ATTACHMENT I

LOGS OF BOREHOLES RF#14 TO RF#29

ATTACHMENT I

LOGS OF BOREHOLES RF#14 TO RF#29

As mentioned in Section 6.2.2, an exploratory program that included fifteen boreholes was undertaken to gain an understanding of the subsurface geologic conditions at the WHB Area and to provide access for downhole and suspension seismic geophysical methods. Drilling of the exploratory boreholes began in June 2000 and concluded in November 2000. The boreholes were located as shown on Figure 2 in the main text and as tabulated in Table I-1. Four of the fifteen boreholes were continuously cored from the surface with PQ (3.35 inch) and HQ (2.5 inch) coring systems. The remaining eleven boreholes were conventional mud rotary holes, although an interval at the bottom of borehole RF#22 was cored. The cored boreholes were logged based on the core, while the mud rotary holes were logged based on the drill cuttings.

Table I-1 Borehole Locations, Total Depth and Drilling Method

Designation	Northing	Easting	Elevation (ft.)	Total Depth (ft.)	Drilling Method
RF#14	N765,309	E571,065	3651.5	550.0	Core
RF#15	N765,774	E570,225	3681.0	330.0	Core
RF#16	N765,056	E570,473	3672.0	452.8	Core
RF#17	N766,076	E571,042	3672.4	667.8	Core
RF#18	N764,522	E570,627	3640.3	493.6	Mud Rotary
RF#19	N765,880	E571,384	3661.8	645.2	Mud Rotary
RF#20	N765,637	E570,797	3671.3	160.0	Mud Rotary
RF#21	N765,899	E570,739	3673.0	192.2	Mud Rotary
RF#22	N766,206	E570,793	3679.2	540.6	Mud Rotary/core
RF#23	N765,311	E570,465	3674.0	159.1	Mud Rotary
RF#24	N766,344	E570,542	3684.5	268.0	Mud Rotary
RF#25	N765,968	E570,626	3676.5	159.0	Mud Rotary
RF#26	N765,248	E570,580	3670.8	264.9	Mud Rotary
RF#28	N765,510	E570,105	3680.6	99.8	Mud Rotary
RF#29	N766,018	E570,836	3672.7	430.0	Mud Rotary

DTN: GS020383114233.003

Note: DTN: GS020383114233.003 has some minor internal inconsistencies, as follows: RF#24: Log page 1 says at the top that total depth is 268.0 feet and at the bottom that total depth is 267.9 feet. RF#26: Log page 1 says at top that total depth is 264.9 feet and at bottom that total depth is 265.0 feet. RF#28: log page 1 says at the top that total depth is 100.0 feet and at the bottom that total depth is 99.8 feet. The values used herein are based on a review of the data.

The borehole logs were initiated in the field and finalized based on examination in the Sample Management Facility. The final logs are presented in alphanumerical order beginning on the second page following this page. The final logs may also be found in DTN: GS020383114233.003.

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,308.73 E 571,065.44	GROUND ELEVATION: 3651.52
BEGUN: 9/13/2000 FINISHED: 9/27/2000	TOTAL DEPTH: 550.0 ft.	ANGLE FROM HORIZONTAL: -90
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 101.8 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

Column headings: NOTES | DEPTH | SHEAR WAVE VELOCITY ft/s (1000 2000 3000 4000 5000 6000 7000 8000 9000) | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION

NOTES

Purpose of Hole:
Develop geologic design data required for Waste Handling Building foundation parameters and seismic hazard analysis.

Drill Equipment:
Schramm T685 Drill Rig, UDR 1000 Drill Rig

Drillers:
D. Harrison, R. Mckay; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Used 12" hammer to 5.02. Cement 10.75 O.D. casing with 1.29 stickup. Re-enter hole on 9/13/2000 with PQ coring system. Cored with PQ to 116.06. Used PQ rods as casing and installed HQ coring system. Cored with HQ to the total depth of 549.99.

Drilling Conditions:
0.00 to 443.06: Replaced 2 bits.

Drilling Fluid:
0.00 to 5.02: Non-potable water. 5.02 to 290.09: Non-potable water, Quick Gel mud with EZ-Mud. 290.09 to 294.15: non-potable water, Quik Gel mud with EZ-Mud and LCM to re-establish circulation. 294.15 to 549.99: Non-potable water, Quick Gel mud with EZ-Mud.

Loss Intervals:
290.09 to 294.15

Casing Record:
0.00 to 4.72: 10.75 O.D. casing.
0.00 to 116.06: PQ casing
116.06 to 549.99: No casing

Hole Completion:
Ream hole from 5.00 to 550.15 with 8.5 Tricone Bit. Set and cement 512.22 of 4.5" PVC casing.

LOG (DEPTH 0–50)

% CORE RECOVERY	GEOLOGIC UNIT [USCS]
0	Qal
100	Qal (GP-GM)s
50	
100	Qal (GP)s
59	Qal GW
100	
63	Qal (GP)s
73	Qal (GP)sc
39	Qal GW
77	Qal (SM)g
100	Qal (GP)s
23	
100	
70	
91	Qal (SP)g
0	NR

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 101.8 ft. QUATERNARY ALLUVIUM (Qal)

0.0 to 5.0: No Recovery

5.0 - 9.1: POORLY GRADED GRAVEL WITH SAND AND SILT (GP-GM)s; About 50% fine to coarse, hard, subrounded to subangular gravel; about 40% predominately fine, hard, subrounded to subangular sand; about 10% nonplastic fines, no dry strength, rapid dilatancy, low toughness; maximum size 65mm, dry, light brown; strong reaction with HCl; firm, strongly cemented.

9.1 - 11.5: POORLY GRADED GRAVEL WITH SAND (GP)s; About 60% fine to coarse, hard subrounded to subangular gravel; about 35% fine to coarse, subrounded to subangular sand; about 5% nonplastic fines, no dry strength, rapid dilatancy, low toughness; maximum size 75mm, dry, light brown; strong reaction with HCl; firm, weak to strongly cemented.

11.5 - 14.9: WELL GRADED GRAVEL (GW); About 100% fine to coarse, hard, subrounded to angular gravel; maximum size 75mm, light brown; 10% of gravel is partially coated with up to 1mm white caliche.

14.9 - 18.1: POORLY GRADED GRAVEL WITH SAND (GP)s; About 70% fine to predominately coarse, hard, subrounded to subangular gravel; about 25% predominately fine sand; about 5% nonplastic fines, no dry strength, rapid dilatancy, low toughness; trace of cobbles; maximum size 95mm, dry, light brown; weak reaction with HCl; firm, weakly cemented.

18.1 - 23.2: POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc; About 65% fine to coarse, hard, subangular to angular gravel; about 30% predominately fine sand; about 5% nonplastic fines, no dry strength, rapid dilatancy, low toughness; trace of cobbles; maximum size 215mm, dry, light brown; weak to strong reaction with HCl; firm, weak to moderately cemented.

23.2 - 26.8: WELL GRADED GRAVEL (GW); About 100% fine to coarse, hard, subrounded to angular gravel; maximum size 75mm, light brown; 10% of gravel is partially coated with up to 1mm white caliche.

26.8 - 30.6: SILTY SAND WITH GRAVEL (SM)g; About 55% predominately fine sand; about 30% predominately fine to coarse, hard, subrounded to subangular gravel; about 15% nonplastic fines, no dry strength, rapid dilatancy, low toughness; maximum size 60mm, dry; weak reaction with HCl; firm, weakly cemented.

30.6 - 44.6: POORLY GRADED GRAVEL WITH SAND (GP)s; About 60% predominately fine to coarse, hard, subangular gravel; about 35% predominately fine to medium sand; about 5% nonplastic fines, no dry strength, rapid dilatancy, low toughness; maximum size 170mm, dry, light brown; weak reaction with HCl; firm, weakly cemented.

44.6 - 47.8: POORLY GRADED SAND WITH GRAVEL (SP)g; About 60% predominately fine to medium sand; about 35% fine to coarse, hard, subrounded to subangular gravel; about 5% nonplastic fines, no dry strength, rapid dilatancy, low toughness; maximum size 160mm, dry, light brown; weak reaction with HCl; firm, weakly cemented.

47.8 - 52.5: NO RECOVERY

52.5 - 55.6: WELL GRADED GRAVEL (GW); About 95% fine to coarse, hard, subrounded to subangular gravel; about 5% fine to coarse, subrounded to subangular sand; maximum size 190mm, moist; no reaction with HCl; approximately 30% of gravel is caliche coated.

COMMENTS:

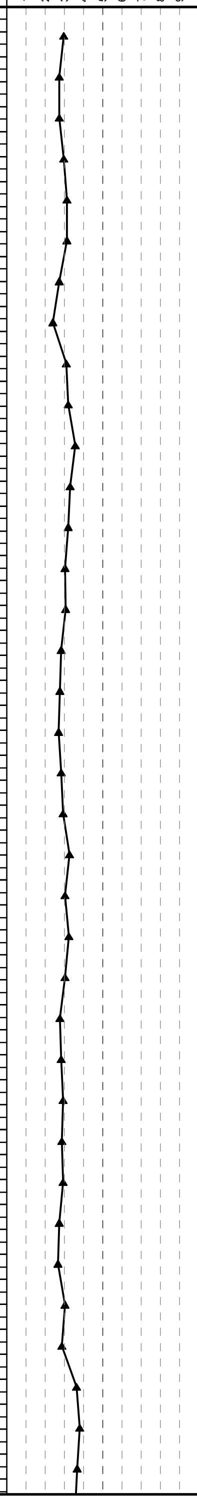
1. All measurements are in feet unless noted otherwise.
2. LCM (Lost Circulation Material) consists of cellephane cuttings.
3. USCS classifications were determined in the field, with limited access to samples to keep samples intact for future tests.
4. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.
5. USCS soil classifications are based on USBR Earth Manual procedure 5005 - Determining Unified Soil Classification (Visual Method)

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

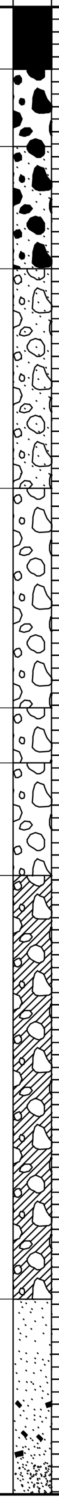
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,308.73 E 571,065.44	GROUND ELEVATION: 3651.52
BEGUN: 9/13/2000 FINISHED: 9/27/2000	TOTAL DEPTH: 550.0 ft.	ANGLE FROM HORIZONTAL: -90
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 101.8 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

NOTES | DEPTH | SHEAR WAVE VELOCITY ft/s | ENGINEERING INDEXES | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION



HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]
			0		NR
			71		Qal GW
			43		Qal (GW)s
			64		Qal (GP)s
			58		
			35		Qal GP
			47		
			0		
			82		Qal (GP)c
			49		Qal (GP)c
H6		FD5	100	73	Qal
		FD6	67	67	
			80	80	
			100	100	
		FD4	88	88	
H7					
H6			88	63	
H7		NR	93	93	
H6		FD2	93	83	
H5			100	65	Tpki
H6		FD1	100	94	



55.6 - 60.5: WELL GRADED GRAVEL WITH SAND (GW)s; About 85% fine to coarse, hard, subrounded to subangular gravel; about 15% predominately fine sand; trace of fines; maximum size 120mm, dry, light brown; weak reaction with HCl; soft weakly cemented.

60.5 - 69.3: POORLY GRADED GRAVEL WITH SAND (GP)s; About 80% fine to coarse, hard, subrounded to subangular gravel; about 15% fine to coarse, subrounded to subangluar sand; about 5% nonplastic fines, no dry strength, rapid dilatancy, low toughness; maximum size 170mm, dry; weak reaction with HCl; soft, weakly cemented.

69.3 - 78.1: POORLY GRADED GRAVEL (GP); About 100% fine to coarse, hard, subrounded to subangular gravel; maximum size 120mm, moist; no to strong reaction with HCl.

78.1 - 80.3: POORLY GRADED GRAVEL WITH COBBLES (GP)c; About 50% coarse, hard, subangular gravel; about 50% cobbles; moist; cobbles have caliche coating.

80.3 - 84.8: POORLY GRADED GRAVEL WITH COBBLES (GP)c; About 80% coarse, subrounded to subangular gravel; about 20% cobbles; moist.

101.8 to 192.5 ft. COMB PEAK IGNIMBRITE - TUFF "X" (Tpki): Pyroclastic flow, nonwelded, moderately indurated light to medium gray tuff with 10 to 15 percent, light greenish-gray, pumice clasts , up to 20 percent grayish-red volcanic lithic clasts and 2 to 3 percent phenocrysts of sanidine and plagioclase. Generally the tuff is slightly weathered (W4), moderately soft (H5) to soft (H6), and very slightly fractured (FD1). Both upper and lower contacts are unconformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
102.3	75	R2	5mm clay
115.8	05	R2	<1mm light brown stain
140.4	15	R2	clean
172.5	25	R2	trace clay
172.2	25	R2	trace clay
188.0	20	R3 to1	sand
189.9	30	R3	trace clay
190.2	35	R3	3mm altered tuff
190.9	30	R2	clean

192.5 to 203.4 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5):
Nonwelded, devitrified, reworked (?) fallout tephra and pyroclastic flows separated by distinct paleosols. Bedded tuffs are very pale orange with 20 to 30 percent pumice clasts and less than 1 percent, pale red, volcanic lithic clasts. The tuff has up to 1 percent quartz, sanidine and lesser plagioclase, with less than 1 percent biotite and manganese oxides. Generally the bedded tuffs are very soft (H7), moderately weathered (W6), and slightly to very slightly fractured (FD2). The lower contact is unconformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
197.3	20	R3	clean
201.8	45	R3	clean

203.4 to 275.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to mostly densely welded, devitrified, pale red to grayish red, with up to 15 percent phenocryts. Phenocryts are mostly sanidine and plagioclase with some quartz and rare biotite. Rare pumice from 212.5 to 222.8 ft. and up to 15 percent pumice clasts from 222.8 to 269.0 ft. From 276.7 to 288.0 ft. the tuff has up to 2 percent pumice clasts and 5 to 8 percent phenocryts of sanidine and plagioclase with rare biotite. Generally the tuff is moderately soft (H5) to mostly moderately hard (H4), moderately to slightly weathered (W4), and intensely to moderately fracture (FD6). The lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
203.6	40	R3	clean
205.0	0	R3	8mm silica
205.4	30	R3	trace white mineral
206.2	35	R3	trace white mineral

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

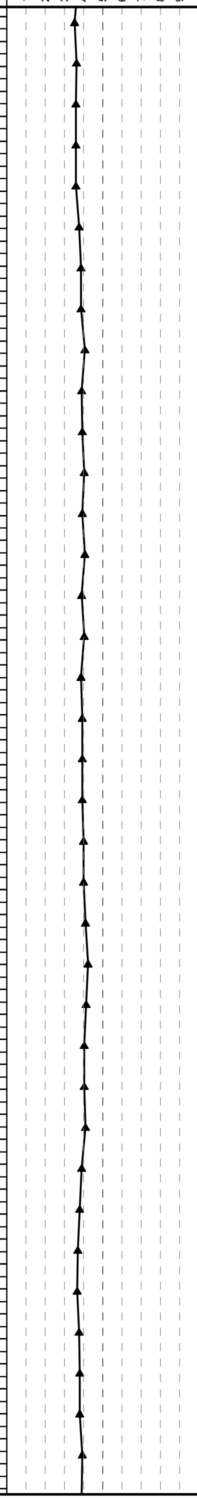
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/13/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,308.73 E 571,065.44
TOTAL DEPTH: 550.0 ft.
DEPTH TO BEDROCK: 101.8 ft.

STATE: Nevada
GROUND ELEVATION: 3651.52
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	110–113					98	96		
	113–115					100	100		
	115–125					96	88		
	125–129					97	97		
	129–139		H6		FD1	96	96	Tpki	
	139–149					100	93		
	149–159					99	99		
	159–168					100	100		



CLASSIFICATION AND PHYSICAL CONDITION

206.5	40	R3	trace white mineral
206.9	20	R3	trace white mineral
208.0	10-20	R3	4mm white mineral
208.6	30	R2	0-5mm white mineral
213.6	35	R2	clean
214.7	10	R2	clean
215.8	10	R3	clean
218.1	30	R3	clean
223.5	25	R3	clean
223.7	50	R3	clean
224.7	40	R2	clean
225.3	20	R2	clean
227.8	15	R3	clean
228.4	25	R2	sand
230.0	05	R3	clean
234.7	40	R2	clean
238.4	30	R2	trace white mineral
240.1	55	R2	clean
243.3	65	R2	clean
250.1	05	R2	10mm tan clay; polished; slickensided
253.2	40	R2	sand; gravel
253.9	30	R3	clean
256.3	45	R2	sand
256.7	15 to 40	R2	sand
257.3	60		1mm white mineral
267.4	10	R3	clean
267.7	60	R2	2mm silica
268.0	0	R3	clean
268.4	0	R3	sand
268.8	20	R3	clean
268.9	25	R3	clean
269.3	30	R3	clean
270.5	10	R2	trace white mineral
270.7	20	R2	trace white mineral
273.4	15	R3	clean
274.3	15	R3	clean

275.0 to 395.0 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, grayish orange to pale red, with 2 to 5 percent lithophysal cavities, up to 20 by 40 mm in size. Lithophysae increase to 15 percent at 310.0 ft and up to 25 percent at 320 ft., with up to 50 percent cavities partially filled with silica. Phenocryts compose less than 1 percent of the tuff mostly sanidine and plagioclase with minor biotite. Also up to 3 percent pumice clasts as large as 40 by 10 mm. Zones of nonwelded, fracture fill(?) from 334 to 359 ft., and 369 to 395 ft. composed of reworked and variously bedded clay/silt sized, tuffaceous material. Generally the tuff is moderately soft (H5) to mostly moderately hard (H4), slightly (W3) to moderately weathered (W5), and intensely to moderately fractured (FD6). Lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
275.9	20	R2	clean
276.0	25	R2	clean
278.7-279.4	30	R2	0.6' breccia; sand & gravel; cemented
279.6-280.0	60	R3	0.4' breccia; sand & gravel; cemented
280.1	35	R3	10mm breccia
282.0	30	R3	trace white mineral
280.9-281.2	50-80		rotated; breccia
281.4	55	R3	breccia
284.0	20	R2	1-2mm silica
283.1-284.9	0-20	R3	clean
285.0	10	R3	1mm silica
285.3	25	R2	clean
286.0	35	R3	trace silica
287.0	25	R2	3mm silica
287.6	25	R3	1mm silica
288.4	60	R3	clean
288.9	35	R3	clean
289.0	70	R3	clean
289.3	15	R2	clean
289.4	65	R3	clean
289.8	10	R3	2mm silica
290.7	25	R2	trace white mineral
291.4-291.6	35	R3	40mm clay, sand, gravel
292.2	35	R3	gravel
291.9	75	R3	2mm silica

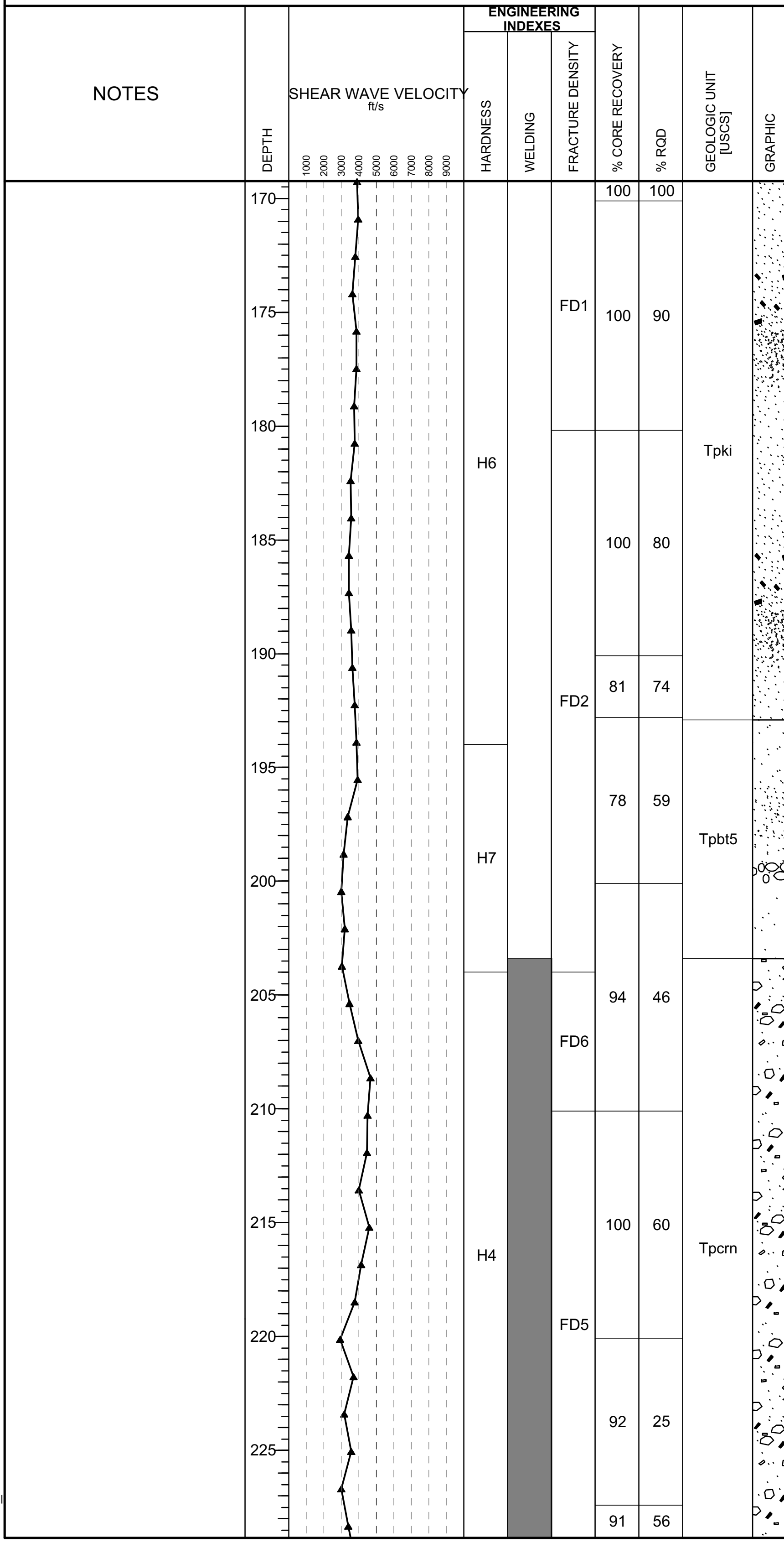
WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/13/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,308.73 E 571,065.44
TOTAL DEPTH: 550.0 ft.
DEPTH TO BEDROCK: 101.8 ft.

STATE: Nevada
GROUND ELEVATION: 3651.52
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown



CLASSIFICATION AND PHYSICAL CONDITION

292.3	80	R3	clean
294.9	45	R3	clay, sand
295.1-295.5	30	R3	breccia, sand, gravel, tr. clay
295.8-296.0	50	R3	breccia, sand, gravel, tr. clay
298.6	30	R3	<1 mm silica
299.2	65	R3	clean
299.8	25	R3	clean
299.7	20	R3	clean
304.2-306.0	70	R2	clay, sand, gravel
306.8	30	R3	1mm silica
307.2	35	R3	1mm silica
308.9	60	R3	20mm silica
308.4	25	R3	2mm silica
310.4	35	R2	1mm quartz
310.6	30	R3	none
311.3	55	R3	none
311.8	55	R3	none
312.0	45	R3	sand, trace quartz
312.2-313.3	45	R2	breccia; sand & gravel
313.8	05	R3	1mm vapor phase minerals
314.5	35	R3	sand
315.2-316.1	45	R2	breccia; sand, gravel, clay
317.0-320.3	20	R2	sand, gravel, clay
322.5	65	R2	none
322.8	05	R2	trace white mineral
322.9	70	R2	none
323.4	50	R3	none
321.0	60	R3	8mm vapor phase alteration
326.3	10	R3	1.2' clay, sand, gravel
327.3	50	R3	clean
329.2	05 to 35	R2	15mm clay
344.8	5 to 15	R4	1mm clay
349.0	05	R3	<1mm white mineral & clay
351.7	35	R3	<1mm clay(?) & MnO(?)
358.0-358.9	85	R2	clay, sand, gravel breccia
359.2	40	R3	1mm clay
359.9	25	R2	3mm sand, gravel, clay
360.4	30	R2	clean
361.6	25	R3	clean
362.2-362.4	65	R2	sand, gravel, clay, MnO
363.4	70	R3	trace white mineral
364.0	35	R3	clean
364.6	55	R3	trace white mineral
364.8	20	R2	MnO coating
366.8-367.5	40	R3	clay, sand, gravel

395.0 to 443.7 ft. TIVA CANYON TUFF CRYSTAL POOR MIDDLE NON-LITHOPHYSAL ZONE (Tpcpmn)
Pyroclastic flow, densely welded, devitrified, pale red, tuff with less than 1 percent lithophysae up to 50 by 10 mm. Less than 1 percent phenocryts of sanidine, plagioclase, and biotite. The tuff has 1 to 2 percent very light gray pumice clasts and pink spherulites, and up to 10 percent volcanic lthic fragments. Zones of nonwelded, fracture fill(?) from 402.7 to 431.7 ft., 434.0 to 435.8 ft., and 442.4 to 443.7 ft. composed of reworked and variously bedded clay/silt sized, tuffaceous material. Generally the tuff is moderately soft (H5), moderately to slightly weathered (W4), with fracture densities ranging from slightly fractured (FD3) to very intensely fractured (FD8). Lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
367.9	60	R3	2mm clay
368.9	05	R2	clay, sand, gravel
370.0	30	R3	MnO stain & 5mm clay
373.7	15	R4	contact between clayey infilling material at Tpc
373.9	60	R2	2mm silica
374.3	35	R2	
374.3	55	R2	
374.8	60	R2	trace of clay
375.1			quartz filled lithophysal cav. 25mm thick
375.4	50	R3	trace of clay
375.6	60	R4	
378.6	45	R3	trace of clay
378.8	35	R3	
378.8	60	R3	
379.0	0	R4	1mm silica
379.6	15	R4	trace silica
379.8	20	R3	
380.0	75	R3	1mm silica
380.2	65	R3	trace silica
380.7	05	R3	

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

SHEET 5 OF 11

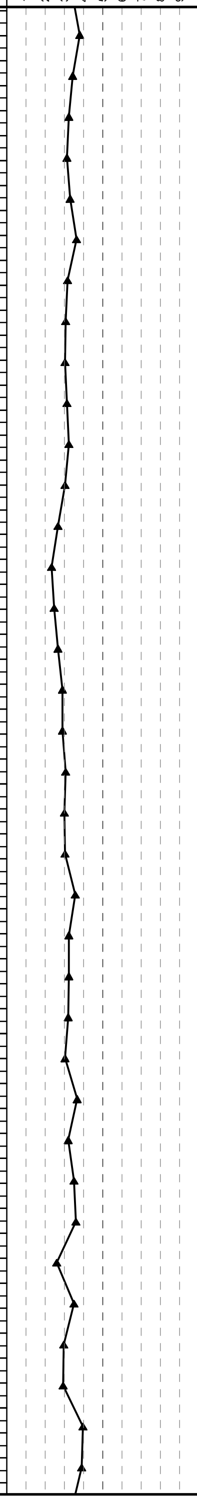
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/13/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,308.73 E 571,065.44
TOTAL DEPTH: 550.0 ft.
DEPTH TO BEDROCK: 101.8 ft.

STATE: Nevada
GROUND ELEVATION: 3651.52
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES | DEPTH | SHEAR WAVE VELOCITY ft/s (1000–9000) | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION

DEPTH: 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285



HARDNESS
H4
H5
H4

FRACTURE DENSITY
FD5
FD3
FD7
FD9
FD6
FD9
FD4
FD9
FD4
FD8

% CORE RECOVERY	% RQD
91	56
90	69
86	18
46	0
77	38
34	0
81	0
97	23
99	32
100	54
98	0

GEOLOGIC UNIT
Tpcrn
Tpcpul

381.0	28	R3	
380.8	55	R3	
381.4	20	R4	
381.5	10	R4	
381.7	20	R4	
382.0	15	R3	trace of clay
382.2	15	R3	trace MnO, trace clay
382.1	45	R3	
382.3	20	R3	
382.8	70	R3	
382.9	35	R4	trace MnO
383.3	30	R4	
383.7	05	R4	trace silica, trace clay
384.5	10	R2	
384.7	60	R3	
384.7	35	R3	
384.9	20	R3	
384.9	25	R3	
385.0	35	R3	
386.1	10	R4	
386.4	40	R4	
386.7	80	R3	
387.8/387.9	75	R2	3 anastamosing vpps, vp coated
388.7	20	R4	
389.3	75	R5	
389.5	75	R3	trace MnO
389.8	80	R4	
390.4	80	R3	vapor phase (Vpp)
390.7	45	R4	
390.8	75	R3	vapor phase (Vpp)
391.5	80	R4	
392.1	75	R3	
392.2	40	R4	trace vapor phase
392.6	75	R2	vapor phase to 2mm (Vpp)
392.8	35	R4	
392.9	80	R2	vapor phase to 1mm (Vpp)
395.2	45	R3	
396.8	75	R2	vapor phase (Vpp)
398.8	80	R2	
399.5	5	R3	
400.3	15	R3	trace MnO
400.7	80	R2	vapor phase (Vpp)
401.7	0	R3	
401.4	80	R4	
403.8	20	R2	clay 0.5 2cm
408.6	45	R4	contact (?) between cobble & pumiceous, lithic-rich infilling
408.9/409.9	40	R4	well cemented pumiceous lithic-rich infilling w/Tpc frags
409.9/413.4	40	R3	tuffaceous infilling w/<15% white/gray altered pumice
417.8	10	R5	clay 20mm
422.9	10	R5	clay 30mm+ extends into next run
429.9	10	R4	bedding; f.grained
428.0	20	R4	bedding; f.grained
431.1	10	R3	2mm clay
432.2	20	R3	trace white mineral
432.4	15	R3	trace white mineral
432.6	25	R3	trace white mineral
433.0	20	R3	1-4mm tuff
434.0	15	R4	tuff
435.9	15	R3	1mm clay & white mineral
437.3	80	R2	vpp alteration
438.7	75	R3	trace white mineral; 5mm clay
440.3	15	R3	trace white mineral
441.3	75	R3	trace white mineral
441.4	65	R3	trace white mineral
441.8	85	R3	trace white mineral
442.0	85	R3	trace white mineral
442.1	15	R4	clay; tuff

443.7 to 455.6 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER LITHOPHYSAL ZONE (Tpcpll)
Pyroclastic flow, densely welded, devitrified, moderate orange pink tuff with 1 percent very light gray pumice. Phenocryts of sanidine and rare biotite compose less than 1 percent of the rock by volume. Lithophysal cavities compose up to 15 percent of the rock by volume and are generally 20 by 30 mm in size. Lithophysae are filled and coated with vapor phase minerals to varying degrees. Generally the tuff is moderately hard (H4), slightly weathered (W3), and intensely fractured (FD6). Lower

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

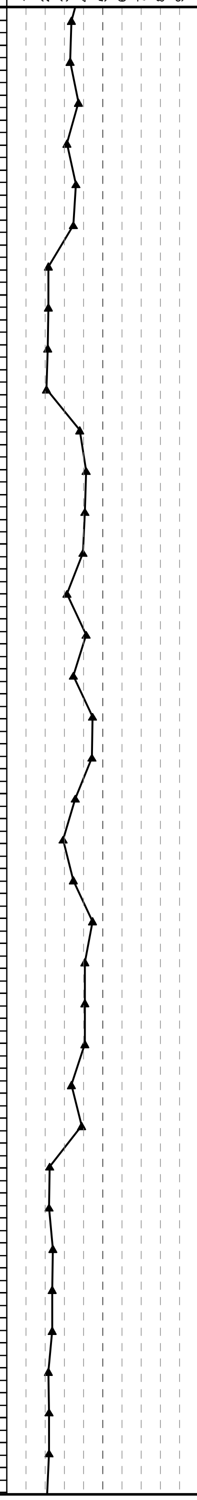
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/13/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,308.73 E 571,065.44
TOTAL DEPTH: 550.0 ft.
DEPTH TO BEDROCK: 101.8 ft.

