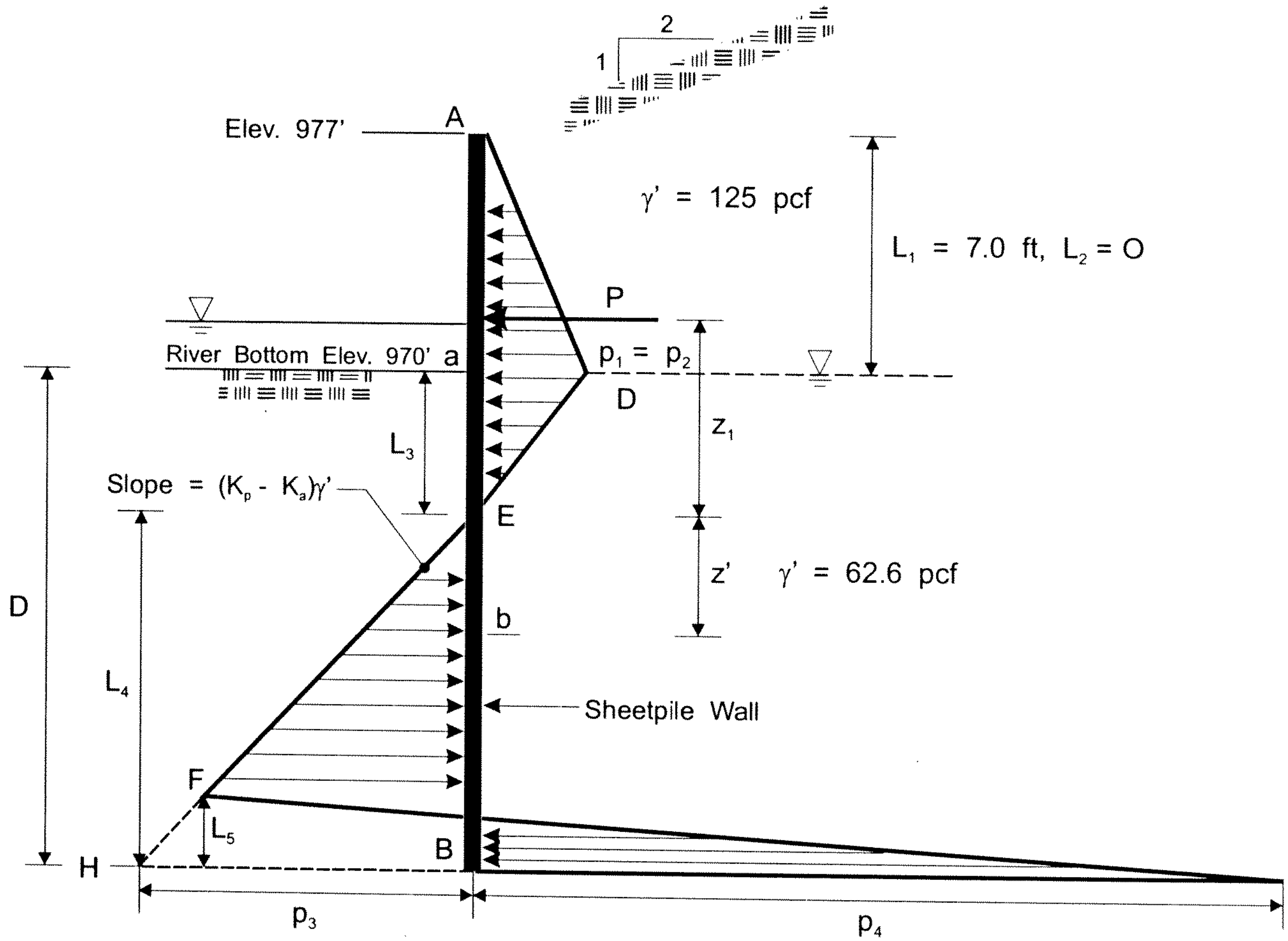
where f_b = 25 ksi for allowable stress on σ_y = 36 ksi steel.

S = 5.79 in^3

The section modulus, S, is less than 15.9 in^3 for WZ-75, therefore OK.

CONCLUSIONS

For exposed wall height of 7 feet with a 2H:1V slope of soil above sheetpile, the required embedment depth is 12.5 feet for a factor of safety of 1.50 under long term conditions. Therefore, the embedment depth of 18 feet from the 25-foot long sheetpile calculated for the temporary case provides a factor of safety above 2.0. The section modulus of a WZ-75 sheetpile is acceptable.



NET PRESSURE DIAGRAM - LONG TERM CASE

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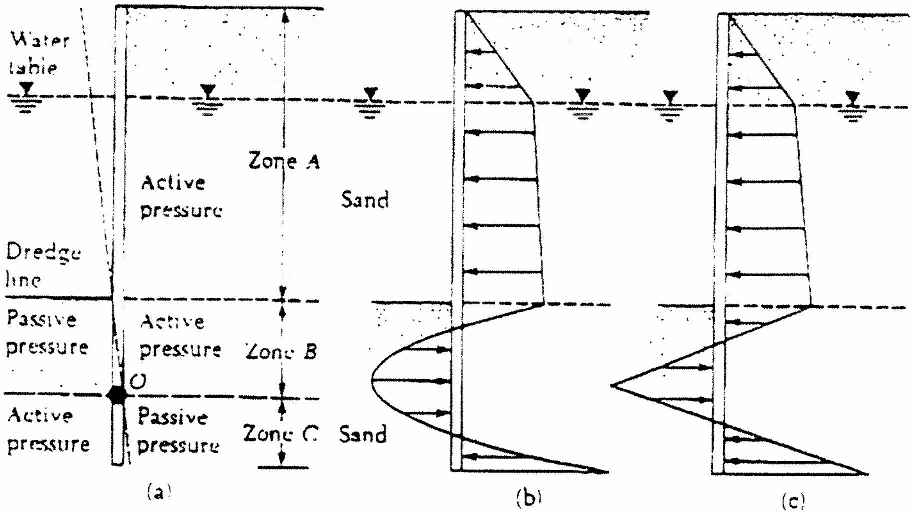

Figure 6.6 Cantilever sheet pile penetrating sand

The following sections (Sections 6.3 through 6.6) present the mathematical formulation of the analysis of cantilever sheet pile walls. Note that, in some waterfront structures, the water level may fluctuate as the result of tidal effects. Care should be taken in determining the water level that will affect the net pressure diagram.

6.3 Cantilever Sheet Piling Penetrating Sandy Soils

To develop the relationships for the proper depth of embedment of sheet piles driven into a granular soil, we refer to Figure 6.7a. The soil retained by the sheet piling above the dredge line is also sand. The water table is located at a depth of L_1 below the top of the wall. Let the angle of friction of the sand be ϕ. The intensity of the active pressure at a depth $z = L_1$ can be given as

$$p_1 = \gamma L_1 K_a \tag{6.1}$$

where K_a = Rankine active pressure coefficient = $\tan^2(45 - \phi/2)$
γ = unit weight of soil above the water table

Similarly, the active pressure at a depth of $z = L_1 + L_2$ (that is, at the level of the dredge line) is equal to

$$p_2 = (\gamma L_1 + \gamma' L_2)K_a \tag{6.2}$$

where γ' = effective unit weight of soil = $\gamma_{sat} - \gamma_w$

Note that, at the level of the dredge line, the hydrostatic pressures from both sides of the wall are of the same magnitude and cancel each other.

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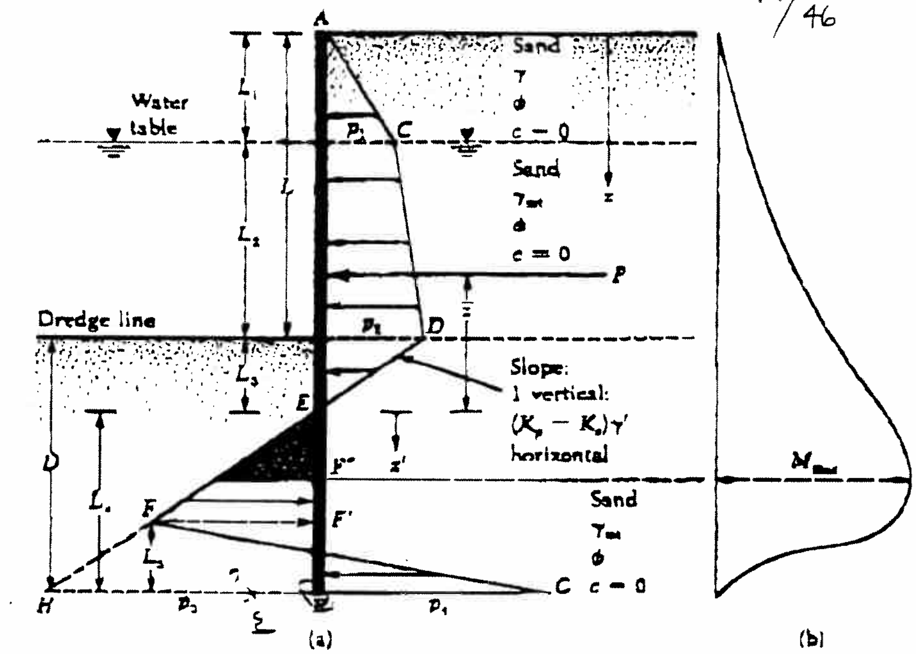

Figure 6.7 Cantilever sheet pile penetrating sand: (a) variation of net pressure diagram. (b) variation of moment

In order to determine the net lateral pressure below the dredge line up to the point of rotation O, as shown in Figure 6.6a, one has to consider the passive pressure acting from the left side (water side) toward the right side (land side) and also the active pressure acting from the right side toward the left side of the wall. For such cases, ignoring the hydrostatic pressure from both sides of the wall, the active pressure at a depth z can be given as

$$p_a = [\gamma L_1 + \gamma' L_2 + \gamma'(z - L_1 - L_2)]K_a \tag{6.3}$$

Also, the passive pressure at that depth z is equal to

$$p_p = \gamma'(z - L_1 - L_2)K_p \tag{6.4}$$

where K_p = Rankine passive pressure coefficient = $\tan^2(45 + \phi/2)$

Hence, combining Eqs. (6.3) and (6.4), the net lateral pressure can be obtained as

$$\begin{aligned} p = p_a - p_p &= (\gamma L_1 + \gamma' L_2)K_a - \gamma'(z - L_1 - L_2)(K_p - K_a) \\ &= p_2 - \gamma'(z - L)(K_p - K_a) \end{aligned} \tag{6.5}$$

where $L = L_1 + L_2$

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The net pressure, p, becomes equal to zero at a depth L_3 below the dredge line; or

$$p_2 - \gamma'(z - L)(K_p - K_a) = 0$$

or

$$(z - L) = L_3 = \frac{p_2}{\gamma'(K_p - K_a)} \tag{6.6}$$

From the preceding equation, it is apparent that the slope of the net pressure distribution line DEF is 1 vertical to $(K_p - K_a)\gamma'$ horizontal. So, in the pressure diagram

$$\overline{HB} = p_3 = L_4(K_p - K_a)\gamma' \tag{6.7}$$

At the bottom of the sheet pile, passive pressure (p_p) acts from the right toward the left side, and active pressure acts from the left toward the right side of the sheet pile. So, at $z = L + D$

$$p_p = (\gamma L_1 + \gamma' L_2 + \gamma' D)K_p \tag{6.8}$$

At the same depth

$$p_a = \gamma' D K_a \tag{6.9}$$

Hence, the net lateral pressure at the bottom of the sheet pile is equal to

$$\begin{aligned} p_p - p_a = p_4 &= (\gamma L_1 + \gamma' L_2)K_p + \gamma' D(K_p - K_a) \\ &= (\gamma L_1 + \gamma' L_2)K_p + \gamma' L_3(K_p - K_a) + \gamma' L_4(K_p - K_a) \\ &= p_5 + \gamma' L_4(K_p - K_a) \end{aligned} \tag{6.10}$$

where $p_5 = (\gamma L_1 + \gamma' L_2)K_p + \gamma' L_3(K_p - K_a)$ (6.11)

$D = L_3 + L_4$ (6.12)

For the stability of the wall, the principles of statics can now be applied; or

$$\sum \text{horizontal forces per unit length of wall} = 0$$

and

$$\sum \text{moment of the forces per unit length of wall about point } B = 0$$

For summation of the horizontal forces,

area of the pressure diagram $ACDE$ − area of $EFHB$ + area of $FHBG = 0$

or

$$P - \tfrac{1}{2}p_3 L_4 + \tfrac{1}{2}L_5(p_3 + p_4) = 0 \tag{6.13}$$

where P = area of the pressure diagram $ACDE$

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Summing the moment of all the forces about point B

$$P(L_4 + \bar{z}) - \left(\frac{1}{2} L_4 p_3\right)\left(\frac{L_4}{3}\right) + \frac{1}{2} L_5(p_3 + p_4)\left(\frac{L_5}{3}\right) = 0 \tag{6.14}$$

