Seattle-Tacoma International Airport

The Journey Begins Here

The Third Runway

Presented to the Technical Review Board

November 16-17, 2000

Delivering smarter solutions

AR 025989

DB

REVISED AGENDA
TECHNICAL REVIEW BOARD
1ST MEETING – NOV. 16, 17 & 18, 2000

SEA-TAC THIRD RUNWAY PROJECT

Thursday – 11/16/00

1:00 to 1:15 Introductions
- Introduction of Attendees & Project Roles
- Purpose and Objectives of Technical Review Board (TRB)
- Key Issues
- Agenda Input from TRB

1:15 to 2:15 Project Overview
- Project Elements
  - General Fill
  - MSE Walls
  - Subgrade Improvements
- Project Constraints
  - 404 Permit
  - Drainage Considerations
  - FAA
  - Project Schedule

2:15 to 5:00 (w/15 minute break ~ 3:00 p.m.)

Subsurface Conditions
- General Subsurface Conditions (by Area)
- Geotechnical Issues/Considerations

Subgrade Improvement
- Types and Extent of Improvement Needed (by Area)
- Subgrade Improvement Methods Selected & Other Alternatives
- Constructability Issues
- Performance Requirements and Monitoring

NOTE: "Seismic Design," scheduled for Friday, 11/17/00, may begin if time permits.

Friday – 11/17/00

8:00 to 9:00 Seismic Design
- Design Level Earthquake
- Seismic Slope Stability
  - Analytical Methods
  - Input Parameters/Assumptions
  - Design Factors of Safety
- Liquefaction
  - Methodology to Evaluate Potential Liquefaction
  - Areal Extent & Thickness of Liquefiable Materials

Friday – 11/17/00 (continued)

9:00 to 10:30 MSE Walls

- Design Approach/Design Criteria
  - Methodology
  - Design Sections
  - Design Criteria
  - Design Analyses and Results
  - Construction Monitoring

10:30 to 10:45 Break

10:45 to 12:00 General Embankment Fill

- Design Approach/Design Criteria
  - Design Sections
  - Soil Parameters
  - Results
- Constructability Issues
  - Surface Preparation
  - Embankment Fill Materials

12:00 to 1:00 Lunch

1:00 to 3:30 Open Discussion

- Revisit issues not previously addressed in sufficient detail
- Questions from the Design Team
- Questions from the TRB members

3:30 to 5:00 Site Tour

Saturday – 11/18/00

8:00 to 11:00 Summary TRB Comments/Recommendations, & Discussions

- Adequacy of Geotechnical Investigations
- Subgrade Improvements
- Seismic Design
- Embankment Fill
- MSE Walls
- Constructability
- Construction Monitoring

11:00 to 12:00 Other Business

- Contents & Timing of TRB Summary Memo to File
- Schedule Next Meeting
- Other

No.	Date Prepared	Hart Crowser Project No.	Title	Date Transmitted
1	7/28/00	J-4978-32	HC PowerPoint Presentation Package for 7/28/00 Mtg. with HNTB	11/1/00
2	7/9/99	J-4978-06	Subsurface Cond., Data Rpt., 404 Permit Support, Third Runway Embankment	11/1/00
3	7/99	J-4978-06	Subsurface Conditions, Data Report 404 Permit Support, Third Runway Embankment	11/1/00
4	10/8/99	J-4978-14	MEMO Sea-Tac Airport Third Runway Probabilistic Seismic Hazard Analysis Results	11/3/00
5	3/20/00	J-4978-18	Subsurface Conditions Data Report, North Safety Area Third Runway Embankment	11/1/00
6	4/7/00	J-4978-23	Subsurface Conditions Data Report, South MSE Wall & Adjacent Embankment	11/1/00
7	4/00		HNTB's 30 % Embankment Plans (selected sheets)	HNTB
8	4/10/00	J-4978-14	MEMO – Seismic Basis of Design, Third Runway Project	11/3/00
9	5/31/00	J-4978-22	Bench Study for Slope Embankment, Sea-Tac Third Runway Project	11/3/00
10	6/00	J-4978-21	Subsurface Conditions Data Report, West MSE Wall Third Runway Embankment	11/1/00
11	6/00	J-4978-22	Prelim. Stability & Settlement Analyses, Subgrade Improvements, MSE Wall Support	11/3/00
12	8/21/00	J-4978-30	MEMO - Geotechnical Input to MSE Wall & Reinforced Slope Design	11/3/00
13	8/28/00	J-4978-27	MEMO - Use of Advanced Testing Data, Sea-Tac Third Runway Project	11/3/00
14	9/00		RECO's 30 % Design Drawings (selected sheets)	HNTB
15	9/00		RECO's MSE Design Calcs. - hand calcs. - Computer Calcs. - at least thru South	HNTB

			Wall P9 46	
No.	**Date Prepared**	**Hart Crowser Project No.**	**Title**	**Date Transmitted**
16	9/5/00	J-4978-23, -26, -27, and -31	Subsurface Conditions Data Report Additional Field Explorations and Advanced Testing, Third Runway Embankment	11/3/00
17	9/7/00	J-4978-28	MEMO - Methods & Results of Liquefaction Analyses	11/3/00
18	11/9/00	J-4978-30	MSE Wall 30% Review Mtg - HC's Limit Equilibrium Analysis of Compound & Global Stability	11/3/00
19	9/27/00	J-4978-25	MEMO - Alternative Acceptance Criteria for Embank Fill Materials, DRAFT Specification: Direct Shear Testing for Fill Material Substitution	11/3/00

O:\Geotech Division\Third Runway\Third Runway DocumentListrev1.doc

Presenters

- Mike Bailey, P.E.
- Barry Chen, Ph.D., P.E.
- Jamie Beaver, E.I.T.
- Doug Lindquist, E.I.T.

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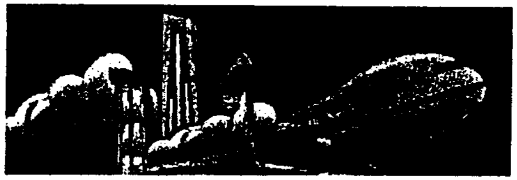

Session One Overview

- Subsurface conditions and lab tests
- Subgrade improvement

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General Exploration Methods and Subsurface Conditions

Geotechnical Data Reports

Report Title	Date	Area
404 Permit Support	Jul 99	North & West Wetlands
Phase 3 Fill	Nov 99	North
North Safety Area	Mar 00	North
South MSE Wall	Apr 00	South
West MSE Wall	Jun 00	West
Advanced Testing	Sept 00	All Embankments

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Exploration Methods

- Hollow-stem auger drilling with the Standard Penetration Test (SPT) (most commonly used)
- Test pits (2:1 embankment, detention ponds)
- Cone Penetration Test (CPTu, SCPTu)

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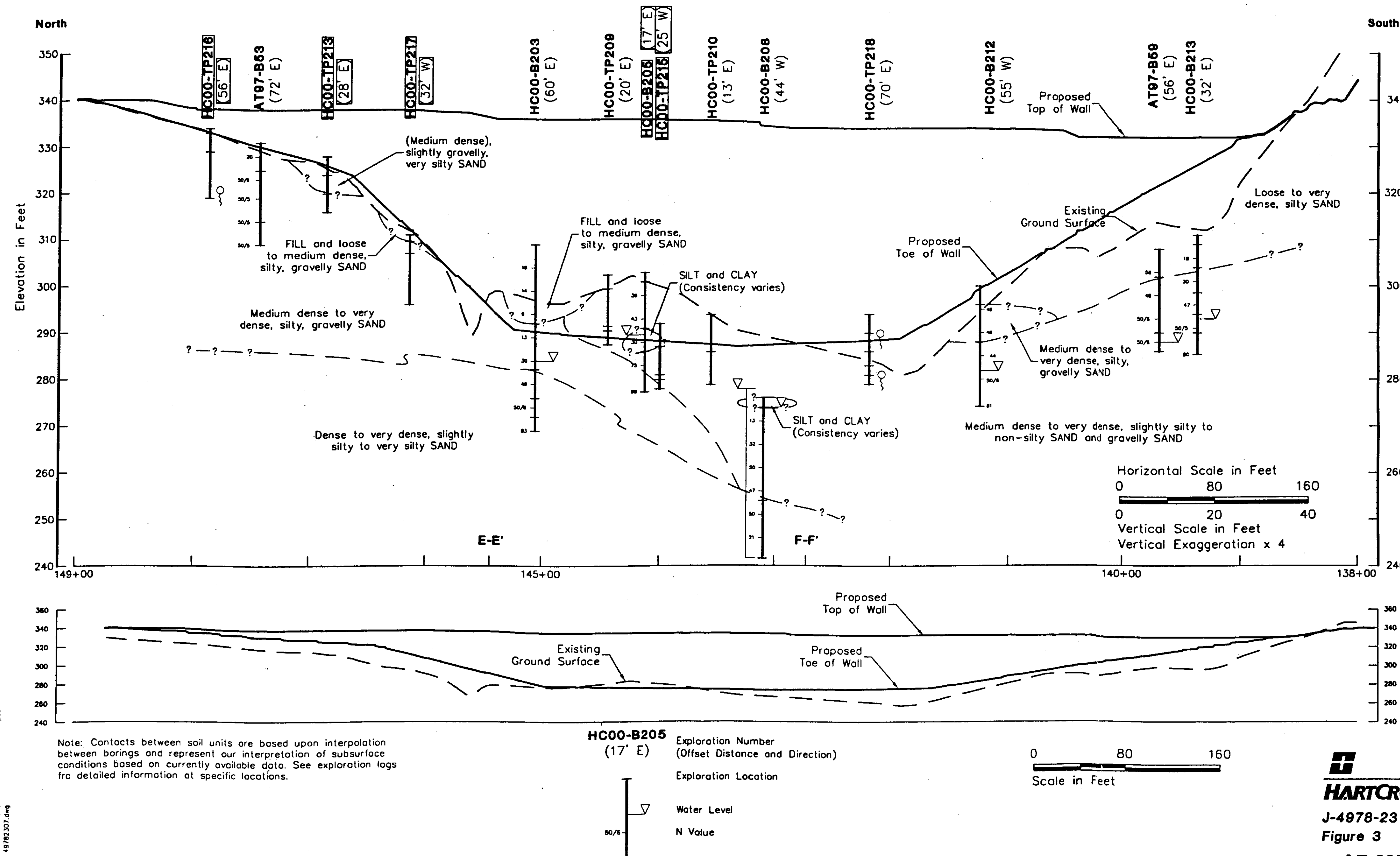
Generalized Subsurface Profile N-S

South MSE Wall (Looking East)

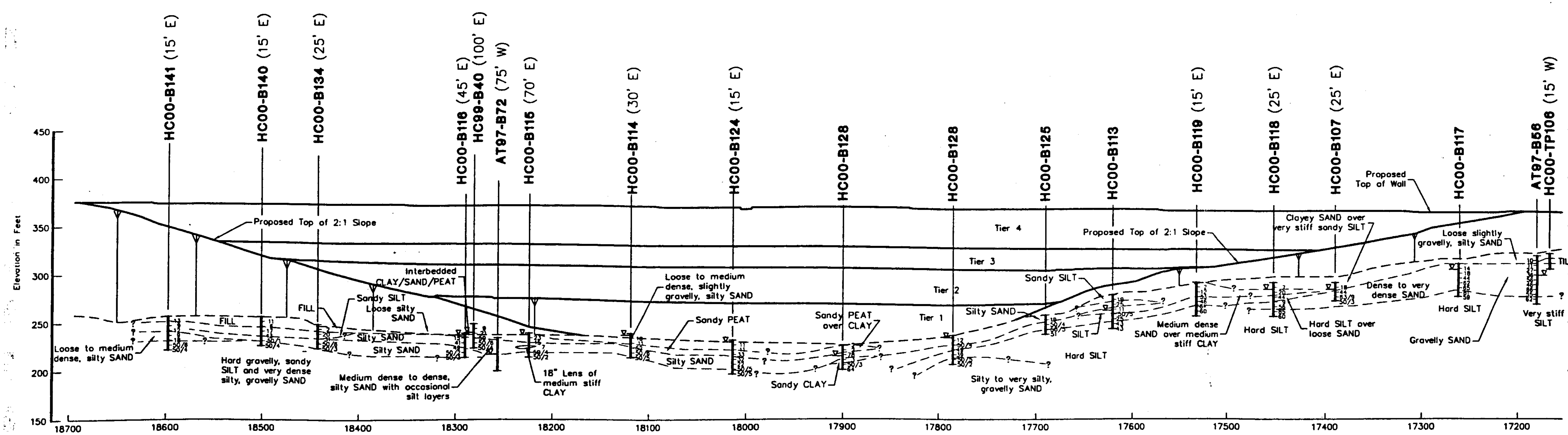


Note: Contacts between soil units are based upon interpolation between borings and represent our interpretation of subsurface conditions based on currently available data. See exploration logs fro detailed information at specific locations.

RC 4/6/00 1=80 woodstck.pc2
4978230?.dwg

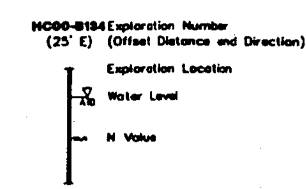
HARTCROWSER
J-4978-23 4/00
Figure 3

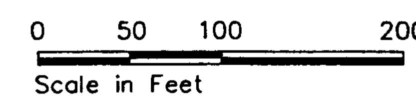
Generalized Subsurface Profile
West MSE Wall (Looking East)



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

MSE wall tiers and other geometric details are only conceptual.





DJH 6/16/00 1=100 charlie.pc2
49782114.dwg

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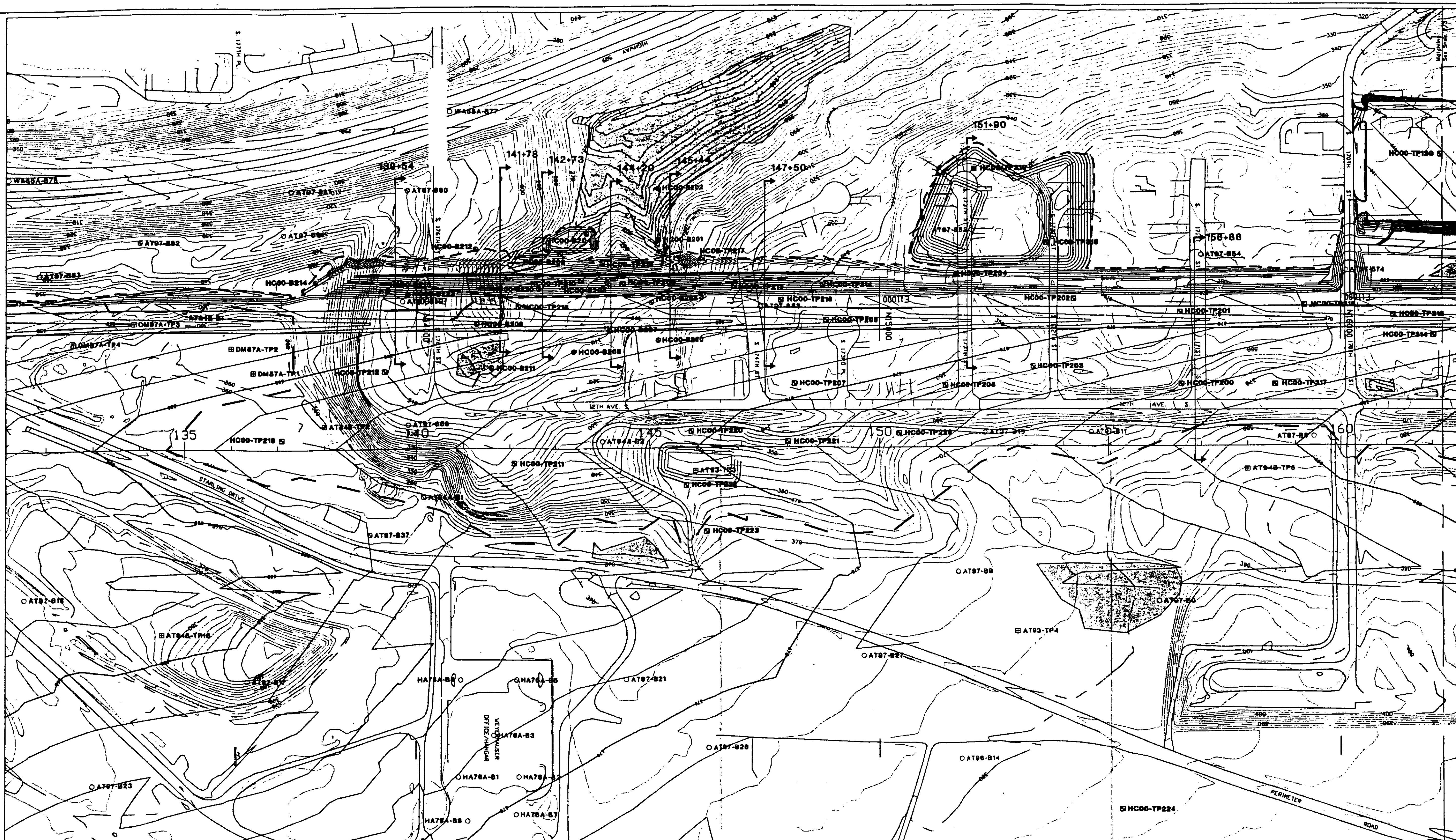
J-4978-21 4/00
Figure 3
AR 026000



Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetlands delineations prepared from drawing provided by Parametrix entitled, "w_110600.dwg", dated November 8, 2000.

AR 026001

HC00-TP219 ⊠ Exploration Location and Number (by Hart Crowser)

AT94B-TP16 ⊞ Exploration Location and Number (by others)

See reference list for explorations not included in this report.

N

0 100 200
Scale in Feet

Bench Mark:					
Proj. Mgr.: M. J. BAILEY		Designed By: M. J. BAILEY		Drawn By: R. CHAO	
Checked By:		Approved By:		Date:	
No.	Date	By	Revision		

HARTCROWSER

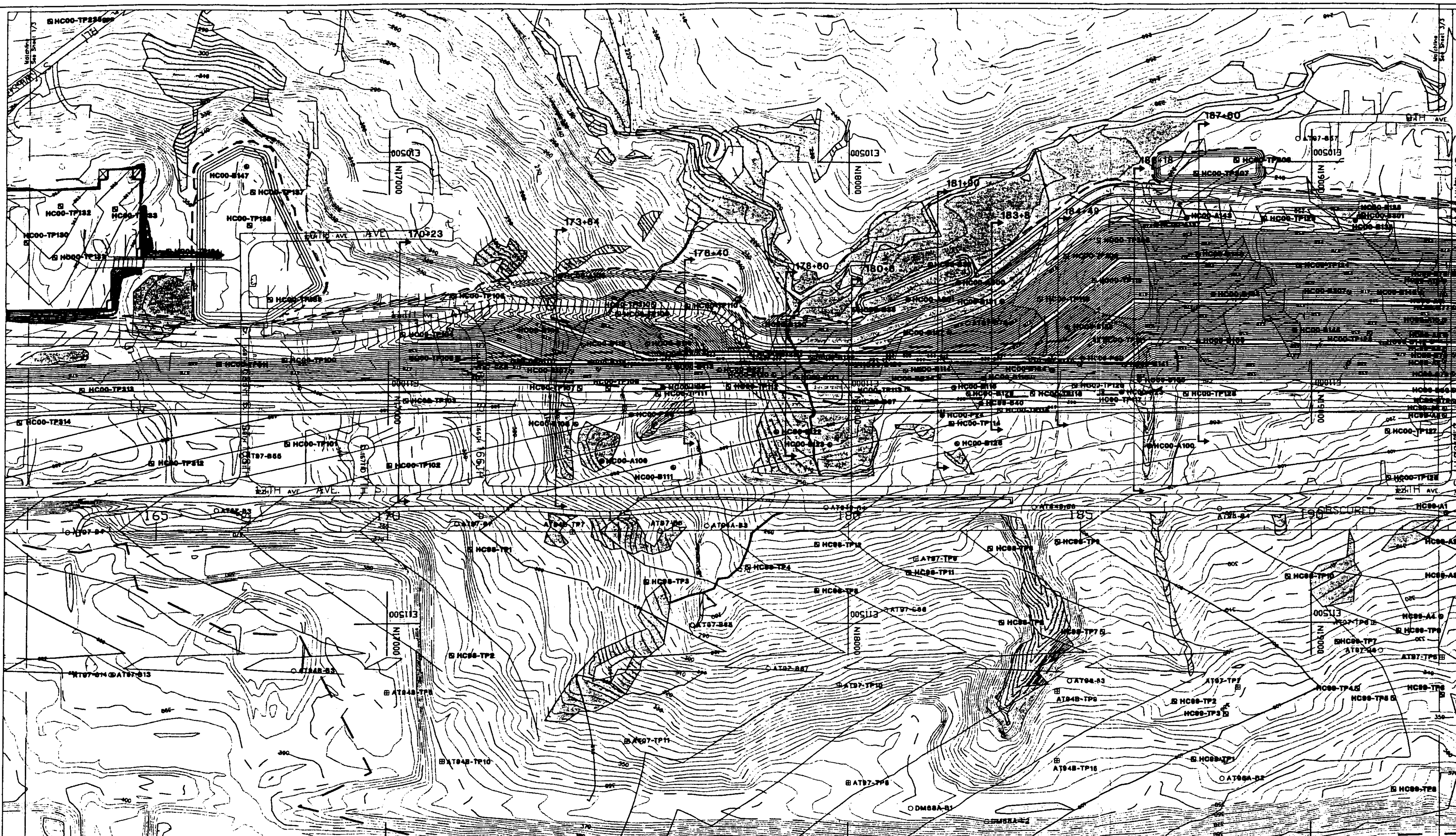
Hart Crowser, Inc.
1910 Fairview Avenue East
Seattle, Washington 98102-3699
FAX 206.328.5581
206.324.9530

SEA-TAC THIRD RUNWAY

SITE AND EXPLORATION PLAN
SOUTH WALL AREA

Drawing Size: 24x36	Scale: AS SHOWN	Date Issued: 11/16/00	Drawing Type: DRAFT	Job No.: 4978-17	SHEET: 1 of 3	Drawing No.: 1

RC 11/16/00 1=100 (xref)see drawing file/755-bw.pc2
4978l700.dwg



Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetlands delineations prepared from drawing provided by Parametrix entitled, "w_110800.dwg", dated November 8, 2000.

HC00-TP219 ⊠ Exploration Location and Number (by Hart Crowser)

AT94B-TP18 ⊞ Exploration Location and Number (by others)

See reference list for explorations not included in this report.

0 100 200
Scale in Feet

AR 026002

RC 11/16/00 1=100 (xref)see drawing file/755-bw.pc2
49781701

Bench Mark:				
Proj. Mgr.: M. J. BAILEY	Designed By: M. J. BAILEY		Drawn By: R. CHAO	
Checked By:	Approved By:		Date:	
No.	Date	By	Revision	

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Hart Crowser, Inc.
1910 Fairview Avenue East
Seattle, Washington 98102-3699
FAX 206.328.5581
206.324.9530

SEA-TAC THIRD RUNWAY

SITE AND EXPLORATION PLAN
WEST WALL AREA

Drawing Size:	Scale:	Date Issued:	Drawing Type:	Job No.:	SHEET:	Drawing No.:
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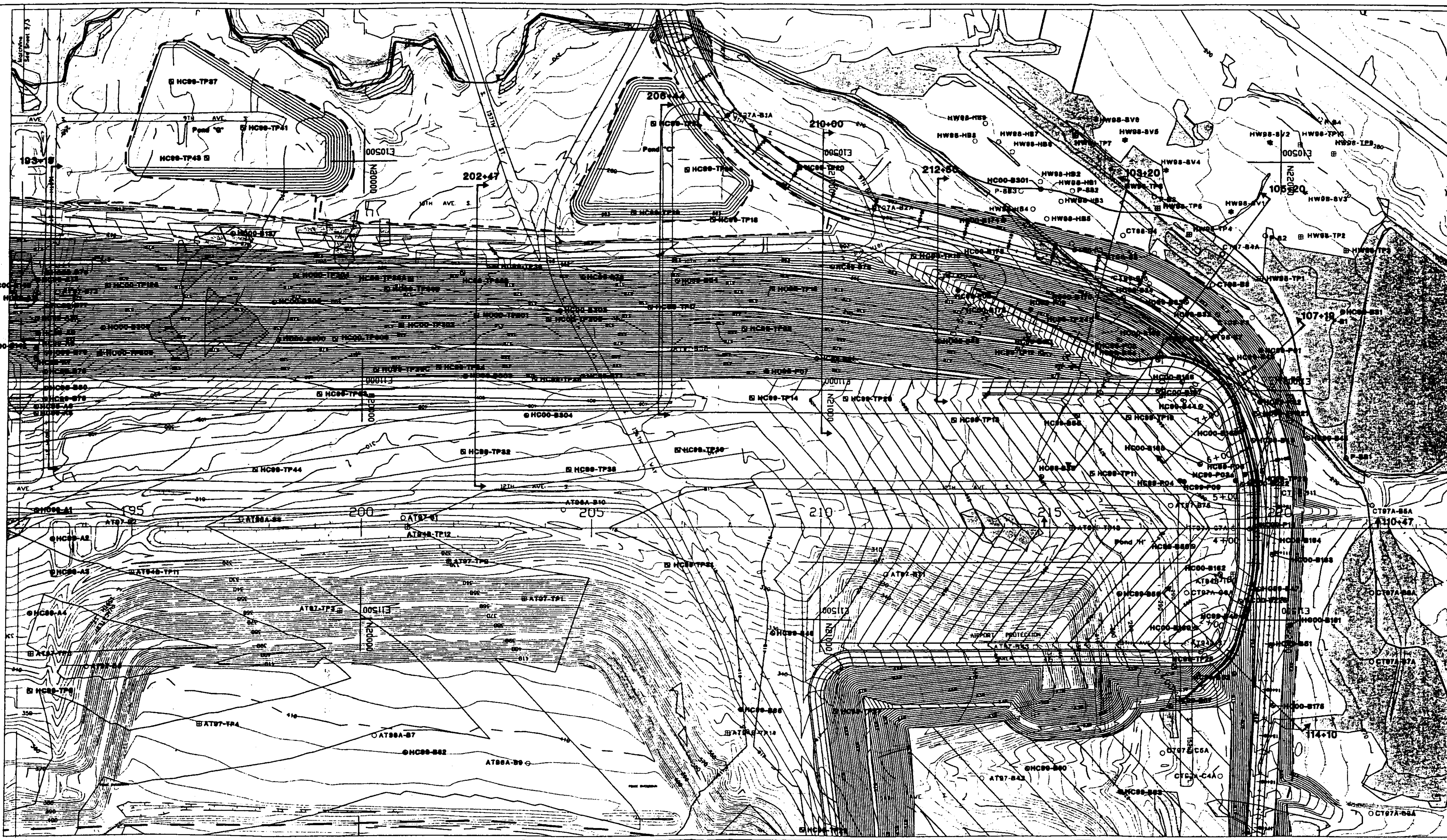

Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetlands delineations prepared from drawing provided by Parametrix entitled, "w_110800.dwg", dated November 8, 2000.

