Avoidance of Wetland Impacts
Temporary Stormwater Pond A
Sea-Tac Third Runway

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Prepared for
HNTB and the Port of Seattle

June 18, 2001
4978-06

AR 050603

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Prepared by
Hart Crowser, Inc.

6/18/01

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AVOIDANCE OF WETLAND IMPACTS
TEMPORARY STORMWATER POND A
SEA-TAC THIRD RUNWAY

SUMMARY

The design and construction of Temporary Stormwater Pond A at the Sea-Tac Third Runway project has been analyzed to avoid potential effects on groundwater flow and wetland hydrology. This report examines the hydrogeologic and geotechnical issues related to design, construction, and operation of Pond A. Potential impacts to the hydrology of riparian wetlands between Pond A and Miller Creek can be mitigated through appropriate engineering design.

Pond A will be excavated about 6 to 10 feet in wetland soils, and would have an operating water level roughly 0 to 10 feet below the current water table in the wetlands. A sheet pile wall has been included in the design that isolates the pond from the surrounding water table and wetland hydrology. This wall will prevent Pond A from acting as a hydraulic sink and potentially altering the hydrology of adjacent wetlands.

To prevent the proposed sheet pile wall from disrupting the natural groundwater flow to the wetlands, a gravel-filled trench is planned to convey groundwater flow around the sheet pile wall and allow it to re-infiltrate on the downgradient side of Pond A. This will help to maintain groundwater levels on the western side of the sheet pile wall and thus avoid temporary impacts to the wetlands.

INTRODUCTION

This report addresses engineering and hydrogeologic issues related to the design and construction of temporary Stormwater Pond A at the Sea-Tac Third Runway project. Figure 1 shows a site plan including location of existing subsurface explorations and elevation contours for the shallow groundwater.

Construction of Pond A is planned to occur at the toe of the Third Runway embankment, near the West MSE Wall. The location is within riparian wetlands adjacent to Miller Creek. This report explains the engineering design for the pond and how this design is to avoid impacts to the hydrology of the adjacent wetland.

The purpose of Pond A is temporary collection of stormwater during part of the embankment construction, and is anticipated to be in service for one to two years. During wet weather, a low water level would be maintained near the bottom of Pond A by pumping to provide storage of runoff from storm events. During the summer months, the pond would fill with groundwater seepage, to avoid cost of pumping.

If the pond were constructed without the sheet pile wall, calculations suggest that the rate of seepage into the pond would be low (less than 5 gpm). Since this could be enough to lower the water table locally and potentially alter the hydrology of the wetland, the Port has developed plans to avoid impacting the wetland hydrology as described herein. The proposed pond design and mitigation includes the following elements:

- Stockpiling native wetland soil for use in restoring temporary wetland impacts.

- Installation of a continuous ring of sheet piles to form a cutoff wall around the pond to limit seepage into the pond. The sheet pile wall would be driven into the top of very dense silty sand soils below the surficial soils, effectively cutting off seepage of groundwater into the pond.

- Installation of a gravel-filled trench (similar to a "French drain") around the outside of the sheet pile wall to maintain existing groundwater flow and avoid potential lowering of water levels on the immediate downgradient side of the pond.

- Monitoring wetland vegetation adjacent to the pond during construction and pond operation to verify no loss of wetland functions and/or to enable supplemental mitigation, if needed.

- Removal of the temporary sheet pile wall and French drain after construction in the area is complete, backfilling with native soil, and revegetation to restore pre-construction conditions (see Section 5.2.4 of the Natural Resources Mitigation Plan; Parametrix 2000). Backfill would consist of soil types similar to those excavated; compaction would be avoided to enhance revegetation and to restore pre-construction seepage conditions.

The following sections of this report provide a summary of subsurface conditions, followed by a detailed description of the proposed design and mitigation. Figure 1 shows a site plan and existing shallow groundwater contours. Figure 2 shows a general geologic cross section through the pond. Figure 3 shows a detailed layout of temporary Pond A including a sheet pile wall

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and French drain around the perimeter. Figure 4 shows a cross section through the sheet pile wall and French drain.

Appendix A presents logs of soil borings at Pond A; Appendix B discusses hydrogeologic modeling used to verify effectiveness of the proposed French drain in maintaining shallow groundwater movement to the downslope wetland; and Appendix C describes geotechnical analysis of the sheet pile.

SUMMARY OF SUBSURFACE CONDITIONS

Subsurface conditions in the vicinity of Pond A generally consist of 5 to 15 feet of soft or loose soils overlying very dense glacial till. The soft surficial soils consist of interbedded silty to very silty sand, peat and slightly sandy silt. Below these soils, the borings encountered silty, slightly gravelly to gravelly sand (glacial till). Logs of borings in the area of Pond A are presented in Appendix A. Figure 2 presents a generalized cross section through the long axis of the proposed Pond A.

The proposed bottom of pond elevation is 220 feet (existing ground surface elevations between about 226 to 230 feet). Groundwater levels vary seasonally between about 224 to 230 feet (Table 1).

Groundwater in the area of Pond A is within a few feet of the ground surface throughout the year. The groundwater level varies seasonally up to about 2-1/2 feet, as indicated by measurements in observation wells HC99-B38 and HC99-B39 from March of 1999 through January 2001 (Table 1).

PROTECTION OF WETLANDS

Given the potential for Pond A to alter wetland hydrology, alternative methods for protecting the wetland were considered. These included modifications to the operating regime for Pond A with operation restricted during the summer to prevent any potential for wetland impacts at this time. A design that hydraulically isolates Pond A was also developed and the effect of this isolation on the hydrology of the neighboring wetlands was analyzed using a simplified groundwater flow model (Appendix B).

The sheet pile wall will completely encircle Pond A, forming a hydraulic barrier from groundwater in the surficial soils surrounding the pond (Figure 3). Seepage below the sheet piles is anticipated to be negligible, due to the low hydraulic conductivity of the very dense silty sand (glacial till) and limited differential head between the bottom of the pond and groundwater level outside the pond. Details of the sheet pile wall design are presented in Appendix C.

Although the sheet pile wall will provide hydraulic isolation of Pond A from the surrounding wetland, a potential effect of the wall could be a disruption of the natural pattern of shallow groundwater movement in the subsoils downslope of the wall. To prevent disruption of groundwater flow, the design also includes a gravel-filled trench, constructed as a French drain encircling the sheet pile wall. This French drain will convey groundwater flow around the "obstruction" created by the pond.

A numerical groundwater flow model was used to assess the potential for changes in groundwater levels and flows as a result of the sheet pile wall, and to test alternatives measures for mitigating these effects (Appendix B). Worst case simulations suggested that without the French drain system, groundwater levels could potentially be reduced by 1 to 2 feet on the downgradient side of the sheet pile wall in the zone between Pond A and Miller Creek. The French drain is designed to avoid this potential impact.

Groundwater flow would be maintained around the sheet pile wall by conventional French drain consisting of a gravel-filled trench with a perforated drain pipe located within the gravel. The gravel-filled trench provides for relatively uniform seepage into the French drain and from the French drain into the adjacent undisturbed soil. The pipe enables effective transmission of water around the sheet piled area with relatively little loss of head. A geotextile filter fabric around the gravel will prevent migration of fine soil particles and potential clogging that might otherwise diminish effectiveness over the one to two year operating life of the system. Dimensions and details of the system are shown on Figure 4.

The trench will collect shallow groundwater on the upstream (eastern) side of Pond A, and convey it to the soils on the downstream (western) side of the pond. Flow can occur around both the southern and northern ends of the pond. Groundwater that seeps into the upgradient side of the drain will be available to re-infiltrate back into the shallow soils on the western side of Pond A, thus maintaining groundwater levels in the wetland.

The rate of flow into and out of the trench will be limited by the hydraulic conductivity of the native soils. Accordingly the drain would not lower water tables in upgradient soils.

USE OF THIS REPORT

This report was prepared for the Port of Seattle for the site and facility described herein. We completed this work in accordance with conventionally accepted geotechnical engineering practices for the nature and conditions of work conducted in the same or similar localities at the time the work was performed.

Hart Crowser would be pleased to address any questions on this report.