STATE: Nevada
GROUND ELEVATION: 3651.52
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES | DEPTH | SHEAR WAVE VELOCITY ft/s (1000–9000) | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION

Depth scale: 290, 295, 300, 305, 310, 315, 320, 325, 330, 335, 340, 345



Hardness	Fracture Density	% Core Recovery	% RQD	Geologic Unit
H4	FD8	98	0	Tpcpul
		66	0	
		100	0	
		91	0	
		89	13	
		78	0	
	FD6	99	32	
H5	FD8	74	0	
H4	FD6	83	38	
		91	41	
H7	FD8	6	0	
	FD2	100	84	(Fracture Fill)
		74	47	
		100	100	
		81	40	

contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
443.7	60	R3	1mm clay
444.2	75	R2	clean
444.9	60	R2	clean
445.1	35	R2	clean
446.3	15	R2	trace white mineral; sand
446.8	30	R2	sand
447.2	30	R2	sand
453.7	60	R2	1mm silica

455.6.0 to 550.0 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER NON-LITHOPHYSAL ZONE (Tpcpln)
Pyroclastic flow, densely welded, devitrified, moderate orange pink tuff with less than 1 percent light gray pumice clasts. Phenocrysts of sanidine and plagioclase compose 1 to 2 percent of the rock by volume. Reddish brown lithic clasts compose less 1 percent of the rock by volume. Generally the tuff is moderately hard (H4), slightly weathered (W3), with fracture densities ranging from slightly fractured (FD3) to intensely fractured (FD6). Lower contact undetermined, bottom of borehole at 550.0 ft.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
455.7	40	R3	clean
456.4	20	R3	0 to 1mm silica
458.0	45	R3	clean
458.1	35	R3	3mm silica
460.2	60	R2	trace white mineral
460.0	30	R3	trace white mineral
460.4	70	R2	clean
460.9	65	R3	trace white mineral
461.1	85	R3	trace white mineral
461.3	35	R4	MnO & trace white mineral
461.8	60	R3	clean
462.1	60	R4	clean
462.7	30	R3	clean
463.1	25	R4	trace white mineral
463.9	75	R4	clean
464.1	55	R3	trace white mineral
464.8	35	R3	trace white mineral
465.0	55	R4	clean
465.5	65	R4	clean
465.9	70	R4	trace white mineral
466.3	65	R4	trace white mineral
467.0	20	R3	trace white mineral
467.1	75	R2	trace white mineral
467.3	50	R2	4mm sand & silica
467.7	50	R3	trace white mineral
468.0	80	R4	trace white mineral
468.2	55	R4	clean
468.4	80	R4	clean
468.5	35	R4	trace white mineral
468.7	60	R4	clean
469.0	70	R4	clean
469.4	45	R4	trace white mineral
470.0	60	R2	trace white mineral
471.2	80	R2	trace white mineral
472.4	80	R3	trace white mineral
472.8	80	R2	trace white mineral
473.1	75	R3	trace white mineral
474.5	10	R2	trace white mineral
476.8	80	R2	trace white mineral
476.2	80	R1	trace white mineral; trace silica
477.3	75	R1	trace white mineral
478.4	85	R1	vapor phase alteration-2mm
478.5	55	R3	trace white mineral
479.0	60	R1	trace white mineral
480.3 (healed)	70	R1	2mm vapor phase minerals
480.9 (healed)	75	R1	2mm vapor phase minerals
482.4 (healed)	55	R1	2mm vapor phase minerals
483.1	45	R4	trace white minerals
484.4	65	R4	clean
484.6	60	R4	clean
485.4	80	R2	trace white mineral
485.6	75	R4	clean
485.9	50	R4	trace white mineral

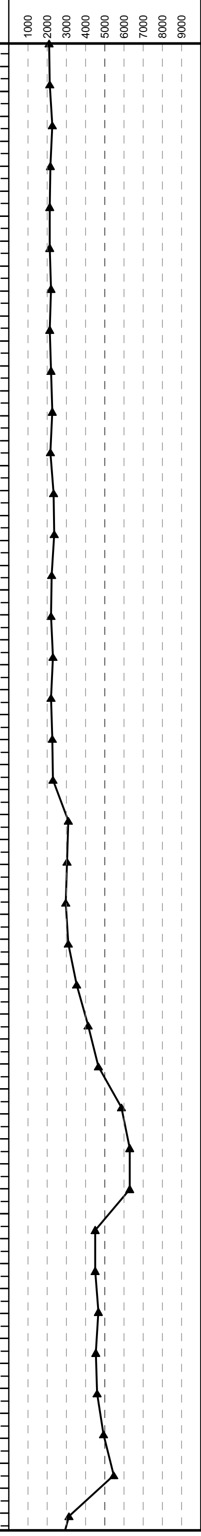
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/13/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,308.73 E 571,065.44
TOTAL DEPTH: 550.0 ft.
DEPTH TO BEDROCK: 101.8 ft.

STATE: Nevada
GROUND ELEVATION: 3651.52
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES | DEPTH | SHEAR WAVE VELOCITY ft/s | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION

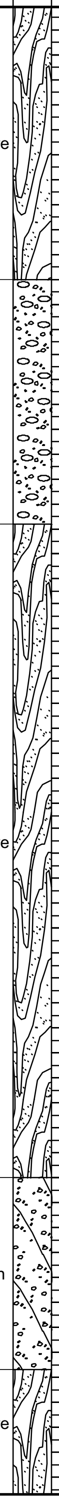


HARDNESS: H7, H4, H6, H3, H6, H4

FRACTURE DENSITY: FD5, FD6, FD4, FD6, FD3, FD7, FD9, FD8, FD6, FD5, FD3, FD6, FD3

% CORE RECOVERY	% RQD
89	67
84	32
86	57
86	17
57	18
87	38
78	64
96	19
100	63
100	86
95	75

GEOLOGIC UNIT: (Fracture Fill), Tpcpul, (Fracture Fill), Tpcpmn, (Fracture Fill)



CLASSIFICATION AND PHYSICAL CONDITION

486.2	70	R4	clean
487.3	85	R3	trace white mineral
487.0	80	R2	clean
488.2	60	R3	trace white mineral
489.1	60	R3	trace white mineral
489.7	30	R3	trace white mineral
490.0	60	R4	trace white mineral
490.0	50	R4	trace white mineral
494.0	0	R2	MnO stain
493.8	30	R3	trace white mineral
493.4	35	R3	MnO stain; trace white
mineral			
492.8	20	R2	clean
491.9	40	R3	clean
491.8	80	R3	trace white mineral
491.6	30	R3	clean
491.2	10	R3	clean
495.0	05	R2	trace MnO & white mineral
495.3	80	R3	clean
495.9	75	R3	clean
497.4	80	R3	clean
498.0	65	R3	clean
498.6	80	R3	clean
498.9	60	R3	trace white mineral
499.2	70	R3	clean
499.4	80	R3	clean
499.6	80	R3	clean
499.8	05	R3	clean
504.0	10	R3	trace MnO & white mineral
503.4	85	R3	trace MnO & white mineral
504.5	15	R3	trace MnO & white mineral
506.8	80	R3	trace white mineral
507.5	35	R3	clean
508.4	65	R2	trace white mineral
500.6	70	R3	trace white mineral
500.7	70	R3	trace white mineral
501.6	75	R3	clean
501.7	70	R3	trace white mineral
502.1	75	R3	trace white mineral
502.3	70	R3	trace white mineral
502.6	65	R3	trace white mineral
502.7	75	R3	trace white mineral
502.8	15	R3	trace white mineral
503.2	85	R3	trace white mineral
512.1	65	R3	trace white mineral
512.9	80	R3	trace white mineral
513.0	70	R2	3mm vapor phase mineral
514.0	25	R2	trace white mineral
514.2	75	R2	trace white mineral
514.3	10	R2	trace white mineral
515.6	15	R3	clean
516.4	15	R2	trace MnO
517.8	10	R1	trace clay
517.9	15	R2	1mm clay; sand
520.4	70	R2	MnO, white mineral stain
520.6	75	R2	MnO stain
520.9	80	R2	clean
520.5	80	R3	clean
521.2	85	R3	MnO stain
522.0	10	R3	clean
522.6	15	R3	clean
523.3	80	R2	15-40mm sand
523.8	80	R2	gravel fragments
524.0	25	R3	healed
526.0	25	R2	0.4ft. Sand, gravel, & clay
breccia			
528.4	75	R3	trace white mineral
528.9	60	R2	clean; slickensides
529.3	65	R2	clean; slickensides
529.4	70	R2	clean; slickensides
530.4	25	R2	3 to 8mm clay;
slickensides;			
			polished; hard
530.8	55	R2	clean
531.2	40	R2	clean
531.7	80	R2	trace MnO
531.5	10	R3	MnO stain
532.0	50	R3	MnO stain
532.1	15	R3	MnO stain
532.5	55	R2	sand
532.7	40	R2	trace clay; sand
532.8	50	R3	sand
533.0	70	R2	sand & gravel
533.1	75	R2	sand & gravel
533.2	70	R3	clean

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/13/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

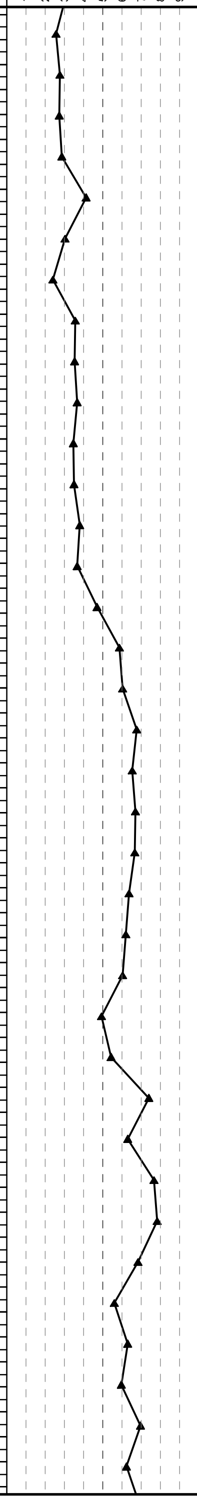
PROJECT: Yucca Mountain Project
COORDINATES: N 765,308.73 E 571,065.44
TOTAL DEPTH: 550.0 ft.
DEPTH TO BEDROCK: 101.8 ft.

STATE: Nevada
GROUND ELEVATION: 3651.52
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES

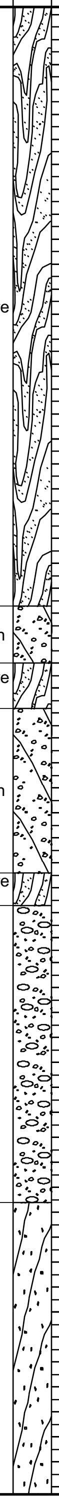
DEPTH: 410, 415, 420, 425, 430, 435, 440, 445, 450, 455, 460, 465

SHEAR WAVE VELOCITY ft/s



ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]
H7		FD9			
H5		FD6	100	92	(Fracture Fill)
H6		FD3			
H5		FD1	98	98	
		FD9	60	0	
		FD3	100	89	
		FD5	96	49	Tpcpmn
					(Fracture Fill)
H4		FD3	100	77	Tpcpmn
H5			67	0	(Fracture Fill)
H4		FD6	95	6	Tpcpll
		FD5	96	48	
			100	67	Tpcpln
			100	39	

GRAPHIC



CLASSIFICATION AND PHYSICAL CONDITION

533.3	65	R3	clean
533.5	65	R3	trace white mineral
536.0	70	R3	clean
534.1	45	R3	clean
534.1	45	R3	clean
534.4	50	R2	clean
534.5	15	R2	clean
534.6	80	R3	clean
534.7	70	R3	clean
534.8	30	R3	trace white mineral
535.4	60	R2	0-1 ft. Sand & gravel
535.6	70	R3	sand
536.1	80	R3	clean
536.3	80	R3	clean
536.6	80	R3	clean
536.9	80	R2	trace white mineral
537.5	60	R2	3mm clay
537.6	70	R2	clean
537.9	75	R2	clean
538.2	80	R2	clean
538.5	55	R2	clean
538.7	85	R2	clean
538.8	85	R2	clean
538.9	85	R2	clean
539.3	65	R3	trace white mineral
539.5	70	R3	clean
539.7	75	R3	clean
539.8	75	R3	clean
540.0	15	R3	trace white mineral
540.9	20	R3	trace white mineral
540.5	70	R2	clean
540.9	60	R2	trace white mineral
540.8	30	R3	clean
541.2	60	R2	trace white mineral
541.4	20	R2	trace white mineral
541.6	80	R3	trace white mineral
541.8	85	R3	trace white mineral
542.2	80	R3	trace white mineral
542.3	80	R3	trace white mineral
542.8	85	R3	trace white mineral
543.0	80	R2	trace white mineral
543.5	10	R2	clean
543.7	85	R3	trace white mineral
543.9	80	R2	clean
544.3	85	R2	1-2mm clay
544.4	85	R3	clean
545.0	85	R3	trace white mineral
545.3	50	R2	clean
545.7	10	R2	clean
545.5	10	R2	clean
546.8	80	R2	1mm clay
546.9	50	R2	1mm clay
547.0	75	R2	1mm clay
549.5	40	R3	clean

* Angles are measured from core axis and are plus or minus 5 degrees.

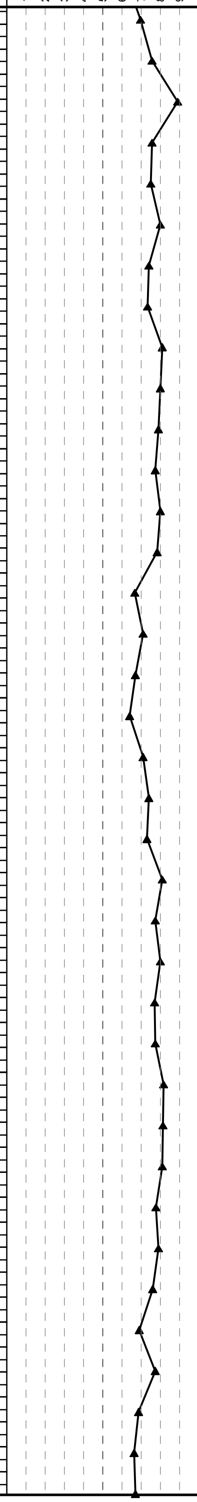
WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/13/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,308.73 E 571,065.44
TOTAL DEPTH: 550.0 ft.
DEPTH TO BEDROCK: 101.8 ft.

STATE: Nevada
GROUND ELEVATION: 3651.52
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown



NOTES	DEPTH	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	467–470	H4		FD5	100	39	Tpcpln		
	470–480			FD4	100	69			
	480–490			FD3	98	76			
	490–500			FD4	100	55			
	500–510				100	45			
	510–520			FD3	100	88			
	520–527			FD4	99	54			

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

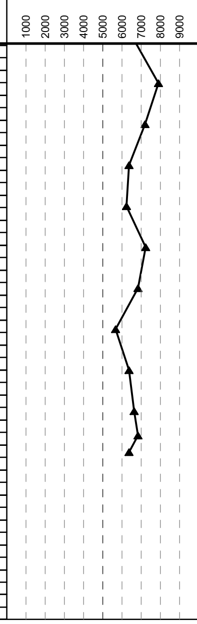
SHEET 10 OF 11

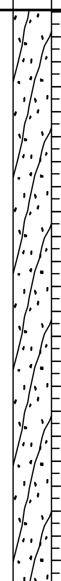
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/13/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,308.73 E 571,065.44
TOTAL DEPTH: 550.0 ft.
DEPTH TO BEDROCK: 101.8 ft.

STATE: Nevada
GROUND ELEVATION: 3651.52
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	530		H4		FD4	99	54	Tpcpln		
	535		H6		FD6	100	18			
	540, 545		H4		FD5	100	36			
	550									





BOTTOM OF HOLE

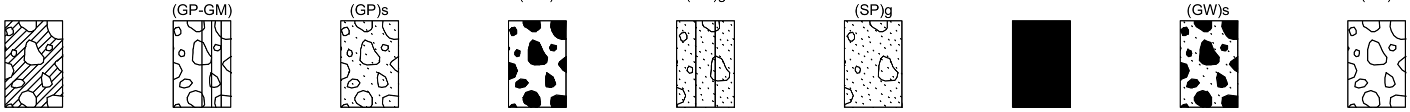
WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#14

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,308.73 E 571,065.44	GROUND ELEVATION: 3651.52
BEGUN: 9/13/2000 FINISHED: 9/27/2000	TOTAL DEPTH: 550.0 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 101.8 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

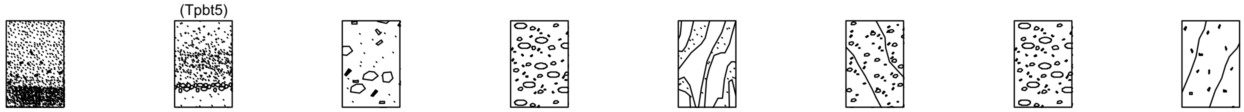
SOIL

Quaterny Alluvium (Qal)	USCS Poorly-graded Gravel with Silt (GP-GM)	USCS Poorly-graded Gravel with Sand (GP)s	USCS Well-graded Gravel (GW)	USCS Silty Sand with Gravel (SM)g	USCS Poorly-graded Sand with Gravel (SP)g	No Recovery	USCS Well-graded Gravel with Sand (GW)s	USCS Poorly-graded Gravel (GP)



ROCK

Tuff "x" (Tpki)	Post Tiva Canyon Bedded Tuff (Tpbt5)	Tpcrn	Tpcpul	Fracture Fill Material	Tpcpmn	Tpcpll	Tpcpln



WELDING

Non-Welded	Densely Welded

HARDNESS

Alpha-numeric descriptor	Descriptor	Criteria
H1	Extremely	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very Hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately Hard	Can be scratched with knife or sharp pick with light pressure. Core or fragment breaks with moderate hammer blow.
H5	Moderately Soft	Can be grooved 1/16 inch (2mm) deep by sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

WEATHERING

Alpha-numeric descriptor	Descriptor	General characteristics (strength, excavation, etc.)
W1	Fresh	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as Siltstones or shales.
W2	Slightly weathered to fresh	
W3	Slightly weathered	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classified as rock excavation.
W4	Moderately to slightly weathered	
W5	Moderately weathered	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstones or shales.
W6	Intensely to moderately weathered	
W7	Intensely weathered	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very intensely weathered	
W9	Decomposed	Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes".

FRACTURE DENSITY

Alpha-numeric descriptor	Descriptor	Criteria (Excludes mechanical breaks)
FD0	Unfractured	No observed fractures.
FD1	Very slightly fractured	Core recovered mostly in lengths greater than 3 feet (1 m).
FD2	Slightly to very slightly fractured	
FD3	Slightly fractured	Core recovered mostly in lengths from 1 to 3 feet (300 to 1,000 mm) with few scattered lengths less than 1 foot (300 mm) or greated than 3 feet (1,000 mm).
FD4	Moderately to slightly fractured	
FD5	Moderately fractured	Core recovered mostly in lengths from 0.33 to 1.0 foot (100 to 300 mm) with most lengths about 0.67 foot (200 mm).
FD6	Moderately to intensely fractured	
FD7	Intensely fractured	Lengths average from 0.1 to 0.33 foot (30 to 100 mm) with fragemented intervals. Core recovered mostly in lengths less than 0.33 foot (100 mm).
FD8	Very intensely to intensely fractured	
FD9	Very intenesely fractured	Core recovered mostly as chips and fragments with a few scattered short core lengths.

RF14_KEY WHB.GPJ WHB.GDT 6/14/02

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GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#15

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/30/2000 FINISHED: 9/11/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,773.64 E 570,224.85
TOTAL DEPTH: 330.0 ft.
DEPTH TO BEDROCK: 5.0 ft.

STATE: Nevada
GROUND ELEVATION: 3680.98
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES

Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig, UDR 1000 Drill Rig

Drillers:
D. Harrison, R. Mckay, D. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 5.03. Cement 10.75 O.D. casing with 1.38 stickup. Re-enter hole on 8/30/2000 with PQ coring system. Cored with PQ to 77.16. Used PQ rods as casing and installed HQ coring system. Cored with HQ to the total depth of 330.00.

Drilling Conditions:
77.16 to 289.26 replace bit.

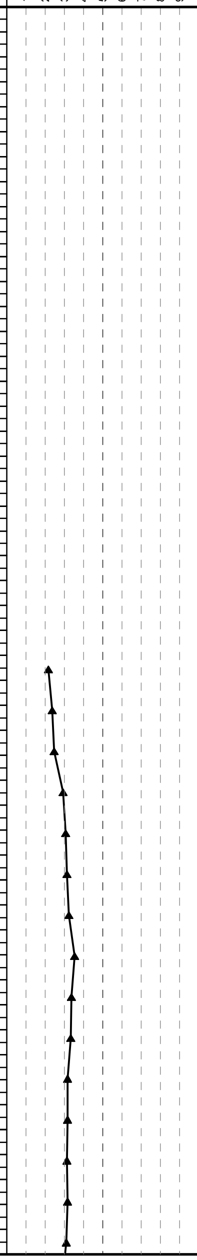
Drilling Fluid:
0.00 to 5.03: Non-potable water. 5.03 to 330.00: Quick Gel mud with EZ-Mud and LCM to re-establish circulation.

Loss Intervals:
Lost circulation from 51.00 to 330.00.

Casing Record:
0.00 to 4.63 : 10.75 O.D. casing.
0.00 to 77.16: PQ casing
77.16 to 330.00: No casing

Hole Completion:
Ream hole from 5.03 to 330.0. Set and cement 4.5" PVC casing.

SHEAR WAVE VELOCITY (ft/s)



ENGINEERING INDEXES

DEPTH (approx.)	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]
0.0 - 5.0				0		Fill
5.0 - 6.5	H4		FD7	67 / 44	0	Tpcrn
6.5 - 10	H4		FD6	92	30	Tpcrn
10 - 15	H4		FD4	100	60	Tpcrn
15 - 27	H4		FD6	100	0 / 58 / 36 / 0	Tpcrn
27 - 33	H4		FD4	100	87 / 65	Tpcrn
33 - 43	H4		FD3	100	84 / 80	Tpcrn
43 - 44	H4		FD7	86	0	Tpcrn
44 - 49	H4		FD3	84	47	Tpcrn
49 - 50	H4		FD7	100	0	Tpcrn

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 6.5 ft. PAD FILL (Fill)
0.0 - 5.0: POORLY GRADED GRAVEL (GP)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.

6.5 to 78.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, densely welded, devitrified, light gray to pale red tuff with 15 to 20 percent phenocrysts of plagioclase, sanidine, and minor (less than 1 percent) biotite. Pumice clasts compose up to 10 percent of the tuff, pumice clasts increase to up to 25 to 30 percent at a depth of67.4 feet. Generally the tuff is moderately hard (H4), moderately to slightly weathered (W4), and intensely to moderately fractured (FD6). Upper contact is unconformable (erosional), lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
5.2	30	R3	0.5" calcite
6.8	65	R2	1.0" Calcite
7.1	80	R2	0.25" Calcite
8.7	30	R3	Clean
9.2	25	R2	0.1" Calcite
9.2	70	R2	0.25" Calcite
11.2	30	R2	0.25" Calcite
13.7	40		0.1" Clay & Sand
14.8	10	R3	Trace Clay
18.0	10	R3	0.3" Calcite & Clay
16.8	40	R3	Clean
17.8	70	R2	Clean
18.5	65	R2	Clean
19.0	35	R2	Clean
20.0	05	R2	0.75" Calcite
22.4	55	R3	Clean
24.5	30	R2	0.25" Clay
24.8	50	R3	<0.1" gray non-crystalline
25.1	60	R2	<0.1" gray non-crystalline
26.6	70	R3	Clean
27.1	60	R3	Trace Fe
28.4	25	R3	Quartz & Clay
29.0	40	R3	Clay
29.3	30-90	R3	Calcite? & Clay
32.6 - 32.8	15	R3	Quartz & Clay
34.5 - 35.3	20	R3	Clay & Pumice
34.4	90	R3	Clean
34.9	90	R3	Clay & Pumice
38.5	45	R2	Clean
43.4 - 43.8	10	R3	Clean
49.3 - 49.5	45	R2	Trace Clay
49.6 - 50.3	5-10	R3	Trace Clay
49.6 - 49.9	10	R3	Clean
53.1	45	R3	Trace Clay
55.1 - 57.8	0-5	R4	White mineral, Clay
59.6 - 59.7	5 0	R3	Clay
61.7 - 62.1	10	R3	Trace Clay
65.6 - 66.7	10	R3	Breccia zone
65.3	65	R3	Sand
67.7	65	R3	0.1" Vapor-phase coating
68.8	70	R2	0.1" Vapor-phase coating, sand
69.8	30	R3	0.1" Quartz, Sand
70.5	30	R2	Sand
68.4	80	R1	Vapor-phase parting
71.4	60	R2	0.1" Vapor-phase
71.7	60	R3	0.1" Vapor-phase
72.2	85	R3	0.1" Vapor-phase
72.8	50	R4	Paper thin white mineral
73.2	55	R3	Clean
74.1 - 74.4	40	R3	0.2" Breccia - clay, sand,

COMMENTS:
1. All measurements are in feet unless noted otherwise.
2. No attempts to re-establish circulation were made below 278 ft.
3. LCM (Lost Circulation Material) consists cellephane cuttings.
4. USCS classifications were determined in the field, with limited access to samples to keep samples intact for future tests.
5. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.
6. USCS soil classifications are based on USBR Earth Manual procedure 5005 - Determining Unified Soil Classification (Visual Method)

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

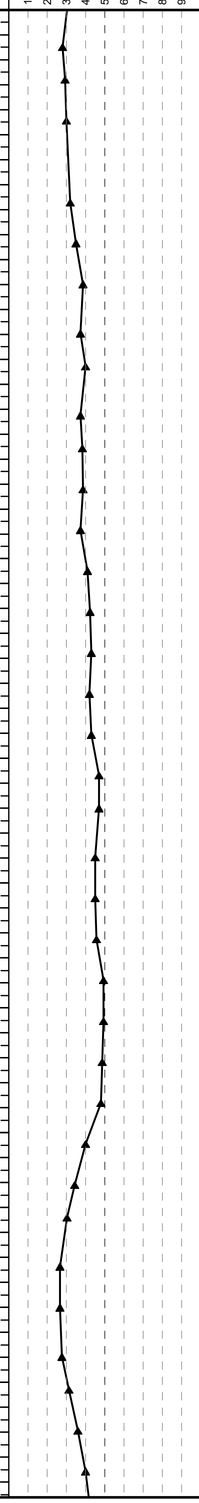
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#15

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/30/2000 FINISHED: 9/11/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,773.64 E 570,224.85
TOTAL DEPTH: 330.0 ft.
DEPTH TO BEDROCK: 5.0 ft.