From Eq. (6.13)

$$L_5 = \frac{p_3 L_4 - 2P}{p_3 + p_4} \tag{6.15}$$

Combining Eqs. (6.7), (6.10), (6.14), and (6.15) and simplifying them further, one obtains the following fourth-degree equation in terms of L_4.

$$\boxed{L_4^4 + A_1 L_4^3 - A_2 L_4^2 - A_3 L_4 - A_4 = 0} \tag{6.16}$$

where

$$A_1 = \frac{p_5}{\gamma'(K_p - K_a)} \tag{6.17}$$

$$A_2 = \frac{8P}{\gamma'(K_p - K_a)} \tag{6.18}$$

$$A_3 = \frac{6P[2\bar{z}\gamma'(K_p - K_a) + p_5]}{\gamma'^2(K_p - K_a)^2} \tag{6.19}$$

$$A_4 = \frac{P(6\bar{z}p_5 + 4P)}{\gamma'^2(K_p - K_a)^2} \tag{6.20}$$

Step-by-Step Procedure for Obtaining the Pressure Diagram

Based on the preceding theory, the step-by-step procedure for obtaining the pressure diagram for a cantilever sheet pile wall penetrating a granular soil is as follows:

1. Calculate K_a and K_p.
2. Calculate p_1 [Eq. (6.1)] and p_2 [Eq. (6.2)]. *Note:* L_1 and L_2 will be given.
3. Calculate L_3 [Eq. (6.6)].
4. Calculate P.
5. Calculate $\bar{z}$ (that is, the center of pressure for the area $ACDE$) by taking the moment about E.
6. Calculate p_5 [Eq. (6.11)].
7. Calculate A_1, A_2, A_3, and A_4 [Eqs. (6.17) to (6.20)].
8. Solve Eq. (6.16) by trial and error to determine L_4.
9. Calculate p_4 [Eq. (6.10)].

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10. Calculate p_3 [Eq. (6.7)].

11. Obtain L_5 from Eq. (6.15).

12. Now the pressure distribution diagram as shown in Figure 6.7a can easily be drawn.

13. Obtain the theoretical depth [Eq. (6.12)] of penetration as $L_3 + L_4$. The actual depth of penetration is increased by about 20–30%.

Note: Some designers prefer to use a factor of safety on the passive earth pressure coefficient at the beginning. In that case, in Step 1

$$K_{p(\text{design})} = \frac{K_p}{FS}$$

where FS = factor of safety (usually between 1.5 to 2)

For this type of analysis, follow Steps 1 through 12 with the value of $K_a = \tan^2(45 - \phi/2)$ and $K_{p(\text{design})}$ (instead of K_p). The actual depth of penetration can now be determined by adding L_3, obtained from Step 3, and L_4, obtained from Step 8.

Calculation of Maximum Bending Moment

The nature of variation of the moment diagram for a cantilever sheet pile wall is shown in Figure 6.7b. The maximum moment will occur between the points E and F'. To obtain the maximum moment (M_{max}) per unit length of the wall, one must determine the point of zero shear. Adopting a new axis z' (with origin at point E) for zero shear

$$P = \tfrac{1}{2}(z')^2(K_p - K_a)\gamma'$$

or

$$z' = \sqrt{\frac{2P}{(K_p - K_a)\gamma'}} \tag{6.21}$$

Once the point of zero shear force is determined (point F'' in Figure 6.7a), the magnitude of the maximum moment can be obtained as

$$\boxed{M_{max} = P(\bar{z} + z') - [\tfrac{1}{2}\gamma' z'^2(K_p - K_a)](\tfrac{1}{3})z'} \tag{6.22}$$

The sizing of the necessary profile of the sheet piling is then made according to the allowable flexural stress of the sheet pile material, or

$$\boxed{S = \frac{M_{max}}{\sigma_{all}}} \tag{6.23}$$

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where S = section modulus of the sheet pile required per unit length of the structure

σ_{all} = allowable flexural stress of the sheet pile

Example 6.1

Refer to Figure 6.7. For a cantilever sheet pile wall penetrating a granular soil, given: $L_1 = 2$ m, $L_2 = 3$ m. The granular soil has the following properties:

$$\phi = 32^\circ$$
$$c = 0$$
$$\gamma = 15.9 \text{ kN/m}^3$$
$$\gamma_{sat} = 19.33 \text{ kN/m}^3$$

Make the necessary calculations to determine the theoretical and actual depth of penetration. Also determine the miminum size of sheet pile (section modulus) necessary.

Solution

The step-by-step procedure given in Section 6.3 will be followed here.

Step 1

$$K_a = \tan^2\left(45 - \frac{\phi}{2}\right) = \tan^2\left(45 - \frac{32}{2}\right) = 0.307$$

$$K_p = \tan^2\left(45 + \frac{\phi}{2}\right) = 3.25$$

Step 2

$$p_1 = \gamma L_1 K_a = (15.9)(2)(0.307) = 9.763 \text{ kN/m}^2$$

$$p_2 = (\gamma L_1 + \gamma' L_2)K_a = [(15.9)(2) + (19.33 - 9.81)3]0.307$$
$$= 18.53 \text{ kN/m}^2$$

Step 3

$$L_3 = \frac{p_2}{\gamma'(K_p - K_a)} = \frac{18.53}{(19.33 - 9.81)(3.25 - 0.307)} = 0.66 \text{ m}$$

Step 4

$$P = \tfrac{1}{2}p_1L_1 + p_1L_2 + \tfrac{1}{2}(p_2 - p_1)L_2 + \tfrac{1}{2}p_2L_3$$
$$= \tfrac{1}{2}(9.763)(2) + (9.763)(3) + \tfrac{1}{2}(18.53 - 9.763)3 + \tfrac{1}{2}(18.53)(0.66)$$
$$= 9.763 + 29.289 + 13.151 + 6.115 = 58.32 \text{ kN/m}$$

Step 5. Taking the moment about E

$$\bar{z} = \frac{1}{58.32}\left[9.763\left(0.66 + 3 + \frac{2}{3}\right) + 29.289\left(0.66 + \frac{3}{2}\right) + 13.151\left(0.66 + \frac{3}{3}\right) + 6.115\left(0.66 \times \frac{2}{3}\right)\right] = 2.23 \text{ m}$$

Step 6

$$p_5 = (\gamma L_1 + \gamma' L_2)K_p + \gamma' L_3(K_p - K_a)$$
$$= [(15.9)(2) + (19.33 - 9.81)3]3.25 + (19.33 - 9.81)(0.66)(3.25 - 0.307)$$
$$= 196.17 + 18.49 = 214.66 \text{ kN/m}^2$$

Step 7

$$A_1 = \frac{p_5}{\gamma'(K_p - K_a)} = \frac{214.66}{(9.52)(2.943)} = 7.66$$

$$A_2 = \frac{8P}{\gamma'(K_p - K_a)} = \frac{(8)(58.32)}{(9.52)(2.943)} = 16.65$$

$$A_3 = \frac{6P[2\bar{z}\gamma'(K_p - K_a) + p_5]}{\gamma'^2(K_p - K_a)^2}$$
$$= \frac{(6)(58.32)[(2)(2.23)(9.52)(2.943) + 214.66]}{(9.52)^2(2.943)^2} = 151.93$$

$$A_4 = \frac{P(6\bar{z}p_5 + 4P)}{\gamma'^2(K_p - K_a)^2}$$
$$= \frac{58.32[(6)(2.23)(214.66) + (4)(58.32)]}{(9.52)^2(2.943)^2} = 230.72$$

Step 8. From Eq. (6.16)

$$L_4^4 + 7.66L_4^3 - 16.65L_4^2 - 151.39L_4 - 230.72 = 0$$

The following table shows the solution of the preceding equation by trial and error.

Assumed L_4 (m)	Left side of Eq. (6.16)
4	−356.44
5	+178.58
4.8	+36.96

So, $L_4 \approx 4.8$ m

Step 9

$$p_4 = p_5 + \gamma' L_4(K_p - K_a)$$
$$= 214.66 + (9.52)(4.8)(2.943) = 349.14 \text{ kN/m}^2$$

Step 10

$$p_3 = \gamma'(K_p - K_a)L_4 = (9.52)(2.943)(4.8) = 134.48 \text{ kN/m}^2$$

Step 11

$$L_5 = \frac{p_3 L_4 - 2P}{p_3 + p_4} = \frac{(134.48)(4.8) - 2(58.32)}{134.48 + 349.14} = 1.09 \text{ m}$$

Step 12. The net pressure distribution diagram can now be drawn, as shown in Figure 6.7a.

Step 13. The actual depth of penetration = $1.3(L_3 + L_4) = 1.3(0.66 + 4.8) = 7.1$ m. The theoretical depth of penetration = 0.66 + 4.8 = 5.46 m.

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Size of Sheet Piling

Using Eq. (6.21)

$$z' = \sqrt{\frac{2P}{\gamma'(K_p - K_a)}} = \sqrt{\frac{(2)(58.32)}{9.52(2.943)}} = 2.04 \text{ m}$$

From Eq. (6.22)

$$M_{max} = P(\bar{z} + z') - \left[\frac{1}{2}\gamma' z'^2(K_p - K_a)\right]\left(\frac{z'}{3}\right)$$

$$= (58.32)(2.23 + 2.04) - \frac{1}{2}(9.52)(2.04)^2(2.943)\left(\frac{2.04}{3}\right)$$

$$= 249.03 - 39.64 = 209.39 \text{ kN-m}$$

The required section modulus of the sheet pile

$$S = \frac{M_{max}}{\sigma_{all}}$$

With $\sigma_{all} = 172.5 \text{ MN/m}^2$

$$S = \frac{209.39 \text{ kN-m}}{172.5 \times 10^3 \text{ kN/m}^2} = 1.214 \times 10^{-3} \text{ m}^3\text{/m of wall}$$

6.4 Special Cases for Cantilever Wall (Penetrating a Sandy Soil)

Following are two special cases of the mathematical formulation shown in Section 6.3.

Case 1: Sheet Pile Wall with the Absence of Water Table

In the absence of the water table, the net pressure diagram on the cantilever sheet pile wall will be as shown in Figure 6.8, which is a modified version of Figure 6.7. For this figure