REFERENCES

Parametrix 2000. "Final Natural Resource Mitigation Plan, Master Plan Update Improvements, Seattle-Tacoma International Airport."

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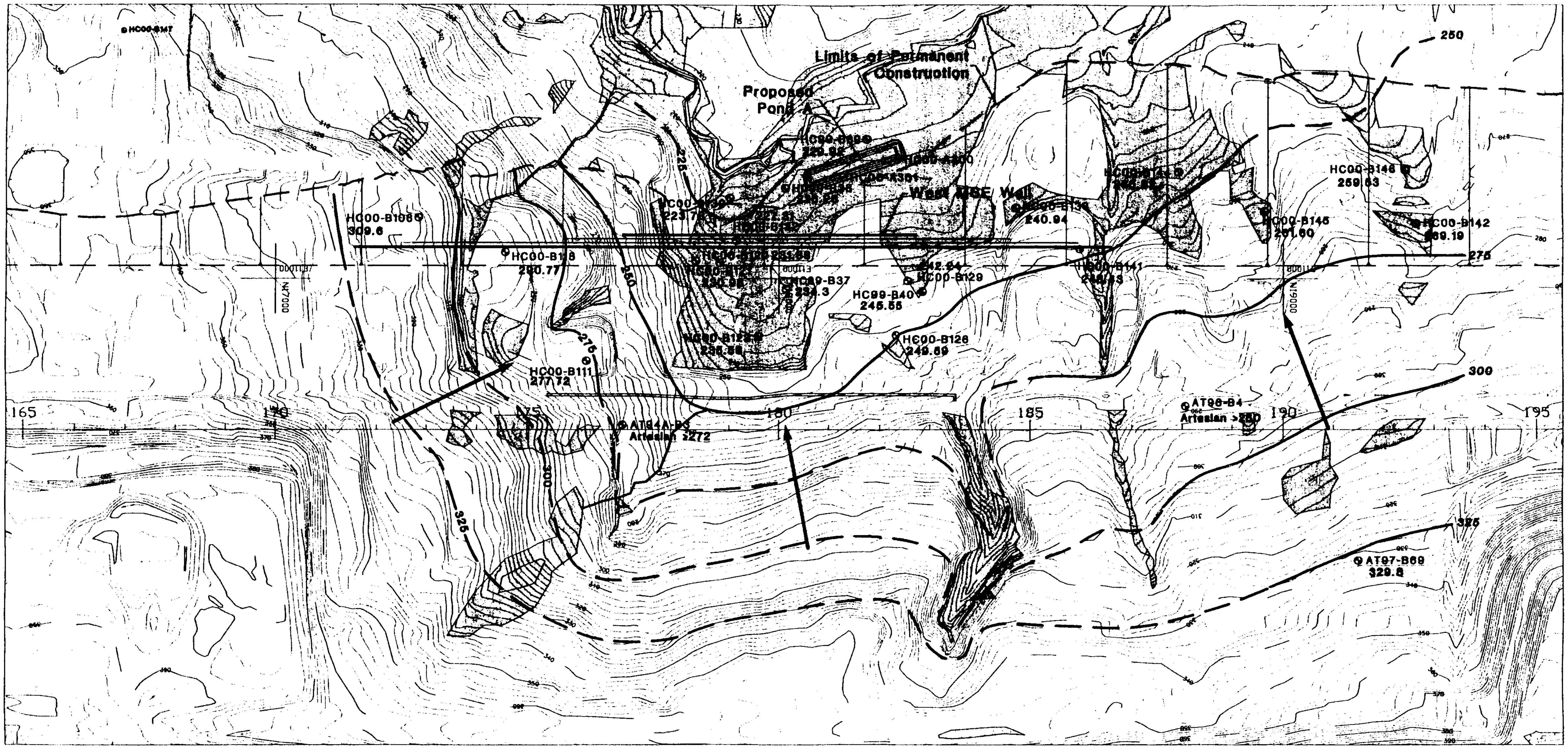
Table 1 - Observed Groundwater Levels in Monitoring Wells near Pond A

Monitoring Well:	HC99-B38		HC99-B39	
	Depth* in Feet	Elevation in Feet	Depth* in Feet	Elevation in Feet
Measuring Point	0.00	230.88	0.00	230.80
Ground Level*	3.3	227.6	-0.3	231.1
Top of Screen*	12.3	218.6	4.7	226.1
Bottom of Screen*	22.3	208.6	14.7	216.1
Date: 3/8/1999	4.40	226.48	0.69	230.11
3/10/1999				
4/5/1999	4.41	226.47	0.74	230.06
5/4/1999	4.60	226.28	0.86	229.94
5/15/1999				
6/14/1999	5.90	224.98	1.68	229.12
7/13/1999	5.93	224.95	2.05	228.75
8/13/1999	6.08	224.80	2.18	228.62
9/14/1999	6.48	224.40	2.51	228.29
10/13/1999	5.98	224.90	2.09	228.71
11/11/1999	4.25	226.63	2.90	227.90
12/9/1999	4.38	226.50	0.27	230.53
1/13/2000	4.35	226.53	0.54	230.26
2/14/2000	4.33	226.55	0.59	230.21
3/9/2000	4.43	226.45	0.61	230.19
4/11/2000	4.60	226.28	0.88	229.92
5/10/2000	4.32	226.56	0.88	229.92
6/19/2000	4.91	225.97	1.15	229.65
7/10/2000	5.72	225.16	1.61	229.19
10/10/2000	5.99	224.89	2.17	228.63
1/22/2001	4.42	226.46	0.79	230.01
5/4/2001	4.58	226.30	1.05	229.75

Depth* All depths are below measuring point (NOT below the ground surface)
Blank indicates data not available.

Site and Exploration Plan
Groundwater Elevation Contour Map
Pond A



Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg," dated October 4, 1999. Wetland delineation prepared from drawing provided by Parametrix entitled "W_020800.dwg," dated February 8, 2000.

⊕HC00-B118	Monitoring Well Location and Number
⊙HC00-A300	Hand Auger Boring Location and Number
290.77	Groundwater Elevation in Feet (April 11, 2000)
Artesian >272	Confirmed Groundwater Estimated Piezometric Level in Feet
(symbol)	Wetland Location
— — 250 —	Groundwater Elevation Contour in Feet (Dashed where Inferred)
←	Inferred Groundwater Flow Direction
185	Proposed Runway Centerline Stationing