HC00-TP219 ⊠ Exploration Location and Number (by Hart Crowser)

AT94B-TP18 ⊞ Exploration Location and Number (by others)

See reference list for explorations not included in this report.

0 100 200

Scale in Feet

AR 026003

RC 11/16/00 1=100 (xref)see drawing file/755-bw.pc2

49781702.dwg

Bench Mark:					
Proj. Mgr.: M. J. BAILEY		Designed By: M. J. BAILEY		Drawn By: R. CHAO	
Checked By:		Approved By:		Date:	
No.	Date	By	Revision		

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1910 Fairview Avenue East
Seattle, Washington 98102-3699
FAX 206.328.5581
206.324.9530

SEA-TAC THIRD RUNWAY

SITE AND EXPLORATION PLAN
NORTH SAFETY AREA

Drawing Size:	Scale:	Date Issued:	Drawing Type:	Job No.:	SHEET:	Drawing No.:
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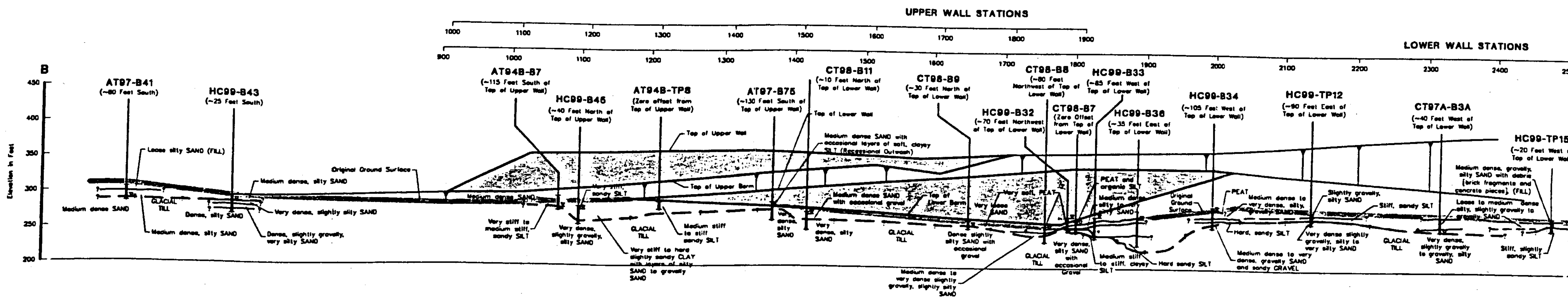
Generalized Geologic Profiles B-B'
Showing Proposed Retaining Walls



HC99-B36 Exploration Number

(40' N) (Offset Distance and Direction)

Exploration Location

Water Level at Time of Drilling

Water Level as Measured 4/5/99

Seepage Noted in Test Pit

Inferred Geologic Contact (Minor Unit)

Inferred Geologic Contact (Major Unit)

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

NOTE: MODIFIED VERSION

AR 026004

0 150 300

Scale in Feet

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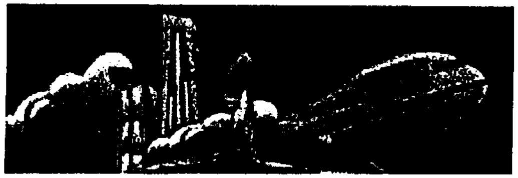
J-4978-06 8/99

Figure 6

DTN 11/15/00 1=150 charlie.pc2
497803/4978061 4



Exploration Methods

- Specialized testing
  - Pressuremeter
  - Shear wave velocity
  - Monitoring wells
  - Infiltration tests

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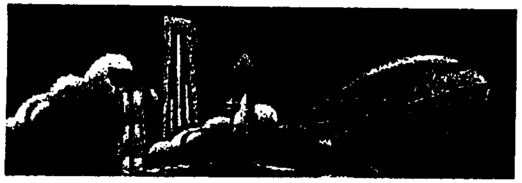

Geologic Summary

- Fill (variable density, gradation, and distribution)
- Alluvial deposits (peat, interbedded sand and clay/silt, sand and gravel)
- Recessional outwash (medium dense sand and gravel, stiff/hard clay/silt)
- Glacially overridden soils (very dense granular soil)

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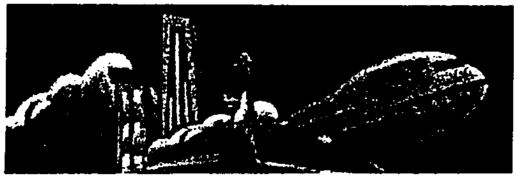

Laboratory Testing

- Samples checked to verify field classifications
- Water contents (all samples)
- Sieve analysis: determine grain size distribution
- Atterberg limits: plasticity
- Shelby tube samples
  - Consolidation tests (compressibility)
  - Triaxial tests (shear strength)
- Field and lab data: engineering parameters

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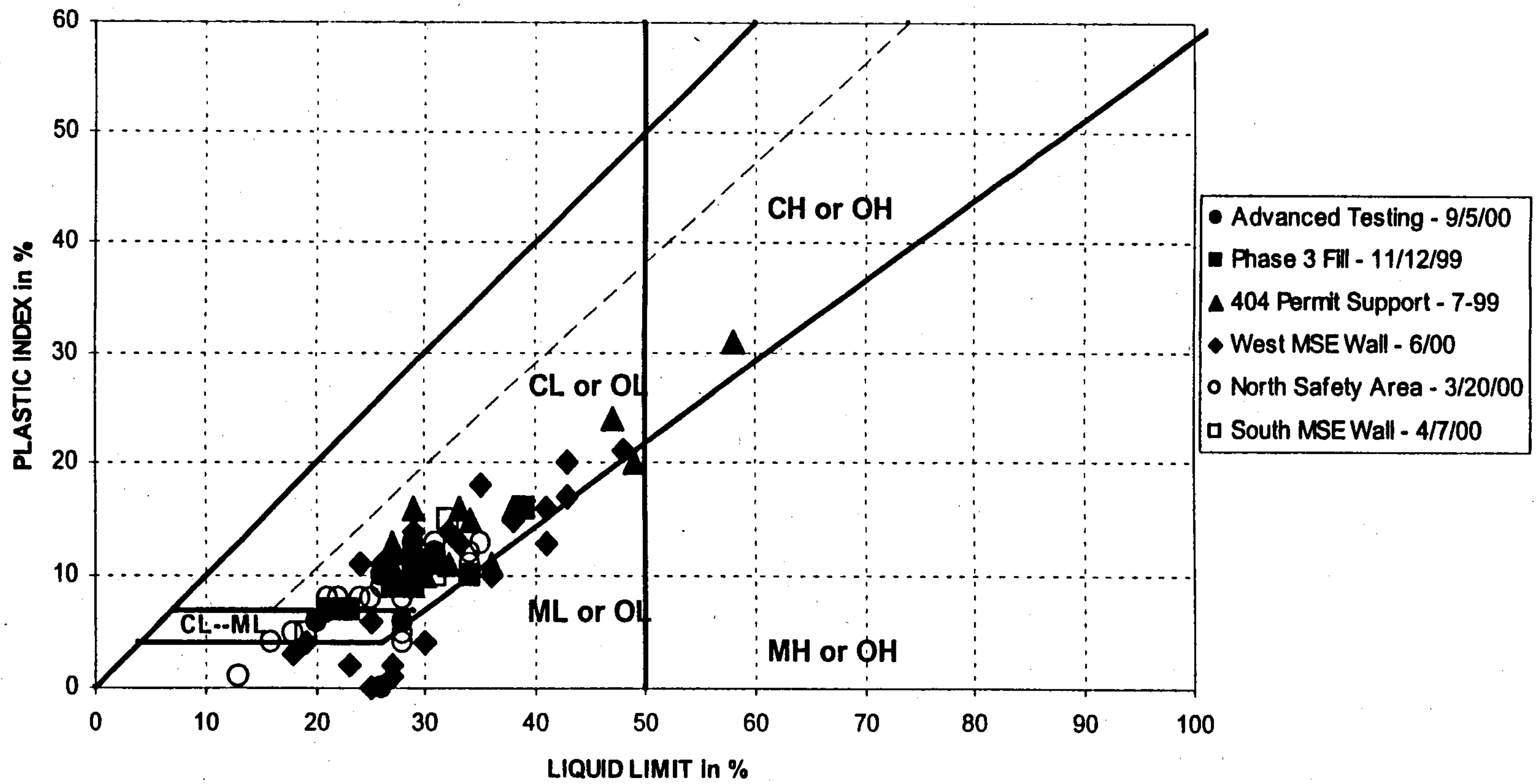
Clay Plasticity Summary Plot



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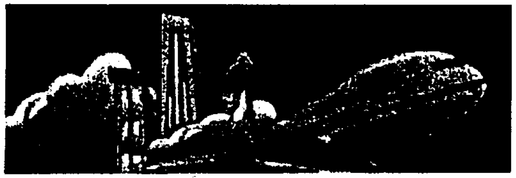
AR 026008



Clay Shear Strength Summary

Soil Consistency	CU Triax ~~Drained~~ w/ pore pressure measurement Strength in degrees	UU Triax Undrained Strength in psf	CPTu Undrained Strength in psf
Soft to Medium Stiff	34 to 35	1000 to 1200	1000 (+/-)
Stiff to Hard	33 to 35	3000 to 9300	N/A

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Table 2 - Summary of Isotropically Consolidated Undrained (CU) Triaxial Compression Test Results

Boring Number	Sample Number	Depth in Feet	Soil Description	W_n %	γ_T pcf	σ_c' ksf	$\sigma_1 - \sigma_3$ ksf	ϕ' deg	ϕ_{ave}' deg	E_{50} ksf	$\sigma_1 - \sigma_3/\sigma_c'$	E_{50}/σ_c'
HC99-B50	S-4	9.5 to 12	Soft CLAY	26.1	133.9	4.0	3.0	33.2		101.4	0.760	25.3
				30.2	122.0	8.0	3.9	33.2	34.3	653.1	0.490	81.6
				32.6	124.3	12.0	4.6	36.4		766.3	0.383	63.9
HC99-B52	S-4	9.5 to 12	Medium stiff CLAY	16.8	138.7	4.0	4.4	35.0		211.0	1.108	52.7
				16.8	138.7	7.0	5.6	34.4	34.6	928.3	0.796	132.6
				16.8	138.7	10.0	6.6	34.3		1104.2	0.663	110.4
HC99-B58	S-3	7 to 9	Medium stiff, sandy, very silty CLAY	23.7	131.4	4.0	3.4	35.5		340.7	0.852	85.2
				23.1	130.8	7.0	3.8	35.8	34.7	627.0	0.537	89.6
				23.1	130.8	10.0	4.1	32.9		682.7	0.410	68.3
HC00-B161	S-3	10.5 to 12.5	Medium stiff, sandy CLAY	21.8	129.4	4.0	3.2	36.5		1052.0	0.789	263.0
				18.4	133.2	7.0	3.8	34.6	35.3	635.7	0.545	90.8
				19.0	133.8	10.0	5.1	34.8		1699.9	0.510	170.0
HC00-B163	S-2/3	6 to 7.7 (S-2)	Stiff, sandy CLAY	29.7	121.6	4.0	4.0	35.8		398.1	0.995	99.5
		8 to 10 (S-3)		22.2	129.8	7.0	5.1	35.6	35.2	1272.3	0.727	181.8
				22.6	122.6	10.0	5.5	34.3		2186.1	0.547	218.6
HC00-B164	S-3	5 to 7.5	Stiff CLAY	23.6	123.6	4.0	4.7	32.9		517.9	1.165	129.5
				23.9	123.9	7.0	6.3	34.1	33.9	963.0	0.894	137.6
				21.4	129.0	10.0	7.4	34.8		1236.6	0.742	123.7
HC00-B175	S-3	10.5 to 12.5	Stiff CLAY	20.3	135.3	6.0	7.4	33.7		351.8	1.231	58.6
				17.9	140.0	9.0	6.4	33.7	33.7	1065.9	0.711	118.4
				19.4	134.3	12.0	6.4	33.7		2117.9	0.529	176.5

497818/NorthSafety.xls - Table 2

Table 2 - Summary of Isotropically Consolidated Undrained Triaxial Compression (CU) Test Results

Boring Number	Sample Number	Depth in Feet	Soil Description	w_n In %	γ_T In pcf	σ_c' In ksf	$\sigma_1 - \sigma_3$ In ksf	ϕ' In deg	ϕ_{avg}' In deg	E_{50} In ksf	$(\sigma_1 - \sigma_3)/\sigma_c'$	E_{50}/σ_c'
HC00-B132	S-5	9.0 to 11.0	Medium stiff, sandy CLAY	40.5	114.0	6.0	6.0	36.7		744.6	0.993	124.1
				32.7	124.3	9.0	8.5	35.1	35.1	426.4	0.946	47.4
				25.3	125.1	12.0	16.4	33.4		341.8	1.367	28.5
HC00-B110	S-4	15.5 to 17.4	Very stiff to hard, slightly sandy, very clayey SILT	25.2	125.0	6.0	7.5	33.2		312.6	1.251	52.1
				23.0	130.5	9.0	17.9	32.9	33.1	497.0	1.988	55.2
				14.2	135.4	12.0	20.0	33.1		4162.6	1.665	346.9
HC00-B111	S-12	40.5 to 42.1	Hard CLAY	29.6	121.3	6.0	13.9	33.0		256.6	2.317	42.8
				30.5	122.2	9.0	22.3	34.6	34.1	557.5	2.478	61.9
				31.2	122.8	12.0	22.0	34.8		915.2	1.833	76.3

497821/LabResults.xls - Table 2

Table 3 - Summary of Unconsolidated Undrained (UU) Triaxial Compression Test Results

Boring Number	Sample Number	Depth in Feet	Soil Description	W_n %	γ_T pcf	LL %	PI %	S_u psf
HC00-B165A	S-2A	9.5 to 11.5	Medium stiff CLAY	31.9	148.3	31	11	1166
HC00-B172	S-3	10.5 to 12.5	Stiff CLAY	14.9	129.2	21	8	1038
HC00-B160	S-4	10 to 12.5	Hard CLAY	16.9	131.5	26	9	3072
HC00-B169	S-5	15.5 to 16.8	Hard SILT	20.7	135.8	28	5	3710
HC00-B170	S-5	20.5 to 21.5	Hard CLAY	22.6	137.9	35	13	5361
HC00-B169	S-3	10.5 to 12.5	Dense, slightly clayey, slightly gravelly, silty SAND	11.9	125.9	n/a	n/a	1511

497818/NorthSafety.xls - Table 3

AR 026012

Table 3 - Summary of Unconsolidated Undrained (UU) Triaxial Compression Test Results

Boring Number	Sample Number	Depth in Feet	Soil Description	W_n in %	[illegible] in pcf	LL in %	PI in %	[illegible] in psf
HC00-B118	S-2	5.5 to 6.5	Medium stiff, slightly sandy, clayey SILT	31.7	123.3	30	4	2023
HC00-B129	S-3	5.5 to 6.8	Stiff, slightly sandy CLAY	28.7	128.5	38	15	1313
HC00-B110	S-11	40.5 to 41.8	Hard, very clayey SILT	31.1	122.8	41	13	9259
HC00-B118	S-6	15.5 to 17.4	Hard, sandy, very clayey SILT	25.0	124.8	41	16	5486

497821/LabResults.xls - Table 3

Consolidation Test Summary

Soil Consistency	e_o	OCR	C_c	C_v in ft^2/day
Soft to Medium Stiff	0.4 to 1.0	1 to 4	~~0.007 to 0.20~~ 0.18 to 0.35	0.75 to 2.7
Stiff to Hard	0.5 to 0.8	2 to >30	~~0.15 to 0.30~~ 0.10 to 0.31	0.85 to 3.0

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AR 026014

Table 1 - Summary of Consolidation Test Results

Boring Number	Sample Number	Depth in Feet	Soil Description	w_n %	γ_T pcf	σ_{v0}' ksf	σ_p' ksf	OCR	C_c	C_r	e_0	c_v at σ_p' ft²/day
HC99-B44	S-3	7 to 8.8	Soft, clayey, very silty SAND	15	139.0	0.9	1.9	2.1	9.57E-02	5.74E-03	0.367	2.6
HC99-B54A	S-1A	6.5 to 8.5	Soft CLAY	39	112	0.8	3.4	4.0	3.47E-01	9.59E-04	1.04	2.1
HC00-B167	S-3	10.5 to 11.5	~~Soft SILT~~ Loose silty SAND	14	137	1.3	1.2	1.0	8.27E-02	7.58E-03	0.378	2.5
HC00-B165A	S-2A	9.5 to 11.5	Medium stiff CLAY	33	121	1.2	6	4.9	1.82E-01	2.58E-02	0.817	2.7
HC00-B163	S-6	15.5 to 16.3	Stiff CLAY	21	131	1.9	2.4	1.2	1.06E-01	1.44E-02	0.517	0.85
HC00-B164	S-4	7.5 to 10	Stiff CLAY	22	128	0.9	7	7.5	2.05E-01	2.24E-02	0.575	2.4
HC00-B169	S-5	15.5 to 16.8	Hard Sandy SILT	21	130	1.4	3.8	2.8	9.19E-02	7.20E-03	0.531	2.2

497818/NorthSafety.xls - Table 1

AR 026015

Table 1 - Summary of Consolidation Results

Boring Number	Sample Number	Depth in Feet	Soil Description	W_{nl} in %	γ_T in pcf	σ_{v0}' in ksf	σ_p' in ksf	OCR	C_c	C_r	e_0	c_v at σ_p' in ft²/day
HC00-B132A	S-1	8.5 to 10.5	Very soft to soft, very silty CLAY	32	120	1.105	1.6	1	0.181	0.010	0.817	0.75
HC00-B115	S-4	10 to 11	Medium stiff, very sandy SILT	18	131	1.3	**> 64**	> 30	not determined	0.007	0.49	not determined
HC00-B118	S-2	5.5 to 6.5	Medium stiff, slightly sandy, clayey SILT	32	119	0.6875	10	15	0.184	0.026	0.837	2.5
HC00-B111	S-3	5.5 to 7.5	Stiff, clayey SILT	31	118	0.715	12	17	0.307	0.017	0.837	2.4
HC00-B142	S-3	5.5 to 7.5	Stiff, sandy SILT	26	125	0.715	**56**	78	0.167	0.016	0.67	1.5
HC00-B111	S-6	15.5 to 16.6	Medium dense, gravelly, very silty SAND	15	135	2.015	**44**	22	0.200	0.007	0.401	2.3
HC00-B118	S-6	15.5 to 17.4	Hard, sandy CLAY	25	123	1.9375	20	10	0.147	0.024	0.687	3
HC00-B110	S-11	40.5 to 41.8	Hard, very clayey SILT	31	119.0	5.265	**42**	8	0.178	0.026	0.817	2.4

Note: 1. Values for σ_p' shown in **bold were determined by extrapolation of the virgin compression curve due to load frame limitations*

2. The value of σ_p' for HC00-B115, S-4 exceeded the maximum load frame load capability

497821/LabResults.xls - Table 1

General Subsurface Conditions
NSA Wall

- Peat (within Miller Creek area; ~~depths from 2' to 3' and increasing to +10' deep toward road)~~ generally 10 feet thick starting at ground surface; primarily below relocated 156th street at northwestern corner of NSA)
- Clays and silts (varying sand and gravel content; 4' to 15' thick)
- Potentially liquefiable sand
- Glacially overridden sand and silt (varying gravel content)

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AR 026017

General Subsurface Conditions

West Wall

- Fill (sand with gravel and silt; variable density and quality; 6′ to 12′ layer thickness; and associated with housing)
- Peat (interbedded with clay and sand, depths from 0′ to 15′)
- Clays and silts (varying sand content; 10′ to 20′ layer thickness; not generally glacially overridden)
- Potentially liquefiable sand
- Glacially overridden sand and clay (varying gravel content)

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General Subsurface Conditions

South Wall

- Fill (sand with gravel and silt; variable density and quality; 9′ to 18′ layer thickness)
- Peat (within a wetland)
- Clays and silts (varying sand content; 3′ to 5′ thick; not generally glacially overridden)
- Potentially liquefiable sand
- Glacially overridden sand (gravel and silt)

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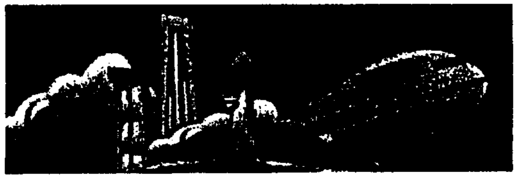
AR 026019



General Subsurface Conditions

2H:1V Embankment

- Fill (mostly granular with silt; variable density and quality; variable thickness)
- Peat (adjacent to NSA wall only, within wetland area)
- Potentially liquefiable sand
- Clays and silts (predominantly in NSA; soft to medium stiff becomes hard to the south)
  - Thickest in NSA
  - Thins toward west wall
  - Generally absent near south wall
- Glacially overridden sand

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Subgrade Improvement

Subgrade Improvement Is Needed to:

- Provide stability; and
- Control settlement

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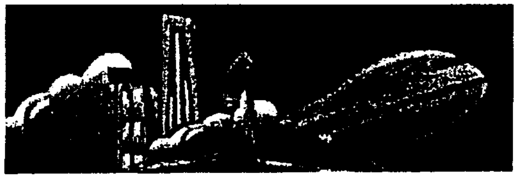

Subgrade Improvement

- Removal of low shear strength, highly compressible peat
- Prevention of seismic-induced soil liquefaction
- Removal or improvement of soft to medium stiff silt and clay soils

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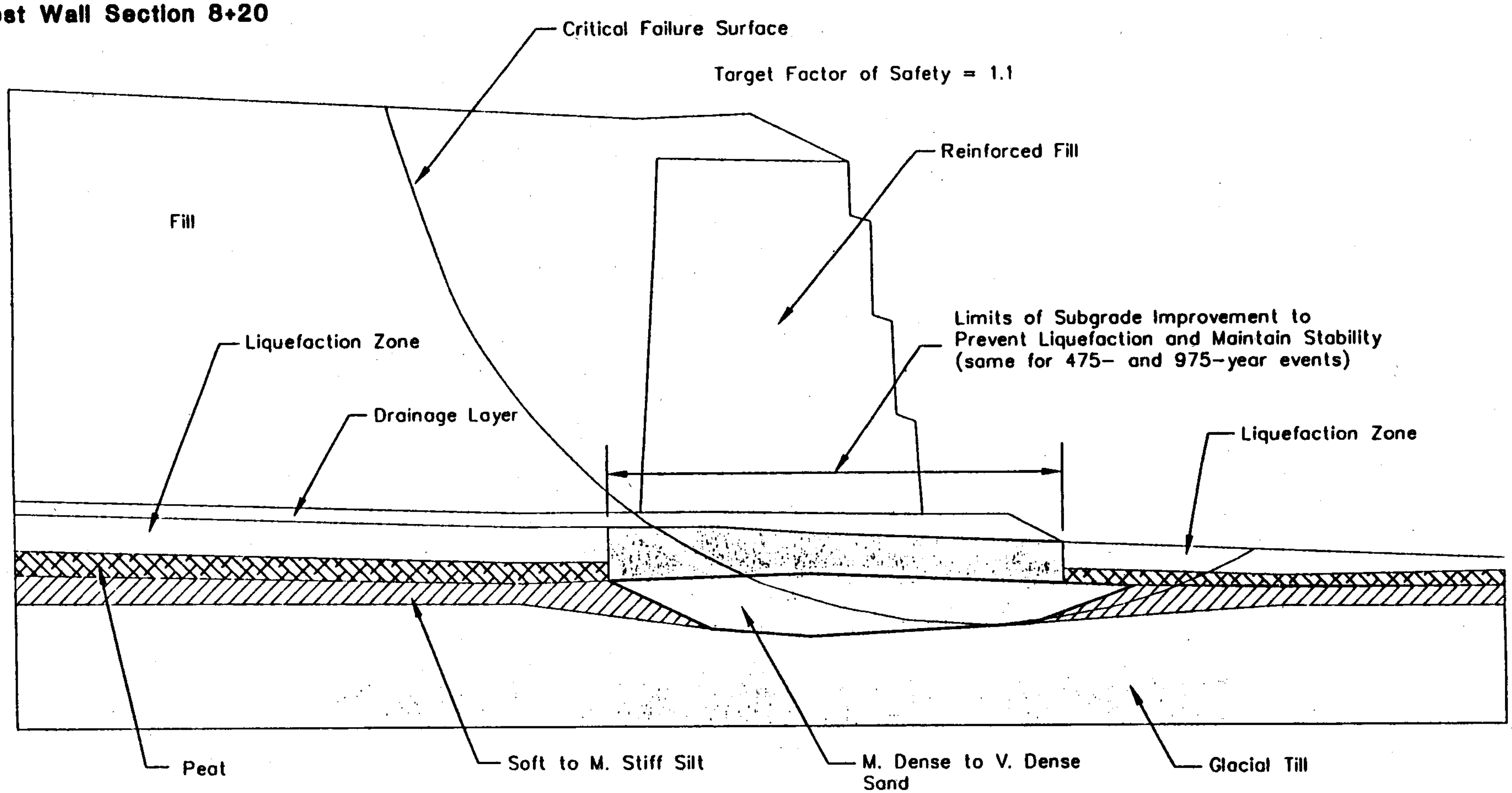
DJH 7/11/00 1=1 Woodsick.pc2 49783207.dwg