$$p_2 = \gamma L K_a \tag{6.24}$$

$$p_3 = L_4(K_p - K_a)\gamma \tag{6.25}$$

$$p_4 = p_5 + \gamma L_4(K_p - K_a) \tag{6.26}$$

$$p_5 = \gamma L K_p + \gamma L_3(K_p - K_a) \tag{6.27}$$

$$L_3 = \frac{p_2}{\gamma(K_p - K_a)} = \frac{L K_a}{(K_p - K_a)} \tag{6.28}$$

$$P = \tfrac{1}{2} p_2 L + \tfrac{1}{2} p_2 L_3 \tag{6.29}$$

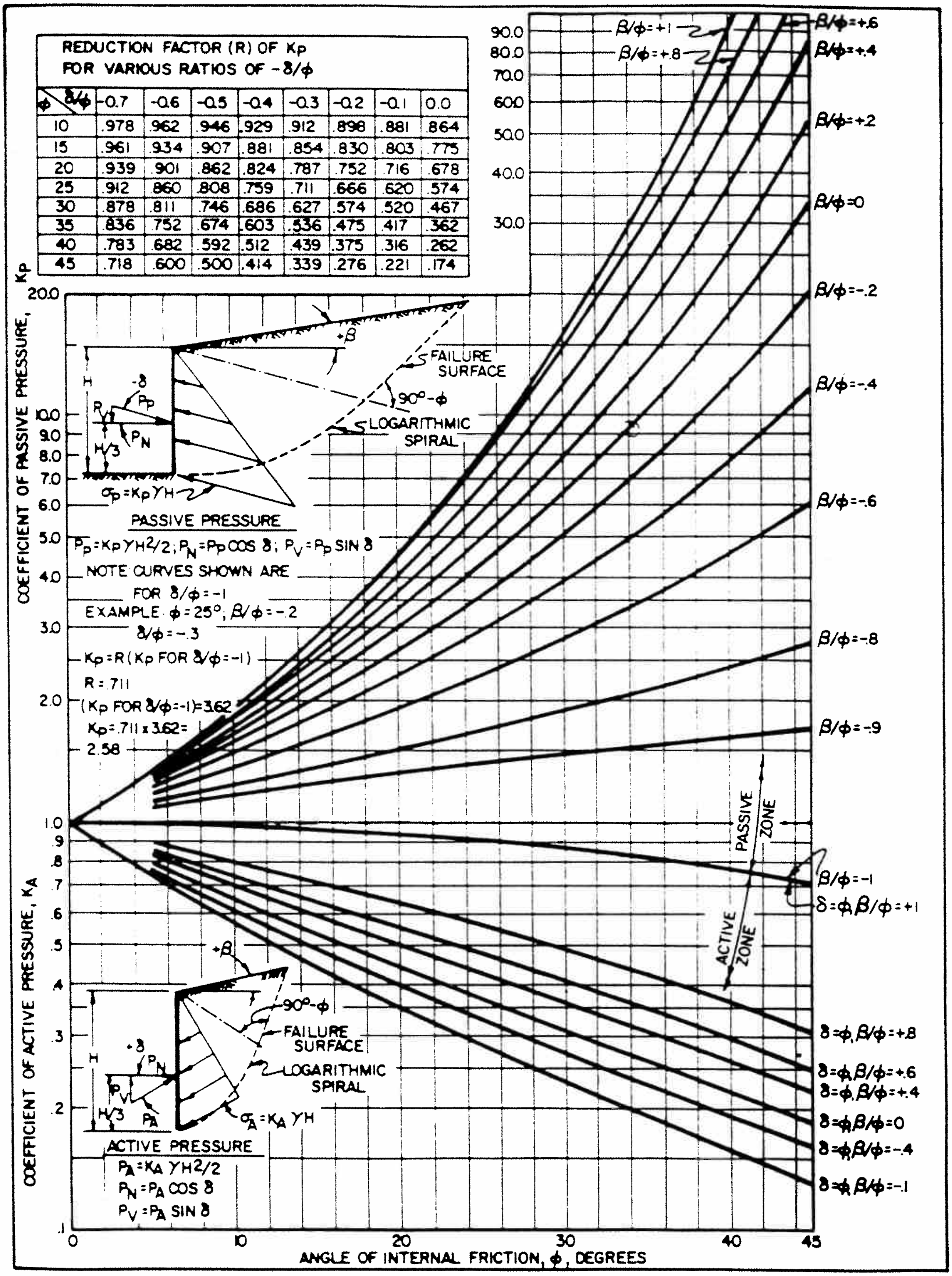
$$\bar{z} = L_3 + \frac{L}{3} = \frac{L K_a}{K_p - K_a} + \frac{L}{3} = \frac{L(2K_a + K_p)}{3(K_p - K_a)} \tag{6.30}$$

TABLE 1

Ultimate Friction Factors and Adhesion for Dissimilar Materials

Interface Materials	Friction factor, $\tan \delta$	Friction angle, δ degrees
Mass concrete on the following foundation materials:		
Clean sound rock........	0.70	35
Clean gravel, gravel-sand mixtures, coarse sand...	0.55 to 0.60	29 to 31
Clean fine to medium sand, silty medium to coarse sand, silty or clayey gravel........	0.45 to 0.55	24 to 29
Clean fine sand, silty or clayey fine to medium sand........	0.35 to 0.45	19 to 24
Fine sandy silt, nonplastic silt........	0.30 to 0.35	17 to 19
Very stiff and hard residual or preconsolidated clay........	0.40 to 0.50	22 to 26
Medium stiff and stiff clay and silty clay........	0.30 to 0.35	17 to 19
(Masonry on foundation materials has same friction factors.)		
Steel sheet piles against the following soils:		
Clean gravel, gravel-sand mixtures, well-graded rock fill with spalls........	0.40	22
Clean sand, silty sand-gravel mixture, single size hard rock fill........	0.30	17
Silty sand, gravel or sand mixed with silt or clay	0.25	14
Fine sandy silt, nonplastic silt........	0.20	11
Formed concrete or concrete sheet piling against the following soils:		
Clean gravel, gravel-sand mixture, well-graded rock fill with spalls........	0.40 to 0.50	22 to 26
Clean sand, silty sand-gravel mixture, single size hard rock fill........	0.30 to 0.40	17 to 22
Silty sand, gravel or sand mixed with silt or clay	0.30	17
Fine sandy silt, nonplastic silt........	0.25	14
Various structural materials:		
Masonry on masonry, igneous and metamorphic rocks:		
Dressed soft rock on dressed soft rock........	0.70	35
Dressed hard rock on dressed soft rock........	0.65	33
Dressed hard rock on dressed hard rock........	0.55	29
Masonry on wood (cross grain)........	0.50	26
Steel on steel at sheet pile interlocks........	0.30	17

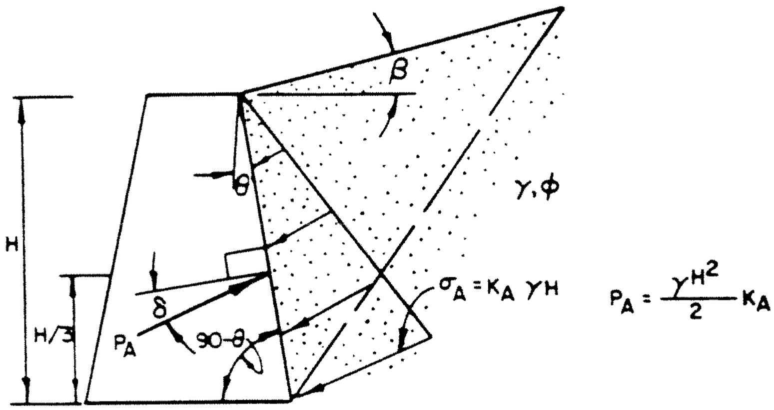
Interface Materials (Cohesion)	Adhesion C_a (psf)
Very soft cohesive soil (0 - 250 psf)	0 - 250
Soft cohesive soil (250 - 500 psf)	250 - 500
Medium stiff cohesive soil (500 - 1000 psf)	500 - 750
Stiff cohesive soil (1000 - 2000 psf)	750 - 950
Very stiff cohesive soil (2000 - 4000 psf)	950 - 1,300



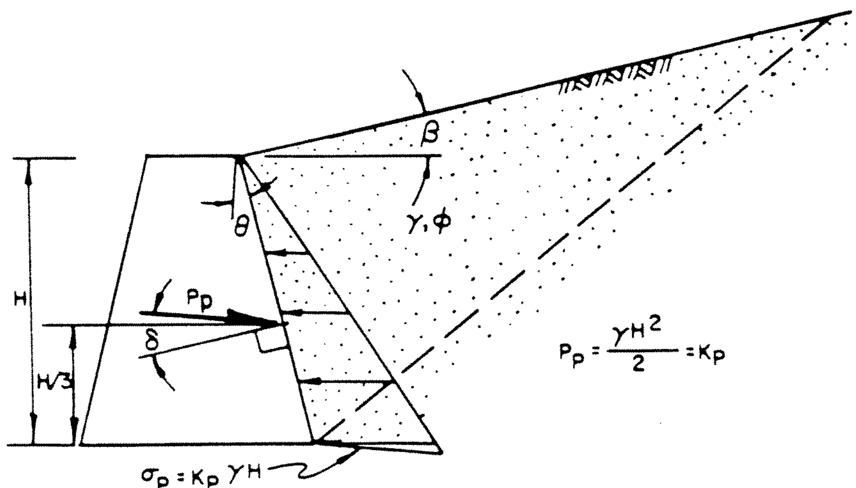
REDUCTION FACTOR (R) OF Kp FOR VARIOUS RATIOS OF -δ/φ

φ \ δ/φ	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0
10	.978	.962	.946	.929	.912	.898	.881	.864
15	.961	.934	.907	.881	.854	.830	.803	.775
20	.939	.901	.862	.824	.787	.752	.716	.678
25	.912	.860	.808	.759	.711	.666	.620	.574
30	.878	.811	.746	.686	.627	.574	.520	.467
35	.836	.752	.674	.603	.536	.475	.417	.362
40	.783	.682	.592	.512	.439	.375	.316	.262
45	.718	.600	.500	.414	.339	.276	.221	.174

FIGURE 6
Active and Passive Coefficients with Wall Friction
(Sloping Backfill)



$$K_A = \frac{\cos^2(\phi-\theta)}{\cos^2\theta\cos(\theta+\delta)\left[1+\sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi-\beta)}{\cos(\theta+\delta)\cos(\theta-\beta)}}\right]^2}$$



$$K_p = \frac{\cos^2(\theta+\phi)}{\cos^2\theta\cos(\theta-\delta)\left[1-\sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi+\beta)}{\cos(\theta-\delta)\cos(\theta-\beta)}}\right]^2}$$

K_p VALUES ARE SATISFACTORY FOR $\delta \leq \phi/3$ BUT ARE UNCONSERVATIVE FOR $\delta > \phi/3$ AND THEREFORE SHOULD NOT BE USED.

FIGURE 8
Coefficients K_A and K_p for Walls with Sloping Wall and Friction, and Sloping Backfill

TASK:

To perform a bending deflection and grout cracking evaluation for a sheetpile wall supporting a slope of 2H:1V with 9.5 feet of sheetpile wall exposed (temporary case).

REFERENCES:

1. Manual of Steel Construction - Load and Resistant Factor Design (1986). First Edition. American Institute of Steel Construction.

METHODOLOGY:

The following procedure was used to evaluate the potential of grout cracking:

(1) Calculate the deflection of the sheetpile wall at the bottom of the exposed sheetpile.

(2) Calculate total equivalent load on the grout core to match the deflection of the sheetpile wall.

(3) Determine maximum moment in the grout core.

(4) Calculate tensile stress in the grout and compare it to the allowable tensile stress.

CALCULATIONS:

Assumptions:

Sheetpile:
Modulus of elasticity = E = 30,000,000 psi
Moment of inertia = I = 64.8 in^4 (Sheet 30 for a WZ-75 sheetpile wall)
Exposed height of sheetpile = L_1 = 9.5 ft = 114 in

1.5" Diameter Grout Core:
Modulus of elasticity = E = 4,560,000 psi (see Sheet 31 for calculation)
Allowable tensile stress = σ_t' = 740 psi (see Sheet 31 calculation)
Moment of inertia = I_x = 19.9 in^4 (see Sheet 31 for calculation)
Section modulus = S = 4.87 in^3 (see Sheet 32 for calculation)

Soil Properties:
Soil unit weight = γ = 125 pcf = 0.072 pci
Buoyant soil unit weight = γ' = 62.5 pcf = 0.036 pci (Note: 62.5 pcf is used as a simplification since it is the average value of the buoyant weight of the soil (62.6 pcf) and the unit weight of water (62.4 pcf), and it is within the required accuracy.)

From Sheet 1:
K_a = 0.52; K_p = 4.73

(1) Calculate the deflection of the sheetpile wall at the bottom of the exposed sheetpile (Point a).

Point b is the location of zero net shear, which was determined on Sheet 4. Therefore, based on Sheet 6:

$D_1 = L_3 + z' = 2.34\ \text{ft} + 5.27\ \text{ft}$

$D_1 = 7.6\ \text{ft} = 91.3\ \text{in}$

$L = L_1 + D_1 = 17.1\ \text{ft} = 205.3\ \text{in}$

Using the deflection formula for a Cantilever Beam - Load Increasing Uniformly to Fixed End in Ref. 1 (Sheet 34), the loading geometry shown on Sheet 35, and the modulus and moment of inertia for the sheetpile:

$$\Delta x_a = \frac{W_1}{60EIL^2}(L_1^5 - 5L^4 L_1 + 4L^5) - \frac{W_2}{60EID_1^2}(4D_1^5)$$

where $W_1 = 0.5K_a\gamma L^2$ and $W_2 = 0.5(K_p + K_a)\gamma' D_1^2$

$\Delta x_a = 0.054\ \text{in}$

(2) Calculate total equivalent load on the grout core to match the deflection of the sheetpile wall.

The deflection formula for a Cantilever Beam - Uniformly Distributed Load in Ref. 1 (Sheet 34), with the Δx_a calculated in Step 2, and the modulus and moment of inertia of the grout is used to calculate the equivalent load on the grout core. The length of this beam is assumed to be D_1 which provides a conservative overestimate of the loading condition (see Sheet 35 for loading geometry).

$$w = \frac{\Delta x_a 24EI}{3D_1^4}$$

$w = 0.56\ \text{lb/in}$

(3) Determine maximum moment in the grout core.

Using the maximum moment formula for a Cantilever Beam - Uniformly Distributed Load in Ref. 1 (Sheet 34):

$$M_{max} = \frac{wD_1^2}{2}$$

$M_{max} = 2{,}351.4\ \text{lb-in}$

(4) Calculate tensile stress in the grout and compare it to the allowable tensile stress.

$$\sigma_t' = \frac{M_{max}}{S}$$

σ_t' = 482.8 psi

483 psi (calculated) < 740 psi (allowable) OK

CONCLUSIONS

Based on the above calculations, it was determined that the stress in the grout is significantly less than the the allowable tensile stress (483 psi < 740 psi) under a worst case loading condition; therefore, grout cracking is unlikely.