STATE: Nevada
GROUND ELEVATION: 3680.98
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105	1000 2000 3000 4000 5000 6000 7000 8000 9000	H4		FD7, FD8, FD7, FD6, FD4, FD6, FD5, FD3, FD7, FD4, FD7, FD8, FD7	100, 97, 80, 86, 100, 96, 100, 94, 43, 85, 53, 84, 100, 88	0, 11, 0, 40, 0, 61, 82, 0, 46, 80, 0, 28, 0, 10	Tpcrn, Tpcpul	



CLASSIFICATION AND PHYSICAL CONDITION

			gravel
74.6 - 74.7	40	R3	0.1" Breccia - clay, sand, gravel
75.0	25	R2	Clean
76.0	30	R2	Fine gravel
77.6	45	R3	Trace white mineral
78.3	55	R3	Trace white mineral
78.8	70	R3	0.1" Calcite
79.5	65	R3	Clean
80.1	25	R2	1.75" Sand, gravel, Calcite
80.6	35	R2	Trace Calcite
80.8	70	R3	Trace Calcite
82.3	55	R3	Clean
82.7	85	R3	Trace Calcite
83.2	60	R3	Trace Calcite
83.6	60	R4	Trace Calcite
85.1	55	R3	1mm crystal Calcite, quartz?
85.3	30	R3	1mm Calcite & clay
85.7	55	R3	Clay & trace Calcite

78.0 to 196.0 ft. TIVA CANYON TUFF UPPER CRYSTAL POOR LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, pale reddish-brown tuff with up to 10 percent lithophysae with light gray crystal coatings. Phenocrysts compose less than 5 percent of the tuff, consisting of plagioclase, sanidine, and biotite. At 150.0 feet lithophysae content decreases to less than 5 percent, becoming mostly grayish vapor phase mottling. Generally the tuff is moderately hard (H4), moderately to slightly weathered (W4), and intensely to mostly moderately fractured (FD5). Lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
93.0	35	R3	2mm Calcite
93.2	80	R3	Trace white mineral
93.4	80	R2	Trace white mineral
94.3	55	R3	Clean
95.6	30	R3	Trace white mineral
101.0	35	R3	Trace white mineral
105.6	50	R3	Clean
108.0	25	R3	Clean
109.4	45	R3	
109.4	45	R2	Clean
111.6	60	R2	Clean
113.9	15	R3	Trace white mineral, 1mm opal(?)
117.0	60	R3	Trace white mineral
118.3	25	R2	2mm white mineral
120.9	30	R2	1mm white mineral
122.3	35	R2	1mm white mineral
122.9	10	R2	Clean
123.9	30	R3	1mm white mineral, sand
129.4	40	R3	4mm white mineral
130.1	90	R2	1mm white mineral
132.4	30	R3	1mm white mineral
131.7	75	R3	1mm white mineral
132.9	60	R2	Sand, gravel
138.4	40	R2	1mm white mineral
136.5	10	R2	2mm white mineral
139.3	40	R3	Trace white mineral
142.0 - 143.9	15	R3	4mm white mineral
143.6	35	R3	1mm white mineral
145.6	60	R2	4mm clay
147.2	70	R2	2mm white mineral
147.6	90	R2	Clay & sand
148.9	75	R2	Clean
151.1	50	R2	Clean
153.0	40	R2	Clay & sand shear zone
153.8 - 154.2	25	R3	1mm white mineral
155.3	85	R3	Trace clay (gray)
156.0 - 157.4	0-5	R3	Trace white mineral
157.4	70	R2	1mm white mineral
159.2	35	R3	1mm white mineral
160.5	15	R2	1mm white mineral, sand
162.1	55	R3	1mm white mineral
164.8	30	R3	1mm white mineral
165.8	20	R2	Sand
167.6	90	R2	2mm vapor-phase minerals
167.0	80	R2	2mm vapor-phase minerals
169.9	15	R3	Trace white mineral
171.1	00	R2	10mm clay & sand breccia
172.2	45	R3	1mm white mineral
173.2	35	R3	Sand

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

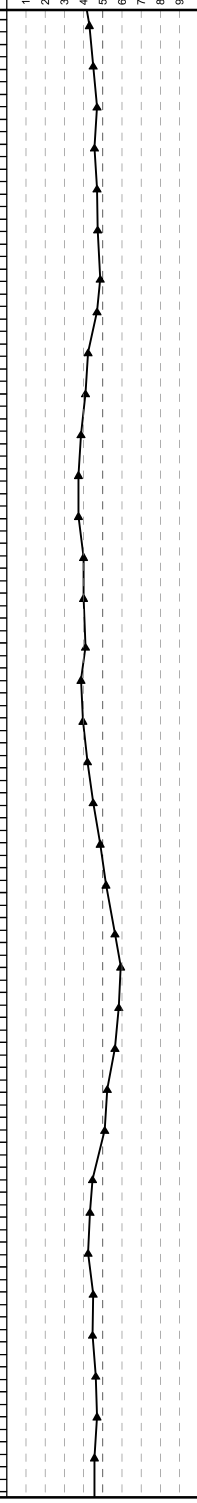
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#15

SHEET 3 OF 7

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/30/2000 FINISHED: 9/11/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,773.64 E 570,224.85
TOTAL DEPTH: 330.0 ft.
DEPTH TO BEDROCK: 5.0 ft.

STATE: Nevada
GROUND ELEVATION: 3680.98
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	110–168		H4		FD7	88	10	Tpcpul	
					FD4	92	59		
						86	46		
					FD3	100	71		
							66		
						99	86		
					FD4	95	59		

CLASSIFICATION AND PHYSICAL CONDITION

Depth	Angle*	Roughness	Infilling
174.1	40	R3	4mm white mineral, sand
175.4	65	R2	1mm white mineral, sand
175.7	80	R2	1mm white mineral, sand
176.0	20	R3	3mm quartz
179.2	40	R2	Trace white mineral
180.6	30	R2	Trace white mineral
181.0	25	R2	Trace white mineral, sand
181.8	70	R2	5mm vapor-phase alteration
183.0	30	R3	Trace white mineral, sand
183.2	25	R3	Trace white mineral, sand
184.1	20	R3	Trace white mineral, sand
186.0	60	R2	Trace white mineral, sand
186.0	30	R3	Trace white mineral, sand
186.5	15	R2	2mm white mineral
187.3	75	R3	1mm white mineral
189.0	30	R3	1mm white mineral
190.6	85	R2	2mm vapor-phase alteration
190.8	70	R2	Clean
190.9	70	R2	Trace vapor-phase alteration
191.0	30	R3	1mm white mineral
193.1	70	R2	1mm vapor-phase alteration
195.1	25	R3	1mm white mineral, sand

196.0 to 242.4 ft. TIVA CANYON TUFF MIDDLE NON-LITHOPHYSAL ZONE (Tpcpmn)
Pyroclastic flow, densely welded, pale red tuff with less than 5 percent flattened pumice and less than 1 percent lithophysae. Phenocrysts content is less than 1 percent composed of plagioclase, sanidine, and biotite. From 242.4 to 256.6 the tuff contains up to 30 percent lithophysae, some larger than core diameter. From 256.6 to 330.0 feet the tuff has less than 1 percent lithophysae and pumice clasts. There is a clayey breccia zone from 276.2 to 280.3. Generally the tuff is hard (H3), moderately to slightly weathered (W4), and moderately to slightly fractured (FD4).

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
196.5	55	R2	3mm vapor-phase alteration
198.1	15	R2	1mm white mineral
197.3	30	R3	0.5" white mineral, sand, gravel breccia
198.8	30	R3	1mm white mineral
199.1	25	R3	1mm white mineral
200.6	30	R2	Clean
201.6	20	R3	Trace white mineral
202.7	75	R2	2mm vapor-phase alteration
203.1	75	R2	10mm vapor-phase alteration
203.6	20	R1	Trace white mineral
204.8	20	R3	8mm white mineral, sand, gravel
205.6	15	R3	1mm white mineral
206.0	25	R3	1mm white mineral
209.1	85	R2	4mm vapor-phase alteration
208.4	45	R2	3mm white mineral
207.7	15	R2	12mm white mineral, sand
207.0	20	R2	4mm white mineral, sand
216.0	25	R3	1mm white mineral
212.0	05	R2	1mm white mineral
212.5	15	R2	1mm white mineral
213.2	75	R2	3mm vapor-phase alteration
214.3	15	R2	1mm white mineral, sand
214.6	80	R2	3mm vapor-phase alteration
215.5	30	R2	Trace white mineral
216.1	30	R3	1mm white mineral
216.3	30	R3	1mm white mineral
216.4	15	R2	1mm white mineral
217.0	10	R2	1mm white mineral
217.8	30	R3	1mm white mineral, sand
218.1	20	R3	1mm white mineral
218.7	70	R2	6mm white mineral
220.1	20	R3	10mm white mineral
221.8	10	R3	Trace white mineral
221.9	45	R3	8mm white mineral
224.7	10	R2	Trace white mineral
225.9	70	R3	Trace white mineral
228.3	80	R3	5mm vapor-phase alteration
231.2	85	R3	3mm vapor-phase alteration
230.5	70	R3	Clean
231.7	70	R2	1mm vapor-phase alteration
233.9	55	R2	Clean
234.3	30	R2	2mm white mineral, trace MnO(?)

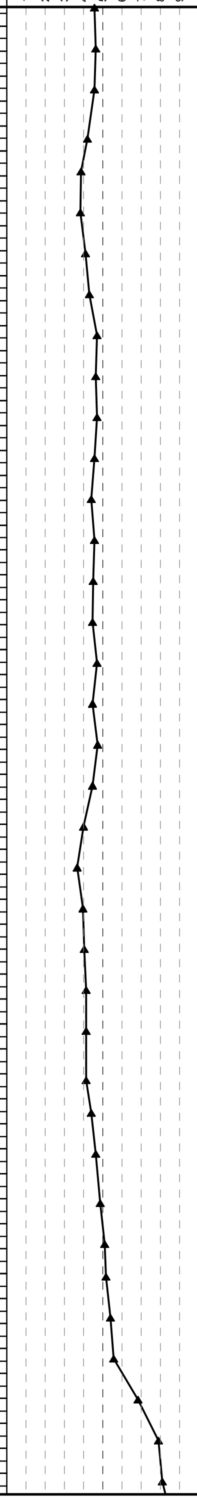
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#15

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/30/2000 FINISHED: 9/11/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,773.64 E 570,224.85
TOTAL DEPTH: 330.0 ft.
DEPTH TO BEDROCK: 5.0 ft.

STATE: Nevada
GROUND ELEVATION: 3680.98
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	170–179		H4		FD4	96	55	Tpcpul	
	179–189		H4		FD4	98	63	Tpcpul	
	189–190		H4		FD7	73	0	Tpcpul	
	190–200		H4		FD4	96	66	Tpcpul / Tpcpmn	
	200–206		H4		FD5	95	49	Tpcpmn	
	206–209		H4		FD7	96	28	Tpcpmn	
	209–220		H4		FD4	98	39	Tpcpmn	
	220–224		H4		FD6	100	0	Tpcpmn	
	224–228		H4		FD4	100	69	Tpcpmn	



CLASSIFICATION AND PHYSICAL CONDITION

Depth	Angle*	Roughness	Infilling
234.7	10	R3	2mm white mineral, trace MnO(?)
235.4	25	R3	Trace white mineral, trace FeO
235.7	20	R3	1" white mineral, 1mm MnO
236.8	40	R2	Clean
237.1	20	R3	2mm white mineral
239.1	30	R2	1mm white mineral
239.8	30	R3	2mm white mineral
240.6	40	R3	10mm white mineral, 1mm MnO
241.9	85	R2	Sand, gravel

242.4 to 256.6 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER LITHOPHYSAL ZONE (Tpcpll)
Pyroclastic flow, densely welded, devitrified, moderate orange pink tuff with rare light gray pumice. Phenocryts of sanidine and rare biotite compose less than 1 percent of the rock by volume. Lithophysal cavities compose 15 to 20 percent of the rock by volume with some larger than core diameter. Lithophysae are filled and coated with vapor phase minerals to varying degrees. Generally the tuff is hard (H3), slightly weathered (W3), and slightly to very slightly fractured (FD2). Lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
243.2	60	R2	2mm white mineral
244.9	15	R3	2mm white mineral
244.8	75	R2	5mm vapor-phase alteration
249.6	80	R2	1mm gray mineral
250.3	80		
250.6	85		
256.5	10	R3	Trace white mineral

256.6 to 330.0 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER NON-LITHOPHYSAL ZONE (Tpcpln)
Pyroclastic flow, densely welded, devitrified, pale red tuff with less than 1 percent light gray pumice clasts. Phenocrysts of sanidine and plagioclase compose less than 1 percent of the rock by volume. Medium gray lithic clasts compose less 1 percent of the rock by volume. Clast supported breccia from 276.2 to 280.3 ft. Generally the tuff is moderately hard (H4), slightly weathered (W3), with fracture densities mostly moderately fractured (FD4) to some intensely fractured (FD7) zones. Lower contact undetermined, bottom of borehole at 330.0 ft.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
259.7	10	R1	Trace white mineral
260.7	10	R2	Trace white mineral
261.7	70	R3	Trace white mineral, MnO
263.1	35	R2	Trace white mineral
264.4	85	R2	Trace white mineral
264.5	60	R2	Trace white mineral
267.2	10		Trace white mineral
266.5	40	R3	Trace white mineral
267.4	25	R2	Trace white mineral
269.5	30	R2	Trace white mineral
270.7	65	R3	Trace white mineral
271.1	60	R2	Trace white mineral
271.3	70	R3	Trace white mineral
271.6	60	R3	Trace white mineral
272.3	85	R2	Trace white mineral
272.8	80	R3	1mm white mineral
274.1	85	R3	Trace white mineral
274.9	85	R3	Trace white mineral
275.3	30	R3	Trace white mineral
276.0	40	R2	Trace white mineral
276.1	25	R2	Trace white mineral
280.3	85	R4	
280.6	10	R3	Trace MnO & vapor-phase mineral
280.9	80	R3	Trace MnO
283.7	65	R3	Trace vapor-phase mineral
284.2	25	R3	
285.1	55	R3	
285.8	75	R3	
286.2	60	R3	Vapor-phase minerals
286.3	30	R3	
286.8	25	R3	Trace vapor-phase minerals
287.1	55	R3	

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#15

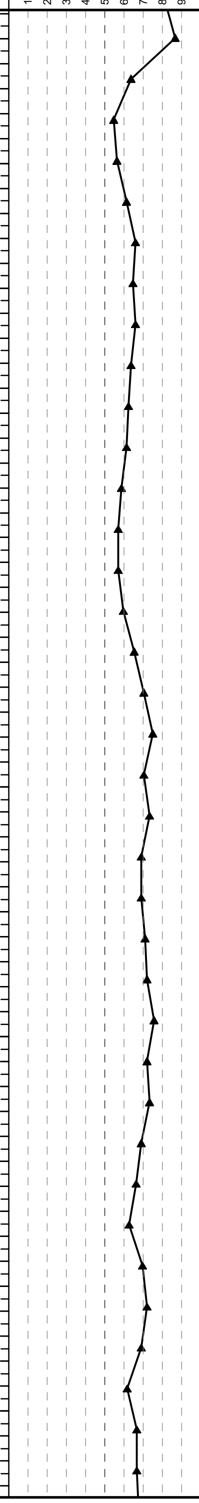
SHEET 5 OF 7

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/30/2000 FINISHED: 9/11/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,773.64 E 570,224.85
TOTAL DEPTH: 330.0 ft.
DEPTH TO BEDROCK: 5.0 ft.

STATE: Nevada
GROUND ELEVATION: 3680.98
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	230		H4		FD4	100	69	Tpcpmn	
	235						54		
	240				FD2	99	80	Tpcpll	
	245								
	250				FD3		79		
	255							Tpcpln	
	260				FD2	100	68		
	265								
	270				FD3		80		
	275							(clayey breccia)	
	280		H3		FD4	99	84	Tpcpln	
	285								



CLASSIFICATION AND PHYSICAL CONDITION

288.3	60	R3	Vapor-phase minerals, trace Calcite
289.0	85	R3	Vapor-phase minerals
289.3	35	R4	1mm quartz
290.2	60	R4	
290.2	30	R4	
291.8	55	R3	
293.0	45	R4	
294.1	75	R4	Trace vapor-phase minerals
294.8			core broken on corroded pumice clast
295.7	25	R4	Trace vapor-phase minerals
296.3	65	R3	
297.3	20	R4	Trace vapor-phase minerals
298.9	25	R3	Vapor-phase minerals
299.5	85	R4	Trace MnO, vapor-phase minerals
300.3			core broken on pumice clast
304.3	80	R4	Possible mechanical break
308.5	60	R3	Mechanical break
311.5	60	R4	Vapor-phase minerals
313.0	15	R4	Vapor-phase minerals
313.6	80	R3	Trace vapor-phase minerals
314.5	05	R2	Trace MnO, Calcite
314.4	85	R3	Trace vapor-phase minerals
314.5	80	R3	Trace MnO, vapor-phase minerals
314.9	85	R3	Trace vapor-phase minerals
315.7	70	R3	Trace vapor-phase minerals
316.2	20	R4	Patchy Calcite, trace MnO
317.1	85		Core broken on argillically altered pumice
317.6	10	R3	Patchy Calcite, trace MnO
318.3	80	R3	3mm botryoidal silica, 3mm clay
319.1	15	R2	3mm silica, most euhedral, some botryoidal, some smooth
319.9	55	R2	1mm silica, 1mm clay
320.5	45	R4	2mm silica, trace clay
322.5	80	R4	Patchy silica & clay

* Angles are measured from core axis and are plus or minus 5 degrees.

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

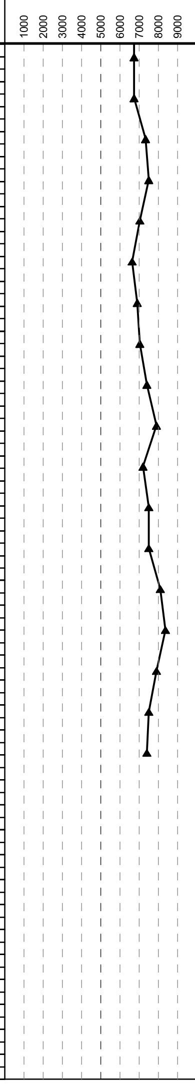
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#15

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/30/2000 FINISHED: 9/11/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,773.64 E 570,224.85
TOTAL DEPTH: 330.0 ft.
DEPTH TO BEDROCK: 5.0 ft.

STATE: Nevada
GROUND ELEVATION: 3680.98
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	HARDNESS (ENGINEERING INDEXES)	WELDING (ENGINEERING INDEXES)	FRACTURE DENSITY (ENGINEERING INDEXES)	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	290					99	84			
					FD7	100	0			
	295				FD4	96	93			
	300									
	305				FD3		97			
	310		H3					Tpcpln		
	315				FD4	100	88			
	320									
	325				FD3		100			
	330				FD4					



BOTTOM OF HOLE

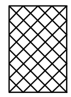
WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#15

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,773.64 E 570,224.85	GROUND ELEVATION: 3680.98
BEGUN: 8/30/2000 FINISHED: 9/11/2000	TOTAL DEPTH: 330.0 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 5.0 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

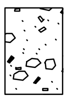
SOIL

Fill (made ground)

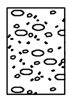


ROCK

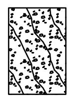
Tpcprn



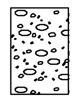
Tpcpul



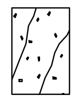
Tpcpmn



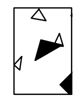
Tpcpll



Tpcpln

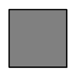


Breccia



WELDING

Densely Welded



HARDNESS

Alpha-numeric descriptor	Descriptor	Criteria
H1	Extremely	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very Hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately Hard	Can be scratched with knife or sharp pick with light pressure. Core or fragment breaks with moderate hammer blow.
H5	Moderately Soft	Can be grooved 1/16 inch (2mm) deep by sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

WEATHERING

Alpha-numeric descriptor	Descriptor	General characteristics (strength, excavation, etc.)
W1	Fresh	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as Siltstones or shales.
W2	Slightly weathered to fresh	
W3	Slightly weathered	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classified as rock excavation.
W4	Moderately to slightly weathered	
W5	Moderately weathered	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstones or shales.
W6	Intensely to moderately weathered	
W7	Intensely weathered	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very intensely weathered	
W9	Decomposed	Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes".

FRACTURE DENSITY

Alpha-numeric descriptor	Descriptor	Criteria (Excludes mechanical breaks)
FD0	Unfractured	No observed fractures.
FD1	Very slightly fractured	Core recovered mostly in lengths greater than 3 feet (1 m).
FD2	Slightly to very slightly fractured	
FD3	Slightly fractured	Core recovered mostly in lengths from 1 to 3 feet (300 to 1,000 mm) with few scattered lengths less than 1 foot (300 mm) or greated than 3 feet (1,000 mm).
FD4	Moderately to slightly fractured	
FD5	Moderately fractured	Core recovered mostly in lengths from 0.33 to 1.0 foot (100 to 300 mm) with most lengths about 0.67 foot (200 mm).
FD6	Moderately to intensely fractured	
FD7	Intensely fractured	Lengths average from 0.1 to 0.33 foot (30 to 100 mm) with fragemented intervals. Core recovered mostly in lengths less than 0.33 foot (100 mm).
FD8	Very intensely to intensely fractured	
FD9	Very intenesely fractured	Core recovered mostly as chips and fragments with a few scattered short core lengths.

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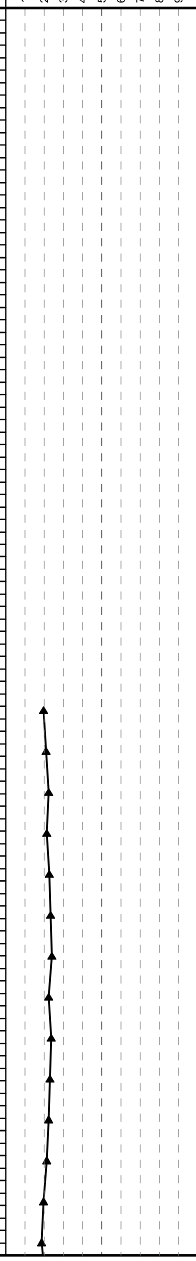
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 8/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,055.54 E 570,472.65
TOTAL DEPTH: 452.8 ft.
DEPTH TO BEDROCK: 75.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.03
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	0–22.4					0, 10, 18, 0, 0		Fill GP	
	22.4–25.9					100		Qal (SP-SM)g	
	25.9–33.8					31, 0, 0, 26		Qal (GP)c	
	33.8–35.2					0			
	35.2–38.1					100, 100		Qal (SM)gc	
	38.1–					58, 35, 0, 91, 100		Qal (GP-GM)sc	



NOTES

PURPOSE OF HOLE:
Develop geologic design data required for Waste Handling Building foundation parameters and seismic hazard analysis.

DRILL EQUIPMENT:
Schramm T685 Drill Rig, UDR 1000 Drill Rig

DRILLER:
G. Fox, M. Fyffe, D. Harrison; Dynatec Drilling, Inc., Salt Lake City, Utah

DRILLING METHOD:
Augered to approximately 3.5' where boulder was encountered. Pulled auger bit and installed 13.75" hammer bit. Continued with hammer to 4.9'. Cemented casing with 1.11' stickup. Re-entered hole with PQ coring system. Cored with PQ to 97.6'. Used PQ rods as casing and installed HQ coring system. Cored with HQ to the total depth of 452.8'.

DRILLING CONDITIONS:
0.0 to 3.5: Hard, difficult drilling with augers in coarse material.
3.5 to 4.9: No problems reported.
4.9 to 66.0: Difficult drilling characterized by short runs, blocking off and often tripping out.
66.0 to 223.6: Easier drilling, less blocking off, longer runs.
223.6 to 452.8: Difficult drilling characterized by loss of circulation, blocking off, and short runs.

DRILLING FLUID:
0 to 3.5: none
3.5 to 4.9: non-potable water
4.9 to 452.8: non-potable water, *Hydrogel* mud with *EZ-Mud* and LCM to re-establish circulation.

DRILL FLUID LOSS INTERVALS:
11 ft.
51 ft.
164.6 ft.
166 ft.
227.5 ft.
233 ft.
237 ft.
245 ft.
250.4 ft.
252.5 ft.
277 ft.
278 ft.*

* Remaining hole drilled without circulation

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 22.4 ft. PAD FILL (Fill)

0.0 - 22.4: POORLY GRADED GRAVEL (GP)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff; approximately 50% have a spotty very light gray vapor phase coating; noncrystalline less than 2mm in thickness; maximum size recovered, 75mm.

22.4 to 75.7 ft. QUATERNARY ALLUVIUM (Qal)

22.4 - 25.9: POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM)g
About 60% coarse to fine sand; about 30% coarse to fine, angular to subangular gravel of welded tuff and felsic phenocrysts, up to 30 x 30mm; about 10% silty fines; maximum size recovered, 50mm; brown with white caliche stringers; hard consistency; weakly cemented with caliche; weak reaction with HCl.

25.9 - 33.8: POORLY GRADED GRAVEL WITH COBBLES (GP)c
About 90% coarse to fine, hard, angular to subangular gravel of welded tuff, approximately 70% with spotty caliche coatings; about 10% fine to medium sand; several fine-grained caliche fragments; loosely cemented. Total interval (by volume) approximately 30% cobbles; maximum size recovered, 120mm.

33.8 - 35.2: No Recovery

35.2 - 38.1: SILTY SAND WITH GRAVEL AND COBBLES (SM)gc
About 45% predominately fine to coarse, angular to subangular sand; about 35% fine to coarse, angular to subangular gravel of welded tuff; about 20% silty fines with no dry strength and low plasticity; brown; moist; strong reaction with HCl. Total interval (by volume) approximately 35% cobbles; maximum size recovered, 230mm.

38.1 - 49.8: POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc
About 60% fine to coarse, angular to subangular gravel of welded tuff; about 30% fine to coarse, angular sand; about 10% silty fines with no to low dry strength; light brown; moist; no to strong reaction with HCl. Total interval (by volume) approximately 5% cobbles; maximum size recovered, 90mm.

49.8 - 53.3: SILTY SAND WITH GRAVEL (SM)g
About 45% fine to medium sand; about 40% fine to coarse, angular to subangular gravel of welded tuff; about 15% silty fines with low plasticity and low dry strength; maximum size recovered, 60mm; light brown; moist; weak to strong reaction with HCl.

53.3 - 56.0: SILTY GRAVEL WITH SAND (GM)s
About 55% fine to coarse, angular to subangular gravel of welded tuff; about 30% fine to coarse, angular sand; about 15% silty, nonplastic fines with low dry strength; maximum size recovered, 50mm; light brown; moist; strong reaction with HCl.

56.0 - 60.4: SILTY SAND WITH GRAVEL (SM)g
About 50% predominately fine to coarse, angular to subangular sand; about 35% fine to coarse, subangular gravel of Tiva Canyon Tuff clasts; about 15% silty fines with no to low plasticity and low dry strength; maximum size recovered, 70mm; light brown, white caliche bed from 58.7-59.0; moist; weak to strong reaction with HCl.

60.4 - 66.0: SILTY GRAVEL WITH SAND (GM)s
About 50% coarse to fine, angular to subangular gravel of Tiva Canyon Tuff clasts; about 35% predominately fine sand; about 15% silty fines with low plasticity and low dry strength; maximum size recovered, 75mm; strongly cemented with caliche, breaks

COMMENTS:
1. All measurements are in feet unless noted otherwise.
2. No attempts to re-establish circulation were made below 278 ft.
3. LCM (Lost Circulation Material) consists of cellophane cuttings.
4. USCS classifications were determined in the field, where limited classification methods were available in order to keep samples intact for future tests.
5. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.
6. USCS soil classifications are based on USBR Earth Manual procedure 5005 - Determining Unified Soil Classification (Visual Method)

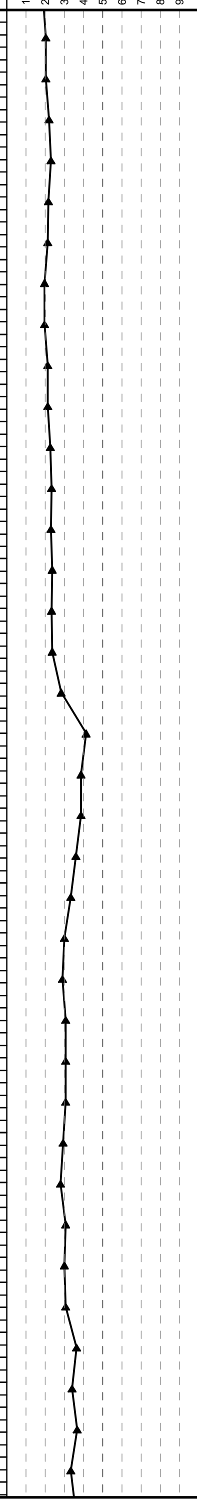
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

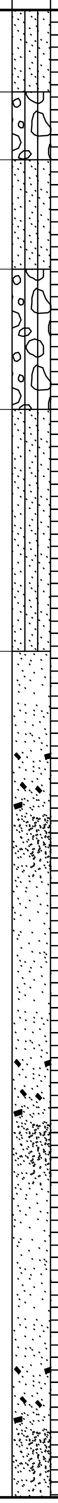
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 8/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,055.54 E 570,472.65
TOTAL DEPTH: 452.8 ft.
DEPTH TO BEDROCK: 75.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.03
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105	1000–9000				70, 87		Qal (SM)g	
						100, 83, 100, 100		Qal (GM)s	
						94, 62		Qal (SM)g	
						100, 100, 73, 100, 100		Qal (GM)s	
						97, 96		Qal (SM)g	
			H4		FD2	100	89	Tpki	
					FD0	98	98		
						100	100		
						97	97		
						100	100		
						100	100		
						99	99		





CASING RECORD:
0 to 4.9: 10.75" O.D. casing
0 to 97.6: PQ casing
97.6 to 452.8: No casing

HOLE COMPLETION:
Pulled all casing and left open for future geophysical studies.

CLASSIFICATION AND PHYSICAL CONDITION

only with hammer blow; light brown to pale orange; moist; strong reaction with HCl.

66.0 - 75.7: SILTY SAND WITH GRAVEL (SM)g
About 45% predominately fine sand; about 35% coarse to fine, angular to subangular gravel of welded Tiva Canyon Tuff and Tuff X; about 20% silty fines; maximum size recovered, 60mm; strongly cemented with caliche, breaks only with hammer blow; light brown to pale orange; moist; strong reaction with HCl.