N

0 200 400
Scale in Feet

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Figure 1

RC 6/18/00 1=200 (xref)see drawing file/cnorie.dc2
49780664

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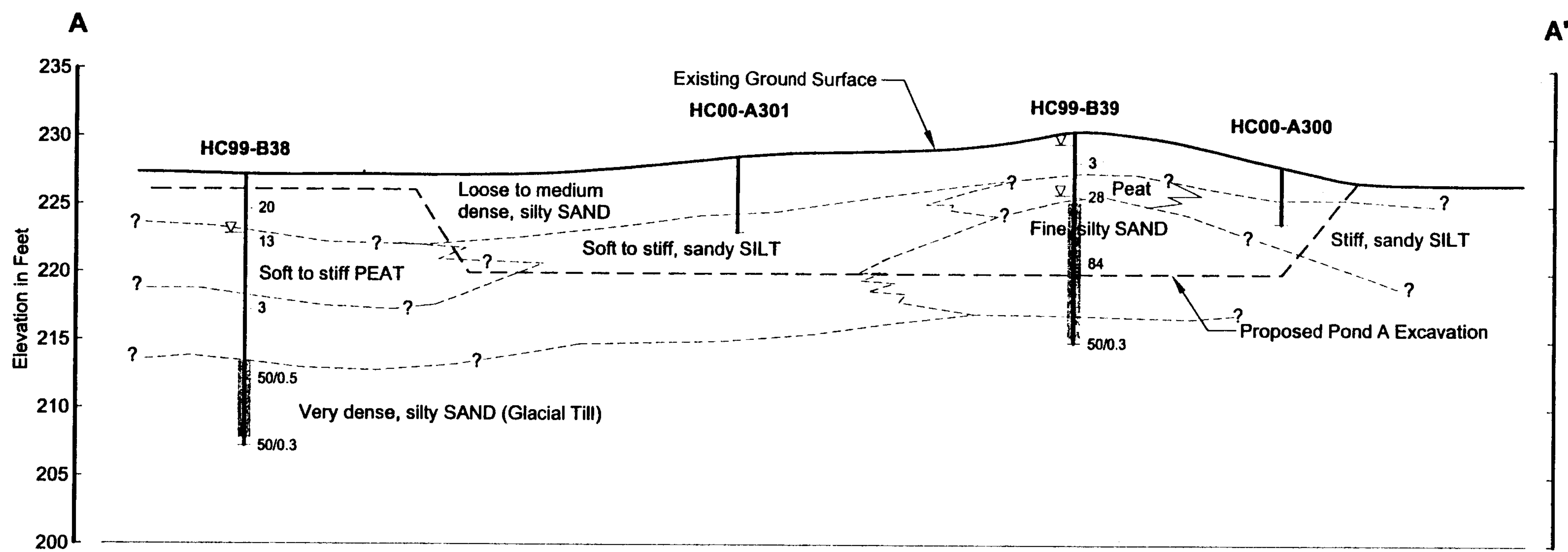
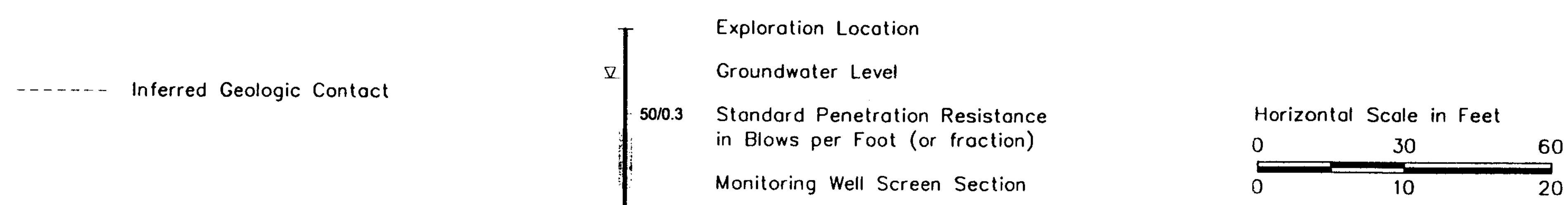
Cross Section A-A'



Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.



DTN 6/18/01 1=1 charlie-8.pc2
4978068!

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Figure 2

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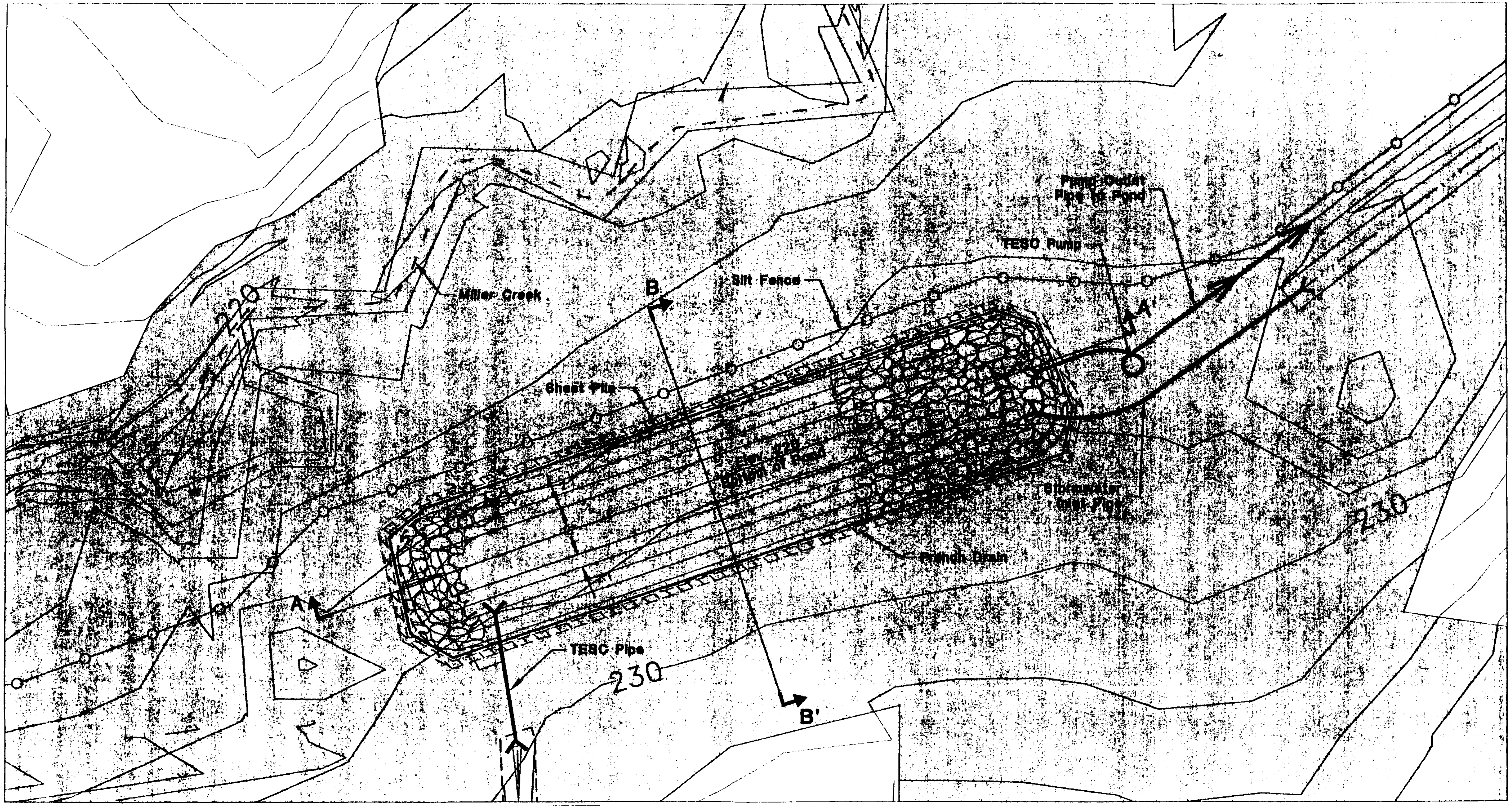
Pond A Detail



Note: Base map prepared from drawing provided by HNTB entitled "X_topo.dwg," dated April 4, 2001. Wetland delineation prepared from drawing provided by Parametrix entitled "W_022201.dwg," dated February 22, 2001.