Subgrade Improvement to Mitigate Liquefaction for a West Wall Section

West Wall Section 8+20



Subgrade Improvement Alternatives

- Overexcavation and replacement
  - Require dewatering
- Vibro-replacement stone columns
  - Specialized contractor
  - Verification testing
- Other options considered
  - Dynamic compaction, vertical drains, preload, vibro-compaction, grouting, soil-mixing

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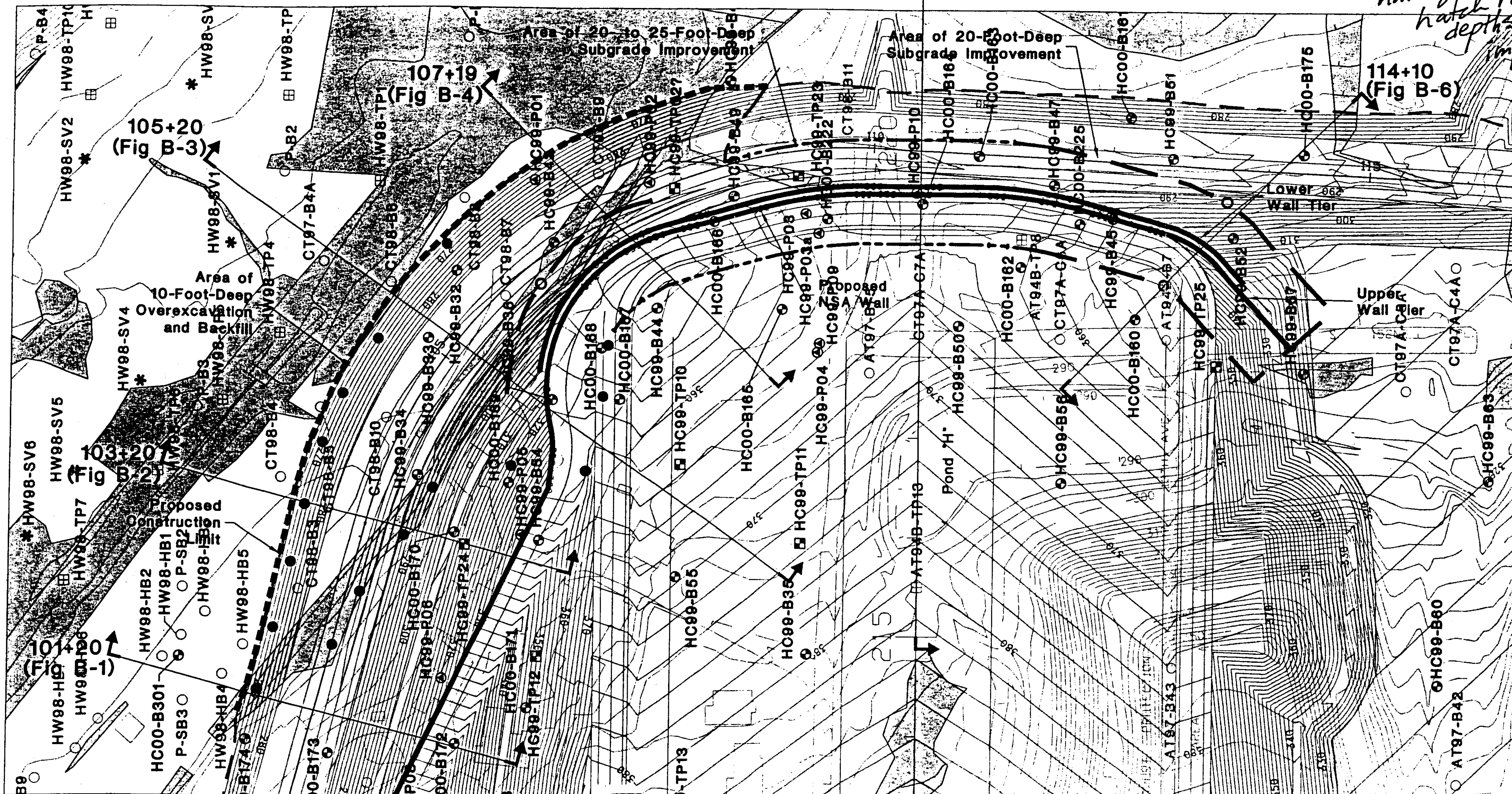
Subgrade Improvement and Groundwater Control Plan

North Safety Area

Replace w/ version having cross hatch for depths of improv.



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.

Proposed Groundwater Control Components

- Wells
- Wellpoints
- Drains and Sumps
- Sheet Pile

103+20 Cross Section Location and Designation

0 100 200 Scale in Feet

N

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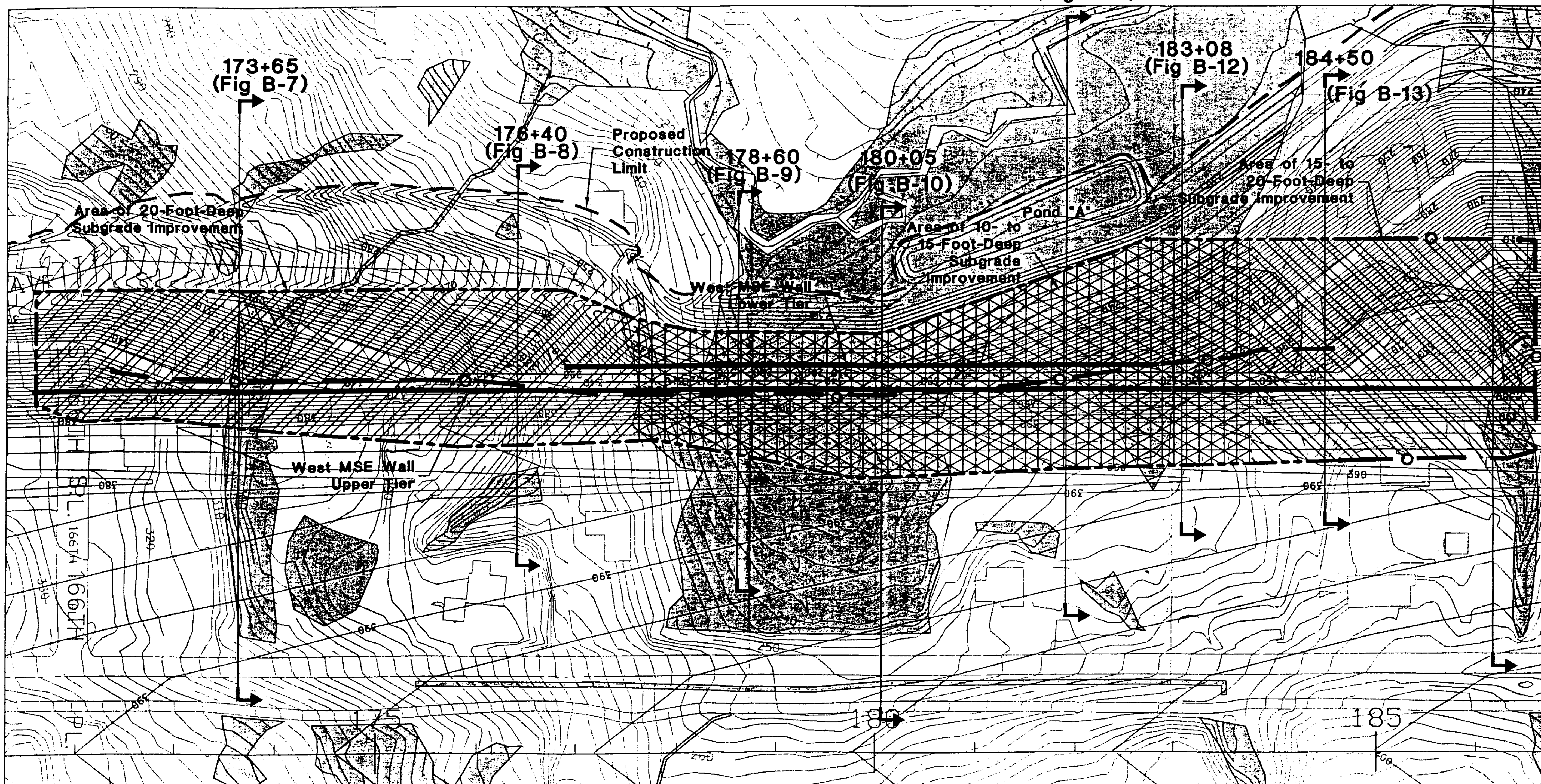
J-4978-22 4/00
Figure 2

DTN 6/21/00 1=100 (xref)see drawing file/charlie.pc2
49782209.dwg

AR 026026

Subgrade Improvement and Groundwater Control Plan

West MSE Wall



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.

Proposed Groundwater Control Components

- Wellpoints
- Drains and Sumps

180+05 Cross Section Location and Designation

Z

0 100 200

Scale in Feet

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J-4978-22 5/00

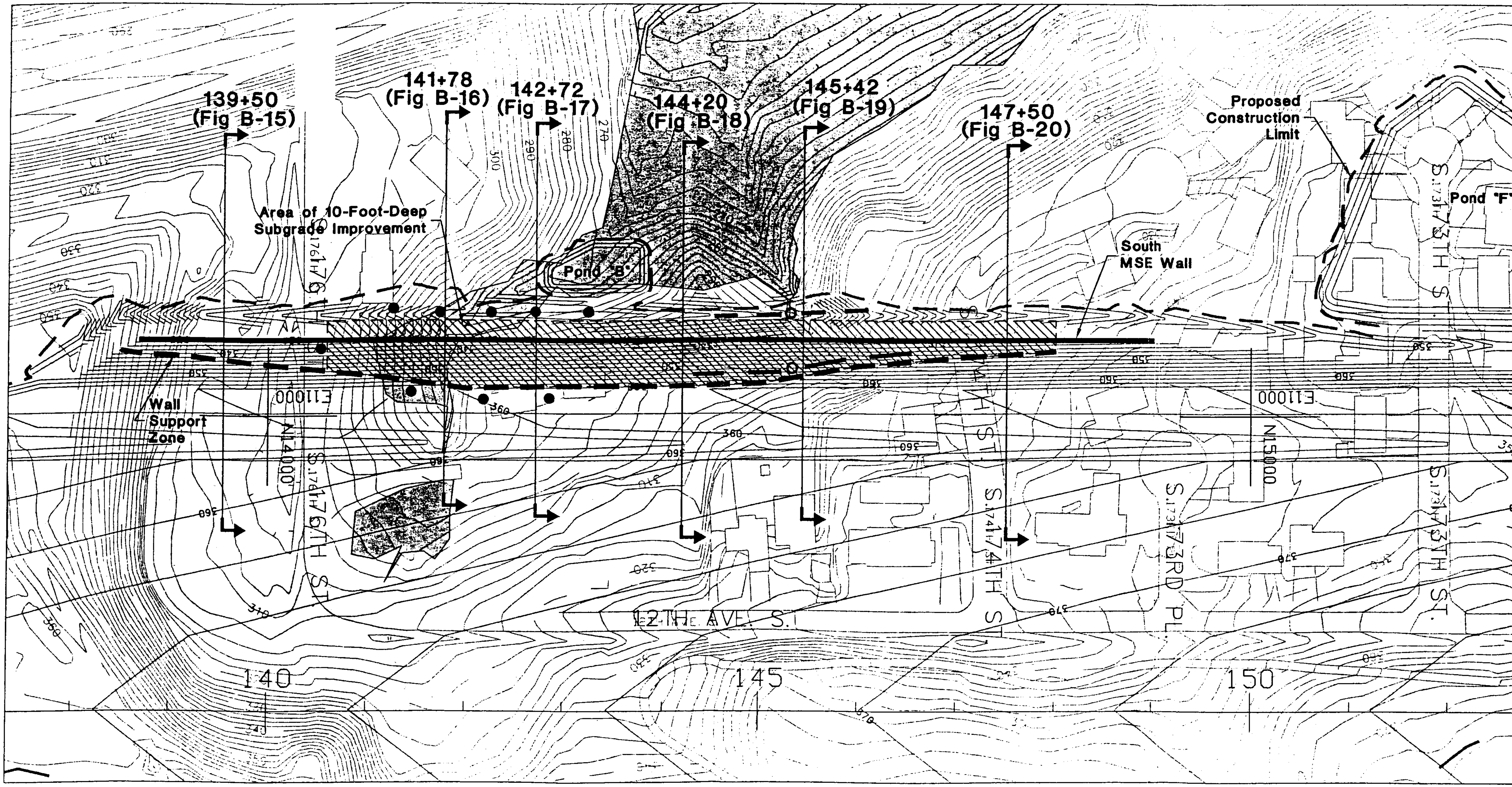
Figure 3

AR 026027

DTN 6/21/00 1=100 (xref)see drawing file/charlie.pc2
49782208.dwg

Subgrade Improvement and Groundwater Control Plan

South MSE Wall



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.

Proposed Groundwater Control Components

● Wells

—o— Drains and Sumps

145+42 Cross Section Location and Designation

N

0 100 200

Scale in Feet

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J-4978-22 5/00

Figure 4

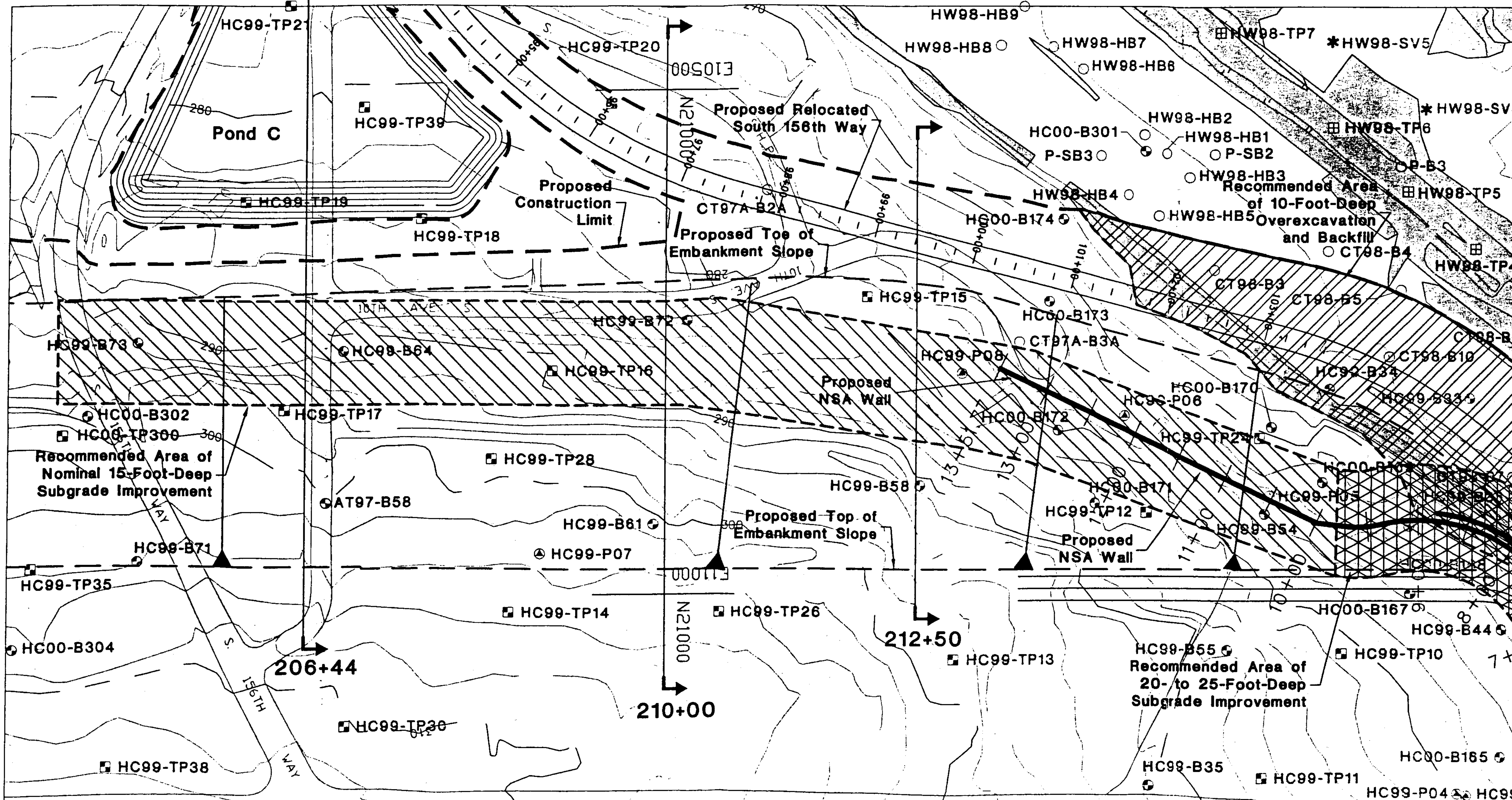
AR 026028

DTN 6/21/00 1=100 (xref)see drawing file/charlie.pc2
4978207.dwg

Site and Exploration Plan and Recommended Subgrade Improvement Areas

for 2H:1V Slope

DRAFT



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_110800.dwg", dated November 8, 2000.

⊕	HC99-P08	Cone Probe Location and Number
⊕	HC00-B306	Boring Location and Number
■	HC00-TP126	Test Pit Location and Number
		Wetland Location
	210+00	Cross Section Location and Designation

N

0 100 200

Scale in Feet

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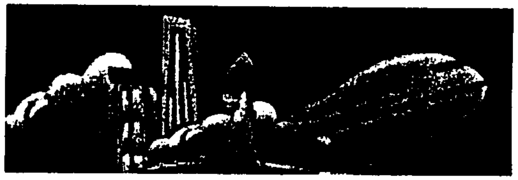
J-4978-28 10/00

Figure 4

AR 026029

RC 11/14/00 1=100 (xref)see drawing file/charlie.pc2 4978206



Session Two Overview

- Seismic design
- MSE walls
- 2H:1V embankment

Seismic Design

Seismic Analyses

- Design level earthquake
- Seismic slope stability
  - Limit equilibrium (SLOPE/W)
  - Displacement-based (FLAC)
- Liquefaction

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Design Level Earthquake

- Site-specific probabilistic seismic hazard analysis
  - Spatial uncertainty
  - Size uncertainty
    - Gutenberg-Richter recurrence law, $\log \lambda m = a - bm$
    - Characteristic earthquakes
  - Attenuation relationships

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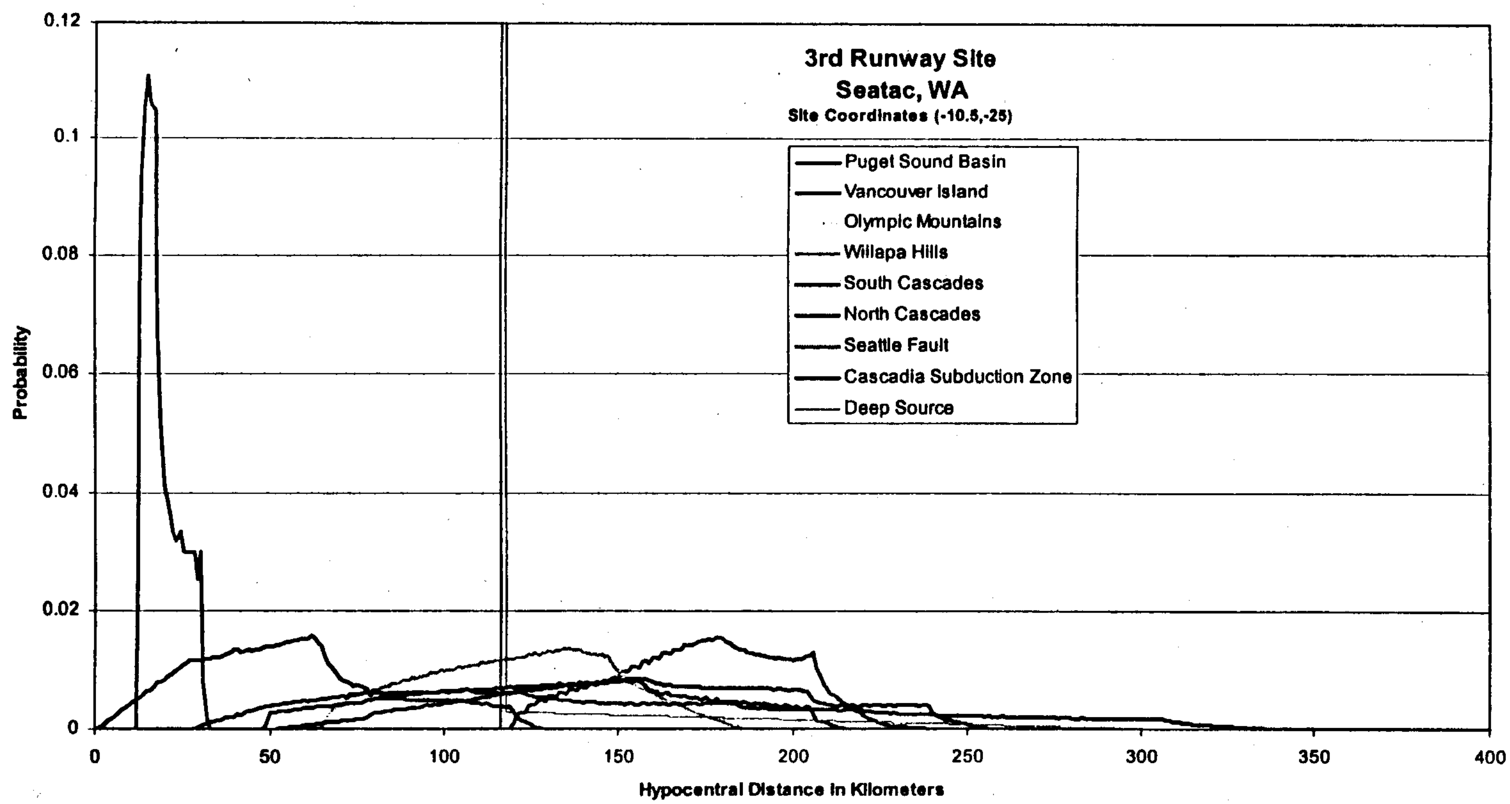
Spatial Uncertainty—Probability Density Function



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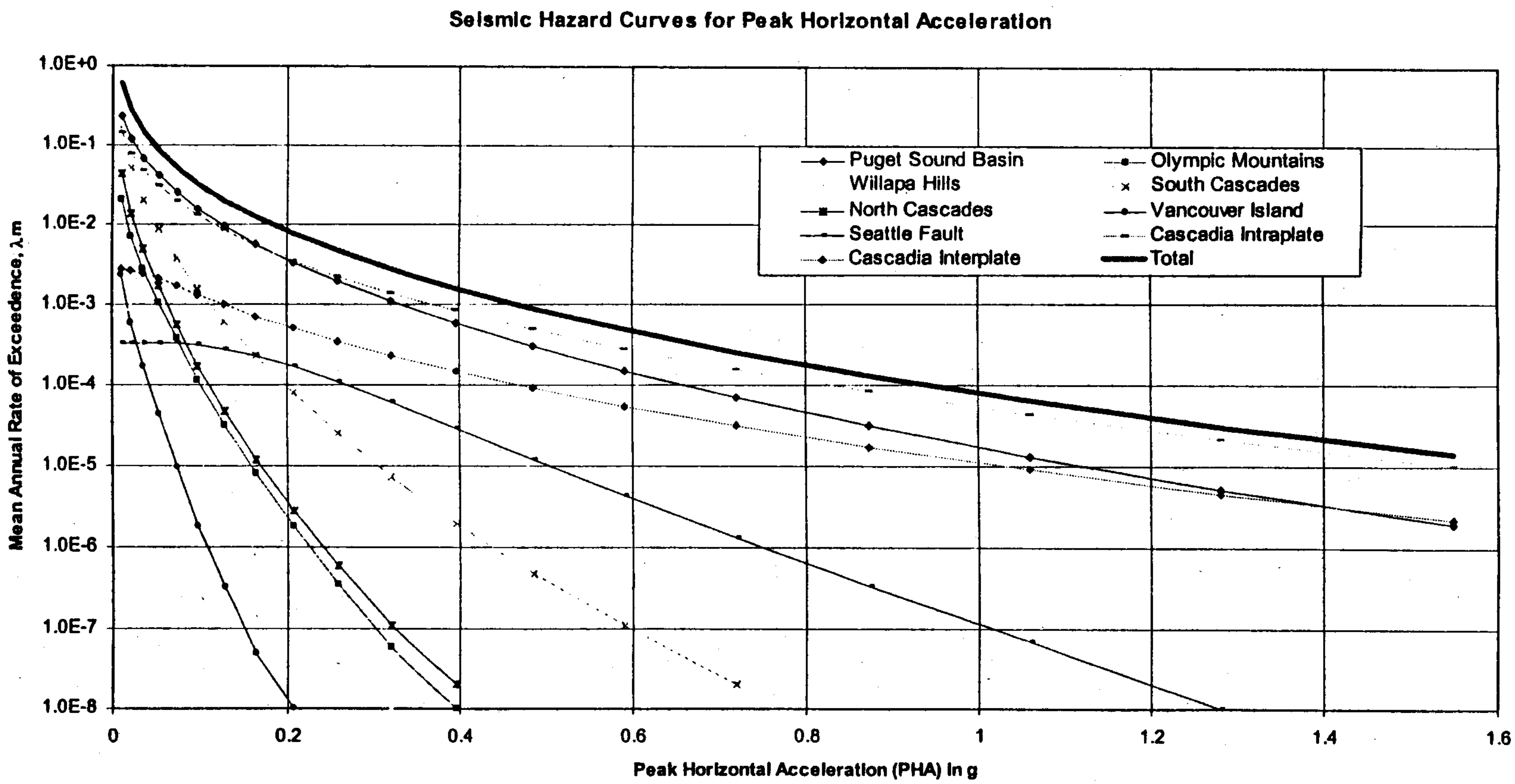
Seismic Hazard Curve for PHA