TASK:

To perform a bending deflection and grout cracking evaluation for a sheetpile wall supporting a slope of 2H:1V with 7 feet of sheetpile wall exposed (long term case).

REFERENCES:

1. Manual of Steel Construction - Load and Resistant Factor Design (1986). First Edition. American Institute of Steel Construction.

METHODOLOGY:

The following procedure was used to evaluate the potential of grout cracking:

(1) Calculate the deflection of the sheetpile wall at the bottom of the exposed sheetpile.

(2) Calculate total equivalent load on the grout to match the deflection of the sheetpile wall.

(3) Determine maximum moment in the grout core.

(4) Calculate tensile stress in the grout and compare it to the allowable tensile stress.

CALCULATIONS:

Assumptions:

Sheetpile:	Modulus of elasticity = E = 30,000,000 psi Moment of inertia = 64.8 in^4 (Sheet 30 for a WZ-75 sheetpile wall) Exposed height of sheetpile = L_1 = 7 ft = 84 in
1.5" Diameter Grout Core:	Modulus of elasticity = E = 4,560,000 psi (see Sheet 31 for calculation) Allowable tensile stress = σ_t' = 740 psi (see Sheet 31 for calculation) Moment of inertia = I_x = 19.9 in^4 (see Sheet 31 for calculation) Section modulus = S = 4.87 in^3 (see Sheet 32 for calculation)
Soil Properties:	Soil unit weight = γ = 125 pcf = 0.072 pci Buoyant soil unit weight = γ' = 62.5 pcf = 0.036 pci (Note: 62.5 pcf is used as a simplification since it is the average value of the buoyant weight of the soil (62.6 pcf) and the unit weight of water (62.4 pcf), and it is within the required accuracy.)
From Sheet 1:	K_a=0.52; K_p=4.73

(1) Calculate the deflection of the sheetpile wall at the bottom of the exposed sheetpile (Point a).

Point b is the location of zero net shear, which was determined on Sheet 10. Therefore, based on Sheet 12:

$D_1 = L_3 + z' = 1.73 \text{ ft} + 3.88 \text{ ft}$

$D_1 = 5.6$ ft = 67.2 in

$L = L_1 + D_1 = 12.6$ ft = 151.2 in

Using the deflection formula for a Cantilever Beam - Load Increasing Uniformly to Fixed End in Ref. 1 (Sheet 34), the loading geometry shown on Sheet 35, and the modulus and moment of inertia for the sheetpile:

$$\Delta x_A = \frac{W_1}{60EIL^2}(L_1^5 - 5L^4L_1 + 4L^5) - \frac{W_2}{60EID_1^2}(4D_1^5)$$

where $W_1 = 0.5K_a\gamma L^2$ and $W_2 = 0.5(K_p+K_a)\gamma D_1^2$

$\Delta x_a = 0.012$ in

(2) Calculate total equivalent load on the grout core to match the deflection of the sheetpile wall.

The deflection formula for a Cantilever Beam - Uniformly Distributed Load in Ref. 1 (Sheet 34), with the Δx_a calculated in Step 2, and the modulus and moment of inertia of the grout, is used to calculate the equivalent load on the grout core. The length of this beam is assumed to be D_1, which provides a conservative overestimate of the loading condition (see Sheet 35 for loading geometry).

$$w = \frac{\Delta x_a 24EI}{3D_1^4}$$

w = 0.43 lb/in

(3) Determine maximum moment in the grout core.

Using the maximum moment formula for a Cantilever Beam - Uniformly Distributed Load in Ref. 1 (Sheet 34):

$$M_{max} = \frac{wD_1^2}{2}$$

$M_{max} = 970.9$ lb-in

(4) Calculate tensile stress in the grout and compare it to the allowable tensile stress.

$$\sigma_t' = \frac{M_{max}}{S}$$

σ_t' = 199.4 psi

199 psi (calculated) < 740 psi (allowable) OK

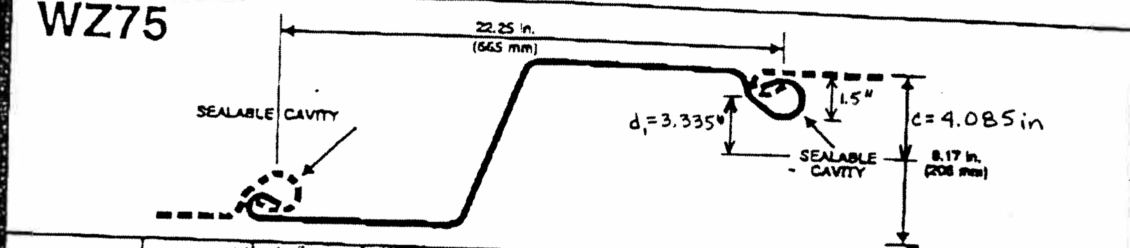
CONCLUSIONS

Based on the above calculations, it was determined that the stress in the grout is significantly less than the the allowable (199 psi < 740 psi) under a worst case loading condition; therefore, grout cracking is unlikely.

WATERLOO BARRIER™

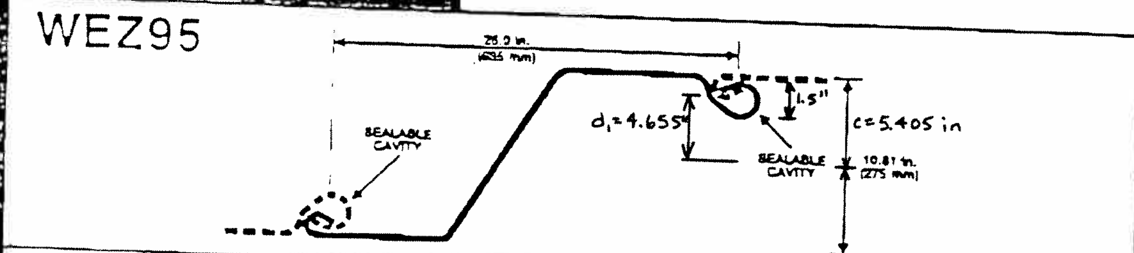
IS AVAILABLE IN TWO DESIGNS. THE MEDIUM WALL WZ75 AND THE HEAVY WALL WEZ95

WZ75



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)
WZ75	.295 (7.50)	8.17 (208)	22.25 (565)	10.5 (67.5)	35.6 (53.0)	19.2 (93.7)	64.8 (8870)	3.39 (86.1)	15.8 (850)

WEZ95



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)
[illegible]	[illegible]	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)

SPECIFICATIONS:

RAW MATERIAL:
ASTM A572 GR50
CSA G40.21 GR 350W

MANUFACTURING:
ASTM A6
CSA G40.20

COATINGS:
1) GALVANIZED ASTM A123, CSA G164
2) COAL TAR EPOXY SSPC-16
3) FUSION BONDED EPOXY RESIN, MFG'S SPEC.

ACCESSORIES:
BENDS CAN BE SUPPLIED TO ANY ANGLE. 'T' SECTIONS AND OTHER WELDED FABRICATIONS ARE AVAILABLE.

TASK:

To determine the allowable tensile stress, the elastic modulus, moment of inertia, and section modulus of the grout core.

REFERENCES:

1. Merritt, F. S., M.K. Loftin, and J.T. Ricketts. (1996) Standard Handbook for Civil Engineers. Fourth Edition. McGraw- Hill Companies, Inc. New York, NY.

CALCULATIONS:

Allowable Tensile Stress

The tensile stress of the grout is usually between 7 to 10 percent of its compressive strength. Using 8.5 percent:

$$\sigma_t' = (0.085)\, f_c'$$

where f_c' = specified compressive strength at 28 days= 60 MPa (8,700 psi) from Sheet 33.

σ_t' = 740 psi

Modulus of Elasticity

Using Ref. 1 the modulus of elasticity of the grout, E, is calculated as follows:

$$E = w^{1.5}(33)\sqrt{f_c'}$$

where w = unit weight of the grout = 130 pcf.

E = 4,560,000 psi

Moment of Inertia

Using the parallel axis theorem (Ref. 1), the moment of inertia about the parallel axis, I_x, is calculated as follows:

$$I_x = I + Ad_1^2$$

where I = moment of inertia about centroidal axis for a circle; A = cross-sectional area; d_1 = distance between centroidal and parallel axes (see Sheet 30 for a WZ-75 sheetpile wall).

$$I_x = \frac{\pi d^4}{64} + \frac{\pi d^2}{4}(d_1^2)$$

where d = diameter of the grout core.

I_x = 19.9 in^4

Section Modulus

The section modulus, S, is calculated as follows:

$$S = \frac{I_x}{c}$$

where c = distance from the outermost fiber of the grout core to the neutral axis of the sheetpile wall (see Sheet 30 for a WZ-75 sheetpile wall).

S = 4.87 in^3

CONCLUSIONS

The allowable tensile strength of the grout core is 740 psi, the elastic modulus is 4,560,000 psi, the moment of inertia is 19.9 in^4, and the section modulus is 4.87 in^3.

MIXING PROPERTIES:

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DESCRIPTION	REQUIREMENTS
SEALANT PACKAGING:	30 kg Bags
MINIMUM WATER VOLUME (per bag):	6.25 L
MAXIMUM WATER VOLUME (per bag):	9.25 L
MIXER TYPE:	Colloidal
MINIMUM MIXING TIME:	2.5 (min.)
MAXIMUM POT LIFE:	180 (min.)

CURING AND SET TIMES:

The initial gel time of the sealant varies from 1.5 to 2.0 hours @ 20°C. Initial set time of the sealant varies from 1 to 2 days after placement. Ultimate strength is reached at approximately 28 days.

COMPRESSIVE TESTING	STRENGTH
1 DAY:	15 Mpa
3 DAYS:	38 Mpa
7 DAYS:	50 Mpa
28 DAYS:	60 Mpa

PERMEABILITY TESING:

Permeability testing was completed by Davroc Testing Laboratories Inc. to confirm a bulk hydraulic conductivity of 3.19×10^{-15} m/s

YIELD:

Each 30 kg (66 lb) bag of WBS 301 sealant produces 0.01 cubic metres of grout.

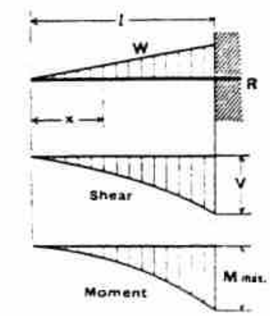
SAFETY PRECAUTIONS:

Waterloo Barrier® Grout - WBS 301 - contains Portland Cement, Fly Ash, Silica Fume and other admixtures. Normal safety wear, such as rubber gloves, dust masks and safety glasses that are used to handle conventional cement based products should be worn. Material Safety Data Sheets available on request.

BEAM DIAGRAMS AND FORMULAS
For various static loading conditions

For meaning of symbols, see page 3-127

18. CANTILEVER BEAM—LOAD INCREASING UNIFORMLY TO FIXED END



Total Equiv. Uniform Load . . . . . $= \frac{8}{3}W$

R = V . . . . $= W$

V_x . . . . $= W\frac{x^2}{l^2}$

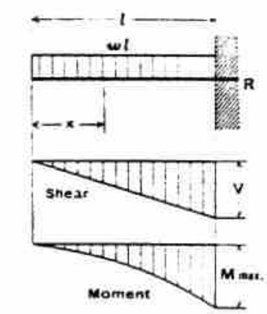
M max. (at fixed end) . . . . . $= \frac{Wl}{3}$

M_x . . . . $= \frac{Wx^3}{3l^2}$

Δmax. (at free end) . . . . . $= \frac{Wl^3}{15EI}$

Δx . . . . $= \frac{W}{60EIl^2}(x^5 - 5l^4x + 4l^5)$

19. CANTILEVER BEAM—UNIFORMLY DISTRIBUTED LOAD



Total Equiv. Uniform Load . . . . . $= 4wl$

R = V . . . . $= wl$

V_x . . . . $= wx$

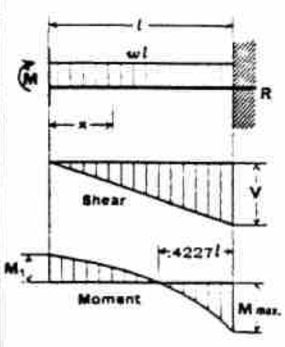
M max. (at fixed end) . . . . . $= \frac{wl^2}{2}$