Wetland

AA' Cross Section Location and Designation

N

0 30 60
Scale in Feet

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Figure 3

RC 6/18/01 1=30 (xref)see drawing file/charlie.pc2
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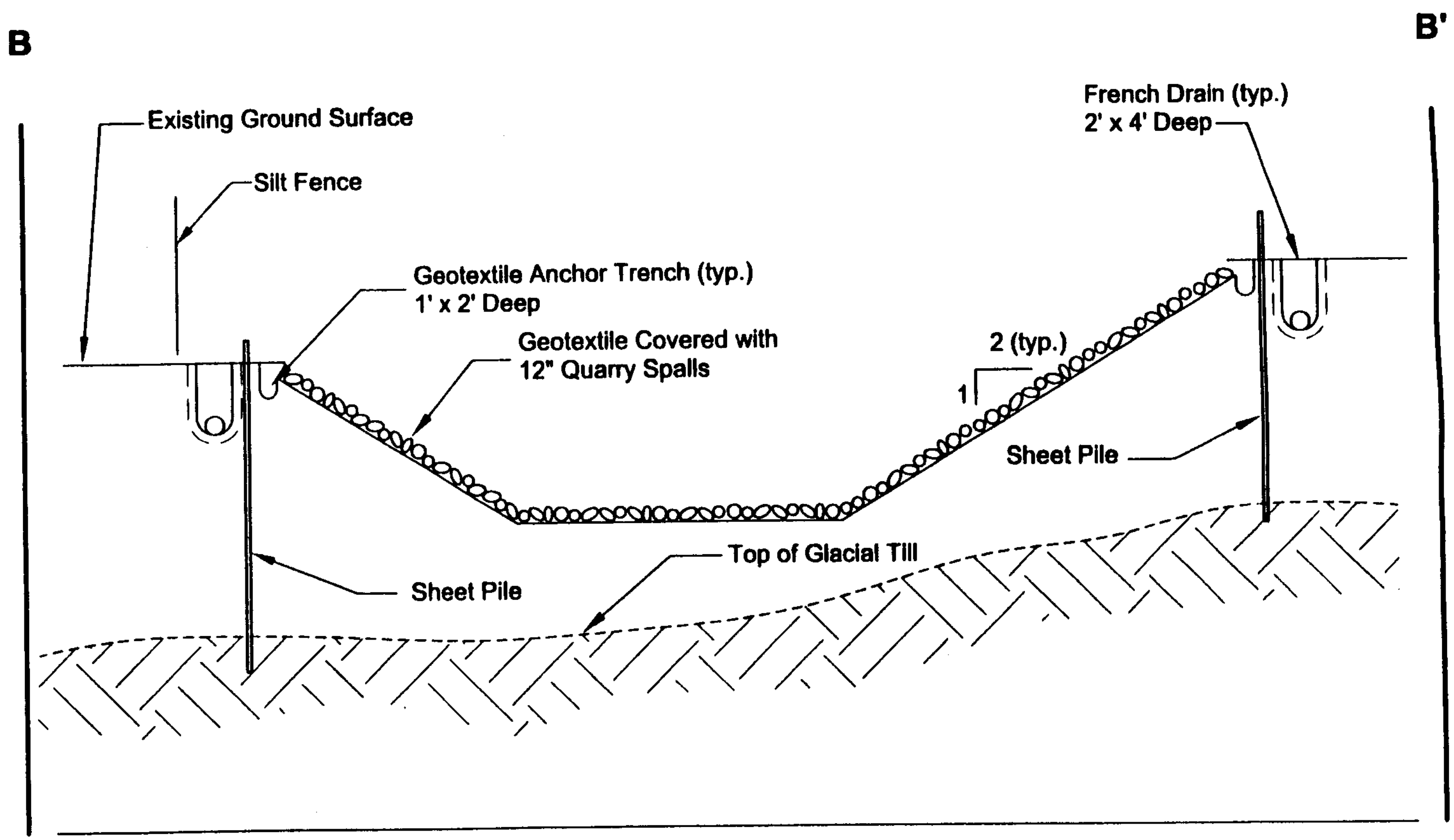
Cross Section B-B'



Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data.

Not to Scale

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Figure 4

APPENDIX A
SUBSURFACE EXPLORATIONS

Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling Test Symbols

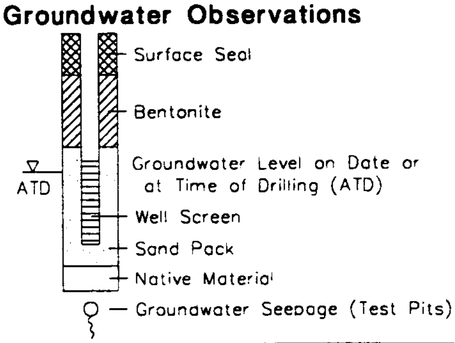
BORING SAMPLES

- ⊠ Split Spoon
- ⧅ Shelby Tube
- ▥ Cuttings
- ◫ Core Run
- * No Sample Recovery
- P Tube Pushed, Not Driven

TEST PIT SAMPLES

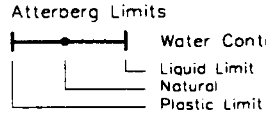
- ⊠ Grab (Jar)
- ⧄ Bag
- ⧅ Shelby Tube

Groundwater Observations



Test Symbols

GS	Grain Size Classification
CN	Consolidation
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits



PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	*In Situ* Density Test

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Figure A-1

1=1 A-1 STANDARD

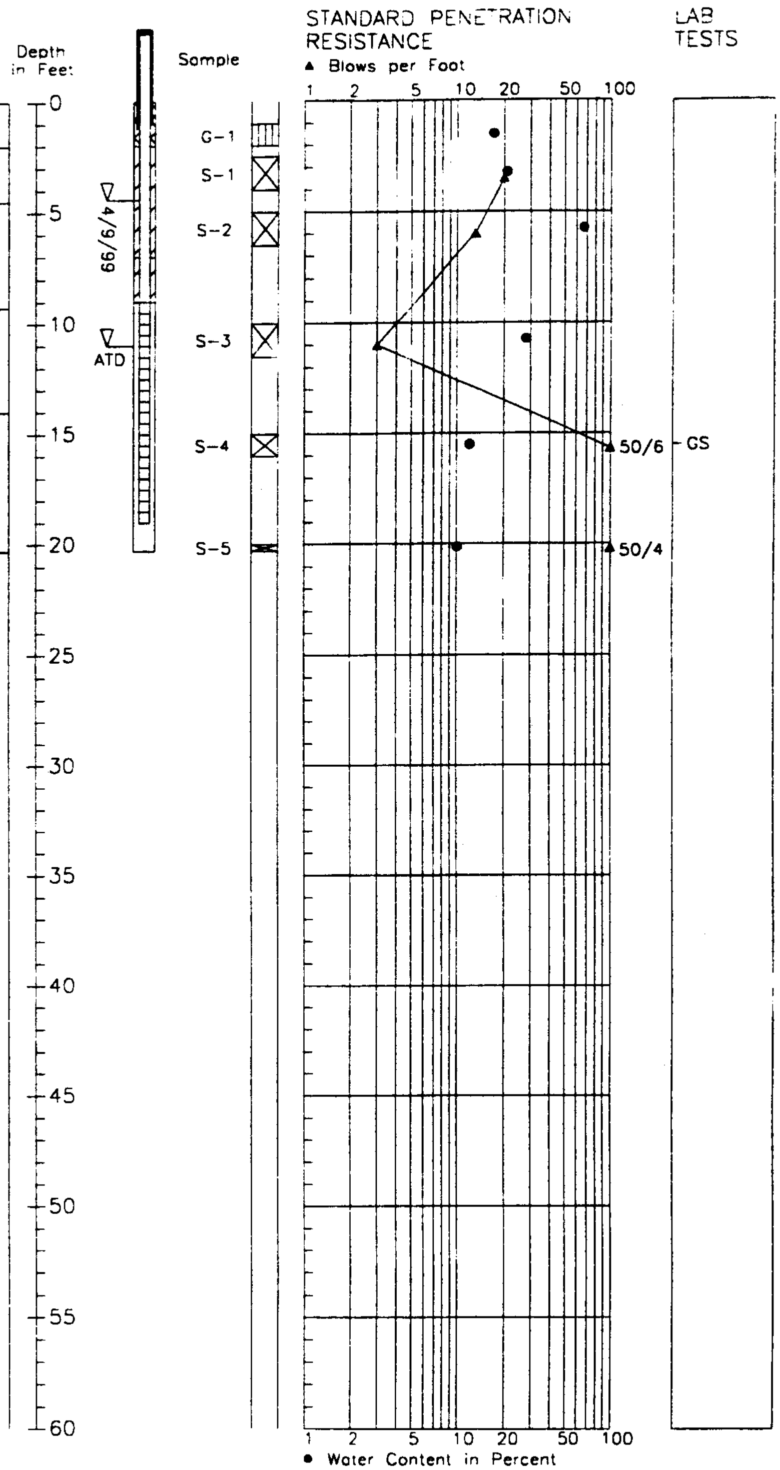
Boring Log HC99-B38

N 18,011.99, E 10,819.39

Soil Descriptions

Ground Surface Elevation in Feet: 227.58

Soil Descriptions
(Loose), moist, brown, silty SAND.
Medium dense, moist, gray, very silty SAND.
Stiff, moist, dark brown, sandy PEAT with occasional wood debris.
Soft, moist, gray, slightly sandy SILT with occasional wood debris.
Very dense, moist to wet, gray, slightly gravelly, silty SAND.
Bottom of Boring at 20.3 Feet. Completed 2/22/99.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

DIN 6/18/01 1=1 charlie.pc2
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Figure A-2

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Boring Log HC99-B39

N 18,174.14, E 10,722.31

Soil Descriptions

Ground Surface Elevation in Feet: 231.10

6 inches of TOPSOIL over very loose, moist, brown and gray, slightly gravelly, silty SAND.