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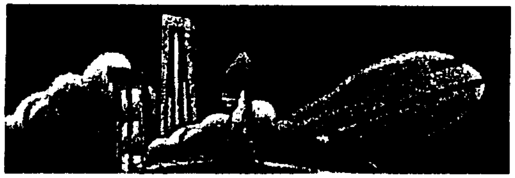
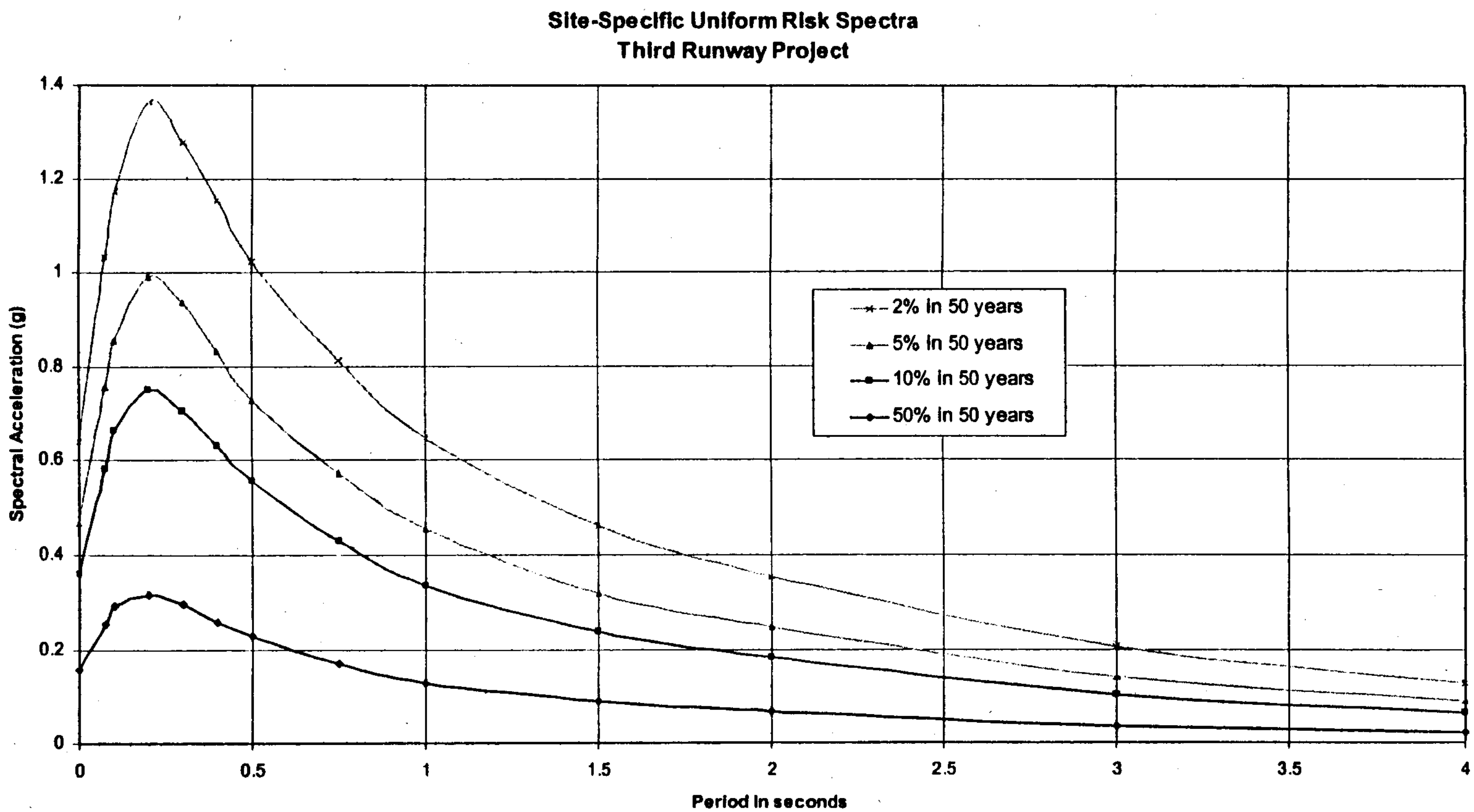
AR 026035



Spectral Acceleration



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Design Level Earthquake Selection

- MSE wall
  - 475-year seismic event
  - 950-year seismic event
- General embankment fill
  - 72-, 175-, 300-, and 475-year seismic event

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Seismic Slope Stability

- Limit equilibrium (SLOPE/W)
  - Seismic input parameters
    - Pseudo-static analysis
      - $K_h = 0.5\ a_{max} = 0.18$ g
      - $K_v = 0$ g
    - Liquefaction analysis with post-liquefaction residual strengths

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Design Factors of Safety

Design Scenario	Target Factor of Safety
Steady State	1.5
Pseudo-Static (475-year)	1.1
Liquefaction (475-year)	1.1

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Seismic Slope Stability (cont.)

- Displacement-based (FLAC)
  - Input parameters
    - Time history at base of model
    - "Free-field" boundary conditions
    - 5% damping
  - Design deformations
    - Location dependant
    - Differential deformations

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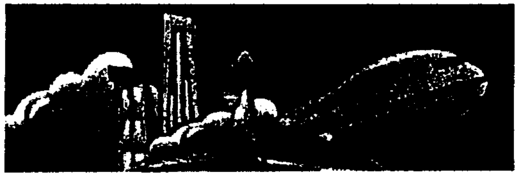

Liquefaction

- Evaluation of liquefaction
  - Trigger liquefaction analysis using both SPT and CPTu data
  - SPT analyses based on work by Seed et al. (1985) and updated at the NCEER Workshop (1996)
  - CPTu analysis based on work by Robertson and Wride (1998)

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Liquefaction Potential of Fine-Grained Soils

- U.S. Army Corps of Engineers criteria to dismiss liquefaction potential used in the foundation design of Sardis Dam (Finn et al., 1994)
  - Fraction of finer than 0.005 mm – 5% ≤ 15%
  - Liquid limit, LL + 1% ≤ 35%
  - Natural water content + 2% ≥ 0.9 LL
  - Liquidity index ≤ 0.75

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Post-Liquefaction Residual Strength

- Properties of liquefied soil
  - Residual shear strength calculated using a middle value of the range suggested by Seed and Harder (1990) for SPT samples

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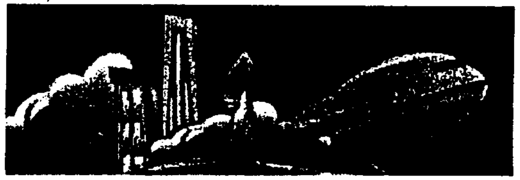

Trigger Liquefaction Plot

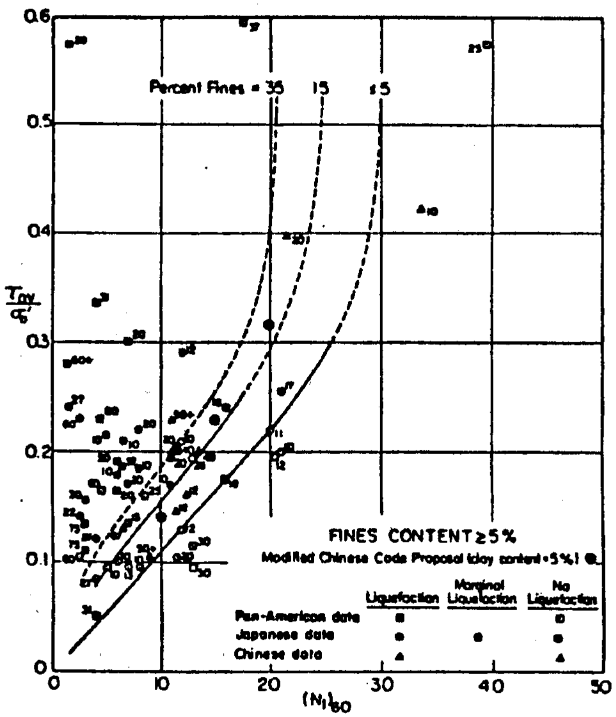

FIG. 6.—Relationship between Stress Ratios Causing Liquefaction and N_1-Values for Silty Sands for M = 7-1/2 Earthquakes

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Residual Strength Plot

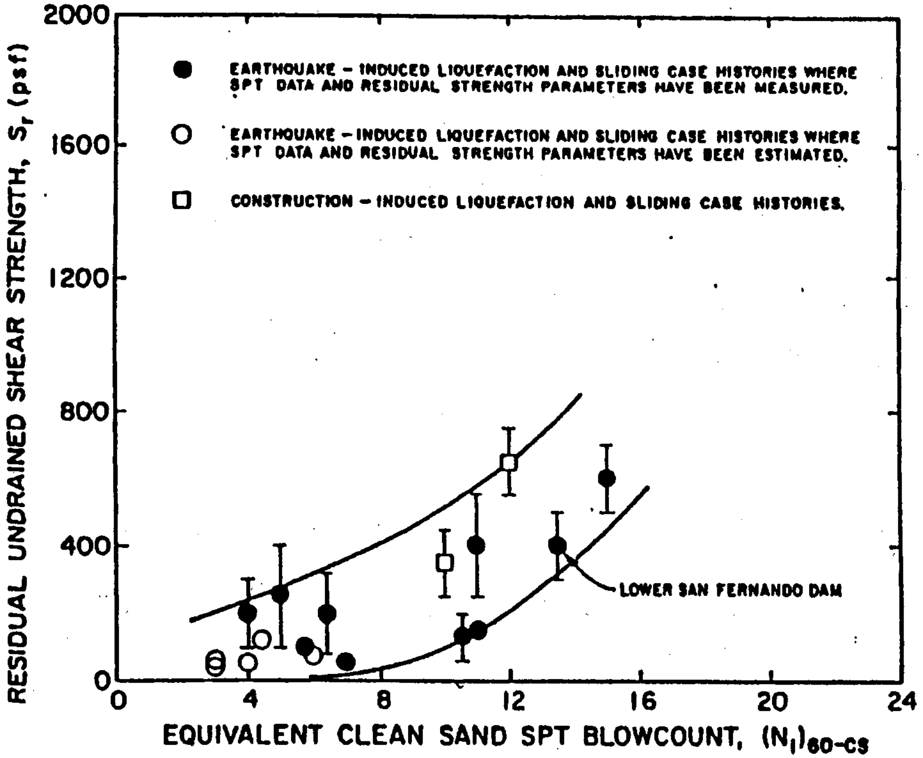

Fig. 11: Relationship Between Corrected "Clean Sand" Blowcount $(N_1)_{60-cs}$ and Undrained Residual Strength (S_r) from Case Studies

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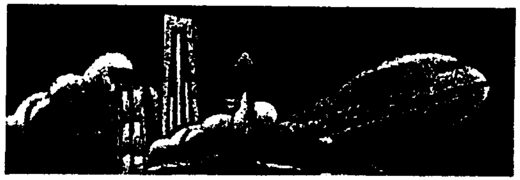

Spatial Extent of Liquefaction

- MSE walls—saturation and high liquefaction potential assumed under drainage layer of MSE wall
- 2H:1V slope—*in situ* water conditions and a groundwater model used with partial liquefaction

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MSE Walls

Stability Analysis

- MSE walls
  - Limit equilibrium analysis (SLOPE/W)
    - Initial global stability analysis: subgrade improvement
    - Review of RECo Design
      - Internal stability (1996 AASHTO)
      - Global stability
      - Compound stability
  - Deformation analysis (FLAC)
    - Static
    - Dynamic

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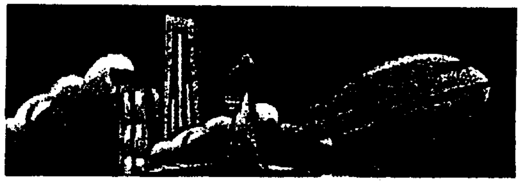

Stability Analysis

- Fill embankment slopes
  - Limit equilibrium analysis (SLOPE/W)
    - Static: end of construction and steady state
    - Pseudo-static: seismic
    - Liquefaction: residual shear strength
  - Deformation analysis (FLAC)
    - Liquefaction: composite of peak and residual shear strength

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Limit Equilibrium Analysis

- Analysis conditions
  - End of Construction (EOC): undrained strength
  - Partially drained EOC: PWP dissipation
  - Steady state: drained shear strength
  - Pseudo-static: used ½ PGA
  - Liquefaction: residual shear strength

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Limit Equilibrium Analysis

- Factor of safety criteria
  - 1.5 for steady state
  - 1.3 for EOC
  - 1.3 for partially drained EOC
  - 1.1 for pseudo-static
  - 1.1 for liquefaction

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Limit Equilibrium Analysis

- Other design assumptions
  - Peat removal
  - Free-draining embankment
  - Saturated drainage layer
  - For initial stability analysis
    - Reinforcement length = 80% wall height
    - Zero embedment
    - Check global stability only

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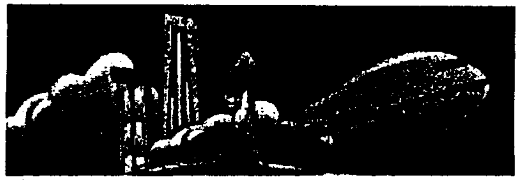

Input Soil Parameters

Soil Type	Unit Weight	Drained Strength		Undrained Strength	
		c'	ϕ'	c	ϕ
	(pcf)	(psf)	(deg.)	(psf)	(deg.)
Loose to Medium Dense Sand	125	0	32	-	-
Medium Dense to Dense Sand	130	0	35	-	-
Dense to Very Dense Sand	135	0	37	-	-
Glacial Till	130	250	40	-	-
Soft Peat or Organic Silt (Topsoil)	110	0	15	-	-
Medium Stiff Silt/Clay	115	0	32	1000	0
Stiff to Hard Silt/Clay	115	0	32	4000	0
Structural Backfill	135	0	35	-	-
Crushed Rock Backfill	145	0	40	-	-
Embankment Fill	135	0	35	-	-
Reinforced Embankment Fill	140	0	40	-	-
Drainage Blanket	140	0	37	-	-
Improved Subgrade	135	0	35	-	-

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Excess Pore Pressure in Medium Stiff to Stiff Clay

- Need to avoid development of considerable excess pore pressure during construction in NSA
  - Pore pressure depends on clay consolidation rate and thickness
  - Clay is most thick in NSA

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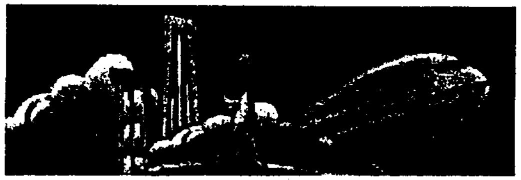

2H:1V Embankment Slope Stability

- Select cross sections where clay layer is thickest, for both soft/medium stiff or hard consistencies

- Analyze both undrained and partially drained cases, where partially drained is defined by excess pore pressure model

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Excess Pore Pressure Analysis

- Time rate of consolidation using Terzaghi 1-D consolidation model
- Coefficient of consolidation from laboratory consolidation tests and CPTu dissipation test
- Drainage path length based on SPT/CPTu
- Incremental load model to represent construction

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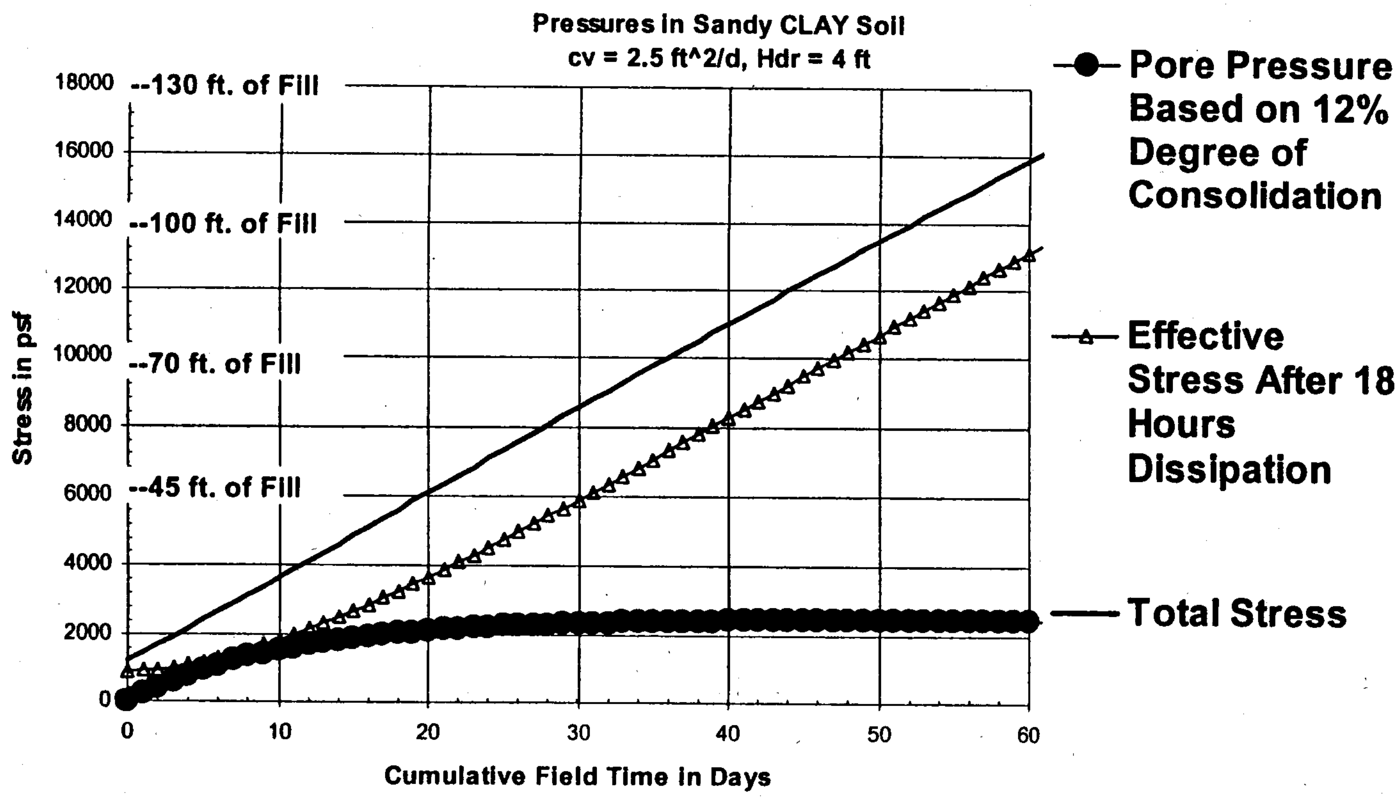
Prediction of Excess Pore Pressure



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Post-Liquefaction Residual Strength

- Trigger liquefaction analysis using SPT and CPTu data
- Correlation between SPT-N and residual strength
- Statistical analysis of residual strength in liquefied soil zones
- Consider various levels of seismic events

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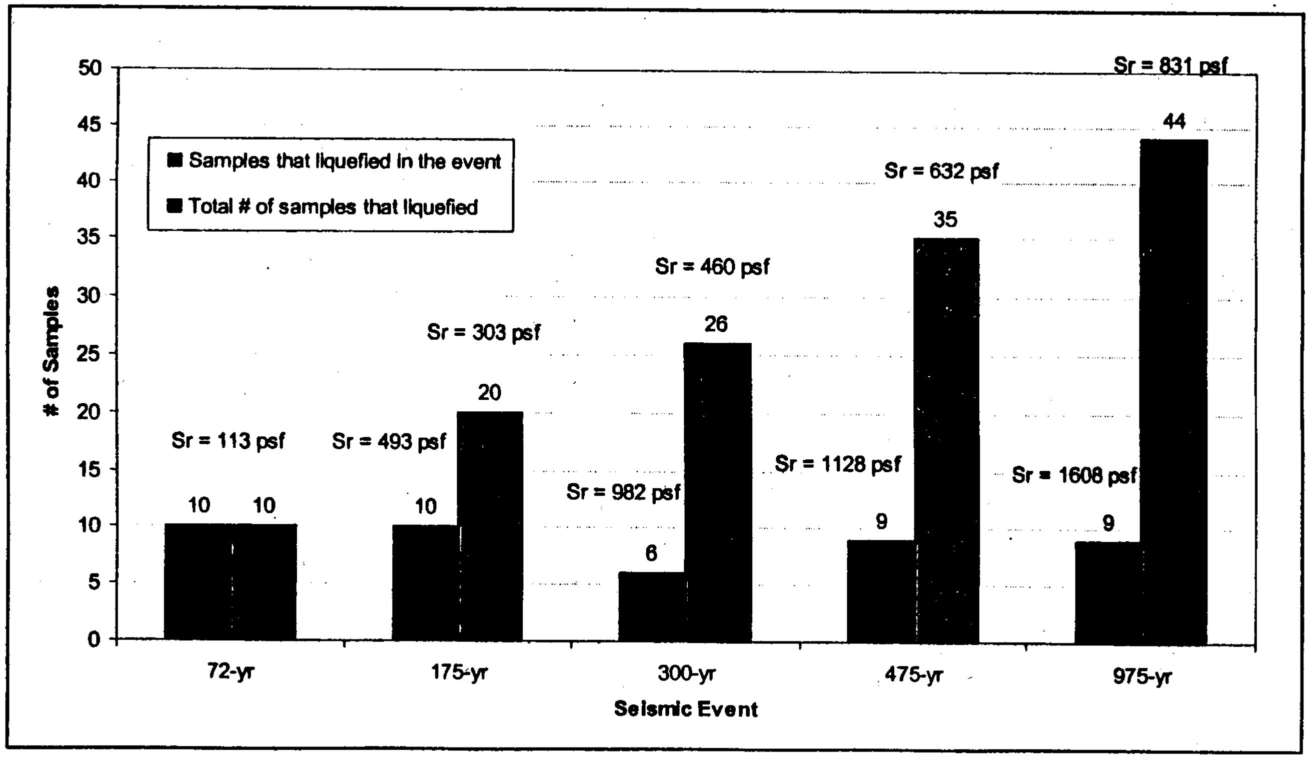
Post-Liquefaction Residual Strength

NSA WAll



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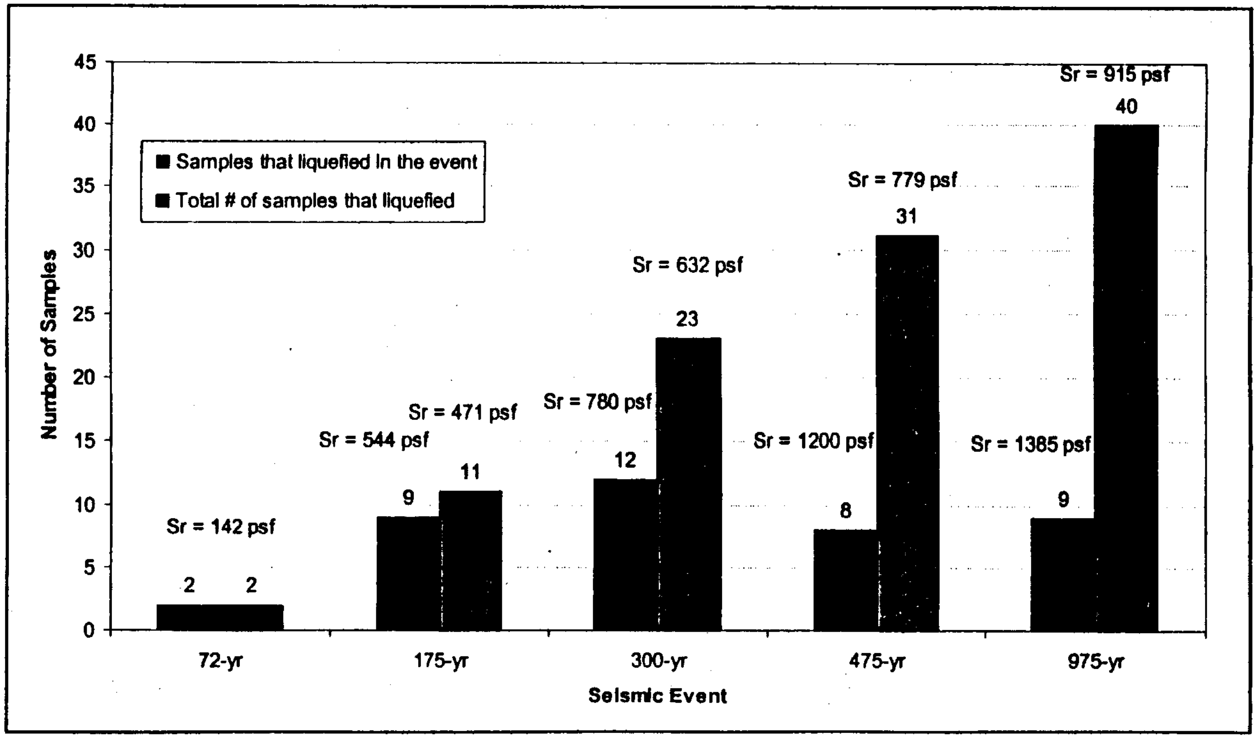
Post-Liquefaction Residual Strength