75.7 to 133.2 ft. COMBS PEAK IGNIMBRITE - TUFF X (Tpki):
Nonwelded flow, moderately indurated, argillized and partially zeolitized, very pale orange with grayish-orange mottling. The tuff has approximately 20-25% pumice, up to 35x30mm in size, with about 10-15% volcanic lithic clasts. up to 25x25mm. Rare phenocrysts of sanidine, biotite (bronze), magnetite (?), and manganese oxides. Generally the tuff is moderately hard (H4) to soft (H6), slightly (W3) to moderately (W5) weathered, and unfractured (FD0) to slightly fractured (FD2). Lower contact is unconformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
75.9	70	R2	Calcite
130.1	70	R3	trace Fe

133.2 to 137.8 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5):
Nonwelded, possibly reworked fallout tephra and pyroclastic flows separated by distinct paleosols. The tuff is moderately indurated, devitrified, pale yellowish-brown with 10 to 15 percent pumice clasts (up to 10x7mm), and less than 10 percent volcanic lithic clasts.(up to 4x5 mm). The bedded tuffs have about 2 percent phenocrysts of feldspar, quartz, and biotite. Generally the tuff is moderately hard (H4) to soft (H6), slightly (W3) to moderately (W6) weathered, and unfractured (FD0) to slightly fractured (FD3). Lower contact is unconformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
137.0	70	R3	light ash
137.3	60	R3	light ash

137.8 to 222.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, densely welded, devitrified, pale red to grayish-red, with 10 to 15 percent phenocrysts. Phenocrysts are mostly feldspar and biotite with lesser quartz and pyroxene. Rare pumice clasts from 145.9 to 157.1 feet. and up to 20 percent pumice clasts from 157.1 to 192.0 feet. The tuff has up to 15 percent lithophysal cavities from 192.0 to 208.0 feet. Generally the tuff is moderately hard (H4), slightly (W3) weathered, and slightly fractured (FD3) to moderately fractured (FD5). The lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
138.3	55	R3	Calcite
138.6	80	R3	Calcite
139.5	80	R2	Calcite
140.7-141.1	25	R4	trace Calcite
141.6	70	R3	trace Calcite
141.6-142.1	25	R3	Calcite
141.85	80	R2	trace Calcite
142.5	70	R3	trace Calcite
142.5-142.8	25	R3	brown mineral
143.7	60	R3	trace Calcite
143.6-144.6	20	R4	Calcite
144.4	80	R2	none
147.2	85	R2	none
147.8-148.1	30	R3	none
148.9-149.5	25	R3	none
150.3-151.6	FRACTURE ZONE		
153.1-157.1	FRACTURE ZONE		
157.1-159.3	FRACTURE ZONE		
160.3-164.4	FRACTURE ZONE		
162.8 (fault?)	30	R3	none
165.3	50	R3	clay, sand
165.6 (fault?)	50	R3	clay, sand
166.3	40	R3	trace sand
168.1	50	R3	healed
168.7	90	R3	sand

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

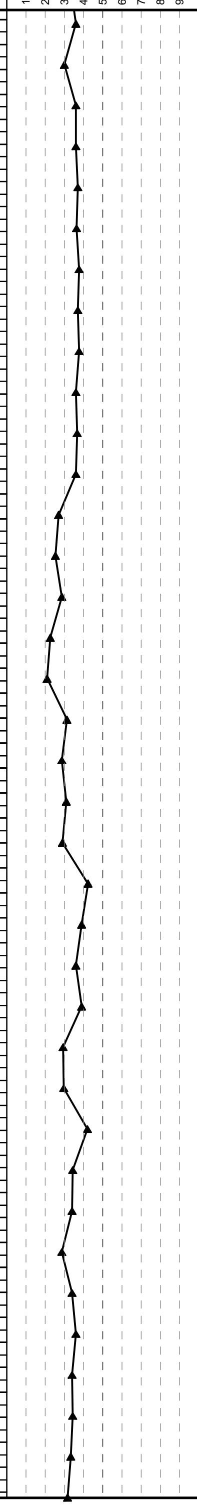
SHEET 3 OF 9

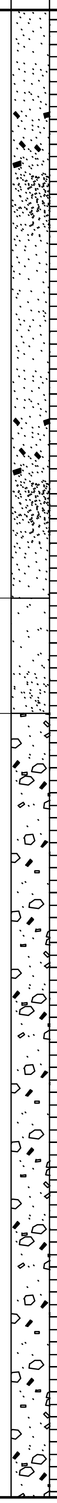
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 8/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,055.54 E 570,472.65
TOTAL DEPTH: 452.8 ft.
DEPTH TO BEDROCK: 75.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.03
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	110–165	1000 2000 3000 4000 5000 6000 7000 8000 9000	H4, H6, H4, H6, H5, H4, H5, H4, H5, H4, H5		FD0, FD1, FD0, FD3, FD5, FD3, FD8, FD2, FD7, FD5, FD7, FD4	98, 100, 82, 98, 100, 97, 91, 97, 97	98, 98, 82, 98, 59, 78, 24, 13, 44	Tpki, Tpbt5, Tpcrn	





CLASSIFICATION AND PHYSICAL CONDITION

169.7	80	R3	clay
169.8	60	R3	clay
170.1	60	R3	clay, sand
170.6	90	R3	clay, sand
171.2	15	R3	sand
171.0-174.6	FRACTURE ZONE		
174.6	55	R4	trace clay
175.1	60	R4	none
176.0	15	R4	sand
176.8	50	R3	healed
177.8	20	R3	clay, sand
179.3	30	R4	clay, sand
179.4	80	R4	sand
179.7	55	R4	trace clay, sand
180.9	20	R2	clay, sand
185.2	40	R3	trace clay
185.6	40	R3	sand, trace clay
187.4	30	R3	trace clay
187.9	60	R3	trace sand
188.1	55	R3	sand
188.5	20	R3	sand, trace clay
189.0	55	R3	sand
190.6	65	R3	vapor phase alteration
191.2	65	R3	none
191.8	40	R3	none
192.0	35	R3	none
193.3	45	R4	none
193.9	45	R4	trace sand
197.3	30	R4	none
197.4	30	R3	none
197.6	25	R3	clay
198.1	60	R3	clay
198.9	25	R4	clay
199.4	55	R4	none
203.4	50	R3	sand
203.8	50	R3	none
204.0	40	R3	none
204.7	35	R3	trace sand
204.9	30	R3	trace sand
203.4-203.6	25	R3	none
203.6	90	R2	none
204.1	90	R3	none
204.2	90	R3	none
204.6	50	R2	none
204.7-204.9	30	R2	none
205.7	45	R3	none
206.8	45	R3	none
206.8-207.3	FRACTURE ZONE		
208.2-208.9	FRACTURE ZONE		
209.3	irreg.	R2	none
210.3	70	R2	none
210.5-210.7	10	R3	none
212.1-212.2	30	R2	none
213.7	45	R3	quartz crystals
216.1	75	R3	quartz crystals
221.0-221.3	25	R4	trace Calcite
221.1-221.3	35	R2	none

222.0 to 360.0 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, moderate orange-pink with light gray mottling, and about 3-5% lithophysae (up to 50x50mm) with light gray crystal coating. Tuff has approximately 5 percent pumice clasts (up to 10x4mm). There are less than 5 percent phenocrysts of plagioclase and sanadine, with less than 1 percent biotite and manganese oxide. At 247.0 the phenocrysts content decreases to less than 1 percent. Lithophysae, both filled and unfilled, content increases to 20 percent at 301.0 feet. Generally the tuff is moderately hard (H4), slightly (W4) to moderately weathered (W6), and slightly fractured (FD3) to very intensely fractured (FD9). The lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
221.8-224.9	FRACTURE ZONE		
225.4	55	R4	trace Calcite
225.4-225.8	FRACTURE ZONE		
225.8-226.0	10	R4	trace Calcite
226.1	70	R3	none
226.1-226.7	FRACTURE ZONE		
226.7-226.8	40	R3	none
226.9-227.0	FRACTURE ZONE		
227.0-227.2	40	R3	none
227.3	80	R2	none

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

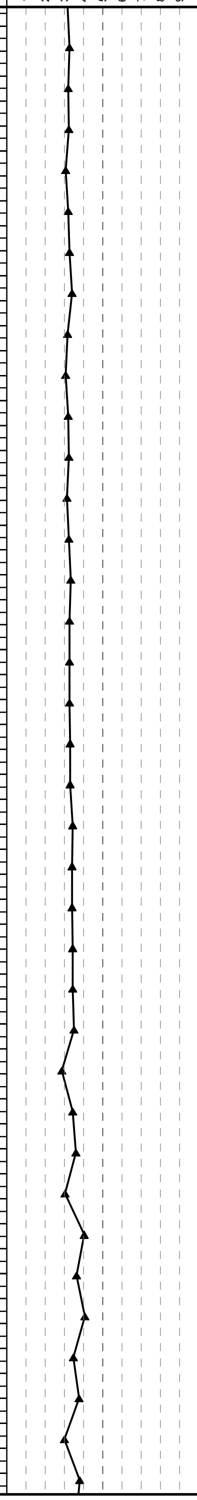
SHEET 4 OF 9

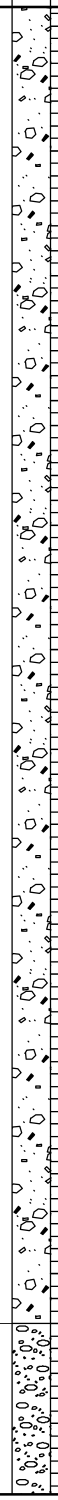
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 8/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,055.54 E 570,472.65
TOTAL DEPTH: 452.8 ft.
DEPTH TO BEDROCK: 75.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.03
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	170		H5		FD4	97	44	Tpcrn	
	175				FD8	100	58		
	180				FD5	100	74		
	185				FD4	100	74		
	190				FD6	76	0		
	195		H4		FD8	82	45		
	200				FD6	76	0		
	205				FD5	62	0		
	210				FD4	79	52		
	215				FD5	97	44	Tpcpul	
	220				FD8	58	0		
	225				FD6	100	36		
					FD8	84	26		
					FD6				





CLASSIFICATION AND PHYSICAL CONDITION

227.7-227.8	90	R3	white mineral
228.0-228.6	15	R3	none
229.2	60	R3	none
229.2-229.6	20	R3	none
230.7-230.9	55	R2	none
231.1	90	R2	none
231.1-231.5	FRACTURE ZONE		
231.8	45	R2	trace quartz crystals
231.8-232.3	FRACTURE ZONE		
232.3	60	R3	trace quartz crystals
233.0-233.2	45	R3	quartz crystals
235.0-235.1	45	R3	trace Calcite
235.8	50	R2	none
235.7-236.3	15	R3	none
235.9-236.3	25	R3	trace Calcite
236.1-236.3	25	R3	none
237.9	45	R2	none
238.7-238.9	15-20	R2	quartz crystals
239.2	70	R2	quartz crystals
239.8	60	R2	quartz crystals
240.0	60	R3	none
240.2	50	R2	trace iron oxide
240.4	70	R3	none
240.4-241.1	10-15	R3	none
241.2-241.7	15	R3	none
241.8-243.8	FRACTURE ZONE		
244.5-244.7	20	R2	trace Calcite
246.8	15	R2	none
248.6	20	R3	trace white mineral
248.9	25	R3	trace white mineral
249.7	30	R3	none
251.8	5	R3	none
252.5	10	R3	none
255.4	10	R2	none
255.8	15	R2	none
256.4	75	R2	lithophysal
257.5	40	R3	trace sand
259.5	30	R2	none
261.1	50	R3	none
263.5	80	R3	none
264.5	20	R2	none
265.9	15	R3	sand, trace clay
266.4	60	R3	none
266.9	30	R3	clay
269.0	20	R3	sandy breccia
272.9-277.3	FRACTURE ZONE		
277.4	0	R4	none
278.6	10	R3	none
279.1	50	R4	none
279.2	40	R4	none
279.5	25	R3	none
280.6-284.4	FRACTURE ZONE		
284.4-284.6	20	R3	none
284.6-284.8	45	R2	none
286.3-286.6	35	R3	quartz crystals
287.7	55	R4	clay, quartz crystals
289.3-290.0	0	R3	none
291.8	35	R3	clayey breccia
292.8	90	R3	clayey breccia
293.0	30	R3	clay
294.7	90	R2	clayey breccia
294.9	60	R2	clayey breccia
297.3-297.8	15	R3	trace Calcite
297.6	70	R3	none
298.0	60	R2	clayey breccia
298.2	80	R3	none
298.9-302.5	FRACTURE ZONE		
301.5	45	R3	quartz crystals
303.1	35	R3	trace clay
305.0-313.7	FRACTURE ZONE		
308.6-309.1	15	R3	none
310.4-310.7	20	R2	clayey breccia
310.2-310.5	30	R2	clayey breccia
312.4-312.6	30	R4	trace clay
314.4-314.8	20	R3	none
315.2	45	R4	none
315.6-316.0	25	R3	none
318.4	50	R2	quartz crystals
322.0-322.2	20	R2	none
323.4-324.0	30	R2	clayey breccia
324.3-325.1	10	R3	clayey breccia
324.7-325.3	25	R3	clayey breccia
324.9-325.6	0	R3	clayey breccia
325.2-325.9	20	R2	clayey breccia
326.1-327.3	FRACTURE ZONE		

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

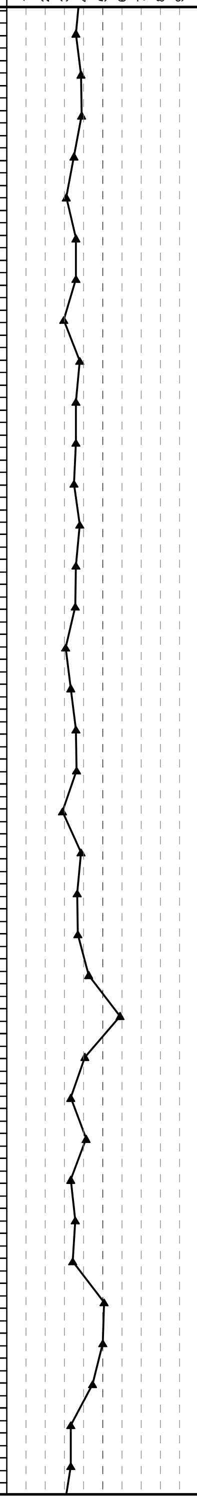
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 8/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,055.54 E 570,472.65
TOTAL DEPTH: 452.8 ft.
DEPTH TO BEDROCK: 75.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.03
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES | DEPTH | SHEAR WAVE VELOCITY ft/s (1000 2000 3000 4000 5000 6000 7000 8000 9000) | ENGINEERING INDEXES: HARDNESS | WELDING | FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION

DEPTH: 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285



HARDNESS: H4

GEOLOGIC UNIT: Tpcpul

FRACTURE DENSITY	% CORE RECOVERY	% RQD
FD6	84	26
FD7	86	32
FD5	100	48
	64	43
	100	32
FD6		
FD8	83	0
	92	0
FD5	89	61
FD8	93	0
	86	0
FD6	95	0
FD8	76	16
FD5	94	63
FD4	96	61
FD6	90	0
	86	0
	73	30
FD9	19	0
	78	0
FD6	82	39
FD9	40	0
	85	0
FD8		
FD3	100	67
	100	52

CLASSIFICATION AND PHYSICAL CONDITION

327.3	35	R2	none
330.8-332.0	CLAYEY BRECCIA ZONE		
333.6	50	R3	none
332.7-333.3	20	R3	quartz, Calcite
332.9	50	R3	none
334.7-335.9	0	R2	quartz crystals
335.1	50	R3	trace clay
335.5	75	R3	none
335.6	55	R3	none
336.1-337.3	FRACTURE ZONE		
337.9	40	R2	clayey breccia
338.0-338.4	CLAYEY BRECCIA ZONE		
338.4	40	R3	none
338.5-338.7	30	R3	none
338.6	45	R3	none
339.5-340.8	FRACTURE ZONE		
341.7-345.3	FRACTURE ZONE		
346.0	60	R2	trace quartz
346.2-347.0	10	R3	none
346.4-346.8	0	R4	none
346.5-346.9	10	R4	none
346.8	80	R3	none
347.3-348.6	FRACTURE ZONE		
348.3-348.7	20	R3	clayey breccia
348.7	40	R3	none
349.2-349.7	15	R3	none
349.0-349.4	20	R3	none
350.9	30	R3	none
351.0	60	R3	trace Calcite
351.1-351.2	0	R3	clay
351.6-352.8	FRACTURE ZONE		
354.3-356.1	FRACTURE ZONE		
356.4	50	R3	trace Calcite
356.5	85	R3	none
356.5-356.7	30	R3	trace Calcite
356.8-357.3	0	R3	none
358.4	60	R2	clay, Calcite
358.5	60	R2	Calcite
358.7-359.0	20	R4	clay, quartz, Calcite
358.9	80	R3	quartz, Calcite
359.6	70	R3	iron oxide, Calcite

360.0 to 403.0 ft. TIVA CANYON TUFF MIDDLE NON-LITHOPHYSAL ZONE (Tpcpmn)
Pyroclastic flow, densely welded, predominately pale red tuff with less than 5% flattened pumice, and less than 1% lithophysae. The tuff has less than 1 percent phenocrysts of plagioclase, sanidine, and rare manganese oxide. Volcanic lithic content increases with depth with poorly developed anastomosing vapor phase partings. Generally the tuff is moderately hard (H4) to moderately soft (H5) in isolated zones, slightly (W3) to moderately weathered (W5), and slightly fractured (FD3) to intensely fractured (FD8).

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
360.1-360.4	40	R3	iron oxide, Calcite
360.5	85	R2	breccia, Calcite
360.6-360.9	40	R3	Calcite
360.7	65	R3	clay,Calcite
361.2	85	R2	quartz, Calcite
362.0	30	R4	Calcite
362.2-362.5	25	R4	none
363.1	90	R3	none
364.0	70	R2	none
364.9-365.2	30	R4	trace Calcite
365.5	80	R4	none
367.2	85	R2	none
372.9	70	R3	clay, quartz
373.1	90	R2	clay, quartz, Calcite
373.2-373.7	25	R3	quartz, Calcite
375.3	60	R3	trace quartz
375.8	60	R3	clay
376.5-376.9	20	R4	none
377.0-377.3	25	R3	none
377.4-377.7	30	R3	none
379.7-381.2	0	R4	none
380.8	20	R3	quartz, Calcite
381.2	90	R3	trace quartz
381.4-381.6	30	R3	trace quartz, Calcite
382.8-383.2	20	R4	none
383.3-383.7	CLAYEY BRECCIA ZONE		
383.8-384.2	20	R4	none
384.3	50	R3	trace quartz

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

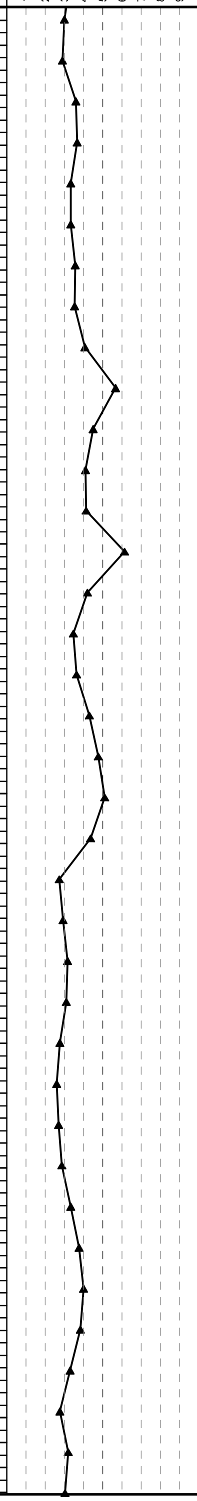
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 8/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,055.54 E 570,472.65
TOTAL DEPTH: 452.8 ft.
DEPTH TO BEDROCK: 75.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.03
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	290–345	1000 2000 3000 4000 5000 6000 7000 8000 9000	H4		FD3	100	52	Tpcpul	
					FD4	97	59		
					FD9	87	0		
					FD7	92	0		
					FD8	33	0		
						50	0		
					FD3	100	48		
					FD7	31	0		
						100	0		
						95	0		
					FD8	91	0		
					FD9				
					FD8	81	0		
					FD6	100	81		
					FD3				
					FD6	98	53		
					FD8				
					FD7	96	34		
					FD3				
					FD6				
					FD9	67	0		
					FD6	92	0		
					FD7	100	0		
					FD8	100	0		
					FD5	83	0		
					FD9	100	18		
					FD8	100	0		
						50	0		
					FD5	78	35		
					FD8				
					FD7	75	0		
					FD6	93	0		
						100	0		



CLASSIFICATION AND PHYSICAL CONDITION

385.2-385.4	30	R3	clay, trace quartz
385.5-386.5	FRACTURE ZONE		
386.5-386.9	10	R3	trace quartz, trace Calcite
388.4-389.5	CLAYEY BRECCIA ZONE		
393.1	55	R3	quartz, Calcite
393.8	45	R4	quartz, Calcite
394.3	30	R3	clay, quartz, Calcite
395.0-395.5	30	R3	trace quartz, Calcite
395.8	70	R3	quartz, trace Calcite
396.2-396.4	30	R3	quartz, Calcite
397.2	45	R3	clay
397.7-398.1	25	R2	none
398.2-398.6	40	R3	none
398.6	40	R3	clayey breccia
398.7	60	R2	trace Calcite
399.3	60	R3	trace Calcite
399.7-399.9	30	R3	none
400.2	85	R3	trace quartz, Calcite
401.0	40	R3	breccia, quartz, Calcite
402.3	50	R4	quartz, Calcite
402.7	90	R2	none

403.0 to 422.5 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER LITHOPHYSAL ZONE (Tpcpll)
Pyroclastic flow, densely welded, devitrified, moderate orange pink tuff with rare light gray pumice. phenocrysts of sanidine and rare biotite compose less than 1 percent of the rock by volume. Lithophysal cavities compose up to 10 percent of the rock by volume with vapor phase mineral coatings, additionally 10 percent of the rock contains light gray vapor phase mineral spots up to 30 by 48 mm in size. Generally the tuff is hard (H3), slightly weathered (W3), and slightly to very slightly fractured (FD2). Lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
403.0-403.4	30	R2	quartz, Calcite
404.0	70	R3	quartz, Calcite
404.3-406.0	5	R2	quartz, Calcite
404.6	80	R2	none
405.9-406.2	35	R3	quartz, Calcite
406.4-406.7	25	R3	none
406.4-407.6	5	R2	none
408.3	60	R3	trace quartz
409.2	60	R3	none
409.5-409.8	25	R3	trace quartz, Calcite
410.2-410.6	5	R3	clay, quartz, Calcite
410.6-411.7	FRACTURE ZONE		
415.7	55	R2	clay, quartz, Calcite
416.0-416.5	15	R2	clayey breccia, quartz
418.8-419.7	FRACTURE ZONE		

422.5 to 452.8 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER NON-LITHOPHYSAL ZONE (Tpcpln)
Pyroclastic flow, densely welded, devitrified, pale red tuff with less than 1 percent light gray pumice clasts. Phenocrysts of sanidine and plagioclase compose less than 1 percent of the rock by volume. Medium gray lithic clasts compose less 1 percent of the rock by volume. Generally the tuff is moderately hard (H4), slightly weathered (W3), with fracture densities mostly moderately fractured (FD5) to intensely fractured (FD7) zones. Lower contact undetermined, bottom of borehole at 452.8 ft.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
422.9-423.6	5	R3	clayey breccia, quartz, iron oxide, Calcite
424.3-424.6	20	R4	quartz, Calcite
424.6-424.9	10	R3	quartz, Calcite
424.7-425.1	40	R3	quartz, Calcite
425.5-425.8	30	R4	Calcite, trace iron oxide
426.2-429.2	FRACTURE ZONE		
429.8	30	R4	trace Calcite, trace iron oxide
430.1-430.8	10	R3	trace Calcite
430.6-431.3	20	R3	quartz, Calcite
430.8	45	R4	Calcite, trace iron oxide
431.0-431.6	0-25	R2	quartz, Calcite
431.5-441.7	FRACTURE ZONE		
435.5-435.8	20	R4	trace Calcite, trace iron oxide
435.4	60	R3	trace Calcite
436.3	45	R4	Calcite, trace iron oxide

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

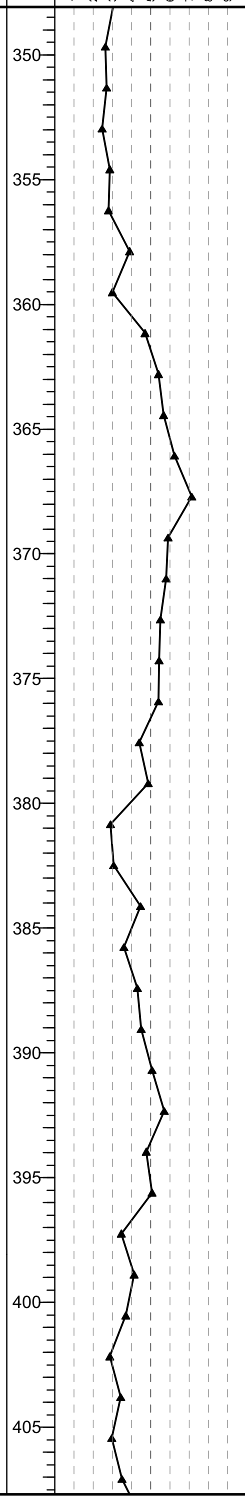
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 8/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,055.54 E 570,472.65
TOTAL DEPTH: 452.8 ft.
DEPTH TO BEDROCK: 75.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.03
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES



ENGINEERING INDEXES

HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]
H4		FD7			Tpcpul
H4		FD6	85	0	Tpcpul
H4		FD7	80	0	Tpcpul
H4		FD8	83	0	Tpcpul
H4		FD5	73	47	Tpcpul
H4		FD9	56	0	Tpcpul
H4		FD7	95	0	Tpcpul
H4		FD7	90	0	Tpcpul
H4		FD6	100	25	Tpcpmn
H4		FD5	100	67	Tpcpmn
H4		FD4	100	89	Tpcpmn
H4		FD3	100	55	Tpcpmn
H4		FD5			Tpcpmn
H4		FD4	94	56	Tpcpmn
H5		FD6	89	0	Tpcpmn
H5		FD7	100	0	Tpcpmn
H4		FD3	100	78	Tpcpmn
H4		FD5	100	63	Tpcpmn
H4		FD6	90	0	Tpcpmn
H4		FD6	100	0	Tpcpll

GRAPHIC

CLASSIFICATION AND PHYSICAL CONDITION

437.8-438.1	25	R4	trace Calcite, trace iron oxide
438.1	45	R3	trace quartz, trace Calcite, trace iron oxide
438.1-438.3	20	R3	trace Calcite
438.9	90	R3	Calcite
441.3-441.5	25	R3	clayey breccia
441.8	60	R3	Calcite
442.0-442.3	40	R3	none
443.1	35	R2	none
443.3-443.7	20	R3	quartz, Calcite, trace iron oxide
443.7-443.9	FRACTURE ZONE		
446.4	45	R3	none
449.4-450.0	5-30	R3	trace quartz, Calcite, trace iron oxide
449.9	80	R3	clayey breccia
449.9-452.8	CLAYEY BRECCIA ZONE		

* Angles are measured from core axis and are plus or minus 5 degrees.

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

SHEET 8 OF 9

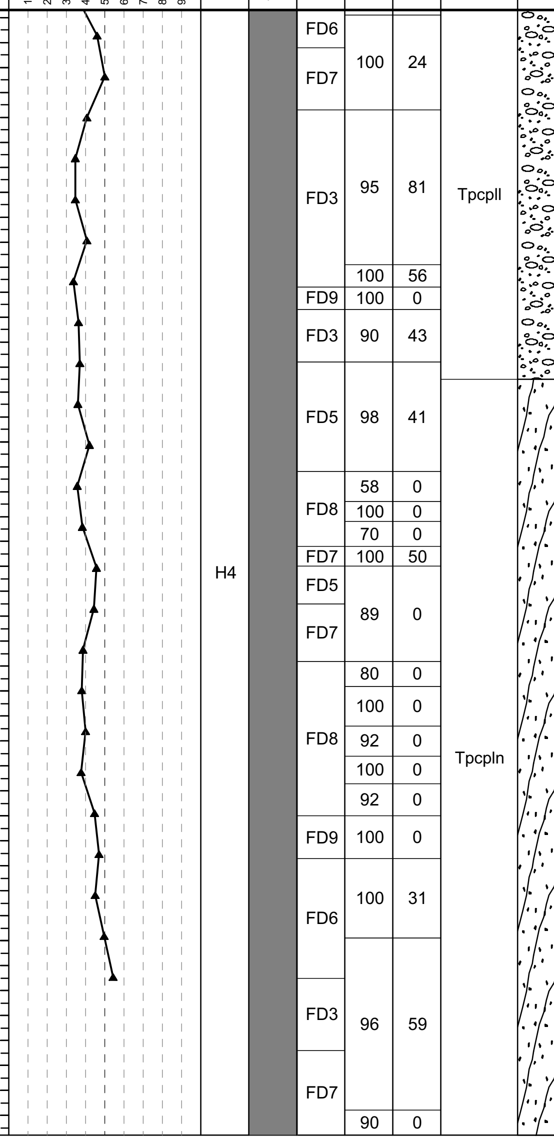
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 8/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,055.54 E 570,472.65
TOTAL DEPTH: 452.8 ft.
DEPTH TO BEDROCK: 75.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.03
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000–9000)	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

Depth scale: 410, 415, 420, 425, 430, 435, 440, 445, 450



HARDNESS: H4

FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT
FD6	100	24	Tpcpll
FD7			
FD3	95	81	
	100	56	
FD9	100	0	
FD3	90	43	
FD5	98	41	Tpcpln
FD8	58	0	
	100	0	
	70	0	
FD7	100	50	
FD5	89	0	
FD7			
FD8	80	0	
	100	0	
	92	0	
	100	0	
	92	0	
FD9	100	0	
FD6	100	31	
FD3	96	59	
FD7			
	90	0	

BOTTOM OF HOLE

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

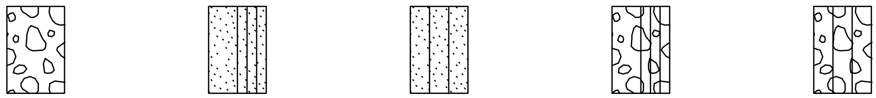
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#16

SHEET 9 OF 9

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,055.54 E 570,472.65	GROUND ELEVATION: 3672.03
BEGUN: 6/26/2000 FINISHED: 8/7/2000	TOTAL DEPTH: 452.8 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 75.7 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

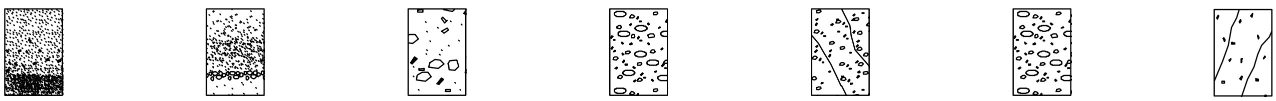
SOIL

USCS Poorly-graded Gravel (GP) | USCS Poorly-graded Sand with Silt (SP-SM) | USCS Silty Sand (SM) | USCS Poorly-graded Gravel with Silt (GP-GM) | USCS Silty Gravel (GM)



ROCK

Tuff "x" (Tpki) | Post Tiva Canyon Bedded Tuff (Tpbt5) | Tpcprn | Tpcpul | Tpcpmn | Tpcpll | Tpcpln



WELDING

Non-Welded | Densely Welded

HARDNESS

Alpha-numeric descriptor	Descriptor	Criteria
H1	Extremely	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very Hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately Hard	Can be scratched with knife or sharp pick with light pressure. Core or fragment breaks with moderate hammer blow.
H5	Moderately Soft	Can be grooved 1/16 inch (2mm) deep by sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

WEATHERING

Alpha-numeric descriptor	Descriptor	General characteristics (strength, excavation, etc.)
W1	Fresh	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as Siltstones or shales.
W2	Slightly weathered to fresh	
W3	Slightly weathered	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classified as rock excavation.
W4	Moderately to slightly weathered	
W5	Moderately weathered	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstones or shales.
W6	Intensely to moderately weathered	
W7	Intensely weathered	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very intensely weathered	
W9	Decomposed	Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes".