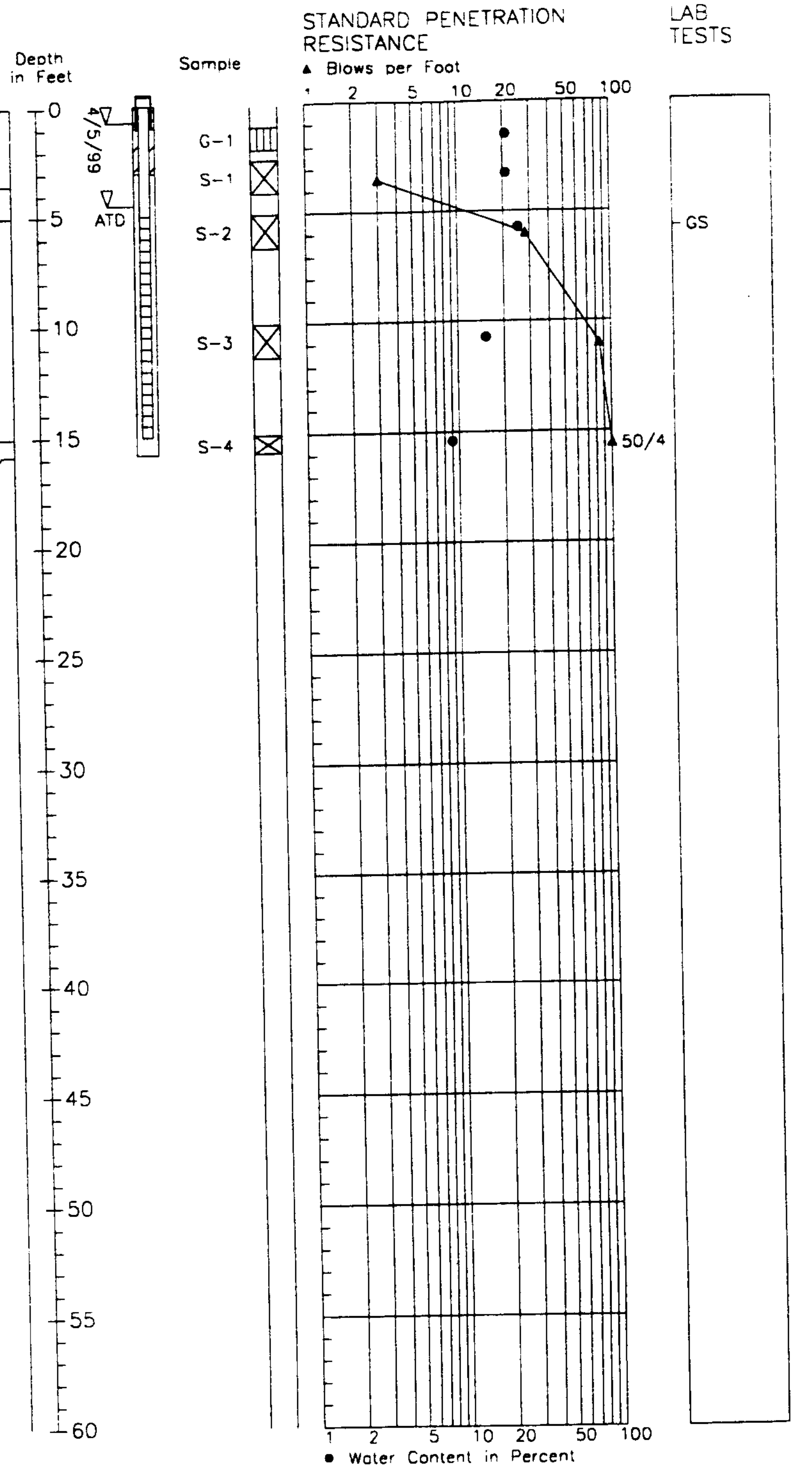
Soft, moist, brown PEAT.

Medium dense to very dense, moist, gray, silty, fine SAND.

8-inch layer of silty CLAY.

Very dense, moist, gray, silty, gravelly SAND.

Bottom of Boring at 15.8 Feet.
Completed 2/16/99.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

DTN 6/18/01 1=1 charlie.pc2
4978\LOGS\99 BORINGS

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Figure A-3

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Hand-Auger Log HC00-A300

N 18235
E 10762

SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 228

Sample	Water Content
S-1	33
S-2	27
S-3	33

Depth in Feet	Soil Descriptions
0 – 1	(Loose to medium dense), wet, dark brown, silty SAND with organic material.
1 – 3	(Medium dense), wet, gray, silty SAND with trace organic material.
3 – 4	(Medium stiff to stiff), wet, gray, clayey, sandy SILT with trace organic material.

Bottom of Hand-Auger at 4.0 Feet
Completed 5/12/00.

Seepage noted @ 1.0'

Hand-Auger Log HC00-A301

N 18127
E 10798

SOIL DESCRIPTIONS
Ground Surface Elevation in Feet: 229

Sample	Water Content
S-1	47
S-2	21
S-3	19
S-4	28
S-5	28

Depth in Feet	Soil Descriptions
0 – 1	(Loose to medium dense), moist to wet, dark brown, very gravelly, silty SAND with abundant organic material.
1 – 4	(Loose to medium dense), wet, brown to gray, silty SAND with trace organic material.
4 – 5.5	(Medium stiff to stiff), wet, gray, slightly clayey, sandy SILT with trace organic material

Bottom of Hand-Auger at 5.5 Feet
Completed 5/12/00.

Seepage noted @ 1.5'

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at the time of excavation. Conditions may vary with time.

DTN 8/30/00 1=1 CHARLIE - 8 PC2
497806 HANDAUGERS.dwg

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Figure A-4

APPENDIX B
GROUNDWATER SEEPAGE ANALYSIS

APPENDIX B
GROUNDWATER SEEPAGE ANALYSIS

This appendix describes the groundwater seepage analysis that was performed to examine the potential hydrologic effect of Pond A on groundwater. The analysis was also used to design sheet pile wall and a gravel-filled trench (French drain) that mitigates the potential hydrologic effect of the pond.

Approach

The approach taken to assess the effect of the sheet pile wall and the French drain on the groundwater flow regime was to prepare a simplified groundwater flow model, using a MODFLOW computer model based on observations of groundwater levels in nearby monitoring wells. The model showed the generalized effect of the sheet pile wall as a blockage to the pre-construction groundwater flow pattern in the area.

The model simulates changes in groundwater flowpaths, as well as the mounding effect on the upstream side of the sheet piles, and the corresponding reduction in groundwater levels on the downstream side of the sheet piles. Simulation of the French drain with the same model shows how it will collect water that mounds on the upstream side, and conduct it around to the downstream side of the sheet piles. On the downstream side, seepage re-infiltrates into the shallow soils so as to maintain groundwater levels in the wetland. The re-infiltration of groundwater is considered important to sustain the hydrologic regime of the riparian wetland adjacent to Miller Creek.

Model Setup

A numerical groundwater flow model was used to assess the likelihood for changes in groundwater levels and flows due to the proposed sheet pile wall around Pond A, and to test alternatives measures for mitigating these effects. The model was created using the USGS MODFLOW code (McDonald and Harbaugh 1988) with the Visual MODFLOW pre- and post-processor (Waterloo Hydrogeologic 2000). MODFLOW is a block-centered finite difference code capable of simulating steady-state and transient groundwater flow in a range of aquifer types and configurations.

The model was set up to provide a simplified representation of the shallow groundwater flow system in the vicinity of Pond A. The model represents a numerical approximation to the general pattern of groundwater flow, for the purpose of demonstrating cause and effect of the proposed sheet piling and French drain relative to an assumed base condition. This approach is valid for the mitigation design since, using a consistent set of groundwater and soil parameters in the model, it focuses on the changes to groundwater flow caused by the proposed construction and shows how these impacts are avoided by the proposed mitigation.

The model domain is shown on Figure B-1 and encompasses an area extending from north of South 166th Street, to Detention Pond G in the south, with Detention Pond A located approximately in the center. The lateral extent covered by the model is the area west of the existing airfield, bounded on the west side by Miller Creek.