West Wall



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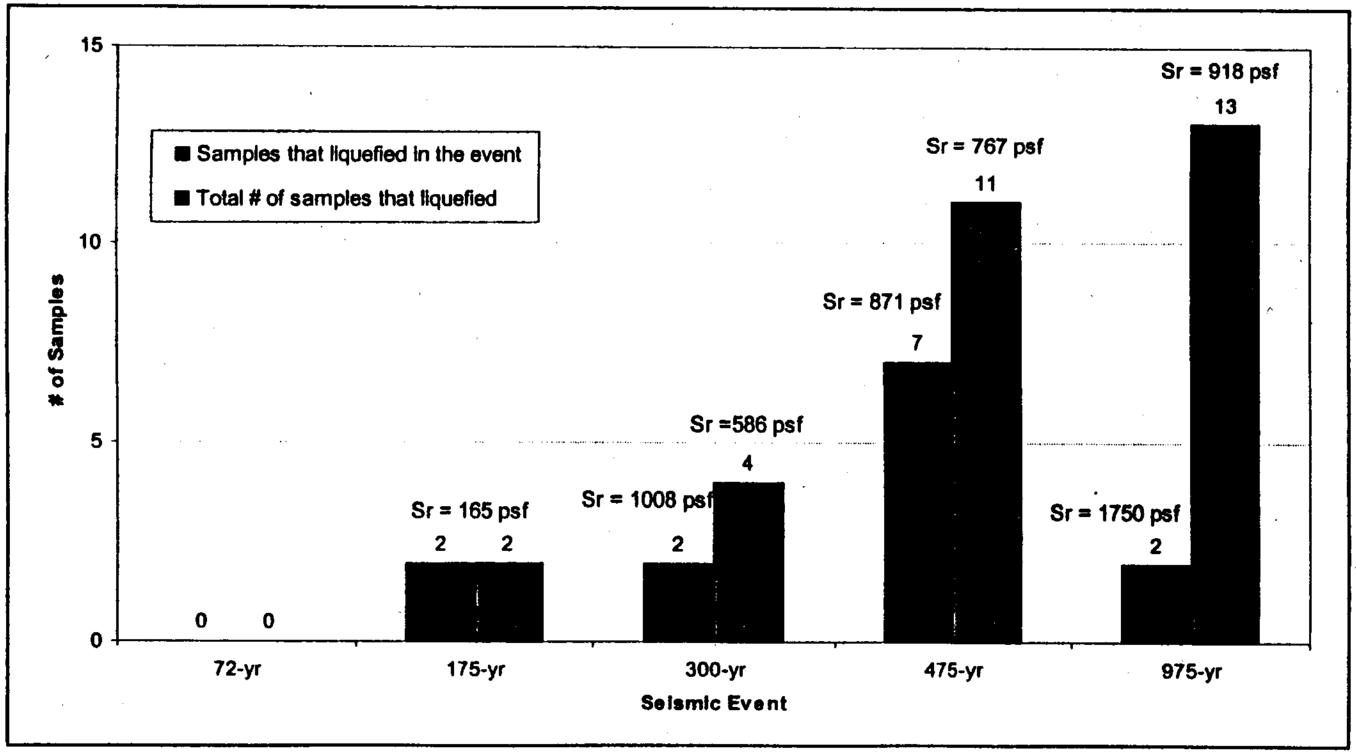
Post-Liquefaction Residual Strength
South Wall



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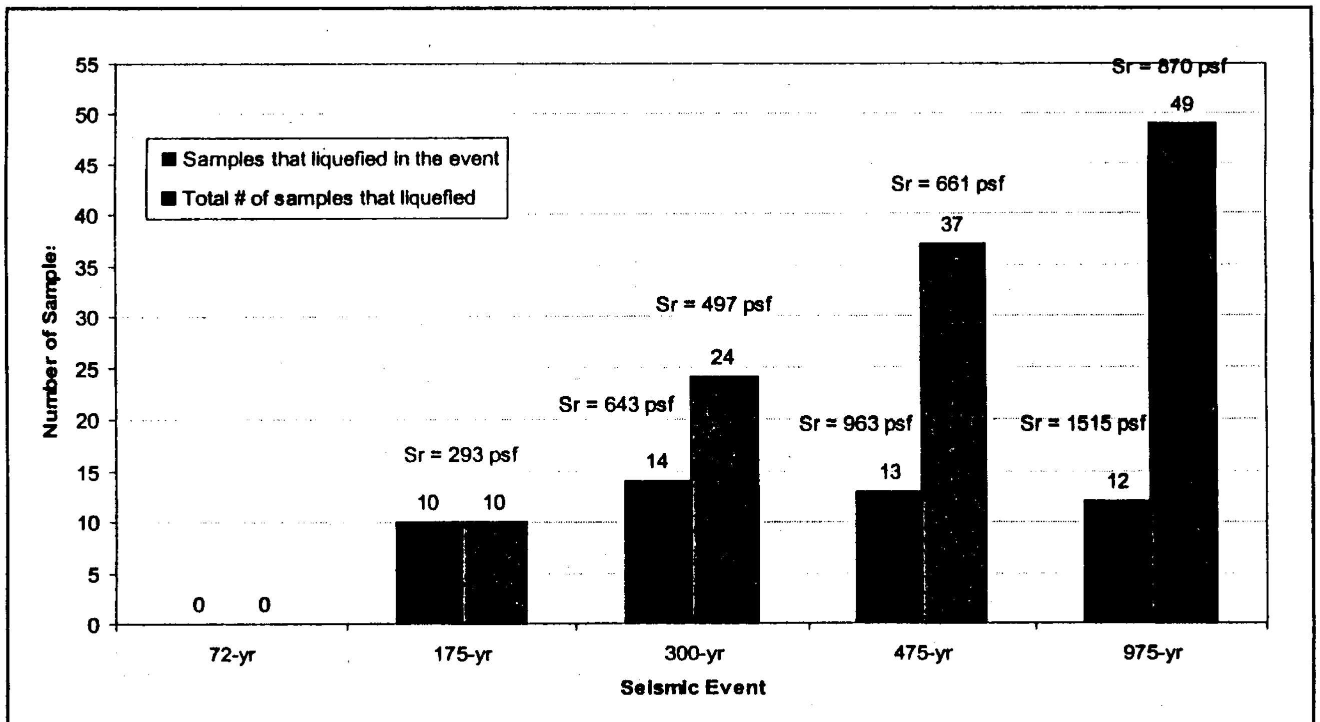
AR 026061

Post-Liquefaction Residual Strength

Embankment Slope



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MSE Wall Analysis

- Selected preliminary sections to study the need and extent of subgrade improvement (SLOPE/W)
- Performed global and compound stability analysis (SLOPE/W) on selected sections to check RECo design
- Performed deformation analysis on sections showing marginal factors of safety (FLAC)

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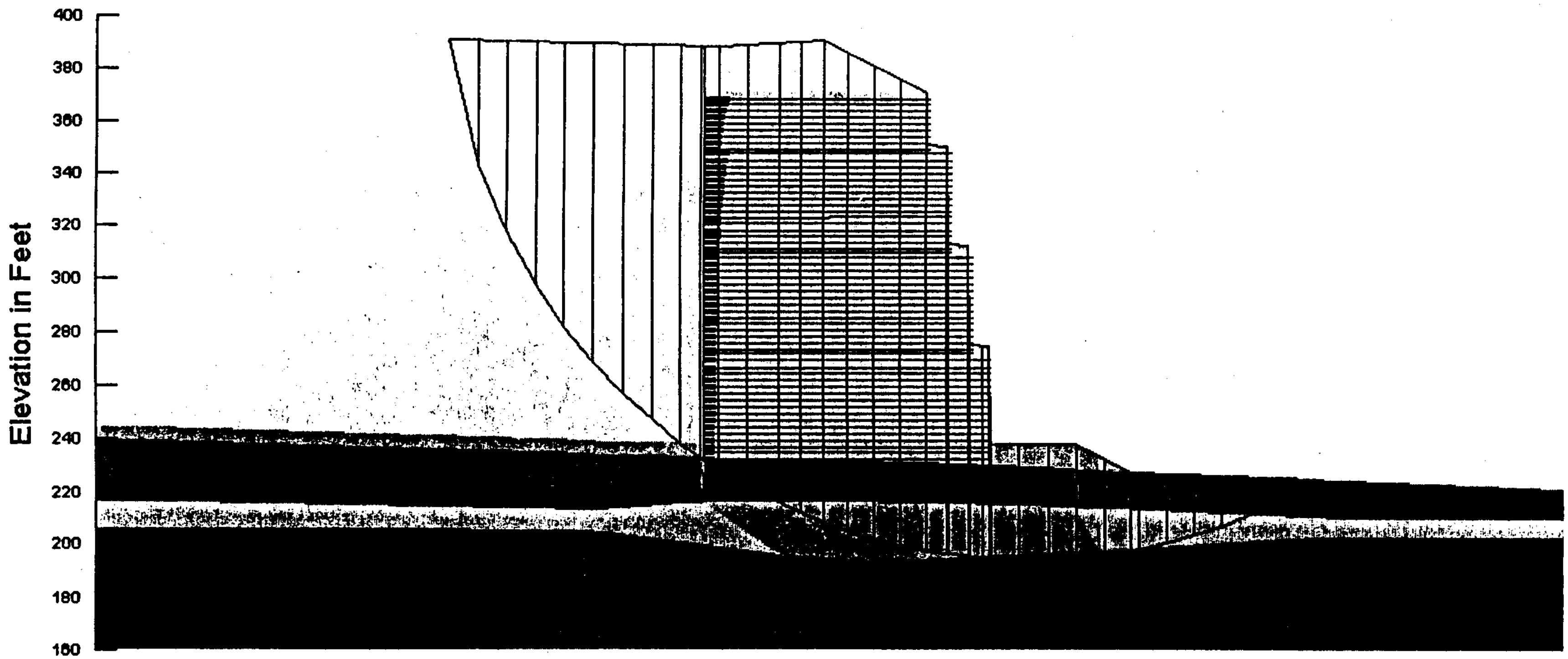
Global Stability—MSE Walls
Station 180+00



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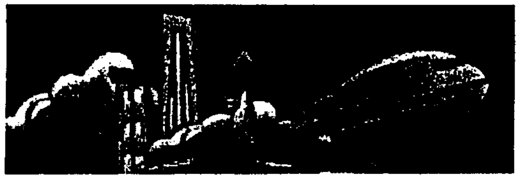
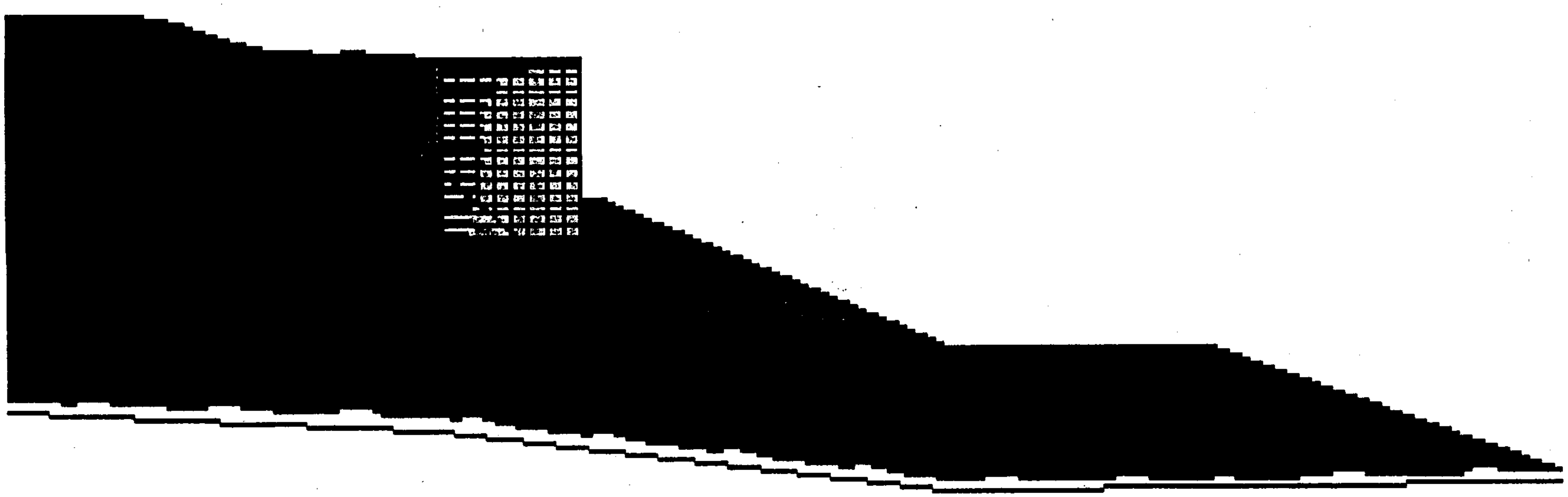
AR 026064



Compound Stability—MSE Walls

Station 144+75



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FLAC Modeling

- Preliminary runs on NSA and west walls
- Based on results of limit equilibrium analysis, verify deformation on:
  - West wall, Sta. 180+00 (H = 133.5 ft); and
  - South wall, Station 147+25
- Deformation analysis on embankment slope station 193+19

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FLAC Modeling

- Soil parameters
  - Density and shear strength: same as in limit equilibrium analysis
  - Deformation modulus: from pressuremeter tests
- Structural properties provided by RECo
- Input ground motion
  - Site-specific PSHA
  - PROSHAKE analysis using downhole V_s

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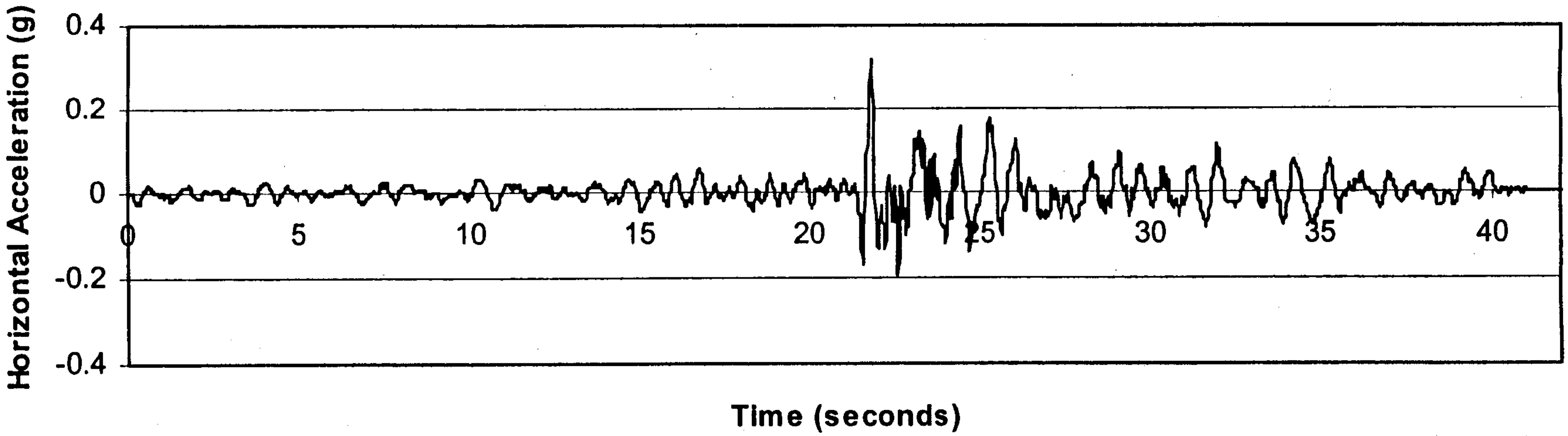
Input Ground Motion



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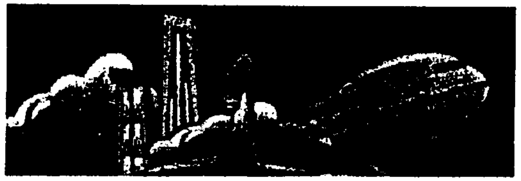
AR 026068



NSA Wall

- Selected 6 sections for preliminary analysis
- Selected 3 critical sections to check global and compound stability, based on:
  - Wall height;
  - Embedment depth; and
  - Strip length
- Results showed adequate factors of safety for the proposed design

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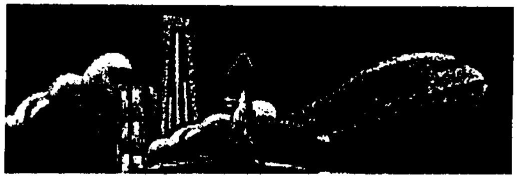
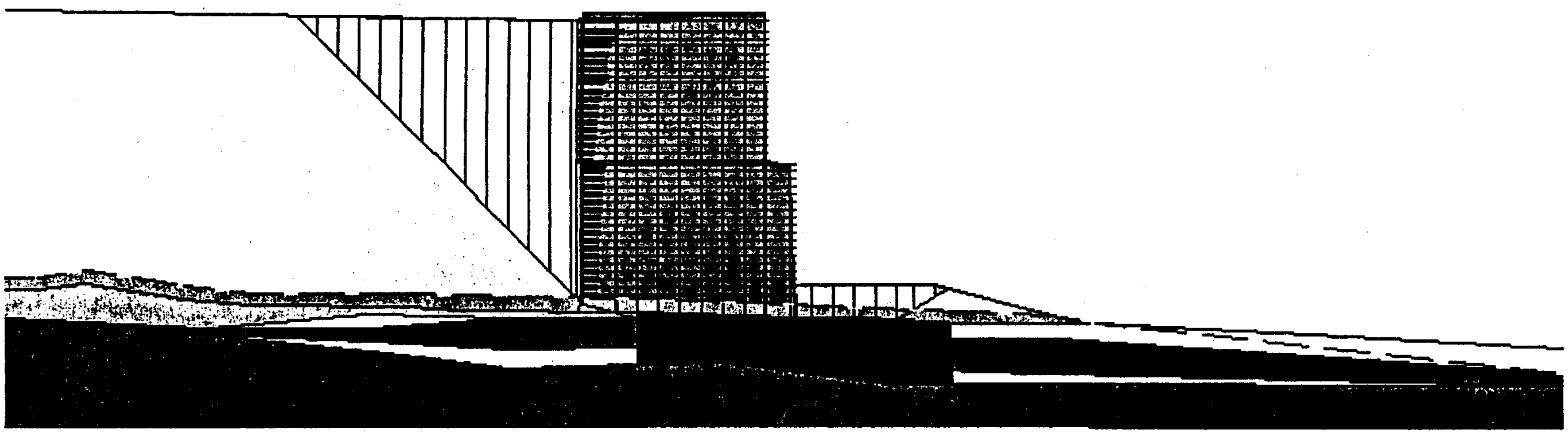


NSA Wall
Station 50+00



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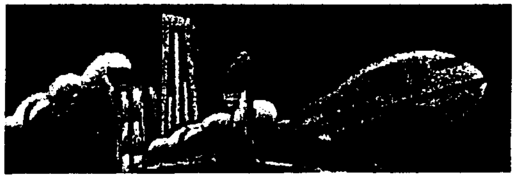
NSA Wall
Station 45+75

HARTCROWSER



West Wall

- Selected 8 sections for preliminary analysis
- Selected 4 critical sections to check global and compound stability, based on:
  - Wall height;
  - Embedment depth; and
  - Strip length
- Results showed marginal factors of safety for compound stability of Station 186+00

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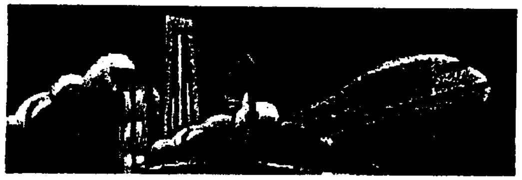
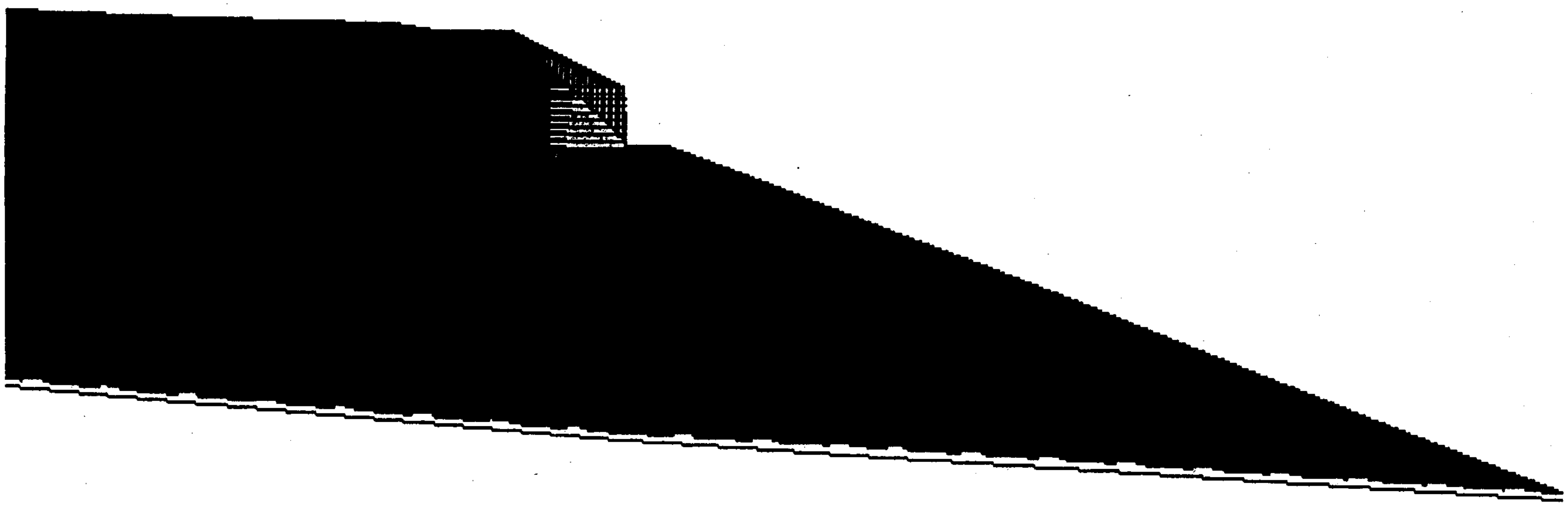


West Wall
Station 186+00



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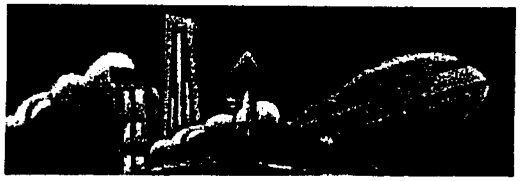

West Wall

- Recommendation:
  - Increase strip thickness from 50 x 4 mm to 50 x 6 mm in all upper tiers
- Alternative:
  - Increase shear strength of backfill

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West Wall—FLAC Model

- Check deformation on Station 180+00 with 50 x 6 mm strips
- 475-year seismic event
- Maximum displacements
  - Horizontal: 10 inches at top of wall
  - Upward: 6 inches at toe of wall
  - Downward: 4 inches at top of embankment behind MSE wall
- No strip exceeds allowable stress (60% yield stress)

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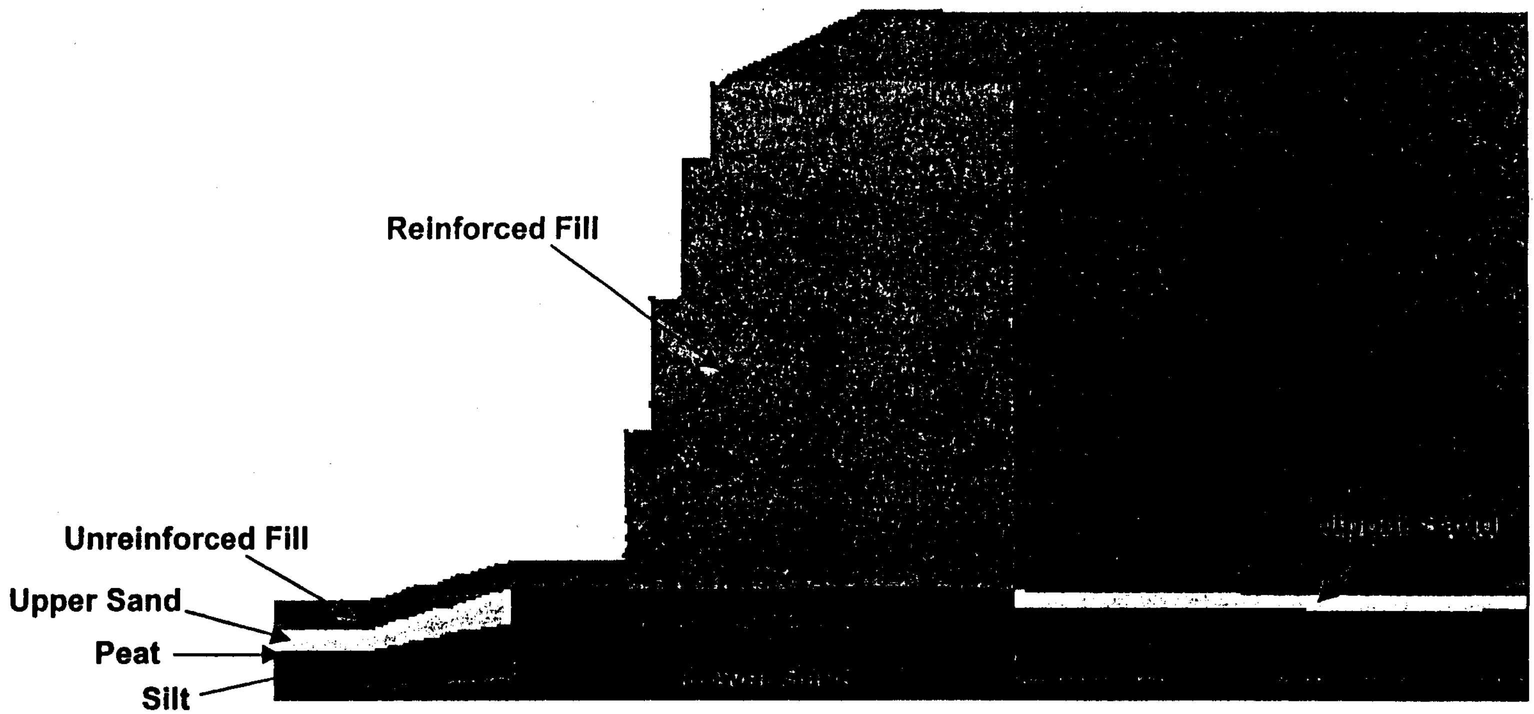
West Wall—FLAC Model
Typical Soil Profile