FRACTURE DENSITY

Alpha-numeric descriptor	Descriptor	Criteria (Excludes mechanical breaks)
FD0	Unfractured	No observed fractures.
FD1	Very slightly fractured	Core recovered mostly in lengths greater than 3 feet (1 m).
FD2	Slightly to very slightly fractured	
FD3	Slightly fractured	Core recovered mostly in lengths from 1 to 3 feet (300 to 1,000 mm) with few scattered lengths less than 1 foot (300 mm) or greated than 3 feet (1,000 mm).
FD4	Moderately to slightly fractured	
FD5	Moderately fractured	Core recovered mostly in lengths from 0.33 to 1.0 foot (100 to 300 mm) with most lengths about 0.67 foot (200 mm).
FD6	Moderately to intensely fractured	
FD7	Intensely fractured	Lengths average from 0.1 to 0.33 foot (30 to 100 mm) with fragemented intervals. Core recovered mostly in lengths less than 0.33 foot (100 mm).
FD8	Very intensely to intensely fractured	
FD9	Very intenesely fractured	Core recovered mostly as chips and fragments with a few scattered short core lengths.

RF16_KEY WHB.GPJ WHB.GDT 6/14/02

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GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000–9000)	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	0.0–5.0					0			
	5.0–7.1					100		Qal (GP)s	
	7.1–14.2					59		Qal (GP-GM)s	
						69			
	14.2–22.2					49		Qal (GP)c	
						84			
	22.2–25.5					67		Qal (GP-GM)s	
	25.5–28.4					48		Qal GW	
	28.4–32.9					100		Qal (GP)c	
						66			
	32.9–34.3					100		Qal (GM)s	
	34.3–36.8					76		Qal (GP-GM)sc	
	36.8–44.0					100		Qal (GP)c	
						93			
						69			
	44.0–					61		Qal (GW-GM)c	
						67			

NOTES

PURPOSE OF HOLE:
Acquire geologic design data required to develop Waste Handling Building foundation parameters and seismic hazard analysis.

DRILL EQUIPMENT:
Schramm T685 Drill Rig, UDR 1000 Drill Rig

DRILLER:
G. Fox, D. Harrison; Dynatec Drilling, Inc.; Salt Lake City, Utah.

DRILLING METHOD:
Installed 12" hammer. Hammered to 4.9'. Cemented casing with 1.1' stickup. Re-entered hole on 8/7/2000 with PQ coring system. Cored with PQ to 195.3'. Used PQ rods as casing and installed HQ coring system. Cored with HQ to the total depth of 667.8'.

DRILLING CONDITIONS:
0.0 to 187.8: Replaced 3 bits, lost circulation at 47.8' and 175.3'.
187.8 to 667.8: No circulation, hard, smooth drilling.

DRILLING FLUID:
0.0 to 4.9: non-potable water
4.9 to 667.8: non-potable water, *Quik Gel* mud with *EZ-Mud* and LCM to re-establish circulation.

LOSS INTERVALS:
47.8 ft.
175.3 ft.
187.5 ft.*

* Remaining hole drilled without circulation

CASING RECORD:
0.0 to 4.9: 10.75 O.D. casing
0.0 to 195.3: PQ casing
195.3 to 667.8: No casing

HOLE COMPLETION:
Pulled all casing and left open for future geophysical studies.

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 96.1 ft. QUATERNARY ALLUVIUM (Qal)

0.0 - 5.0: No Recovery

5.0 - 7.1: POORLY GRADED GRAVEL WITH SAND (GP)s
About 75% coarse to fine, angular gravel; about 20% predominately fine to medium sand; about 5% silty fines; maximum size recovered, 65mm; slightly to moderately cemented with caliche; light brown; moist; strong reaction with HCl.

7.1 - 14.2: POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s
About 60% gap graded fine and coarse, angular to subangular gravel; about 30% coarse to fine sand; 10% fines with low plasticity; maximum size recovered, 70mm; non-cemented to moderately cemented with caliche; light brown; moist; weak to strong reaction with HCl.

14.2 - 22.2: POORLY GRADED GRAVEL WITH COBBLES (GP)c
About 85% predominately coarse and fine, angular to subangular gravel of densely welded tuff with some caliche coating; about 10% predominately fine sand; about 5% fines with low plasticity; non-cemented to slightly cemented with caliche; light brown, maroon and gray; moist; strong reaction with HCl. Total interval (by volume) approximately 10% cobbles; maximum size recovered, 120mm.

22.2 - 25.5: POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s
About 60% coarse to fine, angular gravel; about 30% fine to coarse, predominately angular sand; about 10% fines with low plasticity; maximum size recovered, 65mm; non-cemented to slightly cemented with caliche; light brown to gray; moist; strong reaction with HCl.

25.5 - 28.4: WELL GRADED GRAVEL (GW)
Almost entirely coarse to fine, angular to subangular, well graded gravel; trace of sand and fines that appear to be washed out; maximum size recovered, 65mm; non-cemented; light brown, gray, white and maroon; moist.

28.4 - 32.9: POORLY GRADED GRAVEL WITH COBBLES (GP)c
About 85% coarse to fine, angular to subangular, poorly graded gravel; about 10% predominately coarse to fine, angular sand; about 5% silty fines; non-cemented; brown to gray; moist; strong reaction with HCl. Total interval (by volume) approximately 15% cobbles; maximum size recovered, 130mm.

32.9 - 34.3: SILTY GRAVEL WITH SAND (GM)s
About 45% coarse to fine, angular to subangular gravel with a trace of caliche coating some surfaces; about 40% fine to coarse, angular sand; about 15% silty fines; maximum size recovered, 45mm; non-cemented to slightly cemented; light brown; moist; strong reaction with HCl.

34.3 -36.8: POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc
About 65% predominately fine to coarse, angular to subangular gravel; about 25% fine to coarse, predominately medium sand; about 10% silty fines; non-cemented; light brown; moist; strong reaction with HCl. Total interval (by volume) approximately 5% cobbles; maximum size recovered, 95mm.

36.8 - 44.0: POORLY GRADED GRAVEL WITH COBBLES (GP)c
About 85% coarse to fine, angular to subangular gravel; about 10% predominately fine sand; about 5% fines with low plasticity; slightly to moderately cemented with caliche; light brown; moist;

COMMENTS:
1. All measurements are in feet unless noted otherwise.
2. No attempts to re-establish circulation were made below 187.5 ft.
3. LCM (Lost Circulation Material) consists cellephane cuttings or cotton seed hulls.
4. USCS classifications were determined in the field, where limited classification methods were available due to the desire to keep samples intact for future tests.
5. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.
6. USCS soil classifications are based on USBR Earth Manual procedure 5005 - Determining Unified Soil Classification (Visual Method)

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

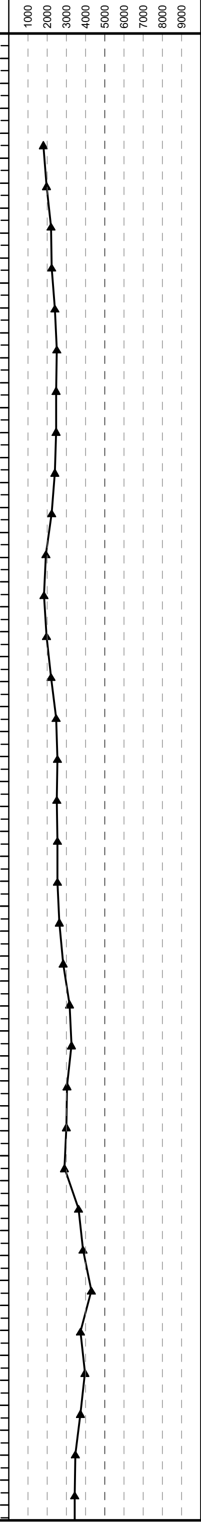
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY



% CORE RECOVERY: 67, 56, 100, 57, 83, 71, 100, 100, 100, 93, 65, 6, 65, 53, 81, 57, 100, 97, 100, 98, 100, 100, 100, 63, 100

% RQD: 98, 100, 100, 100, 63, 100

HARDNESS: H5

FRACTURE DENSITY: FD0, FD1, FD0

GEOLOGIC UNIT [USCS]: Qal (GP)c; Qal SM; Qal (GM)s; Qal (GP-GM)sc; Qal (GP)c; Qal (SM)gc; Tmbt1

strong reaction with HCl. Total interval (by volume) approximately 15% cobbles of welded tuff; maximum size recovered, 190mm.

44.0 - 50.8: WELL GRADED GRAVEL WITH SILT AND COBBLES (GW-GM)c
About 80% fine to coarse, angular to subangular, well graded gravel; about 10% fine to coarse, angular sand; about 10% silty fines; non-cemented; light brown to gray; moist; weak to strong reaction with HCl. Total interval (by volume) approximately 5% cobbles; maximum size recovered, 110mm.

50.8 - 65.4: POORLY GRADED GRAVEL WITH COBBLES (GP)c
About 90% coarse to fine, angular to subangular, poorly graded gravel; about 5% fine to coarse, angular sand; about 5% silty fines; non-cemented to moderately cemented with caliche; light brown to gray; moist; strong reaction with HCl. Total interval (by volume) approximately 15% cobbles (greater near bottom of interval); maximum size recovered, 135mm.

65.4 - 66.3: SILTY SAND (SM)
About 80% predominately fine sand; about 20% silty fines; trace of fine gravel; maximum size recovered, 5mm; non-cemented; light brown; moist; strong reaction with HCl.

66.3 - 69.3: SILTY GRAVEL WITH SAND (GM)s
About 55% coarse to fine, angular to subangular, poorly graded gravel; about 30% predominately fine to coarse, angular sand; about 15% silty fines; maximum size recovered, 75mm; non-cemented; light brown to gray; moist; weak reaction with HCl.

69.3 - 71.9: POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc
About 70% predominately coarse to fine, angular to subangular, poorly graded gravel; about 20% coarse to fine, angular to subangular sand; about 10% silty fines; non-cemented to moderately cemented with caliche; light brown to gray; moist; no to weak reaction with HCl. Total interval (by volume) approximately 30% cobbles; maximum size recovered, 100mm.

71.9 - 85.3: POORLY GRADED GRAVEL WITH COBBLES (GP)c
About 85% predominately coarse to fine, angular to subangular, poorly graded gravel; about 10% coarse to fine, angular sand; about 5% fines with no to low plasticity; non-cemented; some caliche coating on gravel and cobbles; brown to gray; moist; no to strong reaction with HCl. Total interval (by volume) approximately 30% cobbles of welded tuff; maximum size, 150mm.

85.3 - 92.4: SILTY SAND WITH GRAVEL AND COBBLES (SM)gc
About 45% coarse to fine, angular to subangular sand; about 40% coarse to fine, angular to subangular gravel; about 15% fines with no to low plasticity; non-cemented to strongly cemented with caliche at 87.7; light brown, gray, beige; moist; weak to strong reaction with HCl. Total interval (by volume) approximately 5% cobbles; maximum size recovered, 100mm.

92.4 to 287.2 ft. BEDDED TUFF (Tmbt1)
Nonwelded pyroclastic flows with paleosols and reworked tuffaceous sediments. Medium grained (1 to 5 mm), very pale gray and generally massively bedded. Strongly caliche cemented from 92.4 to 96.1 ft. Tuff is moderately to slightly weathered (W4-5), some isolated intensely weathered (W7) zones; ranges from moderately hard (H4) to soft (H6), most moderately soft (H4); mostly unfractured (FD0) to slightly fractured (FD3) with some small zones of up to intensely fractured (FD7). Lower contact is unconformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
102.0	70	R3	clay
104.4	65	R3	clay, calcite calcite
115.3	35	R4	none
120.0	30	R4	none
138.8	90	R2	none
141.4	45	R3	none
141.8	45	R3	none
156.7	30	R3	none
171.0-172.3	0-5	R2	none
176.8	65	R3	trace clay
175.8	60	R3	none
183.8	60	R3	none

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

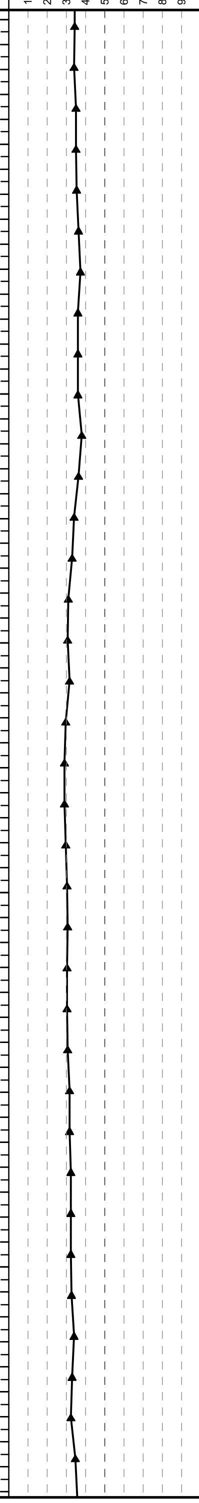
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	110		H5		FD0	100	100	Tmbt1	
						100	100		
						100	100		
	115				FD1	72	72		
					FD2	94	76		
	120				FD1	10	10		
	125					0	NR		
						95	95		
						100	100		
	130				FD0	100	100		
			H6			96	96		
			H5			100	100		
	135					69	69		
						100	100		
	140				FD3	100	78		
					FD1	100	100		
	145				FD0	100	100		
	150					100	100		
	155				FD1	100	100		
	160				FD0	100	100		
	165					100	100		



CLASSIFICATION AND PHYSICAL CONDITION

186.0	40	R3	trace clay
188.0	40	R3	clay
188.6	80	R4	none
188.8	85	R3	none
189.1	90	R3	trace black mineral
192.5	30	R2	clayey breccia
199.3	35	R3	none
199.8	90	R2	none
201.0	80	R4	trace clay
214.3	90	R3	none
231.4-243.9	CLAYEY BRECCIA ZONE		
244.6	25	R2	clay, iron oxide
247.6-247.8	FRACTURE ZONE		
248.0	90	R3	clay
249.1-249.4	15	R3	clay
250.2	60	R3	none
251.3-251.9	20	R2	none
253.8	85	R3	trace clay
254.9	85	R4	none
270.7	80	R3	none
283.2	90	R2	trace clay
291.6	80	R3	clay
300.3-300.7	30	R3	none
300.8	90	R3	none
301.6	80	R2	trace clay
305.6	65	R4	trace clay

287.2 to 348.4 ft. COMB PEAK IGNIMBRITE - TUFF X (Tpki): Nonwelded pyroclastic flow, moderately indurated, approximately 20-25% pumice (up to 35x30mm), about 10-15% volcanic lithic fragments (up to 25x25mm). Tuff is medium gray with rare phenocrysts of sanidine, biotite, magnetite, and manganese oxides. Generally the tuff is moderately soft (H5), moderately to slightly weathered (W4), and unfractured (FD0) to very slightly fractured (FD1).

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
347.5-348.0	15	R2	trace clay

348.4 to 368.9 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5): Nonwelded, possibly reworked fallout tephra and pyroclastic flows separated by distinct paleosols. The tuff is devitrified, pale yellowish-brown, moderately indurated, with 10 to 15 percent pumice, (up to 10x7mm), and less than 10 percent volcanic lithic fragments generally less than 1 mm. The bedded tuffs have about 1 percent feldspar, quartz phenocrysts, and approximately 2% biotite. Generally the bedded tuffs are moderately soft (H5), slightly (W4) to moderately (W6) weathered, mostly unfractured (FD0) to moderately fractured (FD4) with one zone of intensely fractured (FD7)rock.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
364.2-364.8	20	R3	none
366.6	50	R2	none
374.3-376.2	CLAYEY BRECCIA ZONE		
376.1	35	R2	trace clay
381.2-381.6	25	R2	none

368.9 to 478.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn) Pyroclastic flow, moderately to mostly densely welded, devitrified, pale red to grayish red, with 10 to 15 percent phenocrysts. Phenocryts mostly feldspar and some quartz, with rare biotite and pyroxene. Rare pumice from 392.0 to 404.6 feet and up to 20 percent pumice from 404.6 to 457.2 feet. Up to 15 percent lithophysal cavities from 457.2 to 471.4 feet. Generally the rock is soft to mostly moderately hard (H4), moderately to slightly weathered (W4), slightly (FD4) to intensely fractured (FD8).

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
381.3-382.3	10	R2	none
383.8	75	R3	none
383.8-384.3	10	R3	none
384.3-385.1	0	R3	none
385.8-386.0	25	R3	calcite
386.4-387.2	10	R2	breccia
387.0-388.5	5	R3	calcite
387.1-387.5	25	R3	none

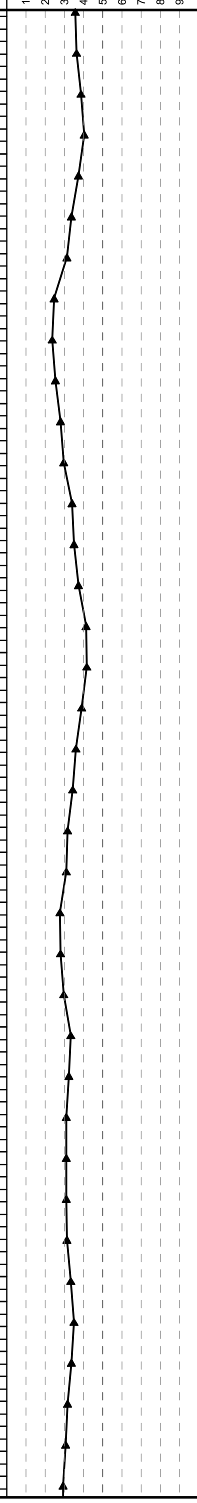
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	170–228		H5		FD1	100	100	Tmbt1	
						100	100		
						100	100		
						87	87		
					FD2	100	100		
					FD6	100	0		
					FD5	100	86		
					FD3	97	85		
						100	100		
						80	80		
						66	66		
						100	40		
						100	100		
						54	50		
						31	11		
						44	39		



CLASSIFICATION AND PHYSICAL CONDITION

390.0	30-90	R2	none
390.7	60	R3	none
391.0	60	R3	none
391.1-391.7	20	R2	none
391.1-391.7	FRACTURE ZONE		
394.5-397.5	FRACTURE ZONE		
397.2	40	R3	none
398.7-399.4	5-10	R2	trace clay
399.8	70	R3	none
401.1	60	R3	none
401.4-402.0	25	R3	clay
402.0-402.5	25	R2	none
403.4	50	R4	trace clay
403.8	30	R3	clay
404.4	60	R3	none
404.6	20-30	R3	clay
405.1-405.3	30	R3	clay
407.0-407.6	5-10	R2	none
407.8	65	R3	none
411.9-412.1	35	R3	clay
412.2-413.8	FRACTURE ZONE		
414.2-414.8	15	R3	clay
415.7	70	R3	quartz, calcite
417.3	35	R3	none
417.8	60	R3	none
418.8-419.9	5-15	R3	clay
419.9	45	R3	clay
421.3	35	R3	clay
422.5	55	R3	clay
423.5-424.0	10-20	R3	none
424.3-425.8	0-35	R2	none
425.9	60	R3	iron oxide
426.0	60-80	R3	trace iron oxide
427.0-427.2	45	R2	breccia
427.4-428.2	50	R2	trace calcite
428.8	55	R3	trace calcite, trace iron oxide
431.2	40	R3	clay
431.7	85-90	R2	clay, sand
434.7-437.3	FRACTURE ZONE		
438.5-440.6	FRACTURE ZONE		
441.5-442.2	5-30	R2	trace iron oxide
442.1	45	R3	trace iron oxide
443.4	50	R2	none
444.0-444.2	35	R2	trace iron oxide
444.4-444.6	40	R3	none
446.7-447.0	40-50	R3	none
447.7	40	R2	none
447.8-448.0	30	R2	none
448.2	40-50	R2	none
448.3-449.5	BRECCIA ZONE		
450.4-451.0	0-20	R2	none
451.6-452.0	0-45	R2	none
451.8-452.4	0-10	R2	none
452.2-452.4	40	R3	none
455.2-455.7	25	R2	none
458.0-458.2	40	R3	trace iron oxide
458.3-458.6	30	R3	trace iron oxide
459.4-462.9	FRACTURE ZONE		
463.5	65	R5	none
463.9	70	R2	breccia
464.2	80	R3	breccia
464.4	80	R3	breccia
466.9	75	R4	none
467.9	55	R4	none
470.7	90	R3	none

478.0 to 587.3 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow; densely welded; moderate orange-pink with light gray mottling; about 3-5% lithophysal, irregular up to 50x50mm with light gray crystal coating; pumice very light gray up to 10x4mm; rare felsics of sanadine; rare biotite. Hard (H3) to soft (H6), most moderately hard (H4); slightly (W4) to intensely (W7) weathered; slightly fractured (FD2) to very intensely fractured (FD9).

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
478.3	25	R4	none
478.4	70	R4	clayey breccia
478.5	70	R4	clayey breccia
478.8	60	R4	none
479.3	55	R4	none

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

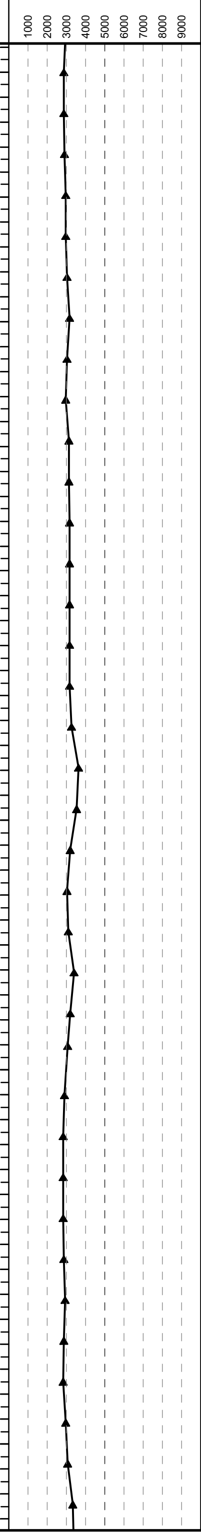
SHEET 5 OF 13

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
	230		H5		FD3	44	39	Tmbt1	
					FD7	46	0		
	235					46	0	(Clayey Breccia)	
	240					95	0		
						100	0		
	245				FD3	100	94	Tmbt1	
			H4		FD4	100	53		
	250		H5						
	255					100	51		
	260				FD3	100	100		
	265					100	100		
	270				FD1				
	275					100	100		
	280								
	285					100	100		



CLASSIFICATION AND PHYSICAL CONDITION

479.7	65	R5	trace calcite
479.8	45	R4	none
479.8	15	R3	none
480.0	50	R4	none
480.1	45	R4	none
480.2	50	R4	none
480.3	60	R4	none
480.3	85	R4	none
480.9	30	R3	breccia
481.3	40	R3	clayey breccia
481.7	70	R4	none
485.4	40	R3	none
488.7	50	R3	sandy, pumiceous breccia
489.8	55	R3	trace manganese oxide
491.1	55	R4	sandy, pumiceous breccia
493.6	60	R4	none
493.6	35	R4	none
493.8	25	R4	none
496.3	40	R6	clay
496.7	45	R4	none
496.9	35	R4	none
496.9	60	R4	none
497.1	55	R4	none
497.6-499.2	BRECCIA ZONE		trace iron oxide
500.1	40	R2	breccia
500.3	20	R3	none
500.5	20	R3	none
502.8	80	R5	none
506.8	45	R3	breccia
509.6	15	R3	none
518.9	45	R2	none
522.4	15	R2	trace iron oxide
522.6	65	R3	none
523.2	65	R3	none
545.0	10	R3	none
551.2	25	R2	none
551.4	30	R4	clay, gravel
552.6	5	R3	none
554.1	5	R3	none
555.8	30	R3	none
557.5	5	R3	clay, sand, gravel
559.0	5	R3	clay, sand, gravel
559.2	30	R4	sand, gravel
561.2	10	R3	none
564.9	35	R3	quartz
565.4	30	R4	clay
565.9	40	R3	none
566.9	20	R3	none
567.4	15	R2	none
568.2	35	R3	none
568.9	20	R3	quartz
569.7	10	R3	quartz
571.1	60	R3	none

587.3 to 637.6 ft. TIVA CANYON TUFF CRYSTAL POOR MIDDLE NON-LITHOPHYSAL ZONE (Tpcpmn)
Pyroclastic flow; densely welded; predominately pale red with mottled dark grayish red and scattered pink spots; mottling becomes fine-grained and merges with rock fabric with depth; mineralization in fractures only; less than 5% flattened and altered pumice; less than 1% lithophysal; lithics increase with depth. Moderately hard (H4); slightly to moderately weathered (W4); very slightly fractured (FD1) to moderately fractured (FD6).

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
580.4	35	R3	none
580.8	70	R3	none
581.2	30	R3	none
582.8	15	R3	trace clay
583.3	15	R3	trace clay
588.8	10	R3	quartz, sand
590.0	15	R3	trace quartz
591.5	65	R3	none
592.1	40	R3	none
594.4	15	R3	sand
595.3	20	R3	none
596.0	20	R3	quartz
597.5	10	R3	quartz
599.1	20	R3	trace quartz
610.8	30	R4	trace clay
611.2	55	R3	none
611.4	50	R3	none
612.1	30	R3	clay

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

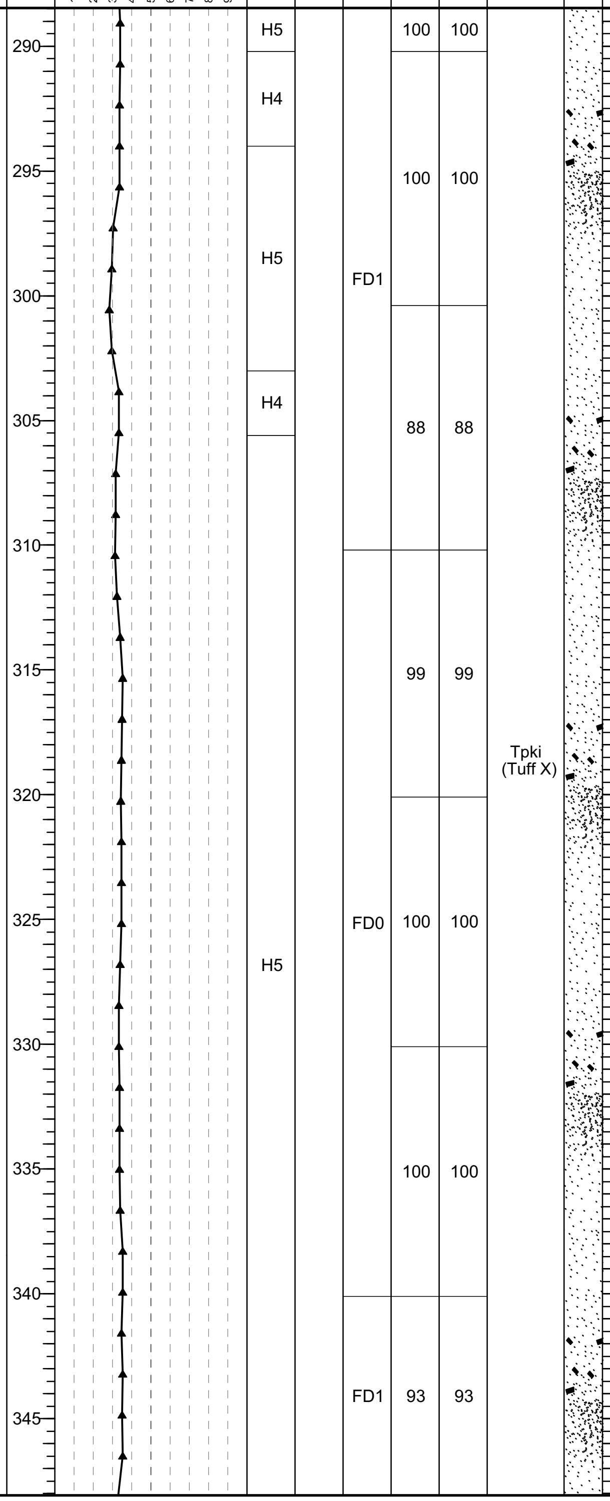
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



615.4	20	R4	none
619.2	35	R2	none
621.1	15	R3	none
622.4	30	R3	none
624.0	15	R2	calcite
624.6	80	R2	none
625.7	40	R3	none
626.4	85	R2	none
628.1	35	R3	quartz
628.4	60	R2	none
630.2	15	R3	quartz
631.0	30	R3	sand, gravel
632.3	50	R3	none
633.7	40	R2	manganese oxide
634.0	15	R3	clay, sand
634.9	40	R3	clay, sand
635.4	30	R3	none
635.9	75	R2	none
636.3	5	R3	none
636.7	25	R3	none
637.4	15	R2	none

637.6 to 653.2 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER LITHOPHYSAL ZONE (Tpcpll)
Pyroclastic flow, densely welded, devitrified, moderate orange pink tuff with rare light gray pumice. Phenocrysts of sanidine and rare biotite compose less than 1 percent of the rock by volume. Lithophysal cavities compose up to 10 percent of the rock by volume, up to 5 by 15 mm in size. Generally the tuff is moderately hard (H4), slightly weathered (W3), and moderately to intensely fractured (FD6). Lower contact is conformable.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
637.8	20	R3	clay, sand, gravel
638.7	65	R3	pumice
639.0	75	R4	manganese oxide
640.1	60	R3	none
640.5	35	R3	none
641.0	35	R2	none
642.1	85	R2	none
644.0	65	R3	clay, sand
645.2	75	R2	none
646.4	70	R2	none
646.6	30	R2	trace white mineral
646.8-647.0	40	R2	clay, sand, gravel
648.0-648.7	20	R2	clay, sand, gravel
650.3	30	R3	sand
650.4	30	R3	sand
651.9	25	R3	sand

653.2 to 667.8 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER NON-LITHOPHYSAL ZONE (Tpcpln)
Pyroclastic flow, densely welded, devitrified, pale red tuff with less than 1 percent light gray pumice clasts. Phenocrysts of sanidine and plagioclase compose less than 1 percent of the rock by volume. Medium gray lithic clasts compose less 1 percent of the rock by volume. Generally the tuff is moderately hard (H4), slightly weathered (W3), with fracture densities mostly moderately to intensely fractured (FD7). Lower contact undetermined, bottom of borehole at 667.8 ft.