The model was configured with its top surface defined by the existing topography, and its base defined as the top of the glacial till (very dense silty sand) underlying the site, as determined from geotechnical borings conducted in the area. Shallow groundwater flow occurs in the surficial soils based on observation of seepage in test pits and inferred from water level measurements in monitoring wells nearby. Groundwater flow conditions in the area are well documented because of various exploratory borings and monitoring wells observations for the Third Runway. Data sources are listed at the end of this appendix.

The MODFLOW model was constructed with two layers to represent the construction of a gravel-filled trench surrounding the sheet piles. The upper layer of the model consisted of a 3-foot-thick layer that mimics the surface topography. The lower layer represents the remainder of the shallow surficial soils (above the glacial till) that varies in thickness from about 3 to 10 feet across the area of the model. The horizontal area of the aquifer to be modeled was discretized into a rectangular grid with a cell size of 10 feet by 13 feet covering the area of interest (Figure B-1).

Aquifer Material

The aquifer parameters listed below were assigned to both layers with the exception of the ring of cells representing the drainage layer in the upper layer. The silty sands and other deposits above the glacial till were represented as general aquifer material with the following uniform properties:

- Hydraulic conductivity: 8.2×10^{-5} fps

No attempt was made to represent the likely spatial variation in aquifer properties within the surficial soils around Pond A.

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Drainage Layer Material

The French drain used to maintain groundwater levels around the outside of the sheet piles was represented in the model with a more permeable material typical of a non-silty free-draining gravel:

- Hydraulic conductivity: 6.6×10^{-3} fps

Boundary Conditions

Constant-head boundaries were established along the eastern edge of the model to represent existing groundwater flow derived from the east. The elevation of the applied head was adjusted along the boundary to simulate the approximate variation in groundwater levels observed at the site. The west side of the modeled domain was represented by a series of river nodes to simulate the course of Miller Creek.

The northern and southern sides of the model were simulated as no-flow boundaries representative of groundwater streamlines in the aquifer, with groundwater flow in the body of the model occurring parallel to these sides. The lateral boundaries of the model were established a sufficient distance from Pond A (with the exception of Miller Creek) such that small changes in the boundaries would not strongly affect the groundwater flow pattern in the area of Pond A. The dense glacial till soils underlying the modeled area are assumed to be relatively low in permeability such that flow through the till is small in comparison to flow in the shallow soils, and can be ignored.

Recharge was applied uniformly over the entire area of the model to help simulate the general shape of the observed water table at the site.

Calibration

The model was calibrated in a general sense to two sets of water levels representative of the range observed in site monitoring wells (Table 1): an average winter high-water level and an average late-summer low-water level were used to define conditions for two separate model scenarios. Different water levels were achieved by varying the areal groundwater recharge value applied in the model from 16 to 10 in/yr.

Monitoring Points

Two virtual observation wells were assigned within the model to track simulated water levels at specific locations: one upgradient and one downgradient of Pond A.

Assumptions

Listed below are the assumptions associated with the construction and use of this groundwater model:

- Groundwater flow in the shallow aquifer is unconfined and modeled as steady-state;
- The underlying till/dense silty sands have lower permeability such that groundwater flow through these layers can be neglected;
- Aquifer materials are homogeneous and isotropic;
- Recharge to the groundwater is uniform over the model domain;
- Miller Creek is treated as a fixed-head river boundary defined by streambed elevation interpolated from topographic map coverage;
- Groundwater discharges to Miller Creek as baseflow;
- The area west of Miller Creek is ignored (inactive) in the model;
- Wetland function is not modeled explicitly but represented by groundwater levels at or close to ground surface; and
- Evapotranspiration from shallow groundwater table and/or wet surface soils is not modeled.

Results

The following results were obtained from steady-state solutions of the groundwater model described above for two different water level regimes.

Simulated Winter Water Levels

Three steady-state solutions were analyzed for determining the effect of the sheet pile wall on the shallow groundwater flow system in winter conditions. The resulting groundwater head distributions and streamflow lines are shown in the following figures:

- Figure B-2 - Existing Winter Conditions
- Figure B-3 - Pond A with Sheet Piles
- Figure B-4 - Pond A with Sheet Piles and Diversion Drain

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Comparison of predicted water levels for the above scenarios show a rise in groundwater levels upgradient of Pond A and decreased groundwater levels downgradient of Pond A when only the sheet piles surround Pond A. Upon adding a groundwater diversion drain around the perimeter of Pond A, the groundwater levels return to pre-construction elevations, thus demonstrating no effect to the method.

Simulated Later Summer Water Levels

Two steady-state solutions were analyzed for determining the effect of the sheet pile wall on the shallow groundwater flow system in late summer conditions. The resulting groundwater head distributions and streamflow lines are shown in the following figures:

- Figure B-5 - Existing Conditions
- Figure B-6 - Pond A with Sheet Piles and Diversion Drain

Comparison of predicted water levels for the above scenarios show the groundwater levels at pre-construction elevations, thus demonstrating no effect to the Wetland.

Data Sources for Appendix B

FAA 1995. DRAFT Environmental Impact Statement for Proposed Master Plan Update Development Actions at Seattle-Tacoma International Airport. US Department of Transportation, Federal Aviation Administration, April 1995.

Hart Crowser 1999, Subsurface Conditions Data Report, 404 Permit Support, Third Runway Embankment, Sea-Tac International Airport, SeaTac, Washington, July 1999.

Hart Crowser 2000. DRAFT Subsurface Conditions Data Report, West MSE Wall, Third Runway Embankment, Sea-Tac International Airport, SeaTac, Washington, June 2000.

Hart Crowser 2000. DRAFT Subsurface Conditions Data Report, Additional Field Explorations and Advanced Testing, Third Runway Embankment, Sea-Tac International Airport, August 2000.

Hart Crowser 2001. Appendix C, DRAFT Geotechnical Engineering Analyses and Recommendations, Third Runway Embankment, Seattle-Tacoma International Airport, SeaTac, WA

Pacific Groundwater Group 2000. "Sea-Tac Runway Fill Hydrologic Studies Report", June 19, 2000.

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Groundwater Modeling Area
Pond A

Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

Extent of Model Area (Groundwater Flow Simulated in Unshaded Portion)

0 300 600
Scale in Feet

N

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Figure B-1

RC 6/18/01 1=300 (xref)see drawing file/charlie.pc2
49780673

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RC 6/18/01 1=100 (xref)see drawing file/charlie-8.pc2 49780682