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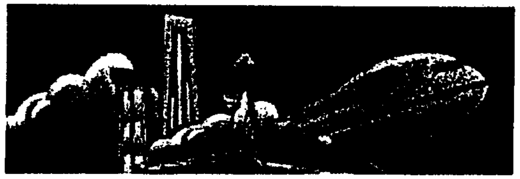
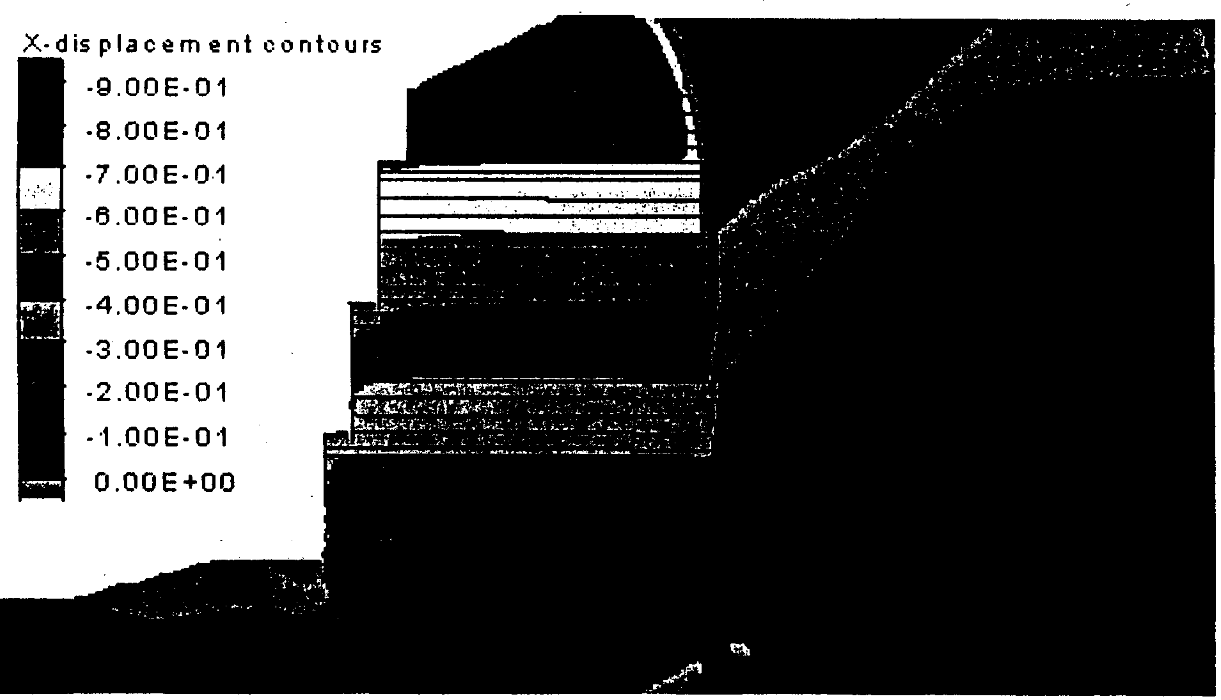


West Wall—FLAC Model

Station 180+00 X-Displacement Contours in Feet



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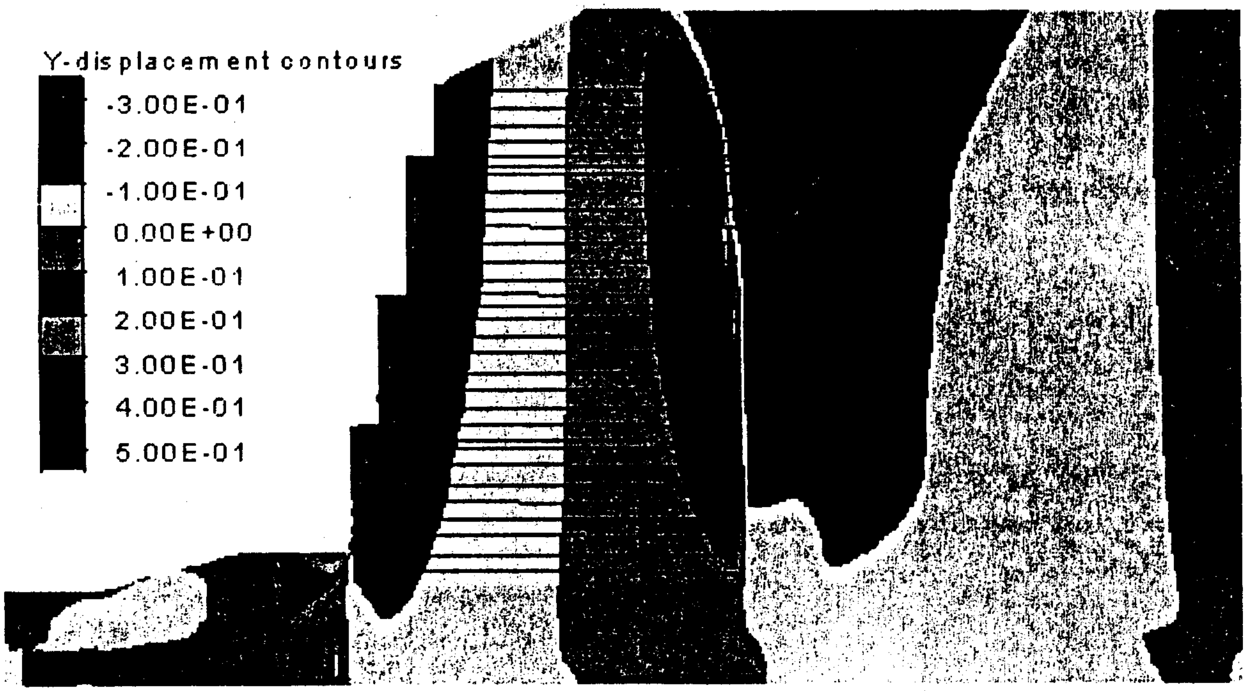
West Wall—FLAC Model

Station 180+00 Y-Displacement Contours in Feet



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South Wall

- Selected 6 sections for preliminary analysis
- Selected 2 critical sections to check global and compound stability, based on wall height, embedment depth, and strip length
- Results showed marginal factors of safety for compound stability of Station 142+75 and 147+25 and global stability of Station 147+25

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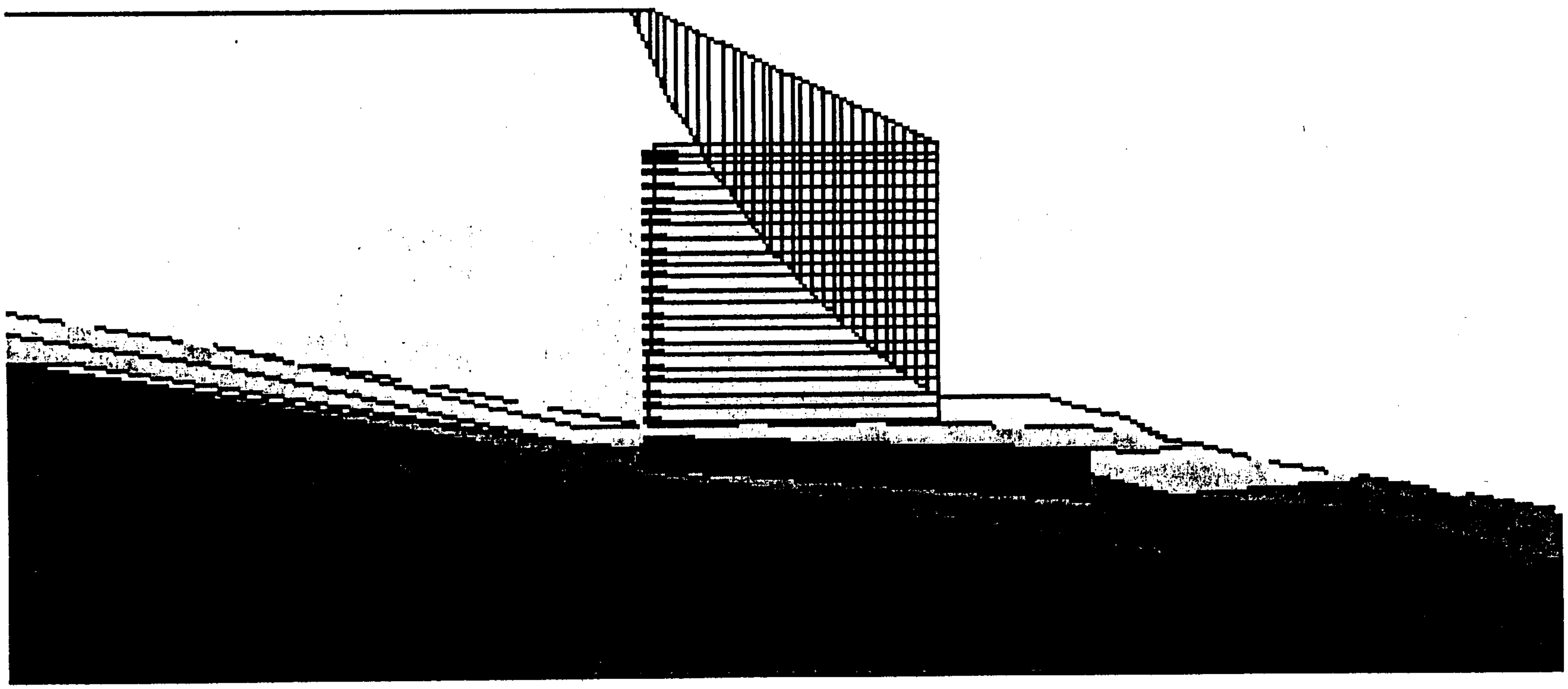
South Wall
Station 142+75



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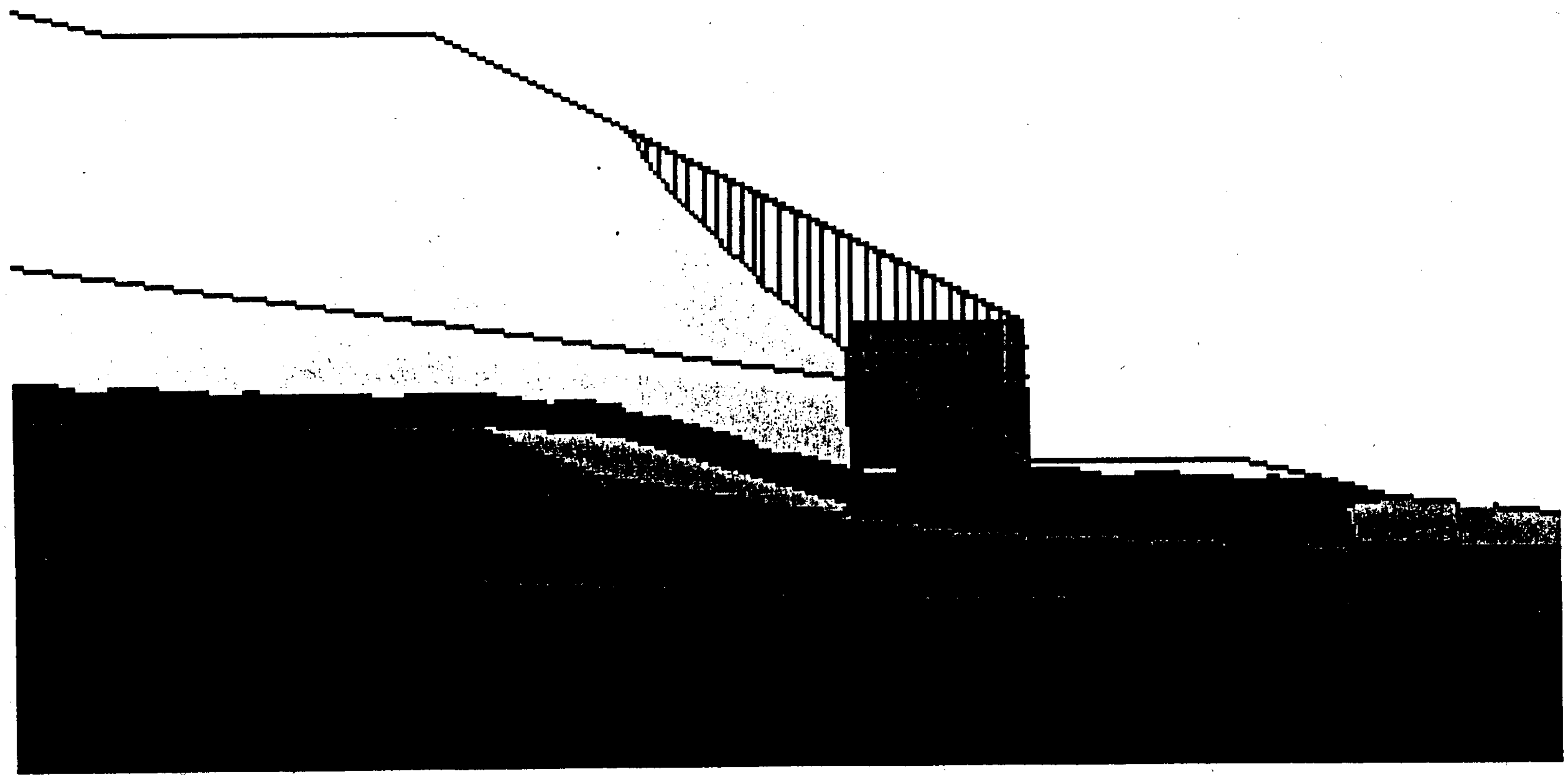
South Wall
Station 147+25



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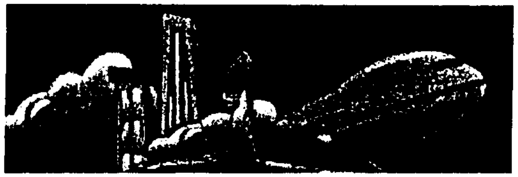
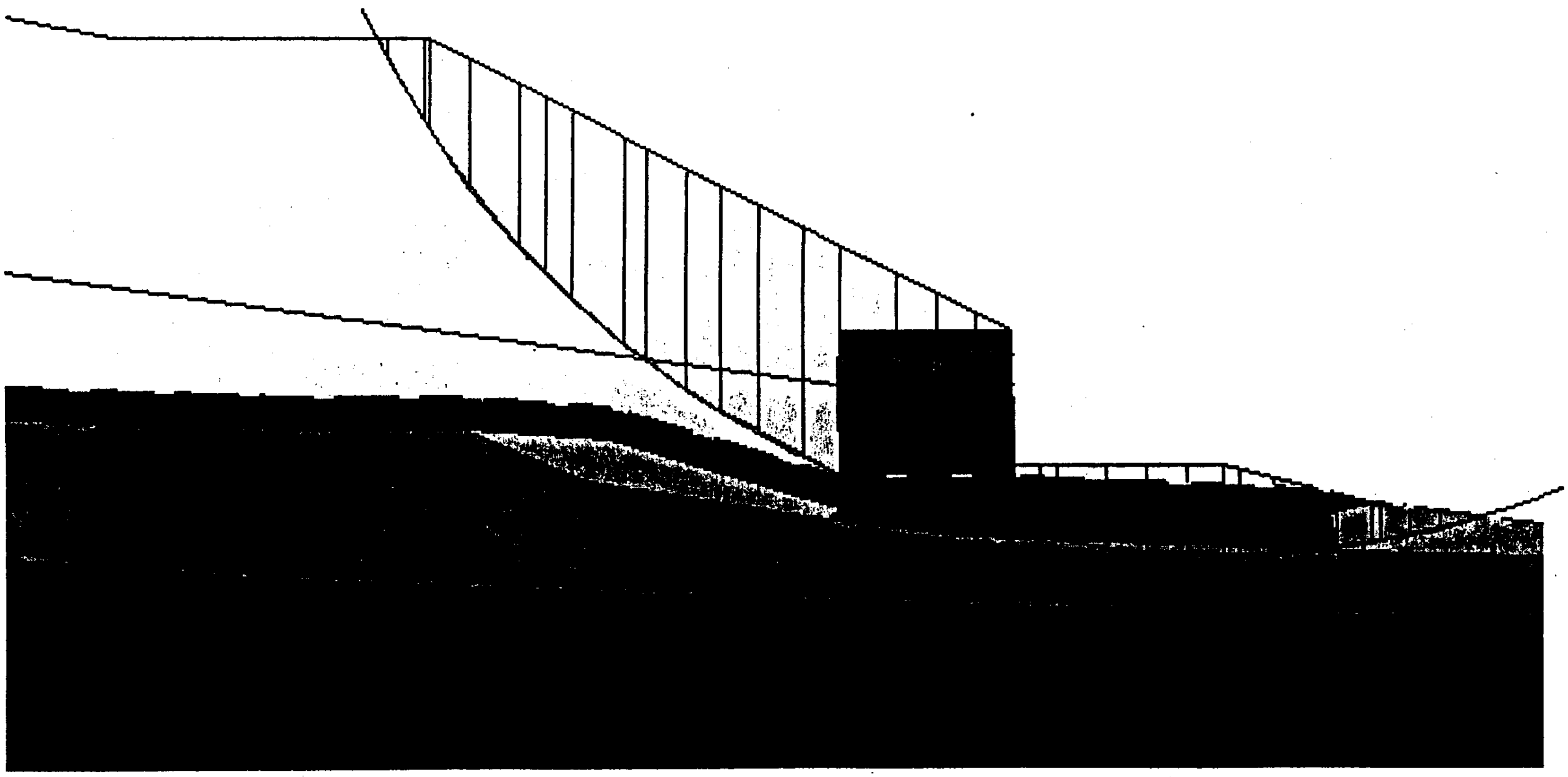


South Wall
Station 147+25



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South Wall

Station 147+25

- Recommendations:
  - Increase strip thickness from 50 x 4 mm to 50 x 6 mm in all upper tiers;
  - Increase embedment depth by 2 feet; and
  - Increase strip length by 2 feet

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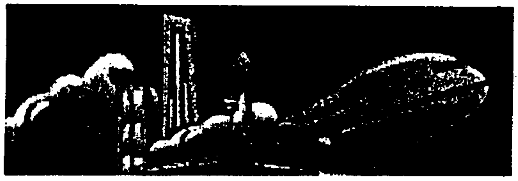

South Wall—FLAC Model

- Check deformation on Station 147+25 with:
  - 50 x 60 mm strips;
  - Increase embedment from 16 to 18 feet; and
  - Increase strip length from 16 to 18 feet
- 475-year seismic event

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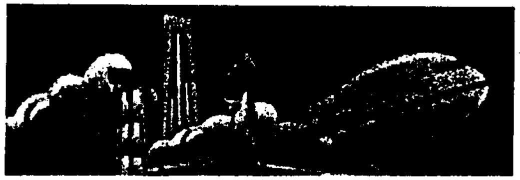

South Wall—FLAC Model

- Maximum displacements
  - Horizontal: 14 inches at top of wall
  - Upward: 9 inches at toe of wall
  - Downward: 5 inches at top of slope
- No strip exceeds allowable stress (60% yield stress)

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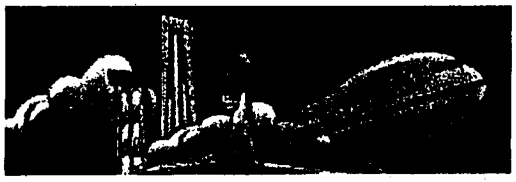
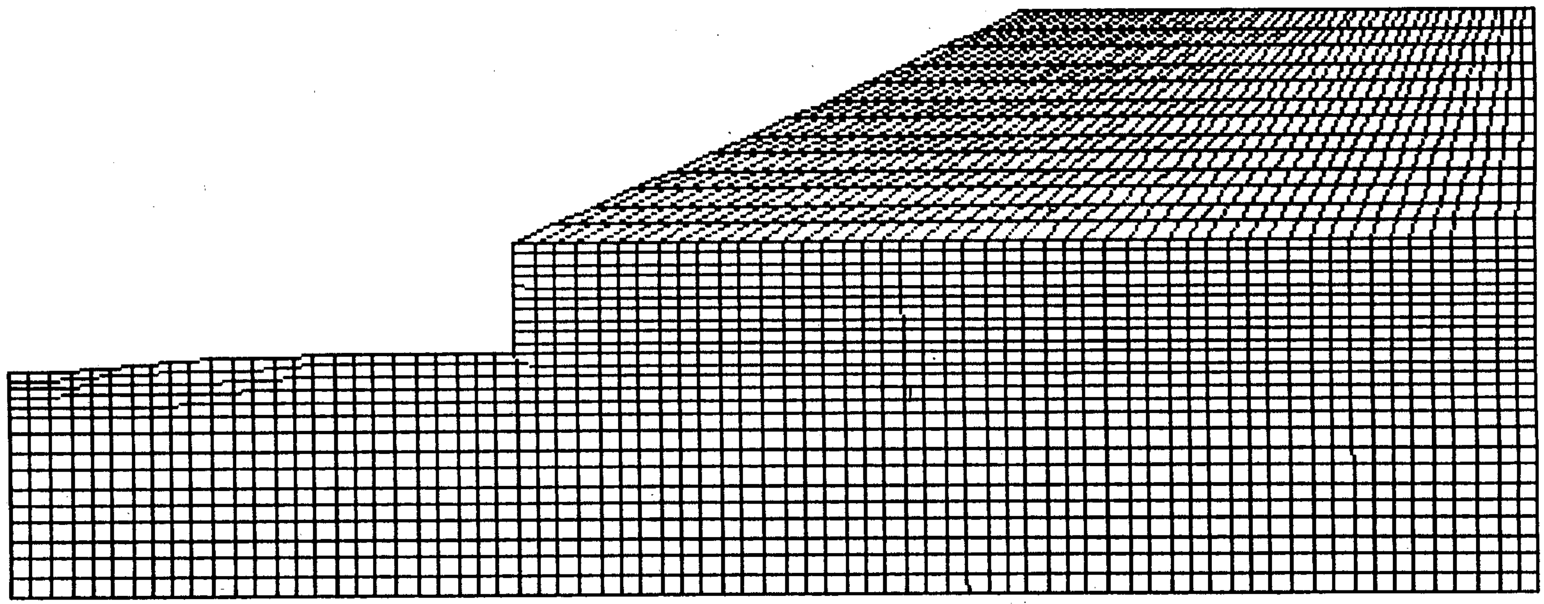


South Wall—FLAC Model
Station 147+25



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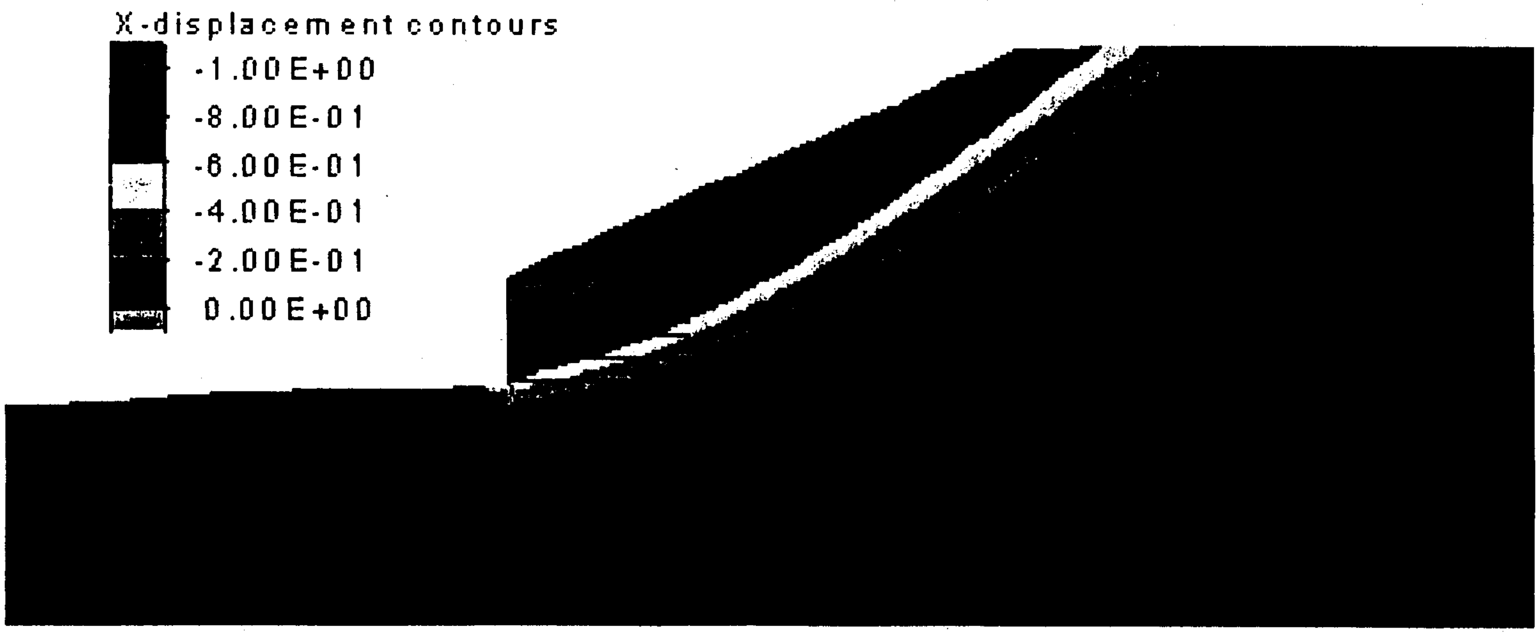
South Wall—FLAC Model
Station 147+25 X-Displacement Contours in Feet