M_x . . . . $= \frac{wx^2}{2}$

Δmax. (at free end) . . . . . $= \frac{wl^4}{8EI}$

Δx . . . . $= \frac{w}{24EI}(x^4 - 4l^3x + 3l^4)$

20. BEAM FIXED AT ONE END, FREE TO DEFLECT VERTICALLY BUT NOT ROTATE AT OTHER—UNIFORMLY DISTRIBUTED LOAD



Total Equiv. Uniform Load . . . . . $= \frac{8}{3}wl$

R = V . . . . $= wl$

V_x . . . . $= wx$

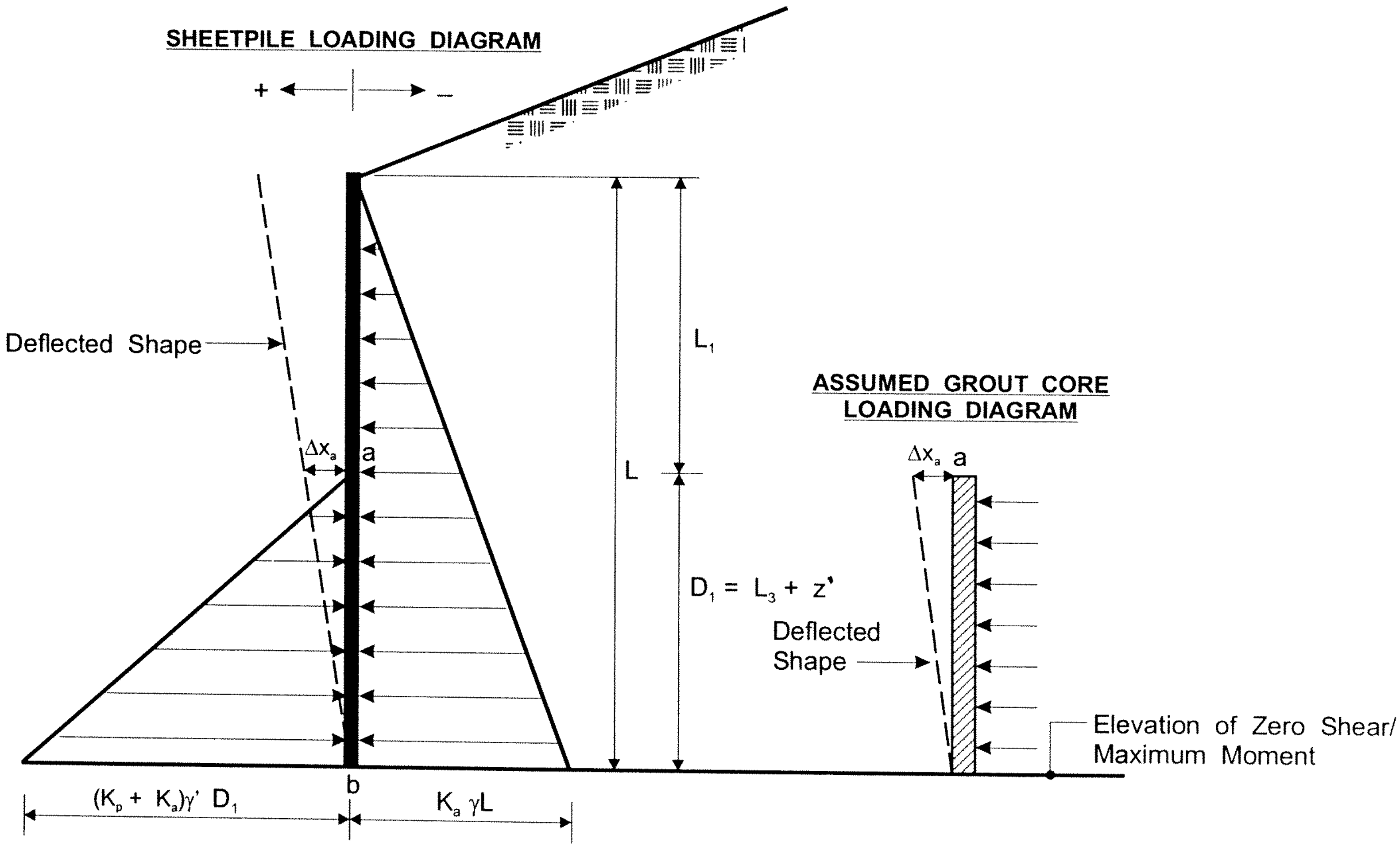
M max. (at fixed end) . . . . . $= \frac{wl^2}{3}$

M_1 (at deflected end) . . . . . $= \frac{wl^2}{6}$

M_x . . . . $= \frac{w}{6}(l^2 - 3x^2)$

Δmax. (at deflected end) . . . . . $= \frac{wl^4}{24EI}$

Δx . . . . $= \frac{w(l^2 - x^2)^2}{24EI}$



LOADING DIAGRAM

02/99 SYR-D54-DJH
20140005/20140g13.cdr

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TASK:

To calculate the required embedment depth, maximum moment, and section modulus for a sheetpile wall supporting a slope of 2H:1V with soil excavated temporarily to 966.5 feet in front of the wall. The elevation of the top of the wall is 977 feet.

REFERENCES:

1. NAVFAC DM-7, March 1971.

2. Das, B. M. (1990) Principles of Foundation Engineering, 2nd Edition, PWS-Kent Publishing Company.

ASSUMPTIONS:

Soil unit weight = γ = 125 pcf
Buoyant soil unit weight = γ' = 62.6 pcf
Exposed height of sheetpile = 10.5 feet

CALCULATIONS:

The following calculation method is outlined in Ref. 2 (Sheets 13 through 20).

(1) Determine net pressure diagram:

(a) Calculate K_a and K_p
Using Table 1 from Ref. 1 (Sheet 21), wall friction angle $\delta = 14°$,

For K_p, $\phi = 30°$, $\beta = 0°$, $\delta = -14°$

Using Figure 6 on Sheet 22, for $\beta/\phi = 0°/30° = 0$, and $\delta/\phi = -14°/30° = -0.47$,

$K_p = R(K_p \text{ for } \delta/\phi = -1) = [(7/10)(0.746 - 0.686) + 0.686]x(6.5) = 0.728 \times 6.5 = 4.73$

$K_p = 4.73$

For K_a, $\phi = 30°$, $\beta = \tan^{-1}(1/2) = 26.6°$, $\delta = 14°$,

Since Figure 6 does not provide values for $\delta \neq \phi$, use general equation on Sheet 23 instead (with $\theta = 0$).

$K_a = \cos^2\phi / \{ \cos\delta[1 + ((\sin(\phi+\delta) \sin(\phi-\beta)/ (\cos\delta \cos(-\beta)))^{0.5}]^2\}$
$= \cos^2(30)/ \{ \cos(14)[1 + ((\sin(30 + 14) \sin(30\text{-}26.6)/ (\cos(14) \cos(-26.6)))^{0.5}]^2\}$
$= 0.75/ \{ 0.9703[1 + (0.6947 \times 0.0591/ (0.9703 \times 0.8942))^{0.5}]^2\}$

$K_a = 0.52$

(b) Calculate pressures and forces acting on wall.

All of the following calculations are based on the information provided on Sheets 41 and 13 through 20.

(i) Calculate active pressure on wall at EL 966.5 ft:

$$p_1 = \gamma L_1 K_a = p_2$$

$\underline{\mathbf{p_1 = 682.5\ psf}}$

(ii) Determine location of zero net pressure as distance below excavation elevation (966.5 ft):

$$L_3 = \frac{p_2}{\gamma'(K_p - K_a)}$$

$\underline{\mathbf{L_3 = 2.59\ ft}}$

(iii) Calculate magnitude and location of active force acting on wall, P.

$$P = 0.5p_1L_1 + 0.5p_1L_3$$

$\underline{\mathbf{P = 4467\ lb}}$

$\sum M_E$ to determine location:

$$Pz_1 = 1/2p_1L_1(L_3 + L_1/3) + 1/2p_1L_3(2/3L_3)$$

$\underline{\mathbf{z_1 = 5.23\ ft}}$

(iv) Formulate equations for pressures acting at the bottom of the sheetpile wall:

$p_3 = L_4(K_p - K_a)\gamma'$ (1)
$p_4 = \gamma L_1 K_p + \gamma' L_3(K_p - K_a) + \gamma' L_4(K_p - K_a) = p_5 + \gamma' L_4(K_p - K_a)$ (2)
where $p_5 = \gamma L_1 K_p + \gamma' L_3(K_p - K_a)$

$\underline{\mathbf{p_5 = 6891\ psf}}$

(c) Satisfy principles of statics.

$\sum F_H = 0$
$P - 0.5p_3L_4 + 0.5(p_3 + p_4)L_5 = 0$ (3)

Solving Eq. 3 for L_5:

$$L_5 = \frac{p_3 L_4 - 2P}{p_3 + p_4} \qquad (4)$$

$\sum M_B = 0$

$$P(L_4+z_1)-(1/2)L_4p_3(L_4/3)+(1/2)L_5(p_3+p_4)(L_5/3) = 0 \qquad (5)$$

Combining Eqs. 1, 2, 4, and 5 and simplifying yields:

$$L_4^4+A_1L_4^3-A_2L_4^2-A_3L_4-A_4 = 0 \qquad (6)$$

where

$$A_1 = \frac{p_5}{\gamma'(K_p-K_a)} \qquad A_2 = \frac{8P}{\gamma'(K_p-K_a)}$$

$$A_3 = \frac{6P[2z_1\gamma'(K_p-K_a)+p_5]}{(\gamma')^2(K_p-K_a)^2} \qquad A_4 = \frac{P(6z_1p_5+4P)}{(\gamma')^2(K_p-K_a)^2}$$

$A_1 = 26.15$; $A_2 = 135.60$; $A_3 = 3723$; $A_4 = 15056$

By trial and error:

L_4	**Equation**	
12.9	-1824	
13.1	1136	
13.0	-363	**OK**

L_4=13.0 ft

CLIENT GE SUBJECT Additional Sheetpile Design Calculations Prepared By LHK Date: 2/24/99
Reviewed By RDD Date 2/25/99
PROJECT East Street Area 2 Source Control Containment Barrier Temporary Case

Using Eqs. 1, 2, and 4 :

p_3 = 3426 psf
p_4 = 10,317 psf

L_5 = 2.59 ft

(d) Determine required embedment depth.

$D = L_3 + L_4$
$D = 2.59 + 13.0 = 15.59$ ft

Increase D by 10 percent (F.S.=1.25 for temporary construction condition) → **D = 17.1 ft**

(2) Calculate the maximum bending moment.
(a) Determine location of maximum moment as distance from Point E (see Sheets 41 and 13 through 20 for clarification):

$$z' = \sqrt{\frac{2P}{(K_p - K_a)\gamma'}}$$

z' = 5.82 ft

(b) Calculate maximum bending moment:

$M_{max} = P(z_1 + z') - [0.5\gamma'(z')^2(K_p - K_a)](1/3)z'$

M_{max} = 40,701 lb-ft/ft

M_{max} = 488,415 lb-in/ft

(3) Calculate required section modulus:

$$S = \frac{M_{max}}{f_b}$$

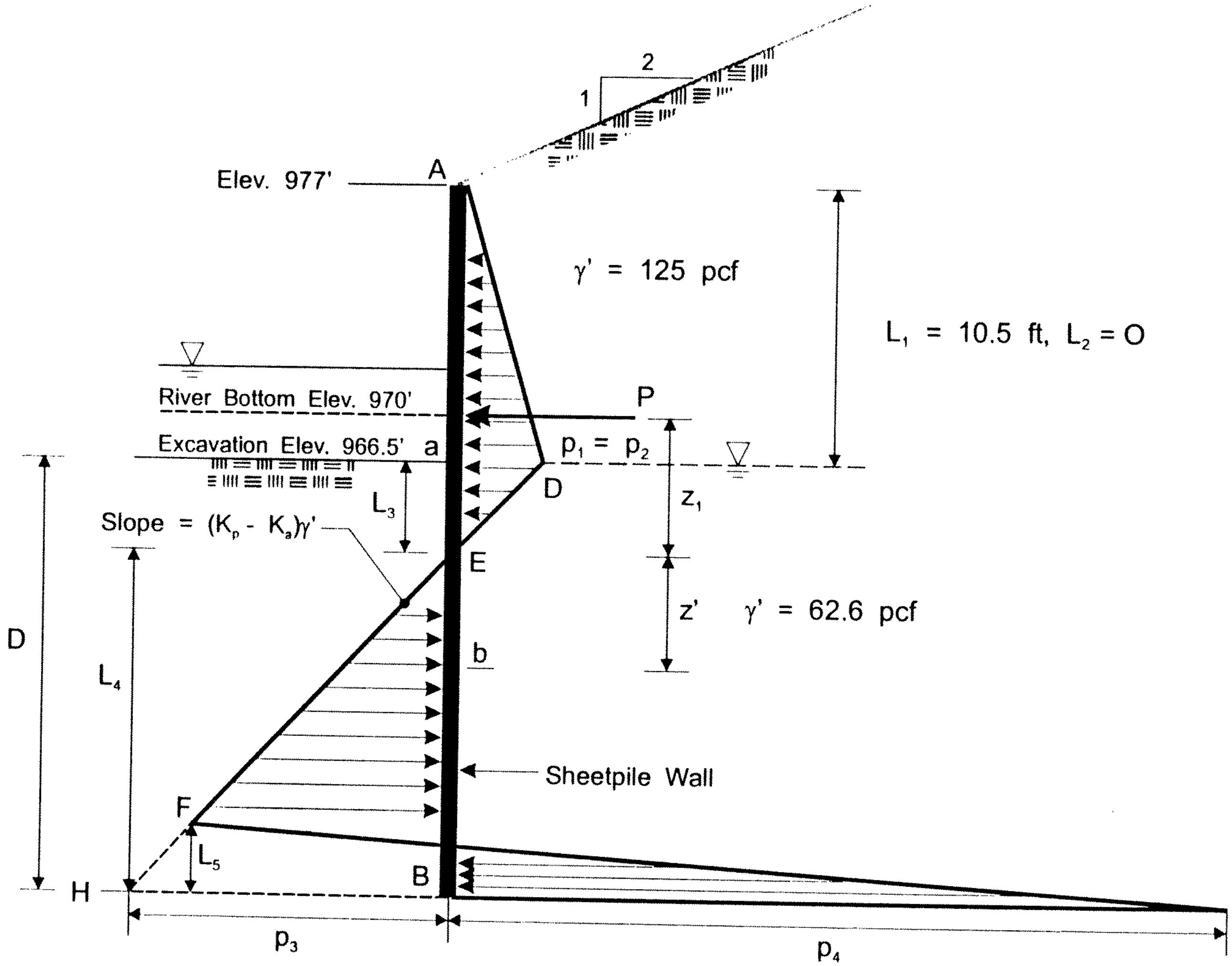
where f_b = 25 ksi for allowable stress on σ_y = 36 ksi steel.