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
653.5-657.4	5-15	R2	lapalli tuff
657.4	40	R2	clay, sand
658.5-658.7	25	R3	clay, sand
661.0-662.0	0-10	R4	none
661.1-661.3	30	R3	none
662.4	60	R4	none
663.0	65	R3	none
663.0-663.3	25	R4	none
663.4	55	R3	none
663.9-664.1	30	R4	quartz
664.2	65	R2	trace quartz
665.3	30	R4	none
665.7	35	R4	none
666.3	45	R3	trace calcite
666.3-666.6	30	R4	none
666.5-667.1	0-10	R3	quartz, calcite
667.2	45	R2	clayey breccia

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

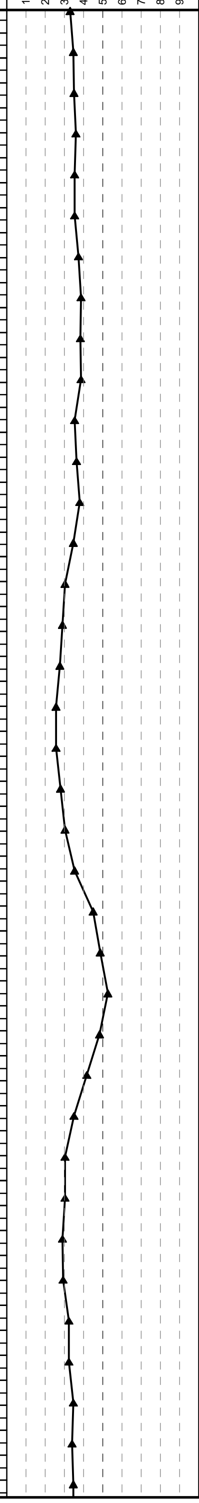
SHEET 7 OF 13

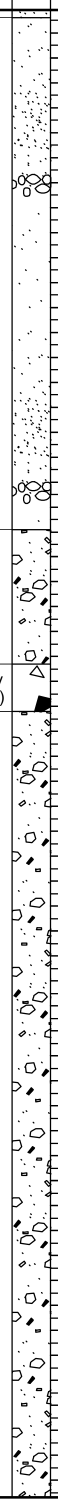
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000–9000)	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	350–405		H5		FD1	93	93	Tpbt5		* Angles are measured from core axis and are plus or minus 5 degrees.
					FD0	77	77			
					FD2	84	47			
						81	81	Tpcrn		
					FD7	100	77	(Clayey Breccia)		
			H4		FD4			Tpcrn		
					FD5	100	59			
					FD4	79	46			
					FD5					
					FD8	100	48			
					FD4					
			H7		FD5	100	28			
			H4							
			H7							
			H4		FD3	96	65			





WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

SHEET 8 OF 13

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

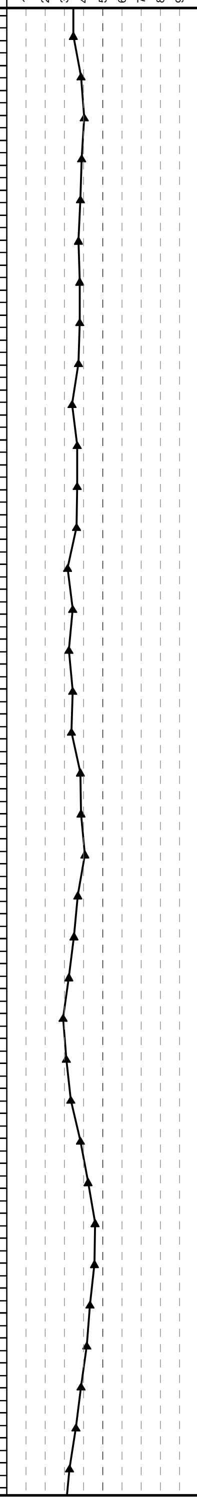
PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

DEPTH: 410, 415, 420, 425, 430, 435, 440, 445, 450, 455, 460, 465

SHEAR WAVE VELOCITY scale: 1000 2000 3000 4000 5000 6000 7000 8000 9000

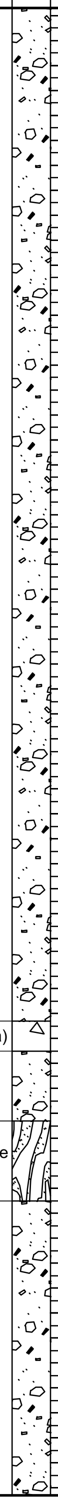


HARDNESS (top to bottom): H4, H6, H4, H6, H4, H6, H4, H6, H4, H6

FRACTURE DENSITY (top to bottom): FD3, FD7, FD5, FD4, FD6, FD4, FD7, FD5, FD8, FD4, FD7, FD5, FD7, FD3, FD7, FD8, FD7, FD8

% CORE RECOVERY	% RQD
96	65
97	47
99	22
97	56
100	57
100	38
75	55
100	0
78	0
69	0
79	38
0	NR

GEOLOGIC UNIT (top to bottom): Tpcrn, (Breccia), Tpcrn, (Fracture Fill), Tpcrn



CLASSIFICATION AND PHYSICAL CONDITION

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

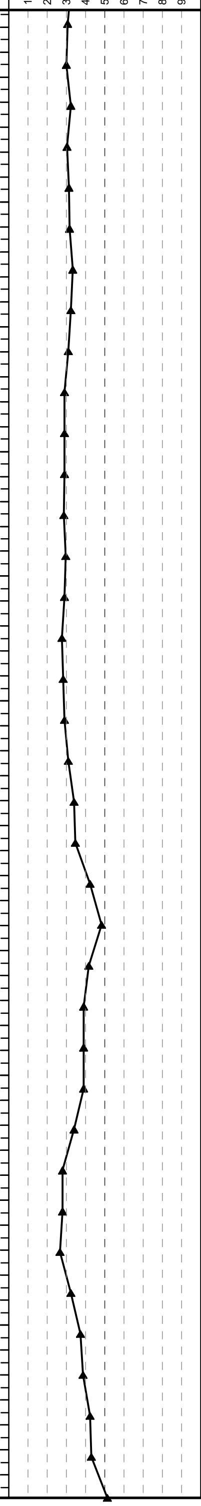
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES | DEPTH | SHEAR WAVE VELOCITY ft/s | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION

DEPTH: 470, 475, 480, 485, 490, 495, 500, 505, 510, 515, 520, 525



HARDNESS (top to bottom): H6, H5, H4, H6, H4, H6, H4, H6, H3, H4

FRACTURE DENSITY	% CORE RECOVERY	% RQD
FD8	82	41
FD7	89	56
FD6	83	83
FD5	93	93
FD4	87	78
FD6	100	52
FD8	100	0
FD7	80	46
FD4	89	74
FD8	69	21
FD7	54	0
FD9	89	43
	100	0
FD8	77	0
FD5	89	64
	100	39
FD7	64	0
FD8	100	0
FD7	75	0
FD8	91	0
FD6	81	0
FD8	60	0
FD3	100	86

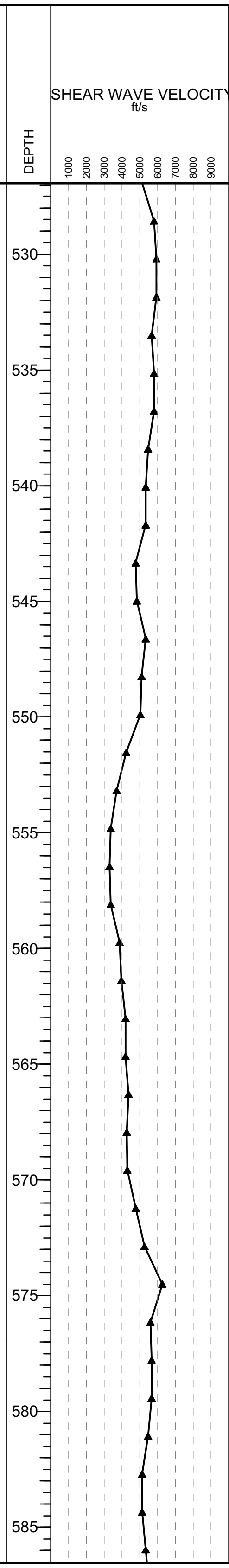
GEOLOGIC UNIT (top to bottom): Tpcrn, (Fracture Fill), Tpcrn, Tpcpul, (Fracture Fill), Tpcpul, (Fracture Fill), Tpcpul, (Fracture Fill), Tpcpul, (Breccia), Tpcpul

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown



NOTES	DEPTH	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		H4		FD3	100	86	Tpcpul		
				FD2	94	90			
					100	97			
				FD5	96	29			
				FD7	100	0			
				FD6	94	0			
				FD3	91	57			
				FD5	97	27			
				FD3	98	87			
					100	63			

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

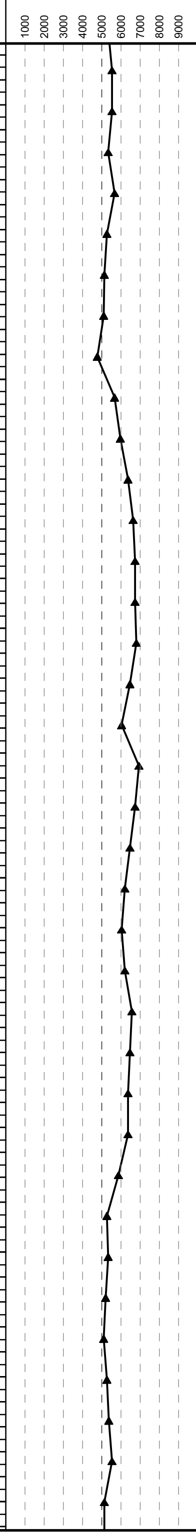
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
			H4		FD3	100	63	Tpcpul		
	590				FD4	100	88	Tpcpmn		
	595, 600				FD1	100	97			
	605, 610				FD2	100	77			
	615, 620					100	97			
	625, 630				FD3	100	62			
	635				FD6	100	0	Tpcpll (Fracture Fill)		
	640, 645				FD4	99	75	Tpcpll		



WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/27/2000 FINISHED: 8/29/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,075.86 E 571,041.88
TOTAL DEPTH: 667.8 ft.
DEPTH TO BEDROCK: 96.1 ft.

STATE: Nevada
GROUND ELEVATION: 3672.38
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000–9000)	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	650		H4		FD4	99	75	Tpcpll		
						100	80			
	655							Tpcpln		
	660					100	67			
	665				FD6	92	19			

BOTTOM OF HOLE

WHB_LOG WHB.GPJ WHB.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#17

SHEET 13 OF 13

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 766,075.86 E 571,041.88	GROUND ELEVATION: 3672.38
BEGUN: 6/27/2000 FINISHED: 8/29/2000	TOTAL DEPTH: 667.8 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 96.1 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

SOIL

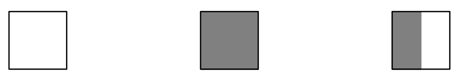
USCS Poorly-graded Gravel with Sand (GP)s	USCS Poorly-graded Gravel with Silt (GP-GM)	USCS Poorly-graded Gravel (GP)	USCS Well-graded Gravel (GW)	USCS Silty Gravel (GM)	USCS Well-graded Gravel with Silt (GW-GM)	USCS Silty Sand (SM)

ROCK

Pre-Ranier Mesa Bedded Tuff (Tmbt1)	Breccia	Tuff "x" (Tpki)	Tpcrn	Fracture Fill Material	Tpcpul	Tpcpmn	Tpcpll	Tpcpln

WELDING

Non-Welded	Densely Welded	Moderately Welded



HARDNESS

Alpha-numeric descriptor	Descriptor	Criteria
H1	Extremely	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very Hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately Hard	Can be scratched with knife or sharp pick with light pressure. Core or fragment breaks with moderate hammer blow.
H5	Moderately Soft	Can be grooved 1/16 inch (2mm) deep by sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

WEATHERING

Alpha-numeric descriptor	Descriptor	General characteristics (strength, excavation, etc.)
W1	Fresh	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as Siltstones or shales.
W2	Slightly weathered to fresh	
W3	Slightly weathered	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classified as rock excavation.
W4	Moderately to slightly weathered	
W5	Moderately weathered	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstones or shales.
W6	Intensely to moderately weathered	
W7	Intensely weathered	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very intensely weathered	
W9	Decomposed	Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes".

FRACTURE DENSITY

Alpha-numeric descriptor	Descriptor	Criteria (Excludes mechanical breaks)
FD0	Unfractured	No observed fractures.
FD1	Very slightly fractured	Core recovered mostly in lengths greater than 3 feet (1 m).
FD2	Slightly to very slightly fractured	
FD3	Slightly fractured	Core recovered mostly in lengths from 1 to 3 feet (300 to 1,000 mm) with few scattered lengths less than 1 foot (300 mm) or greated than 3 feet (1,000 mm).
FD4	Moderately to slightly fractured	
FD5	Moderately fractured	Core recovered mostly in lengths from 0.33 to 1.0 foot (100 to 300 mm) with most lengths about 0.67 foot (200 mm).
FD6	Moderately to intensely fractured	
FD7	Intensely fractured	Lengths average from 0.1 to 0.33 foot (30 to 100 mm) with fragemented intervals. Core recovered mostly in lengths less than 0.33 foot (100 mm).
FD8	Very intensely to intensely fractured	
FD9	Very intenesely fractured	Core recovered mostly as chips and fragments with a few scattered short core lengths.

RF17_KEY WHB.GPJ WHB.GDT 6/14/02

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GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#18

SHEET 1 OF 6

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 764,522.34 E 570,626.93	GROUND ELEVATION: 3640.34
BEGUN: 9/5/2000 FINISHED: 9/21/2000	TOTAL DEPTH: 493.6 ft.	ANGLE FROM HORIZONTAL: -90
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 65.0 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000 2000 3000 4000 5000 6000 7000 8000 9000)	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 6.01. Cement 10.75 O.D. casing with 1.29 stickup. Re-enter hole on 9/15/2000 with 8.50 Tricone bit. Drill from 6.01 to total depth of 493.56.

Drilling Conditions:
Lost circulation from 240.00 to 250.00.

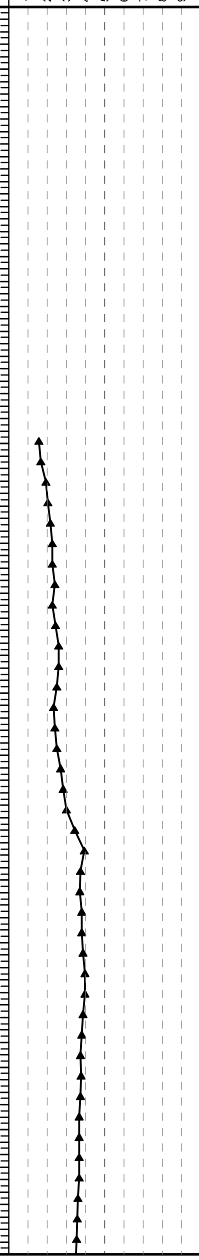
Drilling Fluid:
0.00 to 5.00: Non-potable water. 5.00 to 493.56: Quick Gel mud with EZ-Mud and LCM to re-establish circulation.

Loss Intervals:
240.00 to 250.00

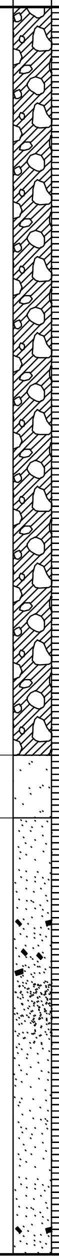
Casing Record:
0.00 to 6.01 : 10.75 O.D. casing. 6.01 to 493.56: No casing

Hole Completion:
Set and cement 492.41 of 4.50 schedule 80 PVC casing.

DEPTH: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95



GEOLOGIC UNIT: Qal (0 to 60); Tmbt1 (60 to 65); Tpki (65 onward)



0.0 to 60.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material has white to light gray caliche coatings.

60.0 to 65.0ft. BEDDED TUFF (Tmbt1)
Bedded tuff, nonwelded, crystalized, very pale-orange with 10 to 12 percent pumice clasts. Tuff contains less than 1 percent pale to moderate red volcanic lithic clasts. Quartz and feldspar phenocrysts range from 10 to 15 percent of the tuff by volume, and biotite and manganese less than 1 percent.

65.0 to 204.0ft. COMB PEAK IGNIMBRITE - TUFF X (Tpki):
Pyroclastic flow, nonwelded, crystalized, with up to 20 percent pumice clasts. Tuff contains 2 to 3 percent sanidine, plagioclase, quartz, and less than 1 percent biotite and hornblende phenocrysts. Up to 20 percent moderate red to medium dark gray, volcanic lithic clasts.

204.0 to 292.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystalized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 207.0 to 211.0 ft. moderately welded tuff has up to 8 percent, light gray pumice clasts. From 211.0 to 217 ft. densely welded tuff has up to 10 percent dark gray pumice. From 217.0 to 223.0 ft. grayish-brown pumice content decreases to 3 to 5 percent. Tuff is pumice poor (less than 1 percent) from 223.0 to 248.0. From 248.0 to 267.0 ft. the tuff has 10 to 15 percent very light gray to medium light gray pumice clasts.

292.0 to 425.0 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, crystalized, vapor phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 5 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor phase altered chips, indicating the edges of voids in the tuff.

425.0 to 470.0 ft. TIVA CANYON TUFF CRYSTAL POOR MIDDLE NON-LITHOPHYSAL ZONE (Tpcpmn)
Pyroclastic flow, densely welded, crystalized, pale red, with less than 1 percent sanidine, plagioclase, and biotite phencrysts. Tuff has up to 1 percent pumice clasts and less than 1 percent volcanic lithic clasts. Vapor phase altered chips indicate some lithophysae from 360.0 to 367.0 ft.

470.0 to 493.6 ft. TIVA CANYON TUFF CRYSTAL POOR LOWER LITHOPHYSAL ZONE (Tpcpll)
Pyroclastic flow, densely welded, crystalized, pale reddish-brown with minor vapor phase alteration. Less than 5 percent, very light gray, pumice clasts and less than 1 percent medium gray volcanic lithic clasts. Tuff contains less than 1 percent sanidine, plagioclase, biotite, and manganese phenocrysts.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

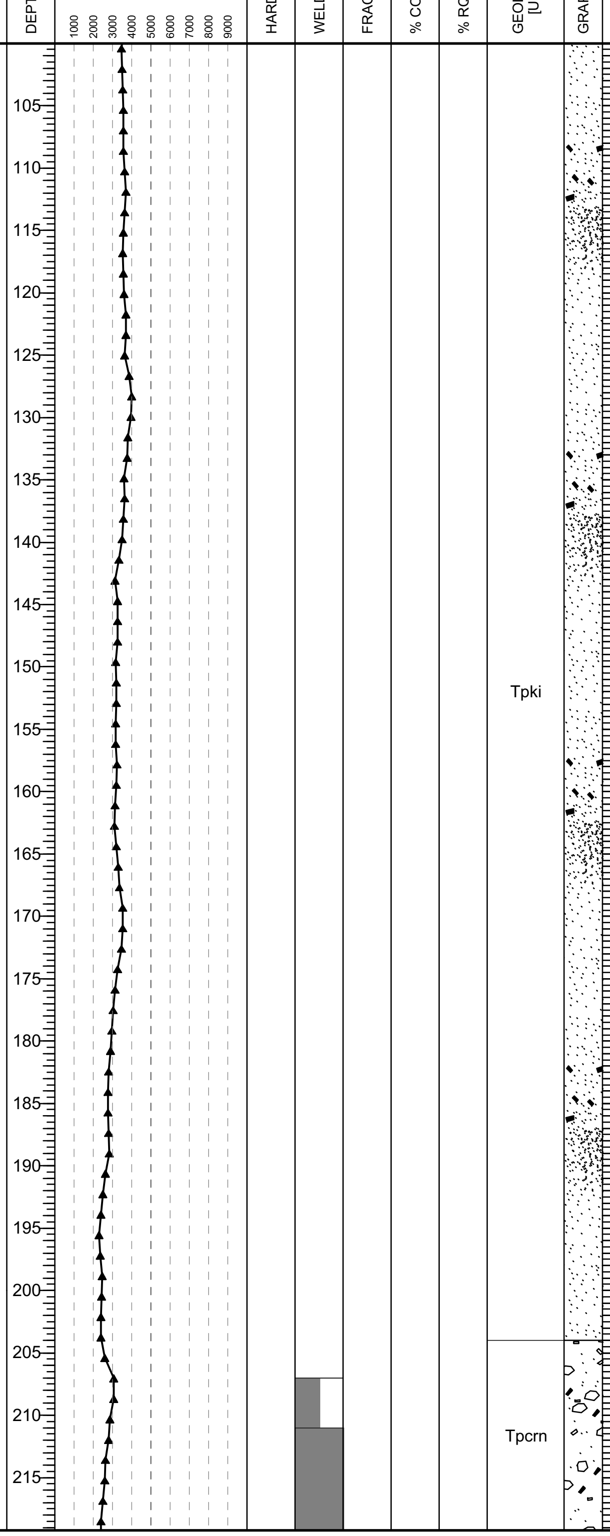
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#18

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/5/2000 FINISHED: 9/21/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,522.34 E 570,626.93
TOTAL DEPTH: 493.6 ft.
DEPTH TO BEDROCK: 65.0 ft.

STATE: Nevada
GROUND ELEVATION: 3640.34
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

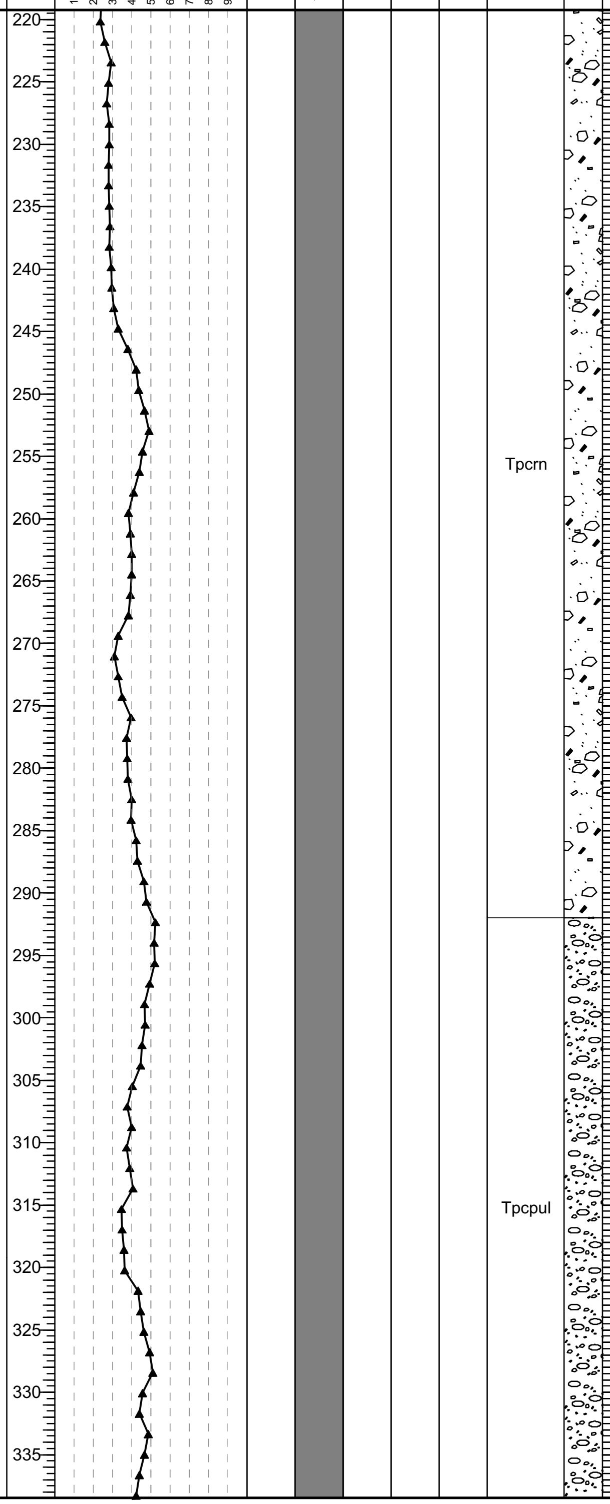
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#18

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/5/2000 FINISHED: 9/21/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,522.34 E 570,626.93
TOTAL DEPTH: 493.6 ft.
DEPTH TO BEDROCK: 65.0 ft.

STATE: Nevada
GROUND ELEVATION: 3640.34
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		1000 2000 3000 4000 5000 6000 7000 8000 9000	HARDNESS	WELDING	FRACTURE DENSITY					

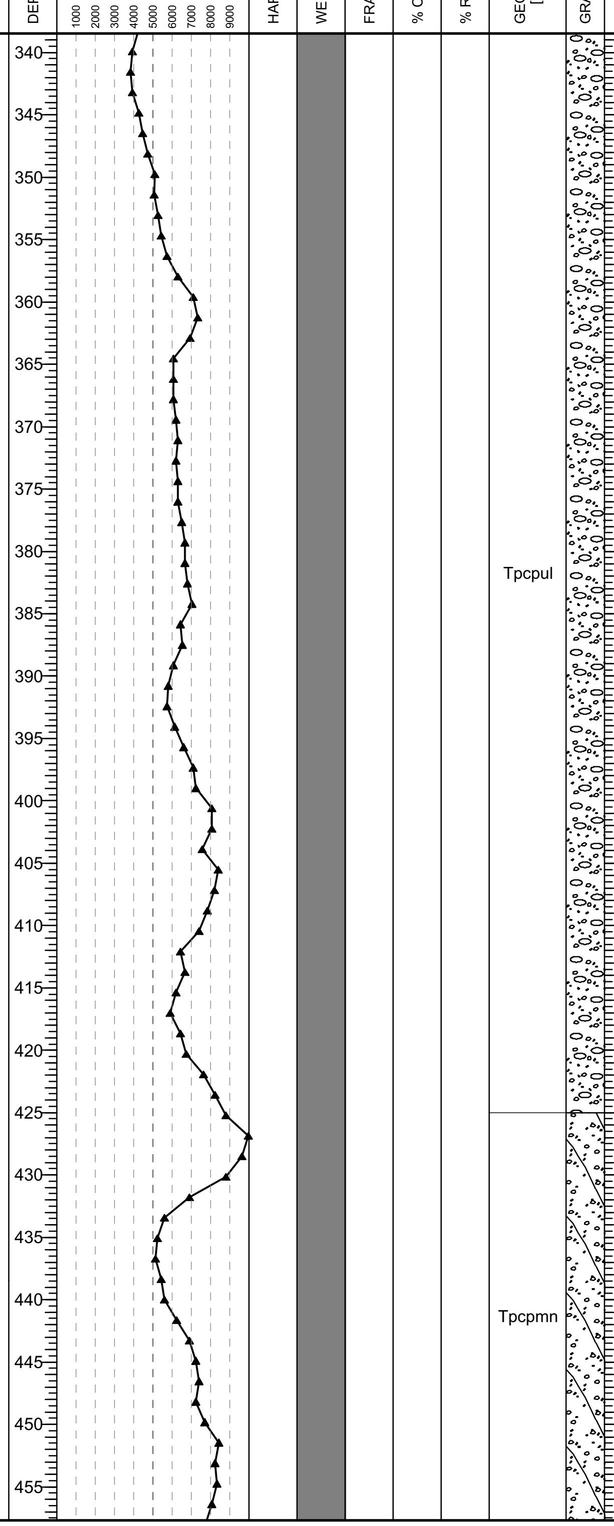


GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#18

SHEET 4 OF 6

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 764,522.34 E 570,626.93	GROUND ELEVATION: 3640.34
BEGUN: 9/5/2000 FINISHED: 9/21/2000	TOTAL DEPTH: 493.6 ft.	ANGLE FROM HORIZONTAL: -90
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 65.0 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

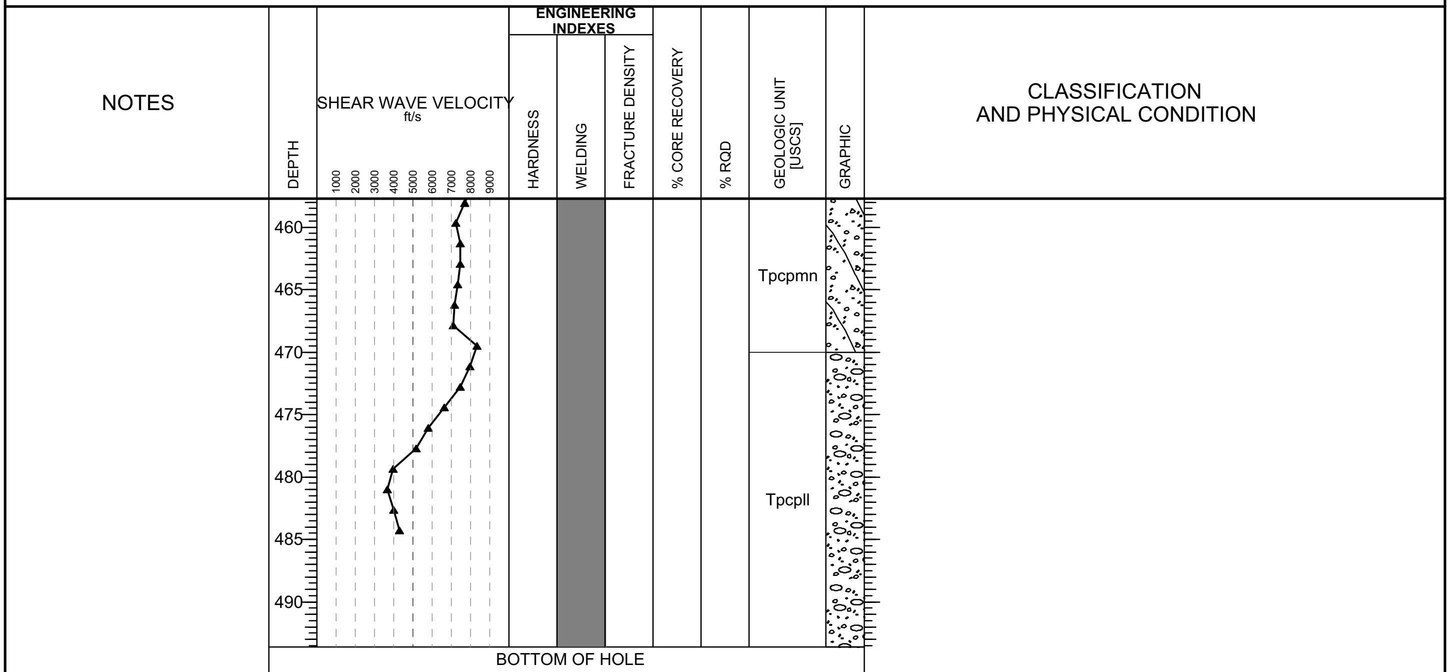
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#18

SHEET 5 OF 6

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/5/2000 FINISHED: 9/21/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,522.34 E 570,626.93
TOTAL DEPTH: 493.6 ft.
DEPTH TO BEDROCK: 65.0 ft.

STATE: Nevada
GROUND ELEVATION: 3640.34
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#18

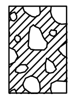
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/5/2000 FINISHED: 9/21/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,522.34 E 570,626.93
TOTAL DEPTH: 493.6 ft.
DEPTH TO BEDROCK: 65.0 ft.