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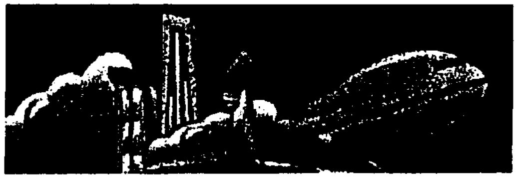
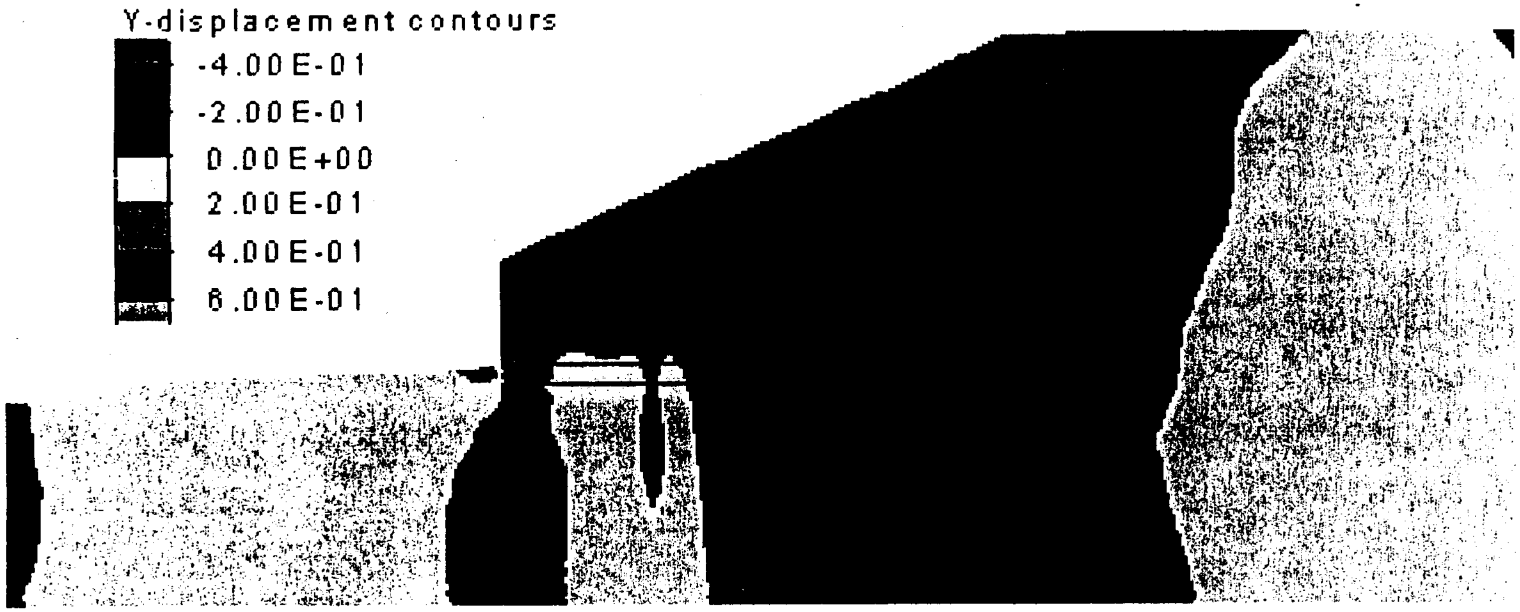


South Wall—FLAC Model

Station 147+25 Y-Displacement Contours in Feet



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Wall Settlements

Subgrade improvement reduces wall settlements

	Without Improvement		With Improvement	
	Total*	Differential	Total*	Differential
NSA	12	1/50	6	1/200
West	~~20~~ 12	1/50	6	1/100 to 1/200
South	3	< 1/200	Negligible	Negligible

*unit = inches

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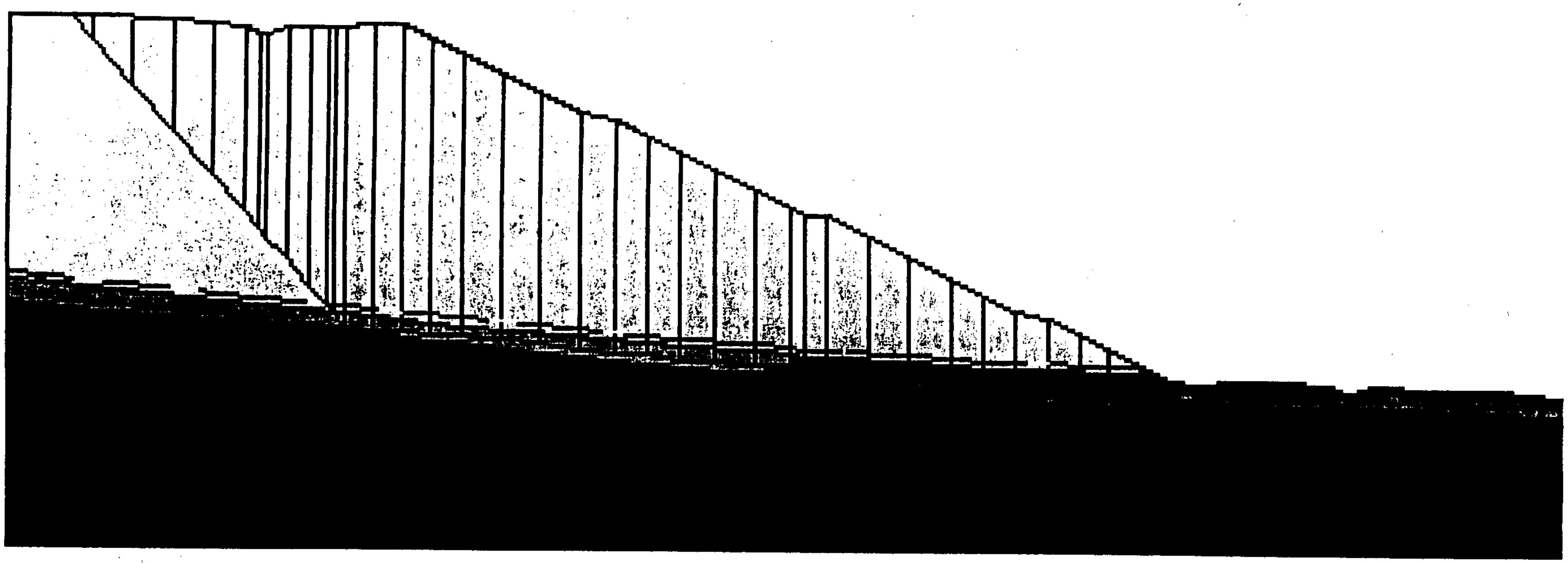
2H:1V Embankment

2H:1V Embankment
Station 193+19



AR 026091

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MAIN POINTS Get into more detail

Embankment Slope

+ soft to m stiff clay where undrained BUT, areas are coincident

- Need for subgrade improvement primarily governed by liquefied soils
- Liquefaction analysis and residual strength for 72-, 175-, 300-, and 475-year events
- Statistical analysis to determine available composite strength
- Risk- and performance-based design

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Soil Conditions of Prime Concern for Stability Analysis

- Liquefiable sand occurs below most of the embankment between north and west walls
- Soft to medium stiff clay with relatively low shear strength occurs in the north embankment footprint

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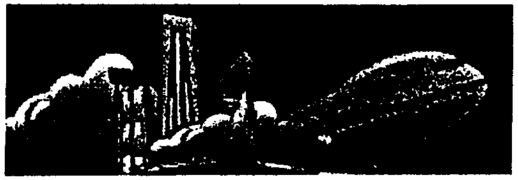

Describe initial approach before

Prediction of Liquefaction

- Loose to medium dense liquefiable soils exist near ground surface
- Liquefiable soil stratified vertically
  - gradational changes w/ fines
  - density
- Groundwater level varies below embankment
  - Seasonal fluctuation
  - Perched condition

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Table 4. Boring Groundwater Data for the 2H:1V Slope Area Between NSA and West Walls

	Exploration	Exploration Depth	Exploration Elevation	Rough Estimate of the Minimum Depth to GWT	Depths that are Potentially Liquefiable (475-yr / 175-yr)	ATD depth	Contour Map December 1999 GWT Depth	Contour Map December 1999 GWT Elevation	Nearby groundwater monitoring well information (elevations, depths, and flux): name	distance	first reading	last reading	duration in days	Ground Elevation	maximum GWT el.	minimum GWT el.	maximum GWT depth	minimum GWT depth	recorded flux
L	HC00-B301	24	263.5	1	12.5-17' / 12.5-14.5'	12	off map	off map	own well	n/a	8/18/00	8/18/00	0	263.5	262.2	262.2	1.3	1.3	0.0
									HC00-B173	170' SE	2/14/00	7/10/00	147	273.63	266.5	263.5	10.2	7.1	3.0
?	HC00-B172	30	280	2-10'	0-8'	14	2	278	HC00-B173	130' W	2/14/00	7/10/00	147	273.63	266.5	263.5	10.2	7.1	3.0
L	HC00-B173	25.8	273	7-10'	0-8', 17-20'	10	off map	off map	own well	n/a	2/14/00	7/10/00	147	273.63	266.5	263.5	10.2	7.1	3.0
L / N	HC00-B174	24	267	7	10-17' / none	7	off map	off map	HC00-B173	85' E	2/14/00	7/10/00	147	273.63	266.5	263.5	10.2	7.1	3.0
?	CT97-B3A	21.5	273	0-19'	0-13' / 0-8'	19	-2	275	HC00-B173	50' NW	2/14/00	7/10/00	147	273.63	266.5	263.5	10.2	7.1	3.0
?	HC99-B58	24.5	291	5	0-8'	5	7	284	own well	n/a	12/9/99	5/9/00	152	291.3	dry	dry	dry	dry	dry
L	HC99-B72	23.9	282	2	0-5'	12	1	282	own well	n/a	12/9/99	7/10/00	214	281.6	279.5	276.7	4.9	2.1	2.8
L	HC99-B61	27.8	302	6	0-10' / 0-5'	11	11	291	own well	n/a	10/13/99	5/9/00	209	301.8	296.4	290.4	11.4	5.4	6.0
L	HC99-B64	34	292	4	0-10' / 0-5', 8-10'	7	4	288	own well	n/a	12/9/99	7/10/00	214	292	288.2	285.7	6.4	3.9	2.5
L / N	HC99-B73	23.8	292	2	0-8' / none	8	4	288	own well	n/a	10/13/99	7/10/00	271	291.7	289.3	283.4	8.3	2.4	5.9
N	HC99-B71	19.9	302	4	none	17	6	296	own well	n/a	10/13/99	7/10/00	271	302	297.8	289.9	12.1	4.2	7.9
L	HC00-B302	18.9	290.5	5-10'	0-12' / 5-12'	10	3	288	own well	n/a	8/18/00	8/18/00	0	290.5	281.5	281.5	9.0	9.0	0.0
									HC99-B73	200' N	10/13/99	7/10/00	271	291.7	289.3	283.4	8.3	2.4	5.9
L / N	HC00-B303	23.5	304	>4'	7-10', 12-15' / none	nw	9	295	HC99-B71	245' N	10/13/99	7/10/00	271	302	297.8	289.9	12.1	4.2	7.9
?	HC00-B304	18.5	286	0-15'	0-5'	15	2	284	HC00-B137	350' SW	6/19/00	7/10/00	21	264.5	264.7	263.1	1.4	-0.2	1.6
? / N	HC00-B300	15.3	291	0-11'	0-4' / none	11	13	278	HC00-B137	175' W	6/19/00	7/10/00	21	264.5	264.7	263.1	1.4	-0.2	1.6
N	HC00-B137	15.6	284	0	none	10.6	-3	287	own well	n/a	6/19/00	7/10/00	21	264.5	264.7	263.1	1.4	-0.2	1.6
N	HC00-B305	18.5	284.4	0-18'	none	16	12	272	own well	n/a	8/18/00	8/18/00	0	284.4	dry	dry	dry	dry	dry
									HC00-B137	80' W	6/19/00	7/10/00	21	264.5	264.7	263.1	1.4	-0.2	1.6
L	HC00-B306	18.3	295	1-8'	0-7', 10-12' / 5-7'	8	26	269	own well	n/a	8/18/00	8/18/00	0	295	287.4	287.4	7.6	7.6	0.0
									HC00-B142	200' S	3/9/00	7/10/00	123	270.1	269.5	267.6	2.6	0.6	1.9
L / ?	HC99-B75	23	284	>1'	0-12' / 0-5'	nw	3	282	HC00-B142	135' W	3/9/00	7/10/00	123	270.1	269.5	267.6	2.6	0.7	1.9
?	HC99-B76	18.3	275	>1'	0-10' / 4-7'	nw	4	272	HC00-B142	55' SW	3/9/00	7/10/00	123	270.1	269.5	267.6	2.6	0.7	1.9
?	HC99-B77	18.6	266	>1'	0-5'	17.5	4	262	HC00-B146	75' SW	3/9/00	7/10/00	123	260.7	259.8	257.6	3.1	0.9	2.1
? / N	HC99-B78	18.5	262	1-18'	4-7' / none	nw	6	256	HC00-B146	80' SE	3/9/00	7/10/00	123	260.7	259.8	257.6	3.1	0.9	2.1
? / N	HC99-B79	17.9	279	>1'	0-7' / none	nw	3	276	HC00-B142	85' SWW	3/9/00	7/10/00	123	270.1	269.5	267.6	2.6	0.7	1.9
?	HC99-B80	17.6	282	>1'	0-5'	nw	3	280	HC00-B142	115' SWW	3/9/00	7/10/00	123	270.1	269.5	267.6	2.6	0.7	1.9
N	HC00-B146	14.4	261	0	none	9	2	259	own well	n/a	3/9/00	7/10/00	123	260.7	259.8	257.6	3.1	0.9	2.1
N	HC00-B142	24.6	270	0	none	14	1	269	own well	n/a	3/9/00	7/10/00	123	270.1	269.5	267.6	2.6	0.7	1.9
? / N	HC00-B138	20.4	247	1-17'	0-5' / none	17	off map	off map	HC00-B146	210' NE	3/9/00	7/10/00	123	260.7	259.8	257.6	3.1	0.9	2.1
N	HC00-B307	18.8	267	1-19'	none	nw	off map	off map	HC00-B145	160' SE	2/14/00	7/10/00	147	262.8	262.2	260.5	2.3	0.6	1.7
L	HC00-B145	19.8	263	0	0-13'	12	off map	off map	own well	n/a	2/14/00	7/10/00	147	262.8	262.2	260.5	2.3	0.6	1.7
N	HC00-B143	10.9	239	1	none	9	off map	off map	own well	n/a	6/19/00	7/10/00	21	239.1	238.0	236.3	2.8	1.1	1.7
L / N	HC00-B144	14.4	247	0	0-7' / none	9	off map	off map	own well	n/a	3/9/00	7/10/00	123	246.6	246.0	243.2	3.4	0.6	2.8
L	HC00-B139	19.5	255	0	0-8'	9	off map	off map	HC00-B144	110' W	3/9/00	7/10/00	123	246.6	246.0	243.2	3.4	0.6	2.8

Site and Exploration Plan

Embankment Slope Between NSA and West MSE Walls

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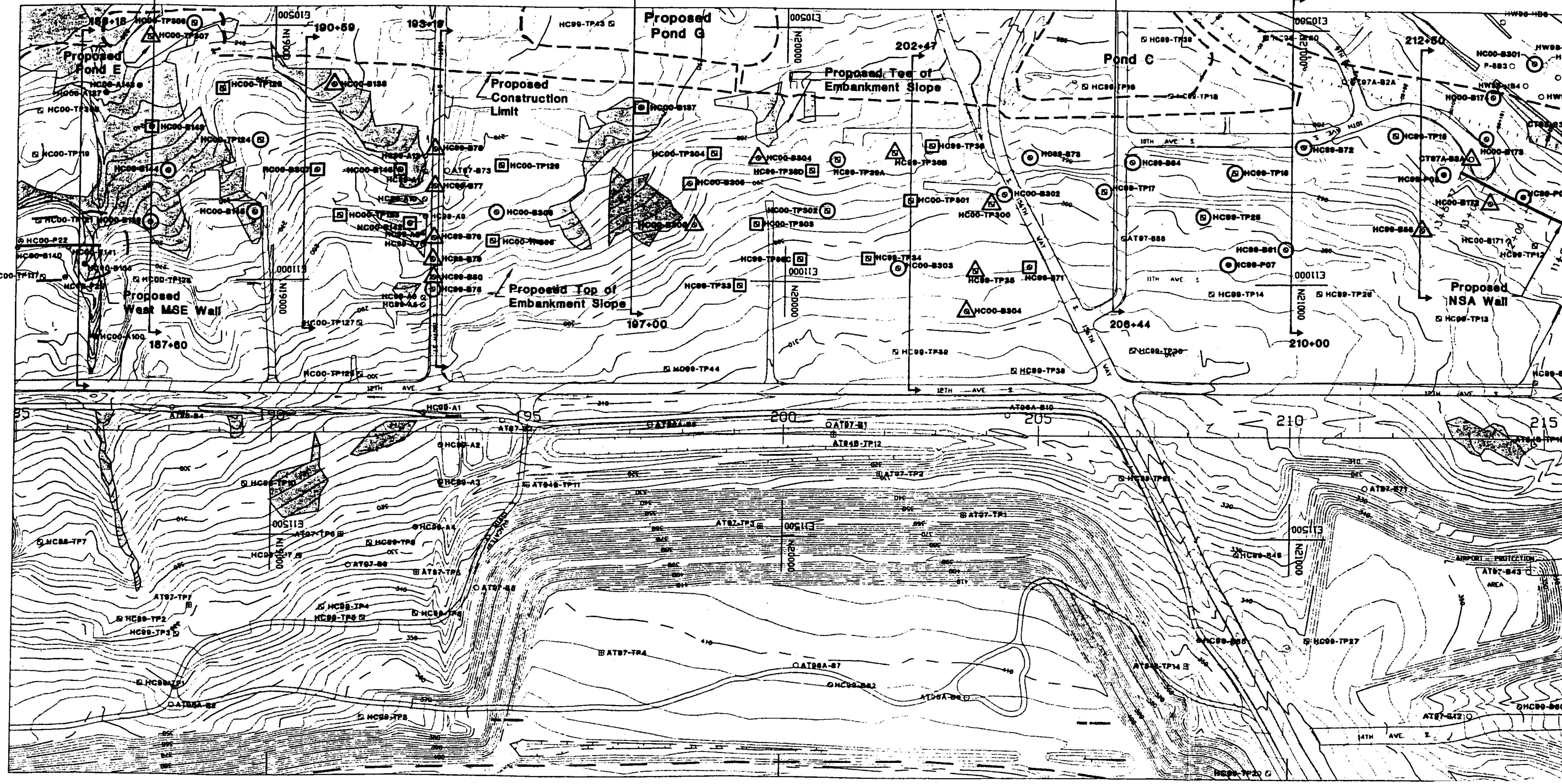

Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetland delineation provided Parametrix drawing entitled, "W_110800.dwg", dated November 8, 2000.

Estimated Liquefaction Susceptibility (10% Probability of Exceedence in 50 Years)

- HC00-TP36A ⊡ Potential Liquefaction for Existing Conditions
- HC00-TP36B △ Potental Liquefaction if Groundwater Table Rises
- HC00-TP301 ⊡ No Liquefaction Expected

- ● HC99-P08 Cone Probe Location and Number
- ⊙ HC00-B306 Boring Location and Number
- ⊡ HC00-TP126 Test Pit Location and Number
- Wetland Location
- 210+00 Cross Section Location and Designation

N

0 200 400
Scale in Feet

AR 026096

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J-4978-28 11/00

Figure 2

RC 11/14/00 1=200 (xref)see drawing file/charlie.pc2
49782805

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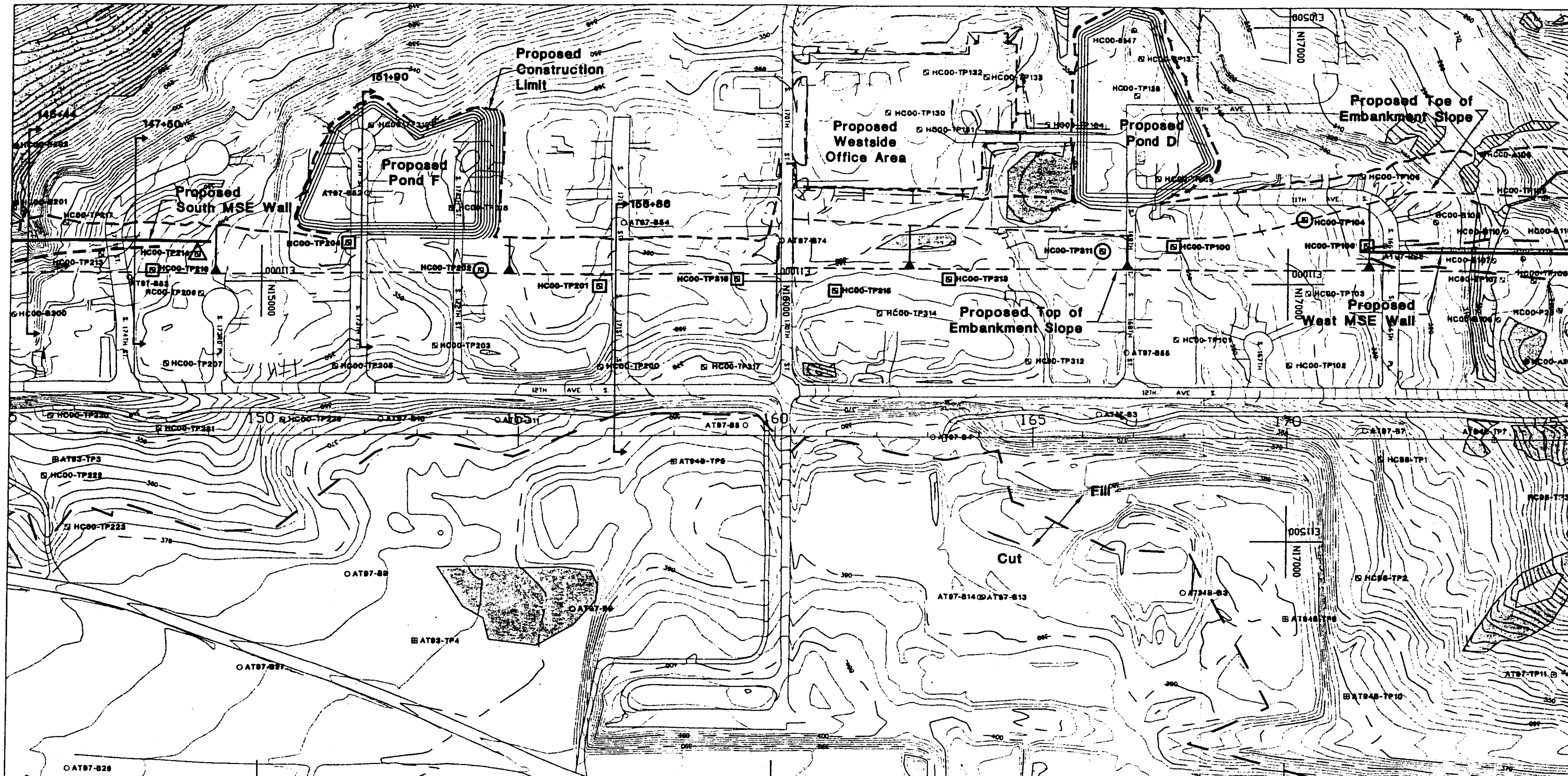
Site and Exploration Plan

Embankment Slope Between West and South MSE Walls



Note: Base map prepared from drawing provided by HNTB entitled "Topo_Full.dwg", dated October 4, 1999. Wetland delineation provided Parametrix drawing entitled, "W_110800.dwg", dated November 8, 2000.