Simulated Average Water Table

Existing Conditions Without Pond A

224 – – – Simulated Groundwater Level in Feet

Simulated Groundwater Flow Path

Wetland

N

0 100 200

Scale in Feet

Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

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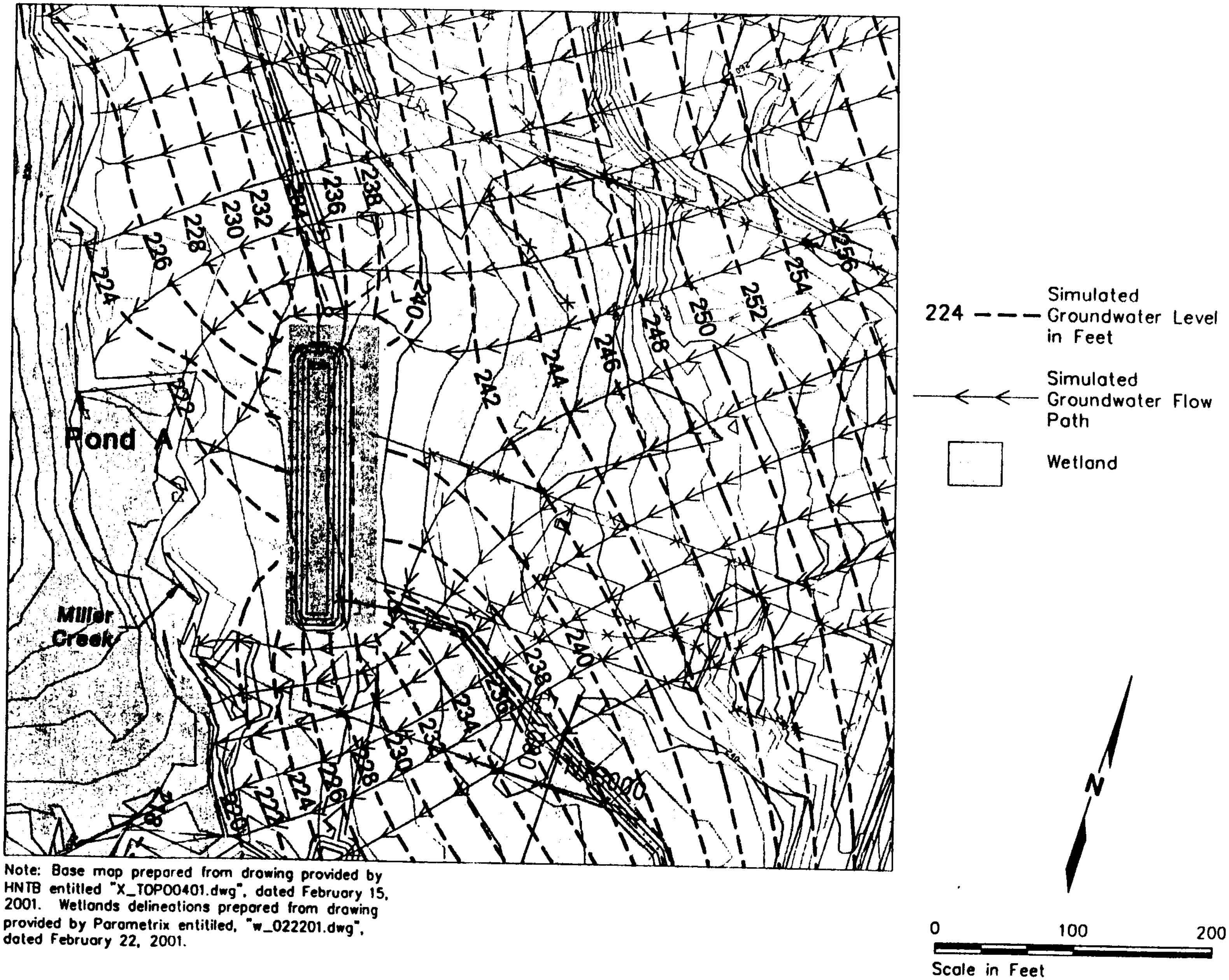
Figure B-2

RC 6/18/01 1=100 (xref)see drawing file/charlie-8.pc2 49780680

Simulated Average Water Table
Pond A with Sheet Piles



Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

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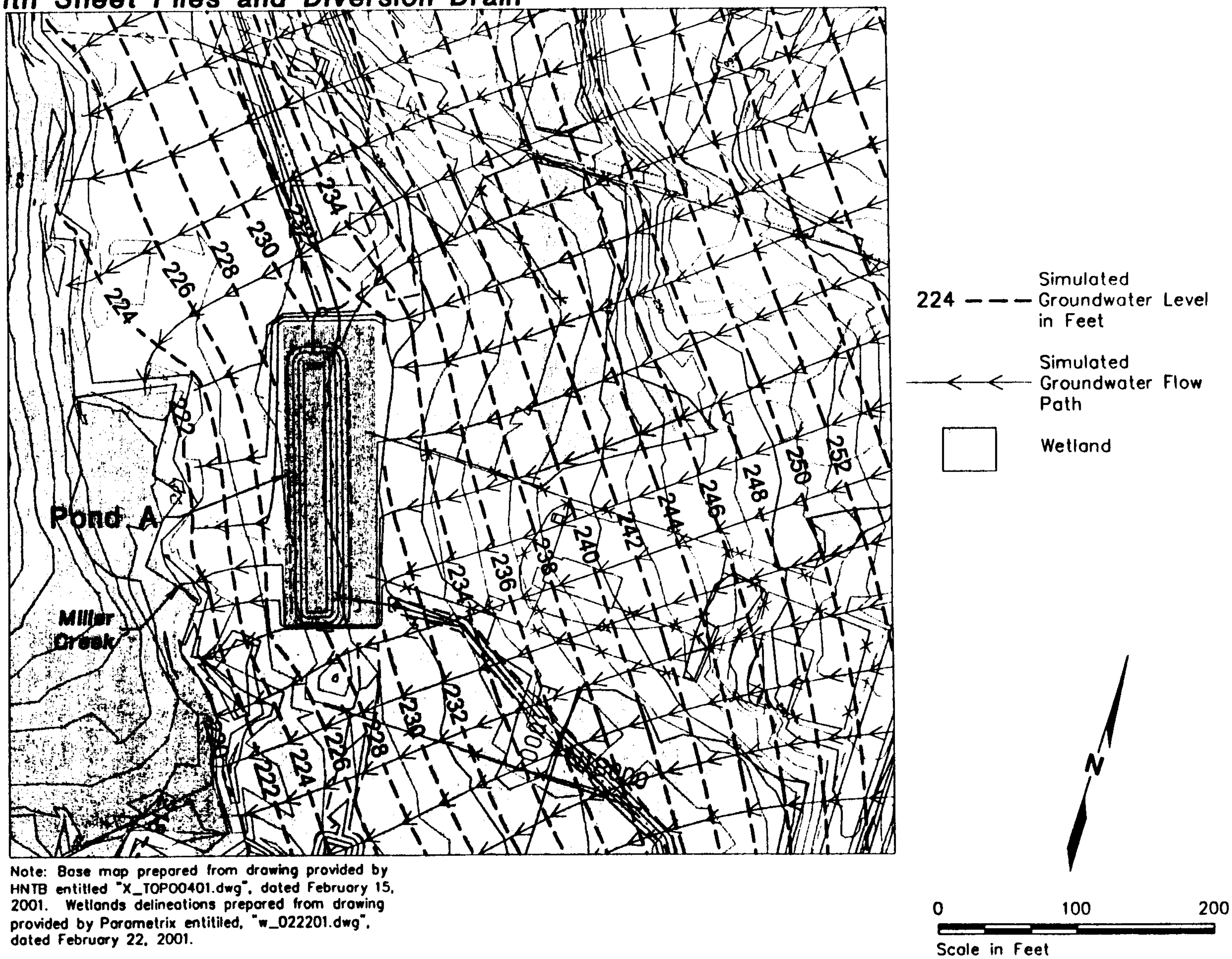
Figure B-3

Simulated Average Water Table

Pond A With Sheet Piles and Diversion Drain



Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

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Figure B-4

RC 6/18/01 1=100 (xref)see drawing file/charlie-8.pc2 49780685

Simulated Late Summer Water Table

Existing Conditions Without Pond A

224 - - - Simulated Groundwater Level in Feet

Simulated Groundwater Flow Path

Wetland

N

0 100 200
Scale in Feet

Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitiled, "w_022201.dwg", dated February 22, 2001.