S=19.5 in³

The section modulus, S, is greater than 15.9 in^3 for WZ-75, therefore a thicker sheetpile is required. A WEZ-95 with a section modulus of 24.9 in^3 is acceptable.

CONCLUSIONS

For an exposed wall height of 10.5 feet with a 2H:1V slope of soil above sheetpile, the required embedment depth is 17.1 feet for a factor of safety of 1.25 under temporary construction conditions. Rounded to the nearest foot, a 28-foot long sheetpile is required. The section modulus of a WEZ-95 sheetpile is acceptable.



NET PRESSURE DIAGRAM - TEMPORARY CASE

02/99 SYR-D54-DJH
20140005/20140g14.cdr

TASK:

To perform a bending deflection and grout cracking evaluation for a sheetpile wall supporting a slope of 2H:1V with 10.5 feet of sheetpile wall exposed (temporary case).

REFERENCES:

1. Manual of Steel Construction - Load and Resistant Factor Design (1986). First Edition. American Institute of Steel Construction.

METHODOLOGY:

The following procedure was used to evaluate the potential of grout cracking:

(1) Calculate the deflection of the sheetpile wall at the bottom of the exposed sheetpile.

(2) Calculate total equivalent load on the grout core to match the deflection of the sheetpile wall.

(3) Determine maximum moment in the grout core.

(4) Calculate tensile stress in the grout and compare it to the allowable tensile stress.

CALCULATIONS:

Assumptions:

Sheetpile:	Modulus of elasticity = E = 30,000,000 psi Moment of inertia = I = 134 in^4 (Sheet 30 for a WEZ-95 sheetpile wall) Exposed height of sheetpile = L_1 = 10.5 ft = 126 in
1.5" Diameter Grout Core:	Modulus of elasticity = E = 4,560,000 psi (see Sheet 45 for calculation) Allowable tensile stress = σ_t' = 740 psi (see Sheet 45 calculation) Moment of inertia = I_x = 38.5 in^4 (see Sheet 45 for calculation) Section modulus = S = 7.13 in^3 (see Sheet 46 for calculation)
Soil Properties:	Soil unit weight = γ = 125 pcf = 0.072 pci Buoyant soil unit weight = γ' = 62.5 pcf = 0.036 pci (Note: 62.5 pcf is used as a simplification since it is the average value of the buoyant weight of the soil (62.6 pcf) and the unit weight of water (62.4 pcf), and it is within the required accuracy.)
From Sheet 1:	$K_a = 0.52$; $K_p = 4.73$

CLIENT GE SUBJECT Grout Cracking Evaluation Prepared By LHK Date: 2/24/99

Reviewed By RDD Date 2/25/99

PROJECT East Street Area 2 Source Control Containment Barrier Temporary Case

(1) Calculate the deflection of the sheetpile wall at the bottom of the exposed sheetpile (Point a).

Point b is the location of zero net shear, which was determined on Sheet 39. Therefore, based on Sheet 41:

$D_1 = L_3 + z' = 2.59 \text{ ft} + 5.82 \text{ ft}$

$D_1 = 8.4$ ft = 100.9 in

$L = L_1 + D_1 = 18.9$ ft = 226.8 in

Using the deflection formula for a Cantilever Beam - Load Increasing Uniformly to Fixed End in Ref. 1 (Sheet 34), the loading geometry shown on Sheet 35, and the modulus and moment of inertia for the sheetpile:

$$\Delta x_a = \frac{W_1}{60EIL^2}(L_1^5 - 5L^4 L_1 + 4L^5) - \frac{W_2}{60EID_1^2}(4D_1^5)$$

where $W_1 = 0.5K_a \gamma L^2$ and $W_2 = 0.5(K_p + K_a)\gamma' D_1^2$

$\Delta x_a = 0.043$ in

(2) Calculate total equivalent load on the grout core to match the deflection of the sheetpile wall.

The deflection formula for a Cantilever Beam - Uniformly Distributed Load in Ref. 1 (Sheet 34), with the Δx_a calculated in Step 2, and the modulus and moment of inertia of the grout is used to calculate the equivalent load on the grout core. The length of this beam is assumed to be D_1 which provides a conservative overestimate of the loading condition (see Sheet 35 for loading geometry).

$$w = \frac{\Delta x_a 24EI}{3D_1^4}$$

w = 0.58 lb/in

(3) Determine maximum moment in the grout core.

Using the maximum moment formula for a Cantilever Beam - Uniformly Distributed Load in Ref. 1 (Sheet 34):

$$M_{max} = \frac{wD_1^2}{2}$$

$M_{max} = 2{,}952.4$ lb-in

(4) Calculate tensile stress in the grout and compare it to the allowable tensile stress.

$$\sigma_t' = \frac{M_{max}}{S}$$

σ_t' = 414.1 psi

414.1 psi (calculated) < 740 psi (allowable) OK

CONCLUSIONS

Based on the above calculations, it was determined that the stress in the grout is significantly less than the the allowable tensile stress (414 psi < 740 psi) under a worst case loading condition; therefore, grout cracking is unlikely.

TASK:

To determine the allowable tensile stress, the elastic modulus, moment of inertia, and section modulus of the grout core.

REFERENCES:

1. Merritt, F. S., M.K. Loftin, and J.T. Ricketts. (1996) Standard Handbook for Civil Engineers. Fourth Edition. McGraw- Hill Companies, Inc. New York, NY.

CALCULATIONS:

Allowable Tensile Stress

The tensile stress of the grout is usually between 7 to 10 percent of its compressive strength. Using 8.5 percent:

$$\sigma_t' = (0.085)\, f_c'$$

where f_c' = specified compressive strength at 28 days= 60 MPa (8,700 psi) from Sheet 33.

$$\underline{\sigma_t' = 740 \text{ psi}}$$

Modulus of Elasticity

Using Ref. 1 the modulus of elasticity of the grout, E, is calculated as follows:

$$E = w^{1.5}(33)\sqrt{f_c'}$$

where w = unit weight of the grout = 130 pcf.

E = 4,560,000 psi

Moment of Inertia

Using the parallel axis theorem (Ref. 1), the moment of inertia about the parallel axis, I_x, is calculated as follows:

$$I_x = I + Ad_1^2$$

where I = moment of inertia about centroidal axis for a circle; A = cross-sectional area; d_1 = distance between centroidal and parallel axes (see Sheet 30 for a WEZ-95 sheetpile wall).

$$I_x = \frac{\pi d^4}{64} + \frac{\pi d^2}{4}(d_1^2)$$

where d = diameter of the grout core.

I_x = 38.5 in^4

Section Modulus

The section modulus, S, is calculated as follows:

$$S = \frac{I_x}{c}$$

where c = distance from the outermost fiber of the grout core to the neutral axis of the sheetpile wall (see Sheet 30 for a WEZ-95 sheetpile wall).

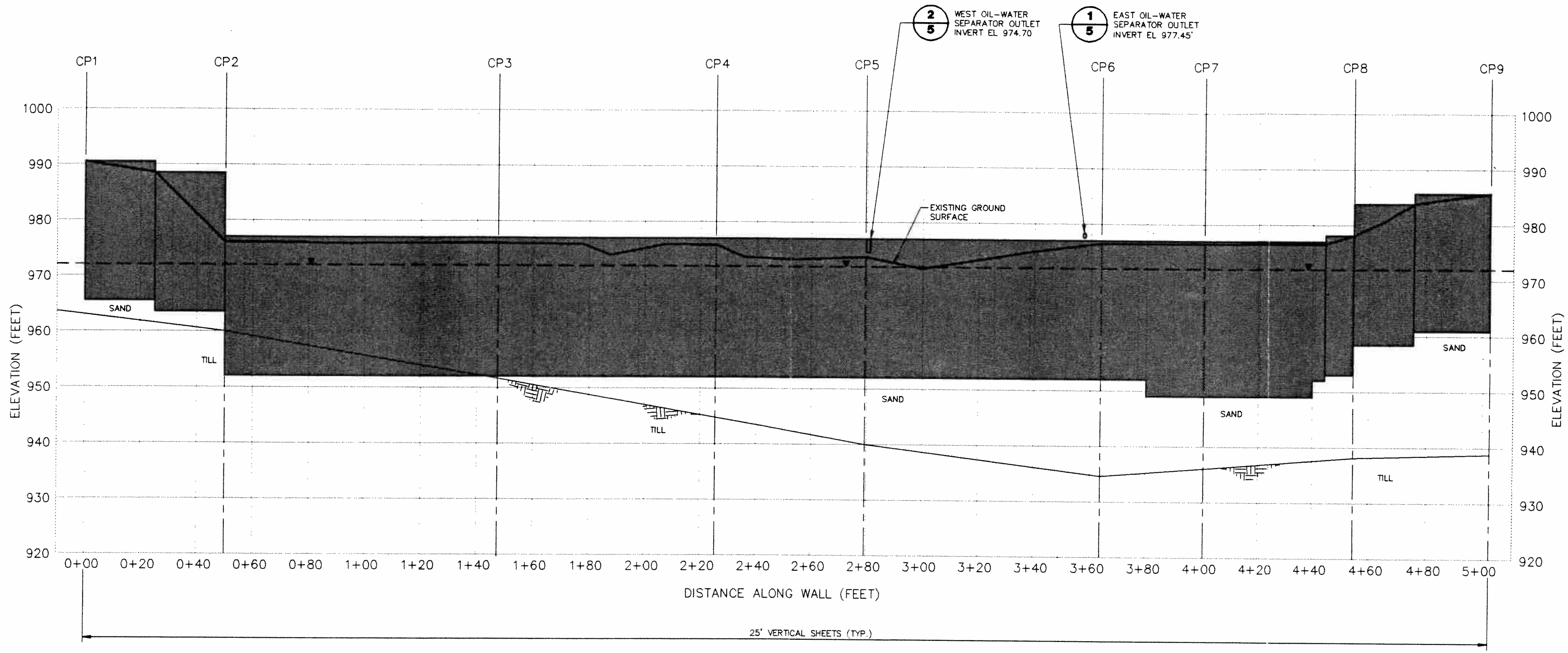
S = 7.13 in^3

CONCLUSIONS

The allowable tensile strength of the grout core is 740 psi, the elastic modulus is 4,560,000 psi, the moment of inertia is 38.5 in^4, and the section modulus is 7.13 in^3.

Attachment 2

Revised Sheet 4 of Appendix D of the Supplemental Source Control Proposal



LEGEND:

CP10	SHEET PILE ALIGNMENT CONTROL POINT
— — ▼	TYPICAL RIVER SURFACE WATER ELEVATION
(shaded)	DEPTH OF THE SHEET PILE

NOTE:

1. TOP OF TILL AND GROUND WATER TABLE ARE PROJECTED FROM SECTION A-A' OF FIGURE 3 IN SOURCE CONTROL PROPOSAL.
2. CONTROL POINT COORDINATES SHOWN ON DRAWING 2.
3. INSTALL STEEL SHEET PILE AND JOINT SEALANT IN ACCORDANCE WITH THE PROJECT SPECIFICATIONS.
4. ALL THE DIMENSIONS AND ELEVATIONS ARE APPROXIMATE. FIELD CONDITIONS MAY VARY.
5. CUTOFF SHEETING AT APPROXIMATELY GROUND SURFACE BETWEEN CP1 TO CP2 AND CP8 TO CP9.
6. THE TOP OF THE SHEET PILE WALL SHALL BE COVERED WITH RIPRAP AT THE COMPLETION OF WORK.
7. RIPRAP TOE PROTECTION SHALL BE WELL GRADED, COMPOSED OF ANGULAR STONE, AND BE SMOOTH AND UNIFORM IN APPEARANCE UPON COMPLETION.