STATE: Nevada
GROUND ELEVATION: 3640.34
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

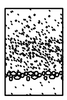
SOIL

Quarternary Alluvium (Qal)

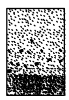


ROCK

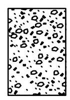
Pre-Ranier Mesa Bedded Tuff (Tmbt1)



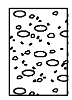
Tuff "x" (Tpki)



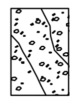
Tpcprn



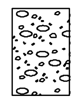
Tpcpul



Tpcpmn



Tpcpll



WELDING

Non-Welded

Densely Welded

Moderately Welded

RF18_KEY WHB.GPJ WHB.GDT 6/14/02

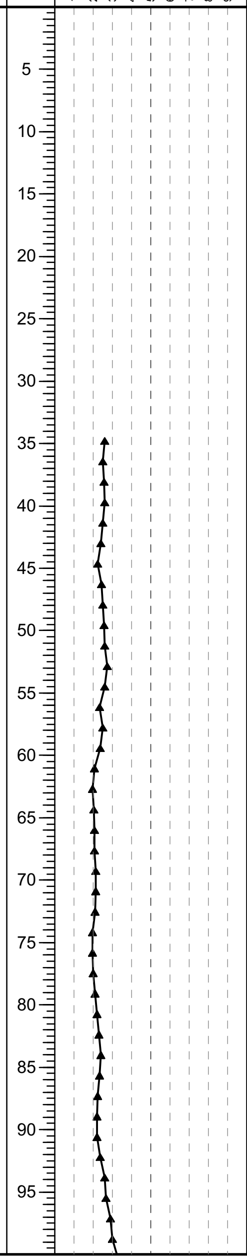
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#19

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/12/2000 FINISHED: 10/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,880.41 E 571,383.73
TOTAL DEPTH: 645.2 ft.
DEPTH TO BEDROCK: 127.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.81
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



Geologic unit (0 to 120.0 ft.): Qal

NOTES

Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 4.87. Cement 10.75 O.D. casing with 1.25 stickup. Re-enter hole on 10/13/2000 with 8.50 Tricone bit. Drill from 4.87 to total depth of 645.15.

Drilling Conditions:
Lost circulation at 285.00, 300.00, 320.00, 572.73 and 585.00.

Drilling Fluid:
0.00 to 4.87: Non-potable water. 4.87 to 645.15: Quick Gel mud with EZ-Mud and LCM to re-establish circulation.

Loss Intervals:
285.00, 300.00, 320.00, 572.73 and 585.00.

Casing Record:
0.00 to 4.87 : 10.75 O.D. casing. 4.87 to 645.15: No casing

Hole Completion:
Set and cement 645.70 of 4.50 schedule 80 PVC casing. Note: Hole was initially drilled to 645.15. Driller advanced at least .58 while conditioning hole on completion of drilling.

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 120.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material have white to light gray caliche coatings.

120.0 to 280.0 ft. BEDDED TUFF (Tmbt1)
Pre-Rainier Mesa Bedded Tuff composed of bedded and reworked tuff. Bedded tuff is nonwelded, argillic, with up to 10 percent quartz, plagioclase, and sanidine phenocrysts. Bedded tuff contains up to 15 percent argillically altered pumice clasts. Some beds have up to 4 percent volcanic lithic clasts. Tuff is predominately grayish-orange pink and drill cuttings returns are sand to silt sized.

280.0 to 410.0 ft. COMB PEAK IGNIMBRITE - TUFF X (Tpki):
Pyroclastic flow, nonwelded, crystalized, with up to 20 percent pumice clasts. Tuff contains 2 to 3 percent sanidine, plagioclase, quartz, and less than 1 percent biotite and hornblende phenocrysts. Up to 8 percent moderate red to medium dark gray, volcanic lithic clasts. Tuff is predominately grayish-orange pink with possible minor silicification.

410.0 to 420.0 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5):
Bedded tuff, nonwelded, argillic with 1 to 2 percent quartz and sanidine phenocrysts. Pumice clasts compose up to 15 percent pumice clasts and 5 percent volcanic lithic clasts. Tuff is predominately very pale orange and white.

420.0 to 510.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystalized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 425 to 436 ft. the tuff has up to 10 percent dark gray pumice clasts. From 436 to 457 ft. the tuff is crystal poor with only 3 percent clasts content. From 457 to 483 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 15 percent of rock.

510.0 to 635.0 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, crystalized, vapor-phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 15 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor-phase altered chips, indicating the edges of voids in the tuff.

635.0 to 645.2 ft. TIVA CANYON TUFF CRYSTAL POOR MIDDLE NON-LITHOPHYSAL ZONE (Tpcpmn)
Pyroclastic flow, densely welded, crystalized, pale red, with less than 1 percent sanidine, plagioclase, and biotite phenocrysts. Tuff has up to 1 percent pumice clasts and less than 1 percent volcanic lithic clasts. Vapor-phase altered chips indicate some lithophysae from 560.0 to 570.0 ft.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

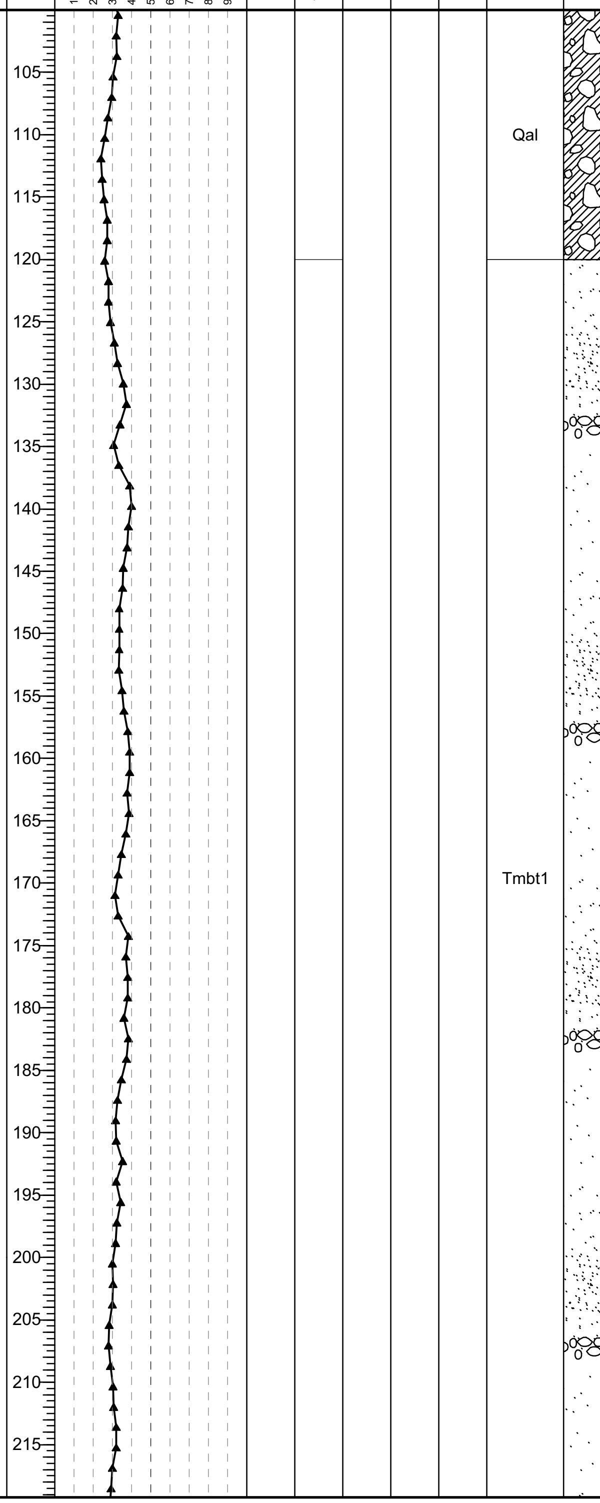
WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#19

SHEET 2 OF 7

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,880.41 E 571,383.73	GROUND ELEVATION: 3661.81
BEGUN: 10/12/2000 FINISHED: 10/23/2000	TOTAL DEPTH: 645.2 ft.	ANGLE FROM HORIZONTAL: -90
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 127.0 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000–9000)	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

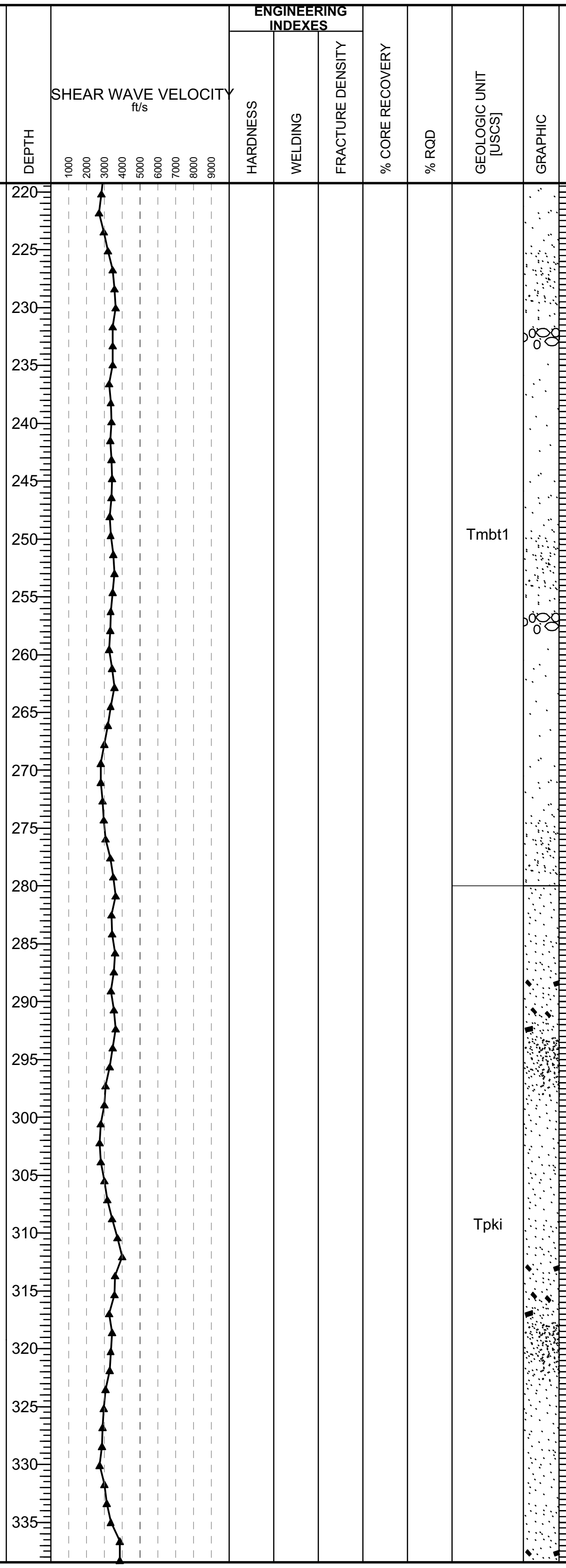
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#19

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/12/2000 FINISHED: 10/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,880.41 E 571,383.73
TOTAL DEPTH: 645.2 ft.
DEPTH TO BEDROCK: 127.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.81
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

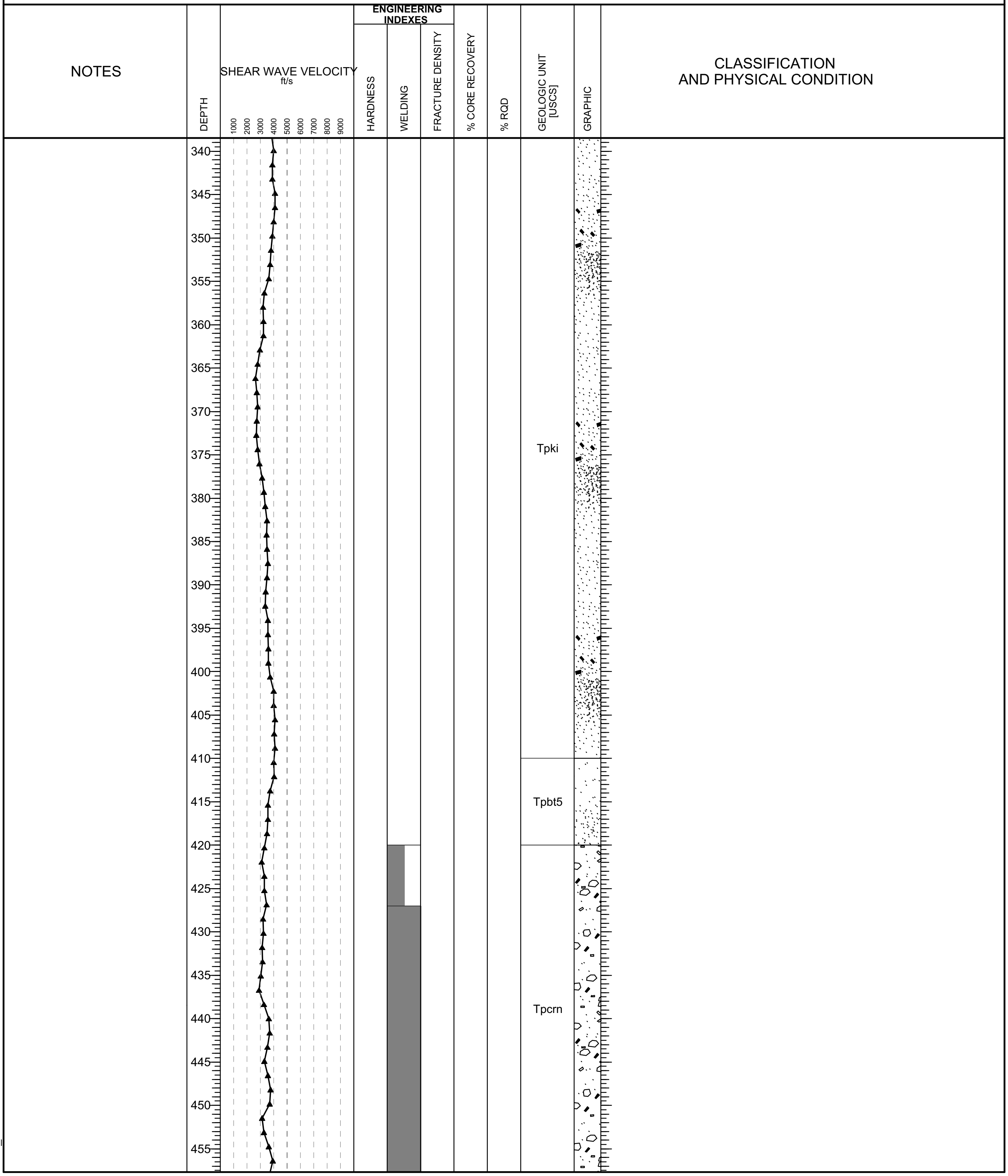
WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#19

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/12/2000 FINISHED: 10/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,880.41 E 571,383.73
TOTAL DEPTH: 645.2 ft.
DEPTH TO BEDROCK: 127.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.81
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

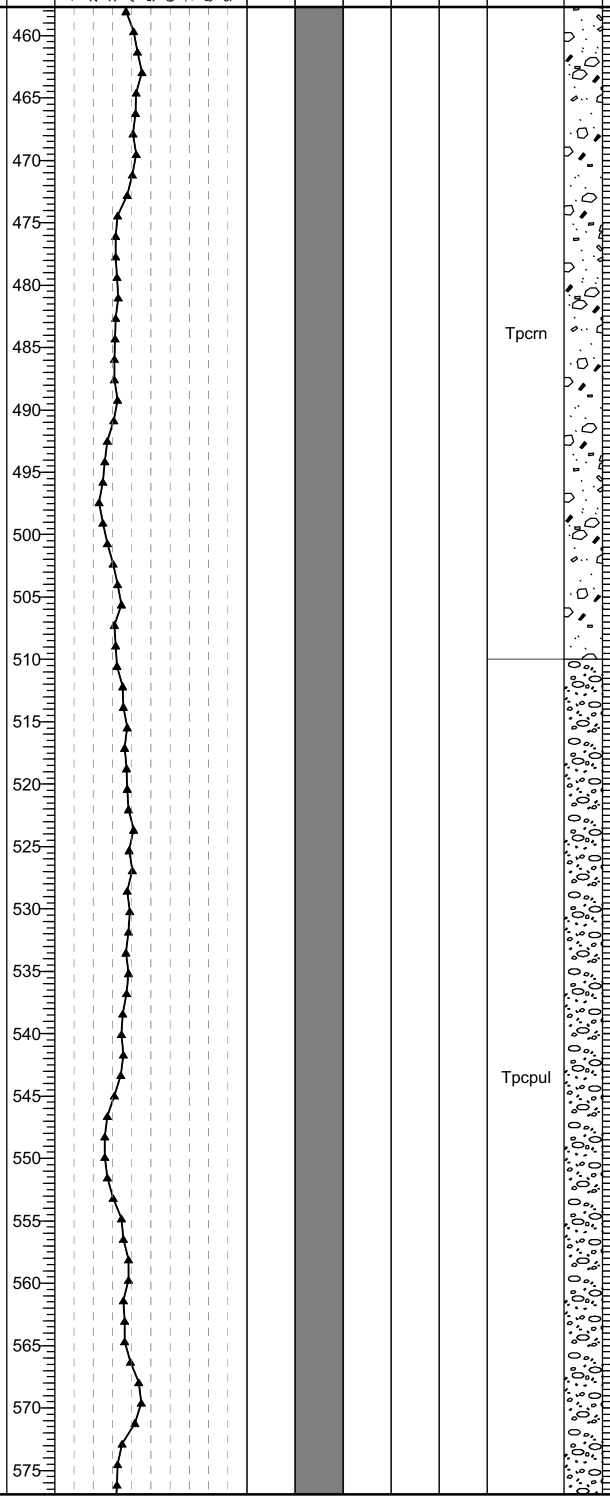
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#19

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/12/2000 FINISHED: 10/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,880.41 E 571,383.73
TOTAL DEPTH: 645.2 ft.
DEPTH TO BEDROCK: 127.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.81
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000 2000 3000 4000 5000 6000 7000 8000 9000)	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
			HARDNESS	WELDING	FRACTURE DENSITY					



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

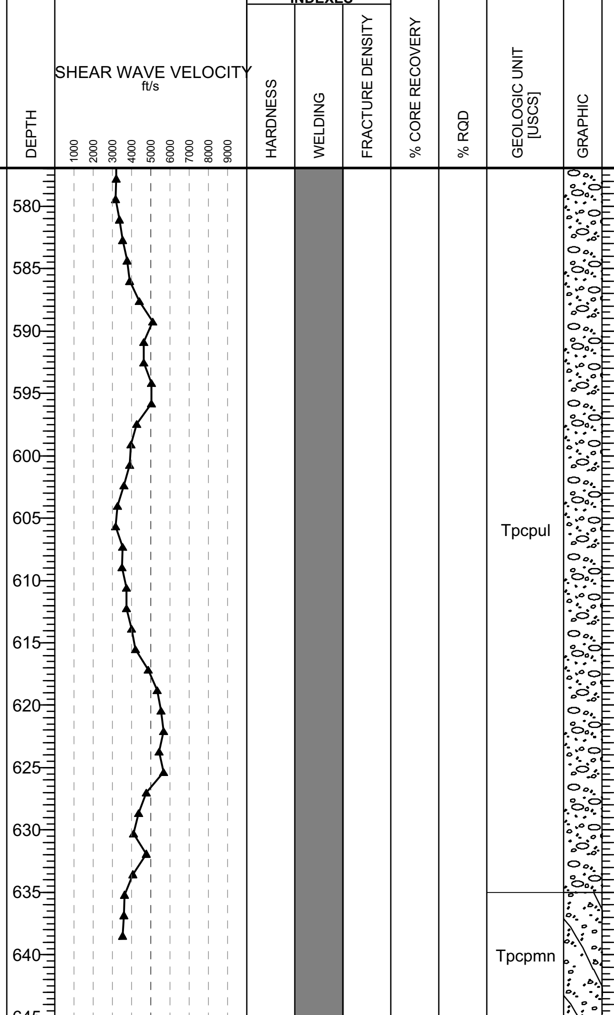
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#19

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/12/2000 FINISHED: 10/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,880.41 E 571,383.73
TOTAL DEPTH: 645.2 ft.
DEPTH TO BEDROCK: 127.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.81
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



BOTTOM OF HOLE

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#19

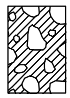
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/12/2000 FINISHED: 10/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,880.41 E 571,383.73
TOTAL DEPTH: 645.2 ft.
DEPTH TO BEDROCK: 127.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.81
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

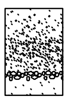
SOIL

Quarternary Alluvium (Qal)

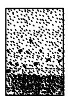


ROCK

Pre-Ranier Mesa Bedded Tuff (Tmbt1)

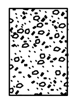


Tuff "x" (Tpki)

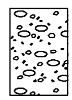


Post Tiva Canyon Bedded Tuff (Tpbt5)

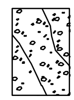
Tpcprn



Tpcpul



Tpcpmn



WELDING

Non-Welded

Densely Welded

Moderately Welded

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GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#20

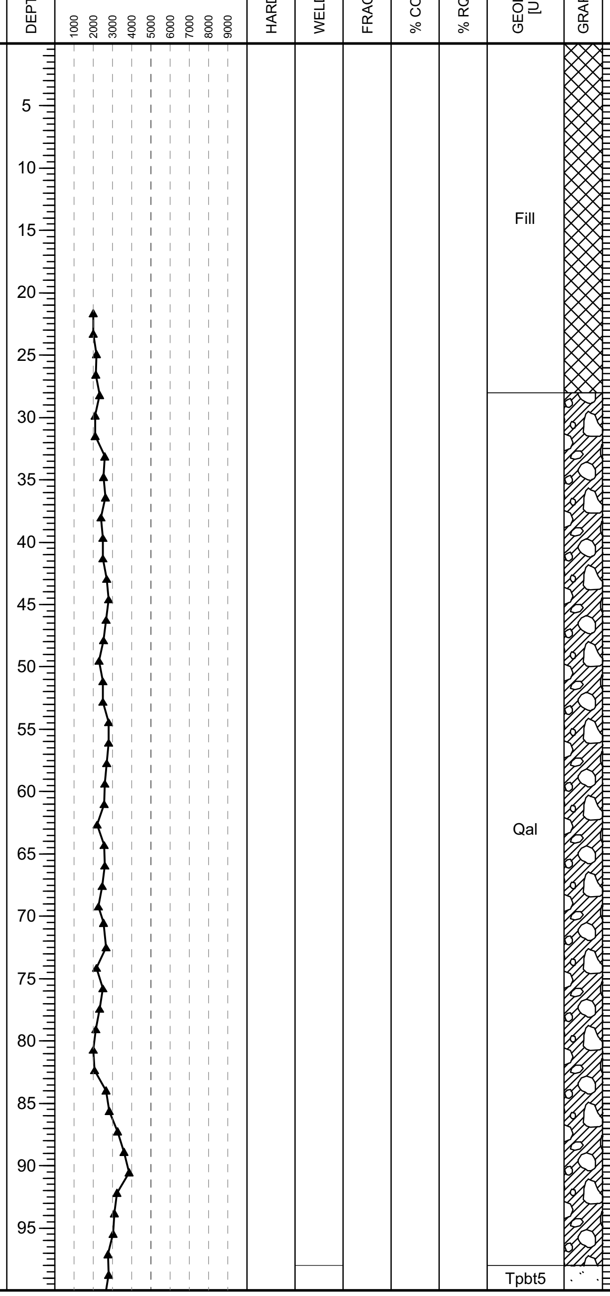
SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/5/2000 FINISHED: 9/8/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,637.36 E 570,796.82
TOTAL DEPTH: 160.0 ft.
DEPTH TO BEDROCK: 98.0 ft.

STATE: Nevada
GROUND ELEVATION: 3671.26
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



Geologic units: Fill (0.0 to 28.0 ft.); Qal (28.0 to 98.0 ft.); Tpbt5 (98.0 ft. –)

Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 5.00. Cement 10.75 O.D. casing with 1.30 stickup. Re-enter hole on 9/8/2000 with 8.50 Tricone bit. Drill from 5.00 to total depth of 160.00.

Drilling Conditions:
Smooth easy drilling.

Drilling Fluid:
0.00 to 5.00: Non-potable water.
5.00 to 160.00: Quick Gel mud with EZ-Mud.

Loss Intervals:
NA

Casing Record:
0.00 to 5.00 : 10.75 O.D. casing.
5.00 to 160.00: No casing

Hole Completion:
Set and cement 159.70 of 4.50 schedule 80 PVC casing.

0.0 to 28.0 ft. PAD FILL (Fill)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.

28.0 to 98.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material have white to light gray caliche coatings.

98.0 to 102.0 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5):
Bedded tuff, nonwelded, argillic with 1 to 2 percent quartz and sanidine phenocrysts. Pumice clasts compose up to 20 percent pumice clasts and 5 percent volcanic lithic clasts. Tuff is predominately very pale orange and white.

102.0 to 127.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystalized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 102 to 110 ft. the tuff has up to 7 percent dark gray pumice clasts. From 110 to 123 ft. the tuff is crystal poor with only 1 percent Clasts content. From 123 to 127 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock.

127.0 to 160.0 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, crystalized, vapor-phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 15 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor-phase altered chips, indicating the edges of voids in the tuff.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

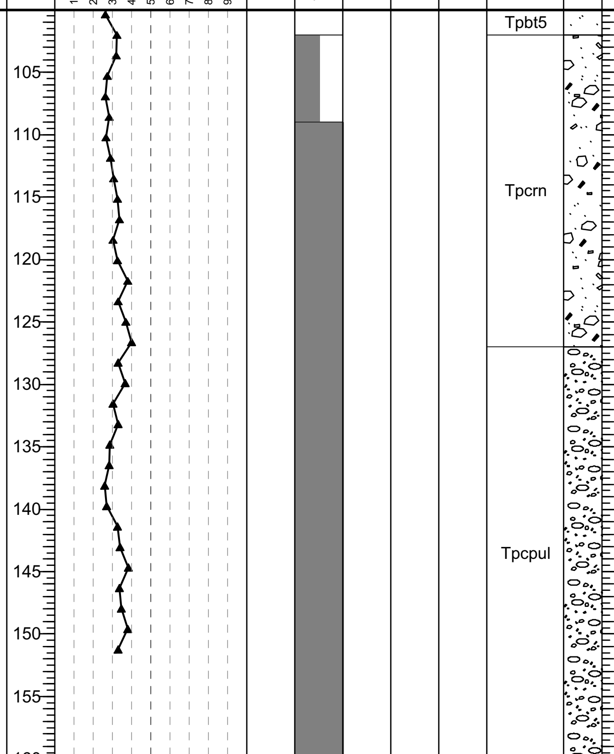
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#20

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/5/2000 FINISHED: 9/8/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,637.36 E 570,796.82
TOTAL DEPTH: 160.0 ft.
DEPTH TO BEDROCK: 98.0 ft.

STATE: Nevada
GROUND ELEVATION: 3671.26
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



BOTTOM OF HOLE

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#20

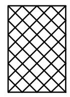
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/5/2000 FINISHED: 9/8/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,637.36 E 570,796.82
TOTAL DEPTH: 160.0 ft.
DEPTH TO BEDROCK: 98.0 ft.

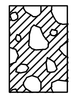
STATE: Nevada
GROUND ELEVATION: 3671.26
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

SOIL

Fill (made ground)

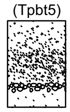


Quaternary Alluvium (Qal)

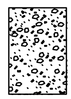


ROCK

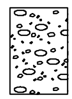
Post Tiva Canyon Bedded Tuff (Tpbt5)



Tpcprn

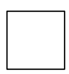


Tpcpul

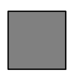


WELDING

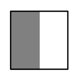
Non-Welded



Densely Welded



Moderately Welded



RF20_KEY WHB.GPJ WHB.GDT 6/14/02

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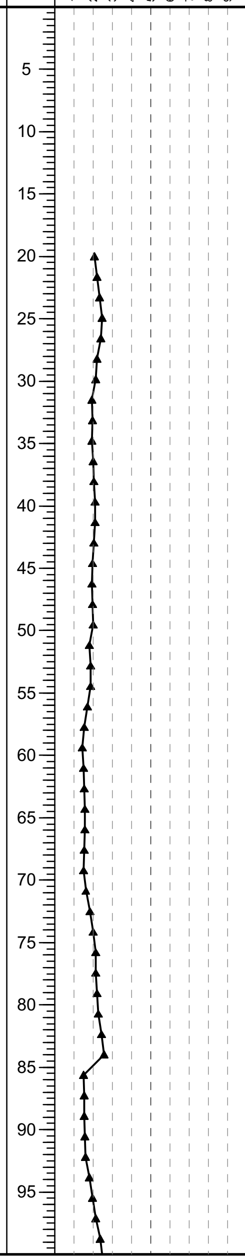
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#21

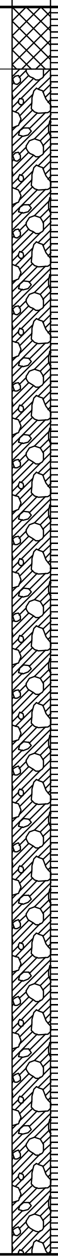
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/6/2000 FINISHED: 9/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,898.81 E 570,739.18
TOTAL DEPTH: 192.2 ft.
DEPTH TO BEDROCK: 115.0 ft.

STATE: Nevada
GROUND ELEVATION: 3673.02
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
								Fill (0.0–5.0)		
								Qal (5.0–115.0)		





Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 5.01. Cement 10.75 O.D. casing with 1.00 stickup. Re-enter hole on 9/6/2000 with 8.50 Tricone bit. Drill from 5.01 to total depth of 192.23.

Drilling Conditions:
Lost circulation at 125.00 and 190.00

Drilling Fluid:
0.00 to 5.01: Non-potable water. 5.01 to 125.00: Quick Gel mud with EZ-Mud. 125.00 to 192.23: Quick Gel with EZ-Mud and LCM to re-establish circulation.

Loss Intervals:
125.00 and 190.00

Casing Record:
0.00 to 5.01 : 10.75 O.D. casing.
5.01 to 192.23: No casing

Hole Completion:
Set and cement 192.04 of 4.50 schedule 80 PVC casing.

0.0 to 5.0 ft. PAD FILL (Fill)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.

5.0 to 115.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material has white to light gray caliche coatings.