Estimated Liquefaction Susceptibility (10% Probability of Exceedence in 50 Years)

- HC00-TP38A Potential Liquefaction for Existing Conditions
- HC00-TP38B Potental Liquefaction if Groundwater Table Rises
- HC00-TP301 No Liquefaction Expected

- HC99-P08 Cone Probe Location and Number
- HC00-B306 Boring Location and Number
- HC00-TP126 Test Pit Location and Number
- Wetland Location
- 156+86 Cross Section Location and Designation

N

0 200 400
Scale in Feet

AR 026097

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J-4978-28 11/00

Figure 3

RC 11/14/00 1=200 (xref)see drawing file/charlie.pc2
4978280

Embankment Slope Stability Analysis

- Selected two cross sections to analyze need for subgrade improvement
- Performed slope stability (SLOPE/W) for conditions described previously
- Continued analysis for liquefaction and pseudo-static cases for additional cross sections based on results

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Potentially Liquefiable Sand

- Evaluated extent of saturation for liquefaction analysis
  - Assumed complete saturation for MSE wall subgrade
  - Used existing moisture conditions in soil for analysis
  - Checked long-term case by modeling subgrade saturation over time
- Areas defined for possible subgrade improvement

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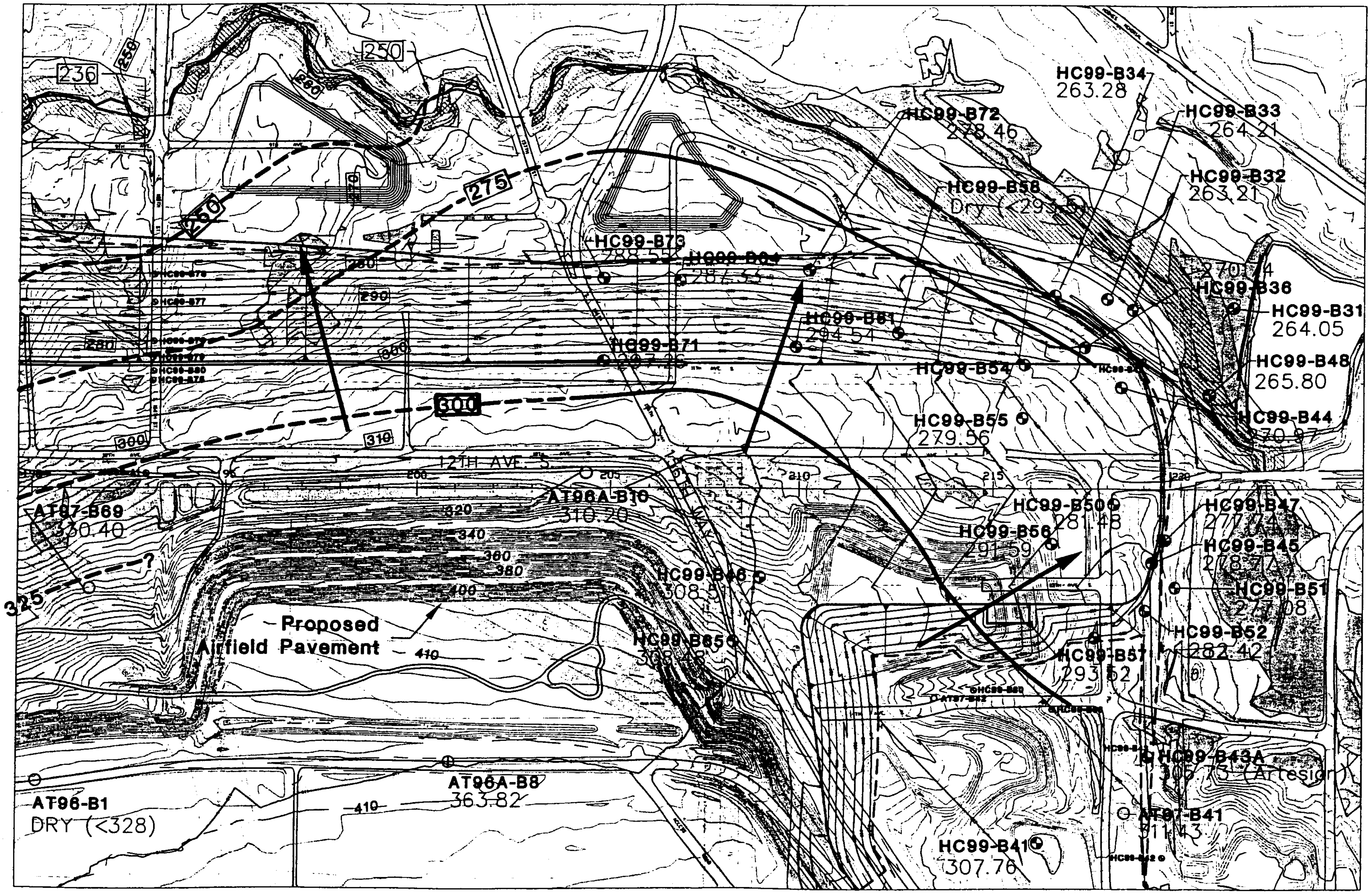
Groundwater Elevation Contour Map

Wet Season (December 9, 1999)



—250—	Groundwater Elevation Contour in Feet (Dashed Where Inferred)	←	Inferred Groundwater Flow Direction
⊕HC99-B35	Monitoring Well Location and Number	175	Runway Stationing
286.79	Groundwater Elevation in Feet (December 9, 1999)		Wetland
(Artesian)	Water Level above Ground Surface		

N

0 300 600

Scale in Feet

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

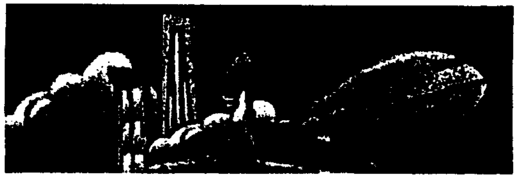
AR 026100

HARTCROWSER

J-4978-18 3/00

Figure 5

RC 3/20/00 1=300 (xref)see drawing file/woodstck.pc2
4978184



Post-Liquefaction Residual Strength

- Trigger liquefaction analysis using SPT and CPTu data
- Correlation between SPT-N and residual strength
- Statistical analysis of residual strength in liquefied soil zones
- *In situ* moisture and post-embankment seepage model for groundwater influence

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Post-Liquefaction Residual Shear Strength Results

Recurrence Interval in years	Percentage of Liquefied Samples*	Undrained Residual Shear Strength in psf
72	0	N/A
175	9	300
300	21	500
475	33	660

*Based on an analysis of 32 borings performed in the embankment footprint that were sampled using SPT method

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"Composite" Soil Shear Strength

- For 475-year design event, calculated 33% of volume undergoes liquefaction:

$$\tau = 0.33 * c + (1 - 0.33)\ \sigma_v * \tan \phi$$

  - $H = 40$ ft → $\tau = 2{,}500$ psf
  - $H = 65$ ft → $\tau = 3{,}900$ psf
  - $H = 85$ ft → $\tau = 5{,}000$ psf
  - $H_{MAX} = 115$ ft → $\tau = 6{,}700$ psf

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Embankment Infiltration and Seepage

- Seepage modeling (HELP)
- Precipitation: runoff, infiltration, seepage
  - Seepage through embankment flow in drain layer
  - Deep percolation below drain
  - Groundwater flow laterally in subgrade
  - Deep percolation through underlying till/clay

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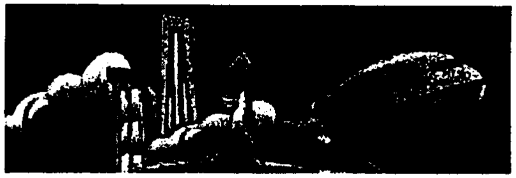
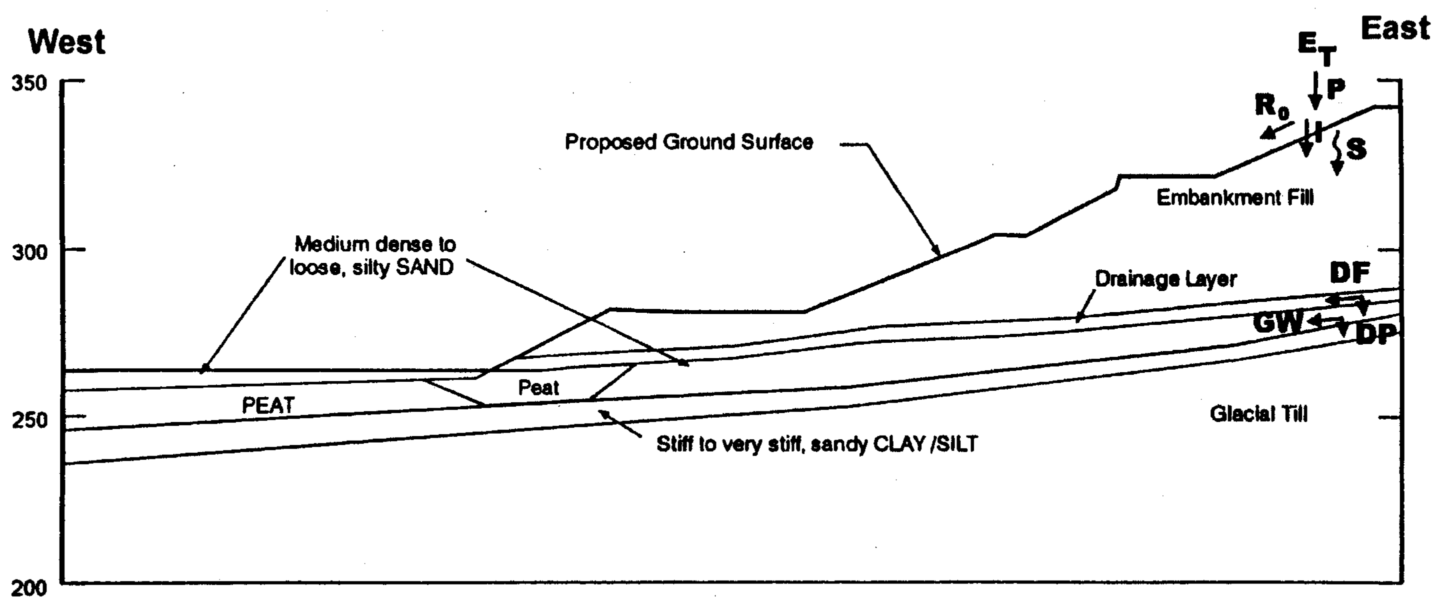


Embankment Slope Section Showing Seepage Model Parameters



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Embankment FLAC Analysis

- Subgrade improvement governed by liquefaction
- FLAC used to assess deformation/stability and assist in finalizing subgrade improvement needs
- Residual and composite shear strength for 72-, 175-, 300-, and 475-year events considered
- Statistical analysis of extent of liquefaction using both both composite and residual shear strength
- Risk and performance basis for selected subgrade improvement area from results of both FLAC and SLOPE/W

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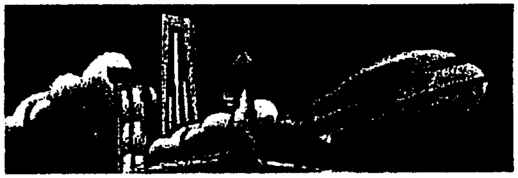
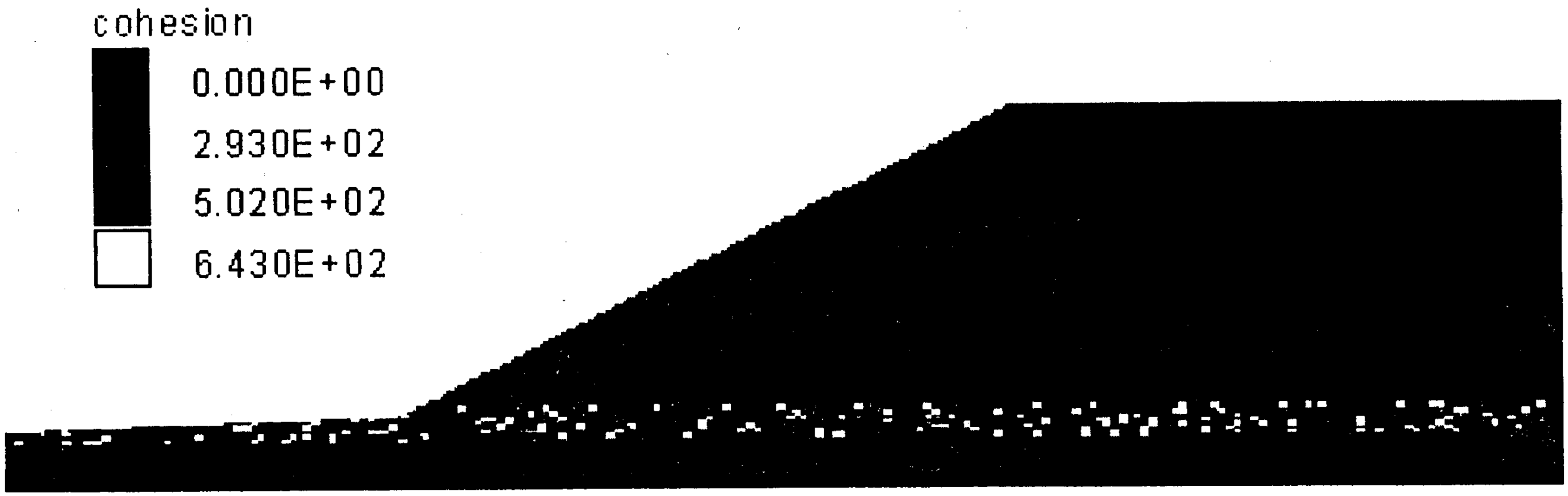


FLAC Model—Statistical Prediction of Liquefaction Extent



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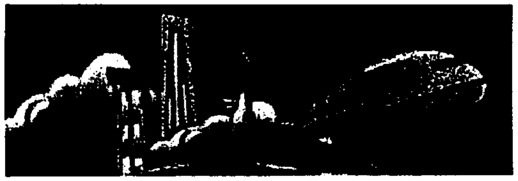

Result of Pore Pressure Analysis

- Adequate factors of safety for fill placement at or less than 4 feet per day over soft to medium stiff layer
- Undrained case results in adequate factors of safety for very stiff to hard clay

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Subgrade Improvements Parametric Analyses

- Critical height analysis for global liquefaction (i.e., factor of safety versus embankment height)
- Raise grade of the road at toe (i.e., buttress)
- Replace subgrade improvement with geogrid reinforcement in embankment
- Location of subgrade improvement zone

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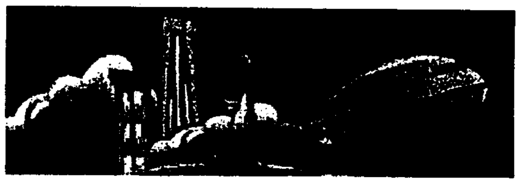

Embankment Constructability Issues

- Surface preparation
- Embankment fill materials
  - Embankment zonation
    - Meet soil shear strength requirements for slope stability
    - Maximize contractor flexibility for fill sources

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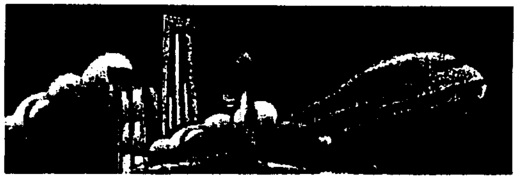
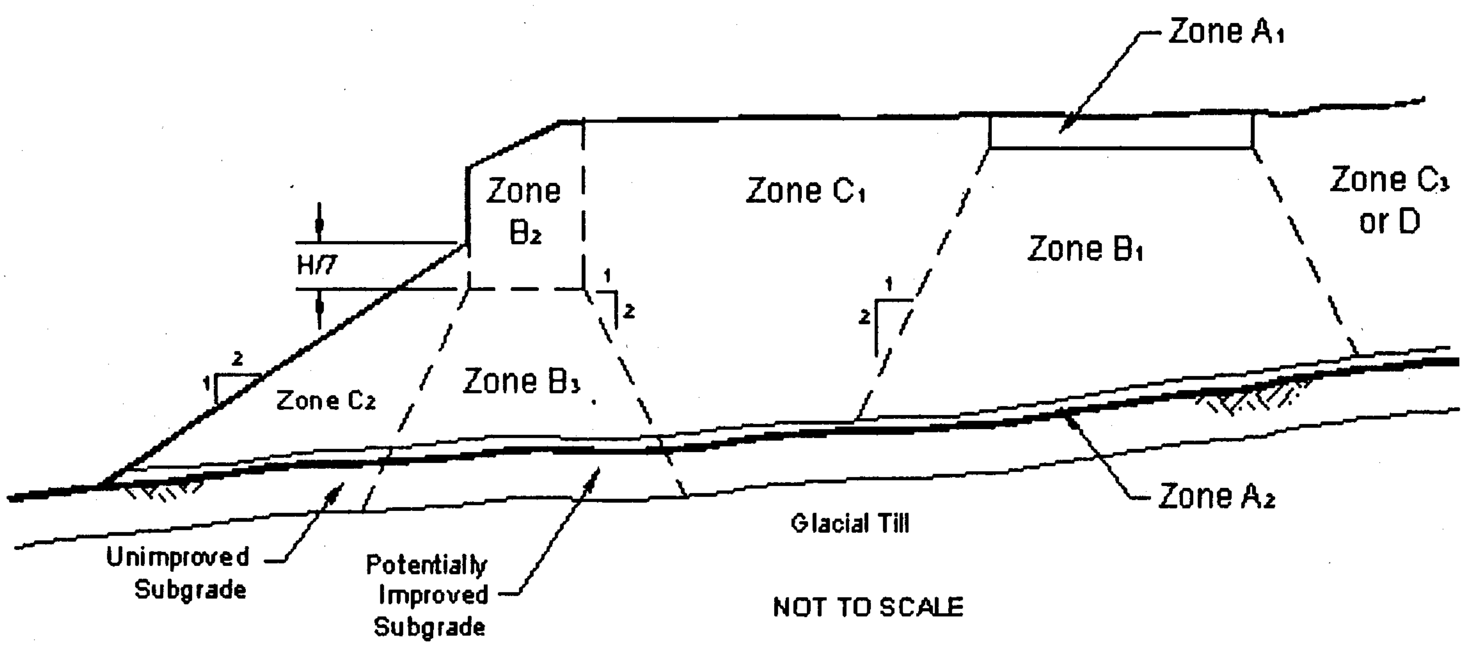


Conceptual Zoned Embankment Cross Sections



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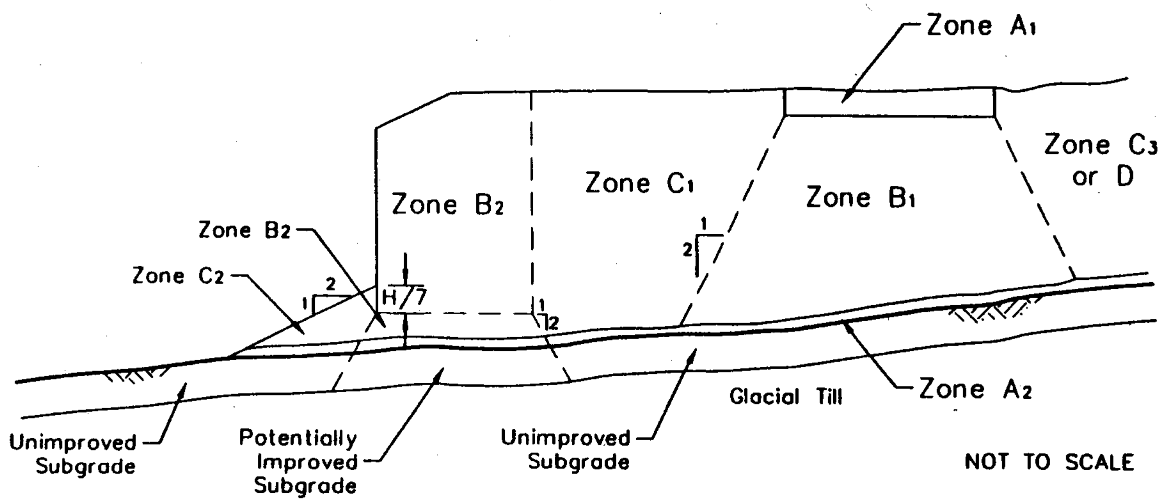
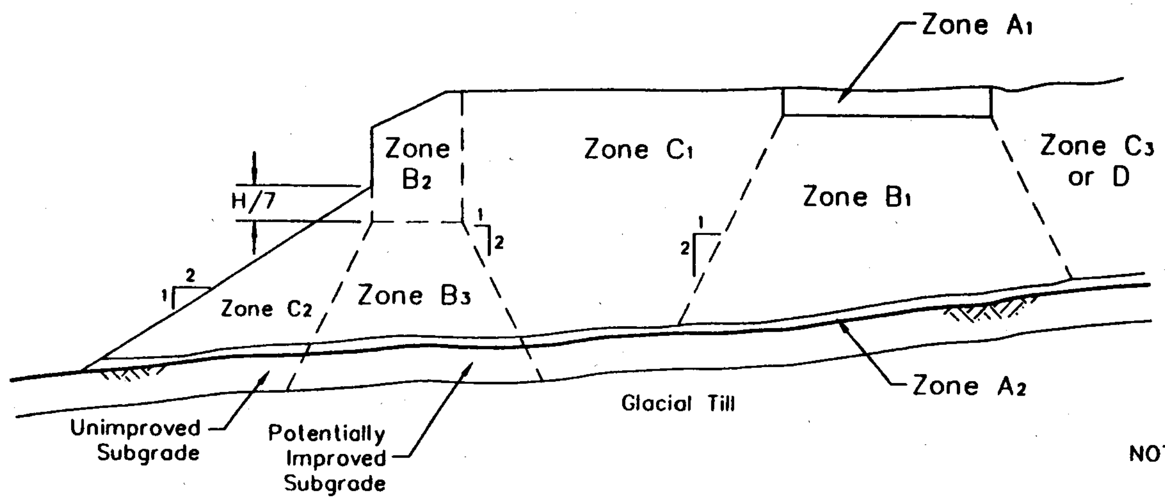
Conceptual Zoned Embankment Cross Sections

EMBANKMENT ZONES

- A_1 PAVEMENT SUBGRADE
- A_2 DRAINAGE
- B_1 PAVEMENT SUPPORT
- B_2 MSE REINFORCING
- B_3 MSE SUPPORT
- C_1 COMMON EMBANKMENT BEHIND WALLS
- C_2 COMMON EMBANKMENT, SLOPES
- C_3 COMMON EMBANKMENT, OTHER
- D NON-STRUCTURAL FILL



(i) MSE RETAINED EMBANKMENT



(ii) MSE RETAINED EMBANKMENT (Walls on Embankment Fill)

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Figure 1

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Table 7 - Zone B_2 Fill

Zone B_2	Proposed Specification Requirements			Recommended Design Parameters[1]		
	Minimum % Compaction ASTM D 1557[2]	**Moisture Range Relative to OMC[3]**	**Maximum Loose Lift Thickness in Inches[4]**	**γ in pcf**	**c′ in psf**	**ϕ′ in deg.**
Group 1A	92	±3	12	140	0	37
Group 1B	92	±3	12	140	0	37
Group 2[5]	95	±2	12	140	0	37
Group 3	-	-	-	-	-	-
Group 4	-	-	-	-	-	-

1. The soil shear strength values shown do not consider any contribution of the reinforcing elements.
2. Less compaction acceptable within 5 feet of wall to control panel displacement during construction.
3. Moisture content for compaction may be reduced to "dry side" of OMC per RECo recommendation.
4. Maximum 10-inch compacted lift thickness.
5. Fines content for Group 2 would preclude wet weather placement.

Table 9 - Zone C_1 Fill

Zone C_1	Proposed Specification Requirements			Recommended Design Parameters		
	Minimum % Compaction ASTM D 1557	**Moisture Range Relative to OMC**	**Maximum Loose Lift Thickness in Inches**	**γ in pcf**	**c′ in psf**	**ϕ′ in deg.**
Group 1A	90	±3	12	135	0	35
Group 1B	90	±3	12	135	0	35
Group 2	90	±2	12	135	0	35
Group 3	92	-2~+3	8	135	0	35[1]
Group 4	92	-2~+1	8	130	0	35[1]

(1) Soil strength value for Group 4 and Group 3 soils should be verified in the laboratory and/or field tests to demonstrate these materials have sufficient strength, or the recommended design parameters may need to be modified for the global stability analysis.

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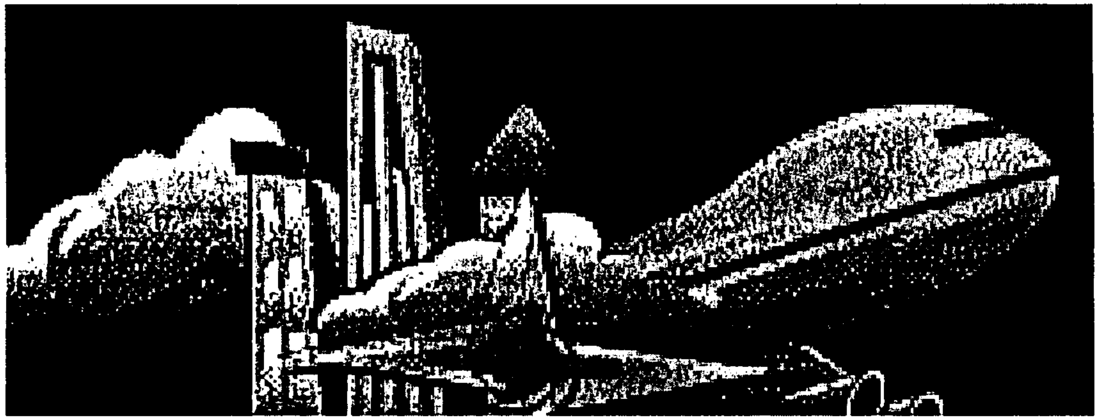
Table 5 - Soil Gradations for Fill Material "Groups"

Sieve Size	Percent Passing		
	Embankment Fill (Not Reinforced)	Steel Strip Reinforced Zones	Geosynthetic Reinforced Zones Below Walls
Group 1A			
6-inch	100	-	-
4-inch	-	100	-
3-inch	70 to 100	70 to 100	-
1¼-inch	-	-	100
¾-inch	50 to 77	50 to 77	50 to 77
U.S. No. 4	30 to 50	30 to 50	30 to 50
U.S. No. 40	3 to 15	3 to 15	3 to 15
U.S. No. 200(1)	0 to 5	0 to 5	0 to 5
Group 1B			
6-inch	100	-	-
4-inch	-	100	-
3-inch	70 to 100	70 to 100	-
1¼-inch	-	-	100
¾-inch	35 to 80	35 to 80	35 to 80
U.S. No. 4	20 to 55	20 to 55	20 to 60
U.S. No. 40	3 to 30	3 to 30	3 to 30
U.S. No. 200(1)	0 to 8	0 to 8	0 to 8
Group 2			
6-inch	100	-	-
4-inch	-	100	-
3-inch	70 to 100	70 to 100	-
1¼-inch	-	-	100
¾-inch	50 to 85	50 to 85	50 to 85
U.S. No. 4	30 to 65	30 to 65	30 to 65
U.S. No. 40	5 to 30	5 to 30	5 to 30
U.S. No. 200(1)	0 to 12	0 to 12	0 to 12
Group 3			
6-inch	100	-	-
U.S. No. 4	50 to 100	-	-
U.S. No. 40	20 to 60	-	-
U.S. No. 200(1)	0 to 35	-	-
Group 4			
6-inch	100	-	-
¾-inch	75 to 100	-	-
U.S. No. 4	50 to 100	-	-
U.S. No. 40	20 to 70	-	-
U.S. No. 200(1, 2)	0 to 50	-	-

1. The fine-grained soil percentage passing the U.S. No. 200 is based on the fraction of the soil passing the ¾-inch sieve
2. P.I. < 4 for fine-grained fraction.

Seattle-Tacoma International Airport



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