L: ON=*, OFF=REF
P: STD-PCP/DL
3/1/99 SYR-54-RCA GMS AK
20140005/20140V04.DWG

10' 0 10' 20'
VERTICAL SCALE (FEET)
20' 0 20' 40'
HORIZONTAL SCALE (FEET)

No.	Date	Revisions	Init

Project Mgr. JMN
Designed by RDD
Drawn by RCA
Checked by RDD
Prof. Eng.
PE License

BBL
BLASLAND, BOUCK & LEE, INC.
engineers & scientists

GENERAL ELECTRIC COMPANY • PITTSFIELD, MASSACHUSETTS
EAST STREET AREA 2 SUPPLEMENTAL SOURCE CONTROL CONTAINMENT

CONTAINMENT BARRIER PROFILE

CONTRACT DRAWINGS

File Number
201.40.005

Date
JANUARY 1999

Blasland, Bouck & Lee, Inc.
Corporate Headquarters
6723 Towpath Road
Syracuse, NY 13214
315-446-9120

4

Attachment 3

Evaluation of Impacts and Mitigation/Restoration Measures for Area Subject to Massachusetts Wetlands Protection Act (3109 CMR 10.00)

Site Location

The location of this proposal activity is designated as USEPA Area 4/MCP East Street Area 2 in the "Proposal for Supplemental Source Control Containment/Recovery Measures" prepared by BBL, Inc. in January, 1999. The area for the proposed work is near a water-oil separator (identified as Building 64x) owned by the General Electric Company. The work will occur along the bank of the Housatonic River in the vicinity of Newell Street and East Street. Presently, the site is secured with gates and fencing.

Proposed Project

As part of the ongoing activities identified in the sources control work plans, the General Electric Company is proposing to implement supplemental containment measures. The activities subject to the Massachusetts Wetlands Protection Act (310 CMR 10.00) are outlined below with associated mitigating measures.

The proposed project will include installing sheet piling approximately five feet from the edge of the lower bank of the Housatonic River. The sheet piling shall extend 25 feet in depth and shall generally have an upper elevation of 977 feet (slightly higher in certain areas). Erosion control silt fence shall be installed at water's edge, between the proposed sheet piling and the water edge. This silt fence shall prevent any soil from entering the river during the installation of the sheet piling. An existing containment boom adjacent to the work area will be extended to include the entire length of the proposed sheetpile wall. In addition, a silt curtain will be installed in the river along the entire length of the work area, prior to beginning the work activities. In order to install the sheetpile, the majority of the trees on the bank of the river will need to be cleared. The trees which occur along the proposed alignment of sheetpiling will be removed, including the roots. Other trees in the work area will be cut to ground level to facilitate use of a crane and excavator to place the sheets and remove some soil form the toe of the riverbank. The roots of these trees will not be removed at this time. In addition, the fence along the top of the bank will be relocated for access by equipment.

Areas Subject to Work Under the Jurisdiction of the Wetlands Protection Act

The proposed work is along the bank of the Housatonic River. In this area, a major portion of the riverbank has a shelf below the upper bank of the river. This shelf is essentially the boundary of a bordering vegetated wetland associated with the river. (See enclosed wetland report). Therefore, the following areas are identified as resource areas as delineated by White Engineering, Inc. on February 19, 1999.

Land Under Waterway: The only work being performed within the river is the installation of the silt curtain and extension of the existing absorbent boom system. These are temporary devices. This resource area extends from the edge of the bank under the river water for the entire 400 feet of proposed work area. There will be no impact to this portion of the resource area from the sheetpile installation.

Bordering Vegetated Wetland: A strip of bordering vegetated wetland (BVW) exists along the lower shelf of the riverbank. See attachments for vegetation analysis. The sheet piling and silt fence will be installed within this BVW. The area will also be cleared of tress in order to accommodate installation crews. Trees will be cut flush with the ground and roots will be removed along the proposed alignment of the sheetpile. Roots will not be removed from those trees which occur outside the alignment of the proposed barrier wall. Additionally, some soil may be excavated from the lower portion of the riverbank to prevent possible sloughing into the river during sheetpile installation. Precautions to minimize erosion into the river include the silt fence and silt curtain. The proposed work will disturb less than 5,000 SF of BVW. Temporary restoration will include the installation of geotextiles to stabilize the bank since this area will be subject to further disturbance during GE's implementation of its proposed removal project for the upper ½ mile of the river. Final bank restoration will occur as part of that project.

Bank: The bank of the river is the first observable break in slope which is essentially where the BVW ends. There is a visible break in slope below the elevation of the top of bank, which occurs approximately along the existing fence line. This activity will involve approximately 400 linear feet. The majority of the existing trees will be removed from this portion of bank. Temporary restoration will include the installation of geotextiles, rolled erosion control products or mulch, to stabilize the bank. This area will be subject to further disturbance during GE's implementation of its proposed removal project for the upper ½ mile of the river and final bank restoration will occur as part of that project.

Bordering Land Subject to Flooding: This site is entirely within the 100-year floodplain of the Housatonic River according to the FEMA maps. The land subject to the 100-year flood begins at the border of the BVW and extends up the slope for approximately 600 feet. The potential effect of the project on flood storage capacity is discussed in Section VI of the forgoing letter from General Electric to USEPA and the Massachusetts Department of Environmental Protection.

Riverfront Area: The installation of erosion controls, sheet piling and clearing of vegetation will occur within the 100 ft. inner riparian zone to the Housatonic River. Incidental work and storage of equipment and materials will occur within the 100-ft. outer riparian zone to the river although no disturbance is proposed in this area. Less than 10% of either zone will be disturbed.

Wetland Reconnaissance Report
Riverbank Area Adjacent to General Electric Building 64X
USEPA AREA 4/ MCP East Street Area 2
Pittsfield, MA

The above mentioned area was reviewed for wetlands boundaries on February 19, 1999 by Shannon Lombardi of White Engineering, Inc. The resource area was delineated based on vegetation alone using the methods described in "Delineating Bordering Vegetated Wetlands Under the Massachusetts Wetlands Protection Act, A Handbook", March 1995 by MA Department of Environmental Protection. The property abuts the Housatonic River which has a bordering vegetated wetland (BVW) approximately 5 feet wide. The wetland boundary was flagged with orange and white-stripped survey flags numbered WF-1, start through WF-10, end. Vegetation and topography were adequate to determine the wetland boundary.

The area consists of the riverine system including land under waterway, bank, bordering vegetated wetland, floodplain, upland and riverfront area. The land under waterway associated with the Housatonic River extends to the bottom of the bank. The associated bank is dominated by Red-Osier Dogwood (*Cornus stolonifera*) shrubs. A bordering vegetated wetland averaging 5 feet wide along the 400 feet stretch of river is dominated by American Elm (*Alnus americana*), Eastern Cottonwood (*Populus deltoides*), Silver Maple (*Acer saccharinum*), and Red-Osier Dogwood (*Cornus stolonifera*). At the top of the bank the land creates a "shelf" several feet wide along most of the 400 foot stretch of river then changes to an upward direction forming the upper bank until leveling off to the open lot. From the edge of the bordering vegetated wetland the 100-year floodplain extends well into the upland. The entire bank of the river is part of the 100-foot inner riparian zone of the riverfront area. At the time of my visit there was no visible groundcover on the bank.

<u>Wetland Indicator Categories:</u>

OBL (Obligate Wetland): Occurs almost always (>99%) in wetlands
FACW (Facultative Wetland): Usually occurs in wetlands (67%-99%) but occasionally found in upland environments
FAC (Facultative): Equally likely to occur in wetland or uplands (34%-66%)
FACU (Facultative Upland): Usually occurs in uplands (67%-99%), but occasionally found in wetland environments
UPL (Obligate Upland): Occurs almost always (>99%) in uplands under natural conditions in this region. May occur in wetlands in other regions of the country.

The following resource areas present at the site are subject to the Massachusetts Wetlands Protection Act; land under waterway (Housatonic River), bank of the Housatonic River, bordering vegetated wetland adjacent to the bank, 100 ft. buffer zone from the bordering vegetated wetland, floodplain extending from the BVW boundary into the upland and 200 ft riparian zone from the Housatonic River bank under the Rivers Protection Act. This site is not included in an area of estimated wildlife habitat by the Natural Heritage and Endangered Species Program. The 400-foot stretch of riverbank is significantly less than the 10% allowable disturbance under the Wetlands Protection Act for wildlife habitat protection.

Shannon D. Lombardi
Environmental Analyst
White Engineering, Inc.

DEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: General Electric Co. Prepared by: S. Lombardi, White Engineering, Inc. Project location: East st/Newell st. DEP File #: ______

Check all that apply:

- [x] Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only
- [ ] Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II
- [ ] Method other than dominance test used (attach additional information)

Section I. Vegetation

Observation Plot Number: A Transect Number: 2 Date of Delineation: 2/19/99

A. Sample Layer and Plant Species (by common/scientific name)	B. Percent Cover (or basal area)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
Trees				
Northern Red oak (Quercus rubra)	10%	10.2%	no	FACU-
American Elm (alnus americana)	6%	6.1%	no	FACW-
Eastern Cottonwood (populus deltoides)	60%	61.2%	yes	FAC*
Norway maple (Acer platanoides)	8%	8.2%	no	UPL
Gray Birch (Betula populifolia)	6%	6.1%	no	FAC
Paper Birch (Betula papyrifera)	8%	8.2%	no	FACU
Shrubs/saplings				
Common Buckthorn (Rhamnus cathartica)	10%	18.9%	no	UPL
Red-osier Dogwood (Cornus stolonifera)	35%	66%	yes	FACW+*
Norway maple (Acer platanoides)	8%	15.1%	no	UPL
Climbing vines				
Bittersweet (celastrus scandens)	60%	100%	yes	FACU-

* Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus *Sphagnum*; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.

Vegetation conclusion:

Number of dominant wetland indicator plants: 2 Number of dominant non-wetland indicator plants: 1

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? (yes) no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent.

MA DEP; 3/95

DEP Bordering Vegetated Wetland (310 CMR 10.55) Delineation Field Data Form

Applicant: General Electric Co Prepared by: S. Lombardi, White Engineering, Inc. Project location: EAST ST/Newell St. DEP File #: ____

Check all that apply:

☒ Vegetation alone presumed adequate to delineate BVW boundary: fill out Section I only

☐ Vegetation and other indicators of hydrology used to delineate BVW boundary: fill out Sections I and II

☐ Method other than dominance test used (attach additional information)

Section I. Vegetation

Observation Plot Number: A Transect Number: 1 Date of Delineation: 2/19/99

A. Sample Layer and Plant Species (by common/scientific name)	B. Percent Cover (or basal area)	C. Percent Dominance	D. Dominant Plant (yes or no)	E. Wetland Indicator Category*
TREES				
EASTERN cottonwood (Populus deltoides)	50%	47.5%	yes	FAC*
Norway maple (Acer platanoides)	30%	28.6%	yes	UPL
Silver maple (Acer saccharinum)	25%	23.8%	NO	FACW
Shrub/sapling				
Common Buckthorn (Rhamnus cathartica)	8%	11.4%	NO	UPL
American Elm (Ulmus americana)	12%	17.1%	NO	FACW-
Silver maple (Acer saccharinum)	10%	14.3%	NO	FACW
Red maple (Acer rubrum)	25%	35.7%	yes	FAC*
Red-osier Dogwood (Cornus stolonifera)	15%	21.4%	yes	FACW*
Climbing vines				
American Bittersweet (Celastrus scandens)	80%	100%	yes	FACU-

* Use an asterisk to mark wetland indicator plants: plant species listed in the Wetlands Protection Act (MGL c.131, s.40); plants in the genus *Sphagnum*; plants listed as FAC, FAC+, FACW-, FACW, FACW+, or OBL; or plants with physiological or morphological adaptations. If any plants are identified as wetland indicator plants due to physiological or morphological adaptations, describe the adaptation next to the asterisk.

Vegetation conclusion:

Number of dominant wetland indicator plants: 3 Number of dominant non-wetland indicator plants: 0

Is the number of dominant wetland plants equal to or greater than the number of dominant non-wetland plants? (yes) no

If vegetation alone is presumed adequate to delineate the BVW boundary, submit this form with the Request for Determination of Applicability or Notice of Intent.