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Figure B-5

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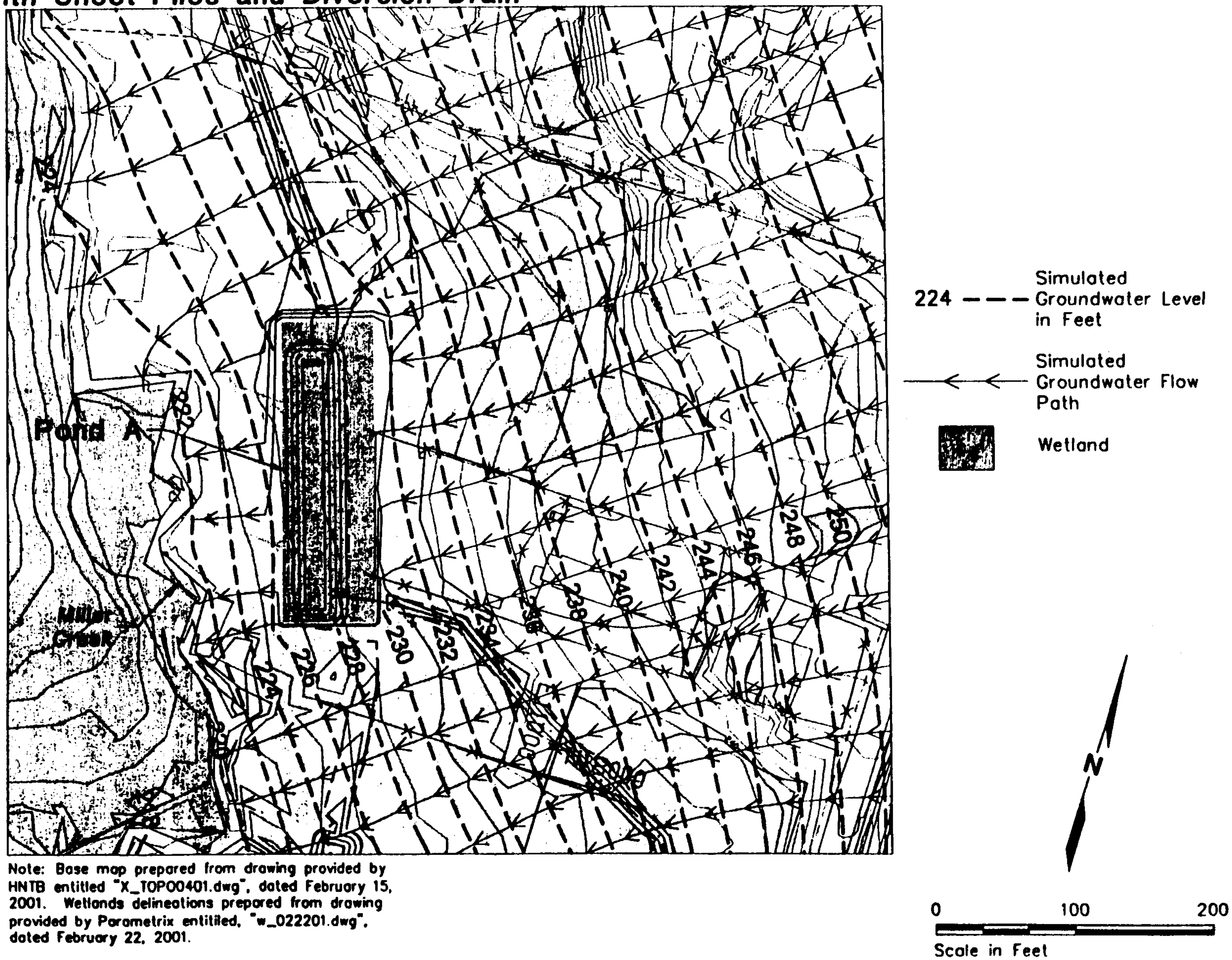
RC 6/18/01 1=100 (xref)see drawing file/charlie-8.pc2 49780686

Simulated Late Summer Water Table

Pond A With Sheet Piles and Diversion Drain



Note: Base map prepared from drawing provided by HNTB entitled "X_TOPO0401.dwg", dated February 15, 2001. Wetlands delineations prepared from drawing provided by Parametrix entitled, "w_022201.dwg", dated February 22, 2001.

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Figure B-6

APPENDIX C
SHEET PILE DESIGN AND CONSTRUCTION

APPENDIX C
SHEET PILE DESIGN AND CONSTRUCTION

The proposed sheet piles around Pond A were designed to fulfill three functions:

a. Cut-off shallow groundwater so that seepage into the pond does not remove shallow groundwater from the adjacent wetland;

b. Protect adjacent wetlands from potential excavation-induced impacts such as slope failure and sloughing of loose/soft soil during excavation of the pond); and

c. Provide long-term static stability for pond constructed within a soil profile of loose and soft soils above glacial till.

Design

Sheet pile design to address the functional requirements noted above was based on soil and groundwater conditions encountered in local borings (see Appendix A). For design, we assumed water level in the pond varied from completely full to completely empty, or about 226 to 220 feet in elevation. We assumed groundwater coincides with ground surface on the upslope side of the sheet pile walls due to the anticipated effects of the perimeter drainage trench.

Table C-1 provides the soil parameters used in our slope stability and force/moment calculation. These analyses are discussed further below.

Earth Pressure Diagrams

Soil strength parameters were used to develop earth pressure diagrams for the embedded portion of the sheet pile. The diagrams enable a structural engineer to calculate the required sheet pile section modulus.

We assumed the sheet pile "cell" around the pond should be designed as a cantilever wall without anchorage. Active earth pressures acting on the piles located east of Pond A typically should include a surcharge pressure equal to the weight of an additional 2 feet of soil, to account for increased loads where the access road is located adjacent to the sheet pile wall. Passive earth pressures were factored to account for the loss of support due to the pond excavation.

Our analysis of sliding and overturning discussed below indicates the passive resistance sufficient to achieve target factors of safety depends on embedment, therefore design may need to be reviewed and/or modified in the event

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minimum embedment is not obtained due to variations in elevation of the glacial till. However, since the till is relatively impermeable and much stronger than the surficial soils, reduced penetration of piles due to shallow glacial till is not anticipated to result in any reduction in slope factors of safety.

Our analysis of the stability of the sheet pile wall and pond slopes consisted of two separate analyses: limit equilibrium analysis using the program Slope/W to analyze global slope stability (i.e., potential for failure below sheet piles) and b) force/moment equilibrium calculations to check factors of safety against sliding and rotation.

Slope Stability Analysis

We used Slope/W with Spencer's method for limit equilibrium analysis to calculate factors of safety for circular and wedge-type failure surfaces passing below the sheet pile wall. We analyzed the following conditions:

- Steady state (pond full) including the effect of soil buoyancy;
- Steady state (pond empty) without the effect of buoyancy; and
- Rapid drawdown (pond empty) including the effect of pore pressures.

Minimum target factors of safety were 1.5 for steady state conditions and 1.1 for rapid drawdown, consistent with normal geotechnical engineering practice for this area.

Factors of safety met target criteria provided sheet pile can be embedded at least 8 feet (to the top of the very dense glacial till) on the north side of the pond, with the case of rapid drawdown of the pond level being most critical. Embedment was critical for stability.

Force and Moment Equilibrium

Analyses were completed to verify that adequate factors of safety were achieved for both force and moment equilibrium, for resistance to sliding (or translation) and rotation. Target factors of safety were achieved for both steady state (pond full, buoyant conditions) and rapid drawdown conditions. By inspection we concluded that the steady state (pond empty) condition was less critical than the other two cases.

Erosion and Sloughing

Hart Crowser used the weighted creep method of analysis to assess potential for piping below the bottom of the sheet piles through fine to medium sand and silt soils. Results indicate mitigation is needed. Also, considering the soft and loose to medium dense soils that will be exposed in the 2H:1V pond side slopes, we expect that the slopes of the pond may undergo sloughing related to water level fluctuations during normal pond operations.

Recommended mitigation consists of driving the sheet piles to refusal in the underlying glacial till and lining the pond with a geotextile separation fabric and minimum 1 foot thickness of quarry spalls.

Construction

Hart Crowser makes the following recommendations for construction:

- Install the perimeter French drain entirely around the proposed pond prior to any sheet pile installation. This will assure adequate access for construction on the west side of the pond without any wetland encroachment and avoid any interruption of groundwater seepage as the sheet piles are installed.
- Install sheet piles on the west, north, and south sides of the pond (i.e., the sides closest to Miller Creek) prior to excavation. This will enable the piles to protect the creek in the event there is any excavation sloughing during pond construction.
- Drive piles to refusal in the top of the glacial till soils. The Port's contract documents should state that "jetting" shall not be used to aid driving.
- Prior to construction, the Contractor should provide the Port with a submittal that describes pile driving equipment and sequence of construction. During construction, the Port should verify that minimum embedment criteria are met.

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Table C-1 - Soil Parameters Used in Design

Soil Type	Moist Unit Weight in pcf	Drained Strength		Undrained Strength	
		c' in psf	ϕ' in deg.	c in psf	ϕ in deg.
Loose to Medium Dense Sand	125	0	32	-	-
Medium Dense to Dense Sand	130	0	35	-	-
Dense to Very Dense Silty Sand (Glacial Till)	135	250	40	-	-
Soft Peat or Organic Silt	90	0	15	300	0
Soft to Stiff Silt/Clay	115	0	30	1000	0

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