MA DEP: 3/95

Riverbank Adjacent to General Electric Company Building 64X
USEPA Area A/ MCP East Street Area 2
General Electric Company Property

Species List
As observed February 19, 1999

Sta 0+50

Trees (# of species >5" dia)	Scientific Name	Wetland Indicator Category
Eastern Cottonwood (3)	*Populus deltoides*	FAC
Norway Maple (5)	*Acer platanoides*	UPL
Silver Maple (5)	*Acer saccharimum*	FACW

Shrubs	Scientific Name	Wetland Indicator Category
Common Buckthorn	*Rhamnus cathartica*	UPL
American Elm	*Ulmus americana*	FACW-
Silver Maple	*Acer saccharimum*	FACW
American Bittersweet	*Celastrus scandens*	FACU-

Sta 50+100

Trees (# of species >5" dia)	Scientific Name	Wetland Indicator Category
None		

Shrubs	Scientific Name	Wetland Indicator Category
Red-Osier Dogwood	*Cornus stolonifera*	FACW+
Smooth Sumac	*Rhus glabra*	FAC
American Bittersweet	*Celastrus scandens*	FACU-

Sta 100+150

Trees (# of species >5" dia)	Scientific Name	Wetland Indicator Category
None		

Shrubs	Scientific Name	Wetland Indicator Category
Red Maple	*Acer rubrum*	FAC
Red-Osier Dogwood	*Cornus stolonifera*	FACW+

Sta 150+200

No vegetation visible at this time

Sta 200+250

Trees (# of species >5" dia)	Scientific Name	Wetland Indicator Category
Northern Red Oak(1)	*Quercas rubra*	FACU-
American Elm (1)	*Ulmus americana*	FACW-
Eastern Cottonwood (5)	*Populus deltoides*	FAC

(Sta 200+250 cont.)

Shrubs	Scientific Name	Wetland Indicator Category
Common Buckthorn	*Rhamnus cathartica*	UPL
Red-Osier Dogwood	*Cornus stolonifera*	FACW+
Norway Maple	*Acer platanoides*	UPL

Sta 250+300

Trees (# of species >5" dia)	Scientific Name	Wetland Indicator Category
Eastern Cottonwood (4)	*Populus deltoides*	FAC
Norway Maple(1)	*Acer platanoides*	UPL

Shrubs	Scientific Name	Wetland Indicator Category
None		

Sta 300+350

Trees (# of species >5" dia)	Scientific Name	Wetland Indicator Category
Northern Red Oak(2)	*Quercas rubra*	FACU-
Eastern Cottonwood (2)	*Populus deltoides*	FAC

Shrubs	Scientific Name	Wetland Indicator Category
Red-Osier Dogwood	*Cornus stolonifera*	FACW+

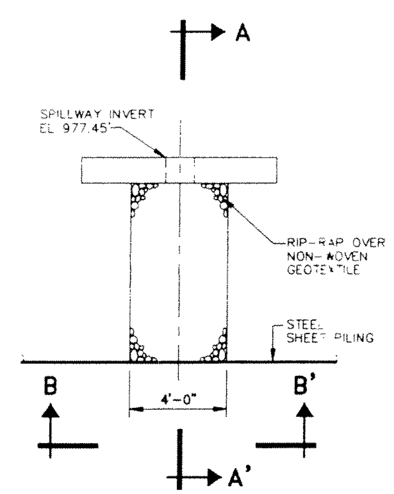
Sta 350+400

Trees (# of species >5" dia)	Scientific Name	Wetland Indicator Category
Eastern Cottonwood (6)	*Populus deltoides*	FAC
Gray Birch(1)	*Betula populifolia*	FAC
Paper birch (1)	*Betula papyrifera*	FACU

Shrubs	Scientific Name	Wetland Indicator Category
None		

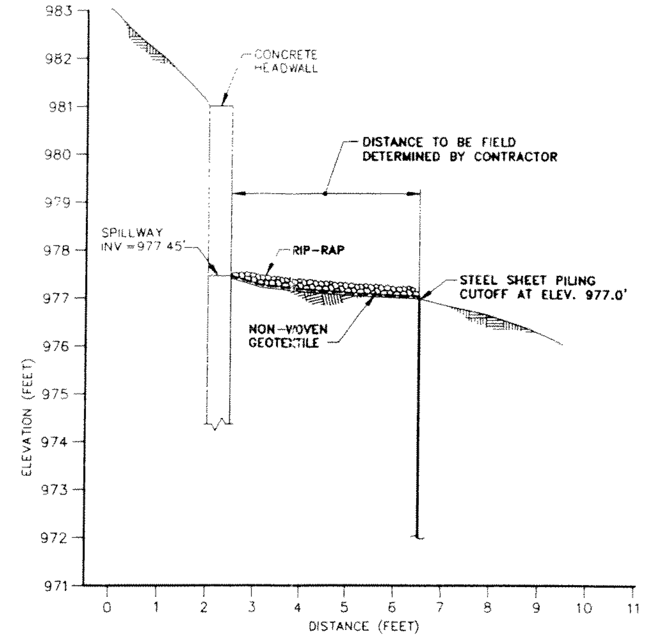
Attachment 4

Revised Sheet 5 of the Supplemental Source Control Proposal



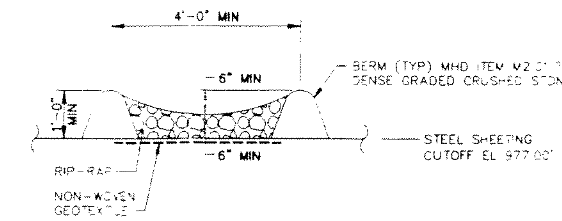
EAST HEADWALL PLAN (1)

NOT TO SCALE



SECTION A-A' (1)

SCALE: 1"=2'-0"

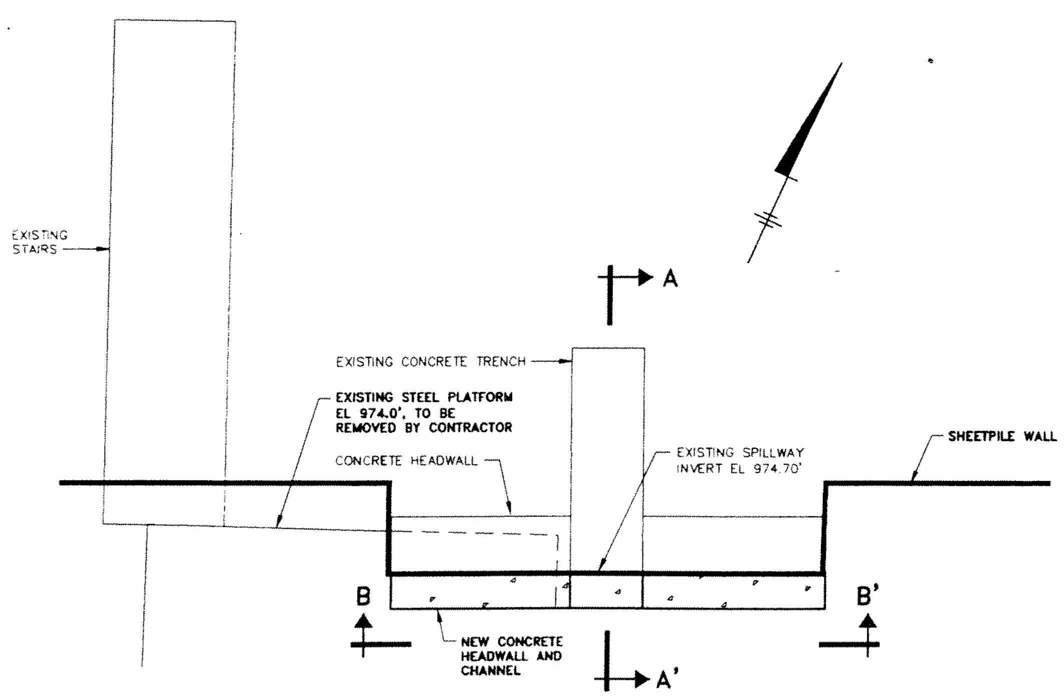


NOTES:

1. RIP-RAP SHALL CONSIST OF HARD, DURABLE ANGULAR ROCK WITH STONE SIZES OF 10 TO 50 LBS OR INTERLOCKING PRECAST CONCRETE BLOCKS.
2. CONTRACTOR MAY USE PRECAST CONCRETE GUTTER SECTIONS PROVIDED SOILS BELOW ENDS ARE ADEQUATELY PROTECTED AGAINST EROSION.

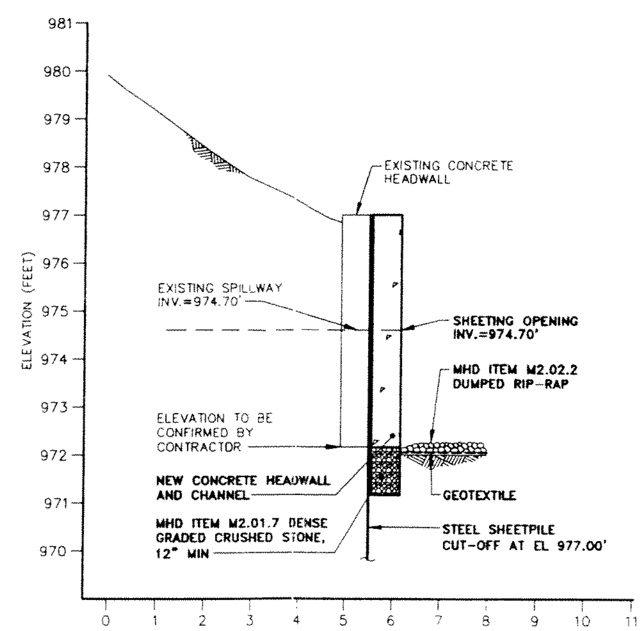
SECTION B-B'' (1)

NOT TO SCALE



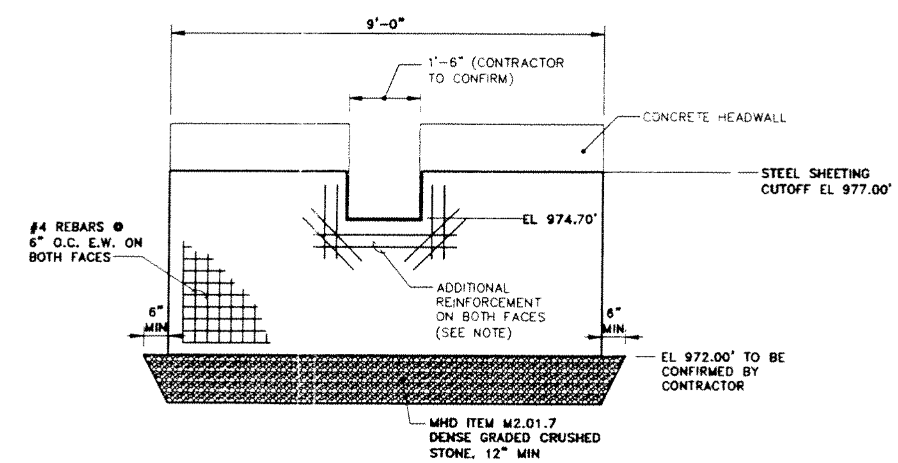
WEST HEADWALL PLAN (2)

NOT TO SCALE



SECTION A-A' (2)

SCALE: 1"=2'-0"



NOTES:

1. REBAR MAT TO BE ATTACHED TO STEEL LUGS WELDED TO SHEETPILING @ 1' O.C.
2. MINIMUM 3" COVER FOR REBAR.
3. PROVIDE ADDITIONAL REINFORCEMENT OF #4 BARS AS SHOWN. THE BARS WILL BE PLACED ABOUT 2" FROM THE CONCRETE FACE. THE REINFORCEMENT WILL BE EXTENDED A MINIMUM OF 12" BEYOND THE OPENING.

SECTION B-B' (2)

NOT TO SCALE

FOR BID ONLY
NOT FOR CONSTRUCTION

L: ON=*, OFF=*REF
P: STD-PCP-DL D2BL
2/25/99 SYR-54-RCA GMS AK
20140005\20140B09.DWG

GRAPHIC SCALE

No.	Date	Revisions	Init

Project Mgr. JMN
Designed by RDD
Drawn by RCA/GMS
Checked by RDD
Prof. Eng.
PE License

BBL
BLASLAND, BOUCK & LEE, INC.
engineers & scientists

GENERAL ELECTRIC COMPANY • PITTSFIELD, MASSACHUSETTS

EAST STREET AREA 2 SUPPLEMENTAL SOURCE CONTROL MEASURES

DETAILS

CONTRACT DRAWINGS

File Number
201.40.005

Date
FEBRUARY 1999

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