115.0 to 165.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystalized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 102 to 110 ft. the tuff has up to 7 percent dark gray pumice clasts. From 110 to 123 ft. the tuff is crystal poor with only 1 percent clast content. From 123 to 127 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock.

165.0 to 192.2 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, crystalized, vapor-phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 15 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor-phase altered chips, indicating the edges of voids in the tuff.

COMMENTS:
1. Hole logged from cuttings
2. LCM (Lost Circulation Material) consists cellephane cuttings or cotton seed hulls.
3. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

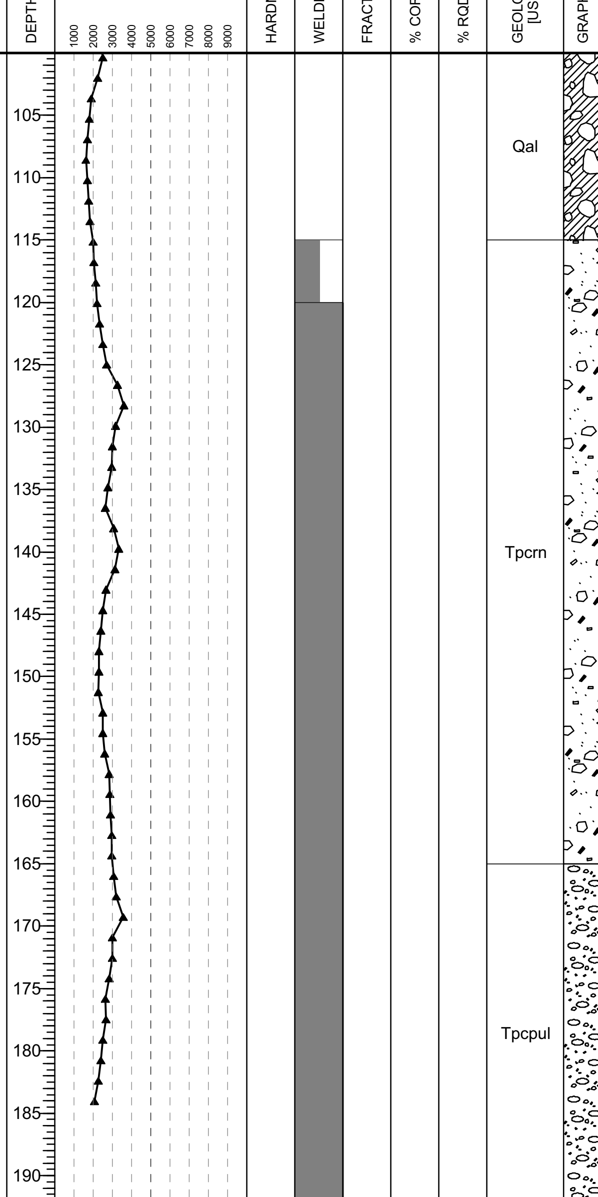
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#21

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/6/2000 FINISHED: 9/7/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,898.81 E 570,739.18
TOTAL DEPTH: 192.2 ft.
DEPTH TO BEDROCK: 115.0 ft.

STATE: Nevada
GROUND ELEVATION: 3673.02
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	HARDNESS (ENGINEERING INDEXES)	WELDING (ENGINEERING INDEXES)	FRACTURE DENSITY (ENGINEERING INDEXES)	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



BOTTOM OF HOLE

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

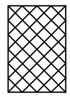
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#21

SHEET 3 OF 3

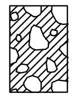
FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,898.81 E 570,739.18	GROUND ELEVATION: 3673.02
BEGUN: 9/6/2000 FINISHED: 9/7/2000	TOTAL DEPTH: 192.2 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 115.0 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

SOIL

Fill (made ground)

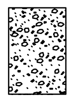


Quaternary Alluvium

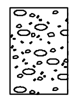


ROCK

Tpcprn

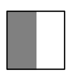


Tpcpul

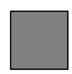


WELDING

Moderately Welded



Densely Welded



RF21_KEY WHB.GPJ WHB.GDT 6/14/02

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GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#22

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 7/25/2000 FINISHED: 8/15/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,206.2 E 570,793.48
TOTAL DEPTH: 540.6 ft.
DEPTH TO BEDROCK: 90.0 ft.

STATE: Nevada
GROUND ELEVATION: 3679.17
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000–9000)	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	0–80							Qal		
	80–98							Tmbt1		

Purpose of Hole:
Develop geologic design data required to develop Waste Handling Building foundation parameters and seismic hazard analysis.

Drill Equipment:
Schramm T685 Drill Rig, UDR 1000 Drill Rig.

Drillers:
George Fox, D Harrison, R Mckay; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 5.00. Cement 10.75 O.D. casing with 1.02 stickup. Drill to depth of 511.47 with 8.50 Tricone bit. Install PQ rods to serve as temporary casing. Install HQ core system. Core with HQ to total depth of 540.56.

Drilling Conditions:

Drilling Fluid:
0.00 to 5.00: Non-potable water.
5.00 to 540.56: Non-potable water, Quick Gel Mud with EZ-Mud and LCM to re-establish circulation.

Loss Intervals:
443.00 to 490.00: circulation was re-established in some intervals.

Casing Record:
0.00 to 5.00: 10.75 O.D. casing.
5.00 to 511.47: No casing
511.47 to 540.56: PQ casing (?)

Hole Completion:
PVC casing set and cemented to total depth of 511.38.

0.0 to 80.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material have white to light gray caliche coatings.

80.0 to 318.0 ft. BEDDED TUFF (Tmbt1)
Pre-Rainier Mesa Bedded Tuff composed of bedded and reworked tuff. Bedded tuff is nonwelded, argillic, with up to 10 percent quartz, plagioclase, and sanidine phenocrysts. Bedded tuff contains up to 15 percent argillically altered pumice clasts. Some beds have up to 4 percent volcanic lithic clasts. Tuff is predominately grayish-orange pink and drill cuttings returns are sand to silt sized.

318.0 to 415.0 ft. COMB PEAK IGNIMBRITE - TUFF X (Tpki):
Pyroclastic flow, nonwelded, crystallized, with up to 15 percent pumice clasts. Tuff contains 2 to 3 percent sanidine, plagioclase, quartz, and less than 1 percent biotite and hornblende phenocrysts. Up to 3 percent moderate red to medium dark gray, volcanic lithic clasts. Tuff is predominately grayish-orange pink with possible minor silicification.

415.0 to 438.0 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5):
Bedded tuff, nonwelded, argillic with 1 to 2 percent quartz and sanidine phenocrysts. Pumice clasts compose up to 15 percent pumice clasts and 5 percent volcanic lithic clasts. Tuff is predominately very pale orange and white.

438.0 to 530.5 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
From 438.0 to 511.5 ft. borehole was mud-rotary drilled, the following is a description of drill chips. Pyroclastic flow, moderately to densely welded, crystallized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 455 to 485 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock. No recovery from 485 to 505.4 ft. Borehole cored from 511.5 to 540.56 ft., the following is a description of drill core. Pyroclastic flow, densely welded, crystallized with vapor phase alteration. Tuff has 10 to 15 percent, brownish-gray pumice clasts up to 20 by 5 mm in size. Up to 10 percent sanidine and plagioclase phenocrysts with less than 1 percent biotite phenocrysts. Generally the rock is soft to mostly moderately hard (H4), moderately to slightly weathered (W4), slightly (FD4) to moderately fractured (FD5).

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
511.7	90	R3	
512.0	90	R3	
512.1	90	R3	
512.15	90	R2	
512.4 - 513.0	Fracture Zone		Vapor Phase
513.1	20	R2	
514.1	90	R3	
514.15	50	R3	
516.35	90	R3	
518.3	90	R3	
518.4	90	R3	
519.9	60	R3	
521.5	60	R3	
522.4 - 522.6	90	R2	
522.8	73	R4	
525.0	90	R3	
525.5	47	R4	
526.4 - 527.1	90	R3	Fracture Zone
528.0	40	R3	

COMMENTS: 1. Hole logged from cuttings to 511.47 and core from 511.47 to 540.56.

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

3. No usable velocity data acquired above 229 feet.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#22

SHEET 2 OF 6

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 7/25/2000 FINISHED: 8/15/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,206.2 E 570,793.48
TOTAL DEPTH: 540.6 ft.
DEPTH TO BEDROCK: 90.0 ft.

STATE: Nevada
GROUND ELEVATION: 3679.17
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000–9000)	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	105–215							Tmbt1		

530.0 90 R3

530.0 to 540.6 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, crystallized, medium gray with less than 5 percent pumice clasts up to 35 by 5 mm. No lithophysae are present in this core run, however contact is distinguished by the decrease in phenocrysts to, 2 to 3 percent sanidine and plagioclase with less than 1 percent biotite. Tuff has less than 1 percent dark-yellowish brown and light gray volcanic lithic fragments. Generally the rock is moderately hard (H4), moderately (W4) weathered, and moderately fractured (FD5).

Discontinuity Measurements:

Depth	Angle*	Roughness	Infilling
530.9	30	R4	
531.7	55	R4	
532.6	15	R3	
533.1	70	R4	Vapor Phase
534.4	75	R4	Vapor Phase
535.0	50	R4	
535.4	90	R4	Vapor Phase
535.6	85	R4	Vapor Phase & calcite
536.2	60	R3	
537.0	60	R2	Rubble
537.5	52	R4	
537.7	48	R3	Vapor Phase
538.5	60	R3	Vapor Phase
538.9 - 540.6	Breccia Zone		

* Angles are measured from core axis and are plus or minus 5 degrees.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#22

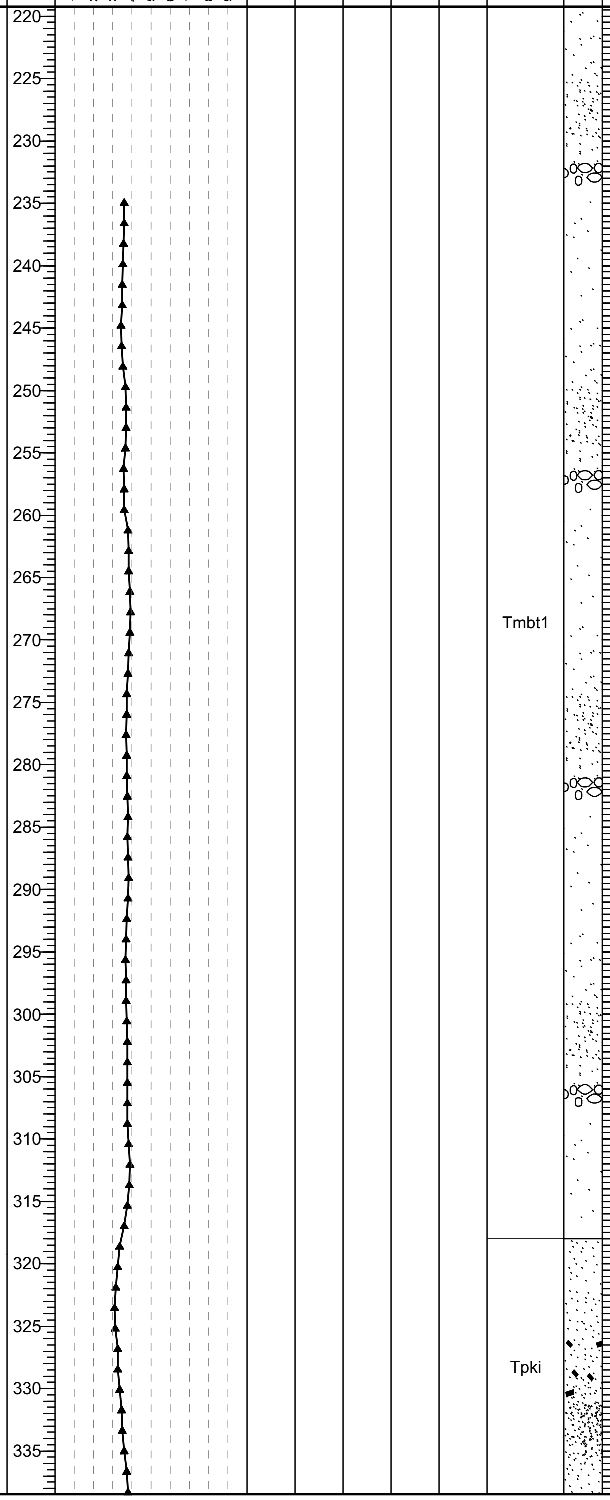
SHEET 3 OF 6

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 7/25/2000 FINISHED: 8/15/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,206.2 E 570,793.48
TOTAL DEPTH: 540.6 ft.
DEPTH TO BEDROCK: 90.0 ft.

STATE: Nevada
GROUND ELEVATION: 3679.17
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



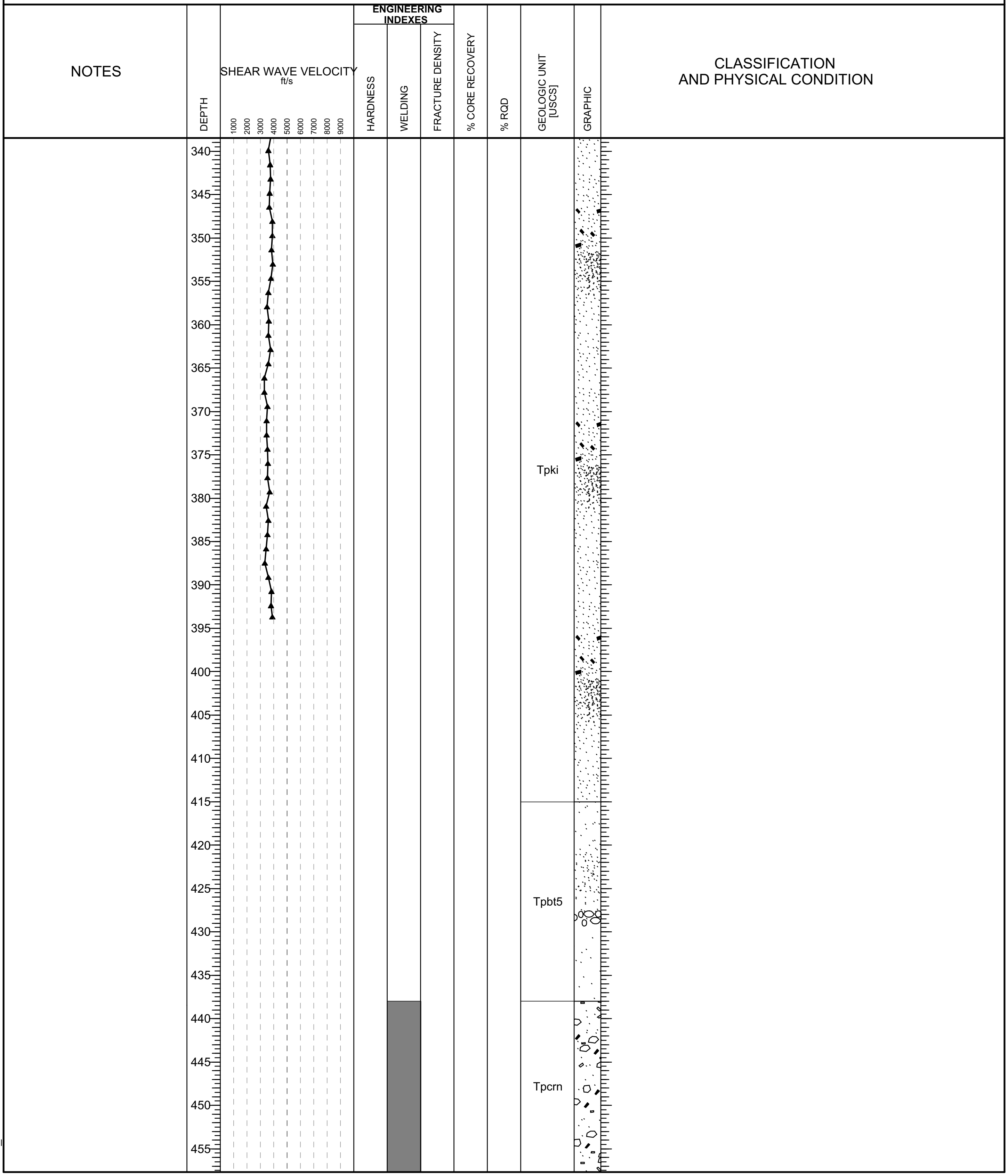
WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#22

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 7/25/2000 FINISHED: 8/15/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,206.2 E 570,793.48
TOTAL DEPTH: 540.6 ft.
DEPTH TO BEDROCK: 90.0 ft.

STATE: Nevada
GROUND ELEVATION: 3679.17
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#22

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 7/25/2000 FINISHED: 8/15/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,206.2 E 570,793.48
TOTAL DEPTH: 540.6 ft.
DEPTH TO BEDROCK: 90.0 ft.

STATE: Nevada
GROUND ELEVATION: 3679.17
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000–9000)	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	460–511.5							Tpcrn		
	511.5		H4		FD4	97	54			Begin core drilling at 511.5
						94	77			
					FD5	99	71	Tpcpul		
						93	86			
	–540				FD4	98	59			

BOTTOM OF HOLE

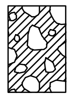
WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#22

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 766,206.2 E 570,793.48	GROUND ELEVATION: 3679.17
BEGUN: 7/25/2000 FINISHED: 8/15/2000	TOTAL DEPTH: 540.6 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 90.0 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

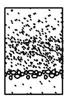
SOIL

Quaternary Alluvium (Qal)

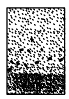


ROCK

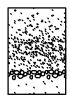
Pre-Rainier Mesa Bedded Tuff (Tmbt1)



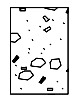
Tuff "x" (Tpki)



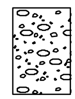
Post Tiva Canyon Bedded Tuff (Tpbt5)



Tpcprn



Tpcpul



WELDING

Non-Welded

Densely Welded

HARDNESS

Alpha-numeric descriptor	Descriptor	Criteria
H1	Extremely	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very Hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately Hard	Can be scratched with knife or sharp pick with light pressure. Core or fragment breaks with moderate hammer blow.
H5	Moderately Soft	Can be grooved 1/16 inch (2mm) deep by sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

WEATHERING

Alpha-numeric descriptor	Descriptor	General characteristics (strength, excavation, etc.)
W1	Fresh	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as Siltstones or shales.
W2	Slightly weathered to fresh	
W3	Slightly weathered	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classified as rock excavation.
W4	Moderately to slightly weathered	
W5	Moderately weathered	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstones or shales.
W6	Intensely to moderately weathered	
W7	Intensely weathered	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very intensely weathered	
W9	Decomposed	Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes".

FRACTURE DENSITY

Alpha-numeric descriptor	Descriptor	Criteria (Excludes mechanical breaks)
FD0	Unfractured	No observed fractures.
FD1	Very slightly fractured	Core recovered mostly in lengths greater than 3 feet (1 m).
FD2	Slightly to very slightly fractured	
FD3	Slightly fractured	Core recovered mostly in lengths from 1 to 3 feet (300 to 1,000 mm) with few scattered lengths less than 1 foot (300 mm) or greated than 3 feet (1,000 mm).
FD4	Moderately to slightly fractured	
FD5	Moderately fractured	Core recovered mostly in lengths from 0.33 to 1.0 foot (100 to 300 mm) with most lengths about 0.67 foot (200 mm).
FD6	Moderately to intensely fractured	
FD7	Intensely fractured	Lengths average from 0.1 to 0.33 foot (30 to 100 mm) with fragemented intervals. Core recovered mostly in lengths less than 0.33 foot (100 mm).
FD8	Very intensely to intensely fractured	
FD9	Very intenesely fractured	Core recovered mostly as chips and fragments with a few scattered short core lengths.

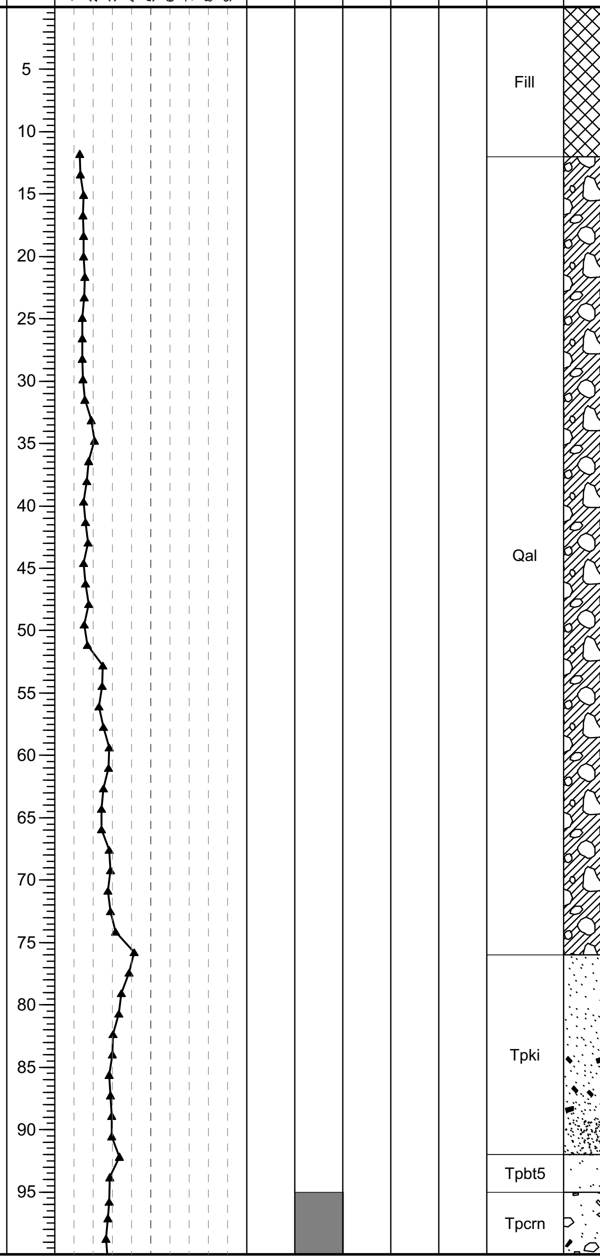
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#23

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/25/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,311.43 E 570,465.03
TOTAL DEPTH: 159.1 ft.
DEPTH TO BEDROCK: 76.0 ft.

STATE: Nevada
GROUND ELEVATION: 3673.98
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 5.00. Cement 10.75 O.D. casing with 1.03 stickup. Re-enter hole on 9/26/2000 with 8.50 Tricone bit. Drill from 5.00 to total depth of 159.10.

Drilling Conditions:
1 new bit. Circulation weak from 119.71 to 139.40

Drilling Fluid:
0.00 to 5.00: Non-potable water. 5.00 to 119.71: Quick Gel mud with EZ-Mud. 119.71.00 to 159.10: Quick Gel with EZ-Mud and LCM to improve circulation.

Loss Intervals:
119.71.00 to 139.40: Circulation weak

Casing Record:
0.00 to 5.00 : 10.75 O.D. casing.
5.00 to159.10: No casing

Hole Completion:
Set and cement 158.96 of 4.50 schedule 80 PVC casing.

0.0 to 12.0 ft. PAD FILL (Fill)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.

12.0 to 76.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material has white to light gray caliche coatings.

76.0 to 92.0 ft. COMB PEAK IGNIMBRITE - TUFF X (Tpki):
Pyroclastic flow, nonwelded, crystalized, with up to 15 percent pumice clasts. Tuff contains 2 to 3 percent sanidine, plagioclase, quartz, and less than 1 percent biotite and hornblende phenocrysts. Up to 20 percent moderate red to medium dark gray, volcanic lithic clasts. Tuff is predominately grayish-orange pink with possible minor silicification.

92.0 to 95.0 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5):
Bedded tuff, nonwelded, argillic with 1 to 2 percent quartz and sanidine phenocrysts. Up to 15 percent pumice clasts and 5 percent volcanic lithic clasts. Tuff is predominately very pale orange and white.

95.0 to 159.1 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystalized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 108.0 to 115.0 ft. the tuff has up to 10 percent dark gray pumice clasts. From 115.0 to 135.0 ft. the tuff is crystal poor with only 3 percent Clasts content. From 135.0 to 159.1 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 15 percent of rock.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

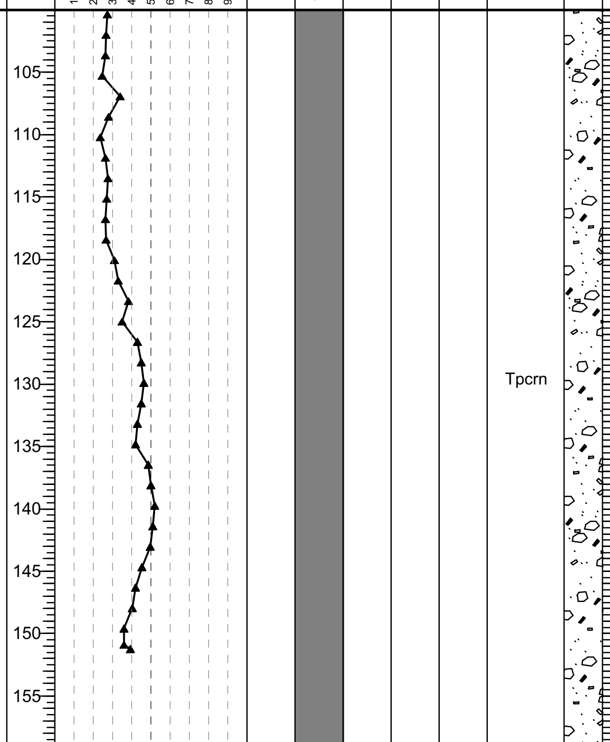
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#23

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/25/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,311.43 E 570,465.03
TOTAL DEPTH: 159.1 ft.
DEPTH TO BEDROCK: 76.0 ft.

STATE: Nevada
GROUND ELEVATION: 3673.98
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



BOTTOM OF HOLE

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#23

SHEET 3 OF 3

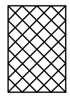
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/25/2000 FINISHED: 9/27/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,311.43 E 570,465.03
TOTAL DEPTH: 159.1 ft.
DEPTH TO BEDROCK: 76.0 ft.

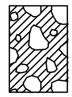
STATE: Nevada
GROUND ELEVATION: 3673.98
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

SOIL

Fill (made ground)

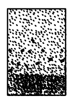


Quaternary Alluvium (Qal)

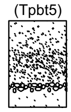


ROCK

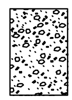
Tuff "x" (Tpki)



Post Tiva Canyon Bedded Tuff (Tpbt5)



Tpcprn



WELDING

Non-Welded

Densely Welded

RF23_KEY WHB.GPJ WHB.GDT 6/14/02

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GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#24

SHEET 1 OF 4

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/15/2000 FINISHED: 8/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,344.31 E 570,542.26
TOTAL DEPTH: 268.0 ft.
DEPTH TO BEDROCK: 45.0 ft.

STATE: Nevada
GROUND ELEVATION: 3684.48
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES

Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 5.06. Cement 10.75 O.D. casing with 1.07 stickup. Re-enter hole on 8/17/2000 with 8.50 Tricone bit. Drill from 5.06 to total depth of 267.96.

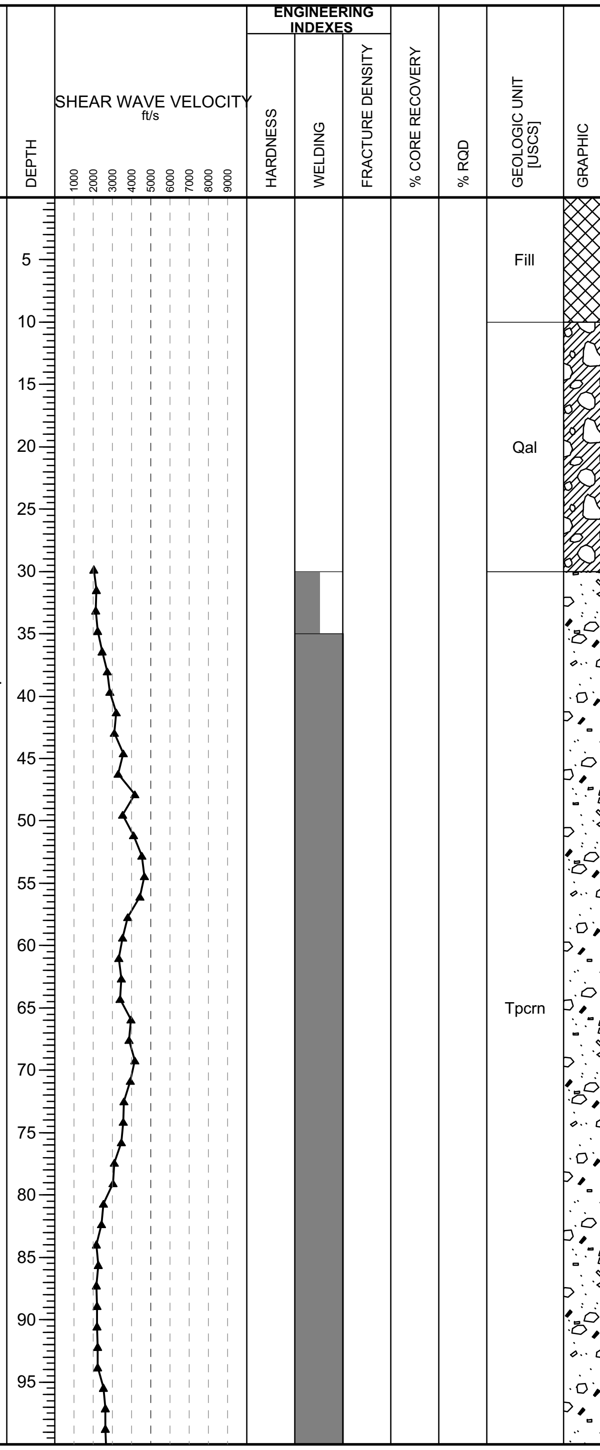
Drilling Conditions:
Lost circulation to weak circulation from 100.00 to 267.96. 233.00 to 236.00 very soft drilling. Smooth to rough drilling in some intervals.

Drilling Fluid:
0.00 to 5.06: Non-potable water. 5.06 to 100.00: Quick Gel mud with EZ-Mud. 100.00 to 267.96: Quick Gel with EZ-Mud and LCM to re-establish circulation.

Loss Intervals:
100.00 to 267.96: Lost circulation to weak circulation.

Casing Record:
0.00 to 5.06 : 10.75 O.D. casing.
5.06 to 267.96: No casing

Hole Completion:
Set and cement 266.05 of 4.50 schedule 80 PVC casing.



CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 10.0 ft. PAD FILL (Fill)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.

10.0 to 30.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material has white to light gray caliche coatings.

30.0 to 110.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystalized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 44.0 to 57.0 ft. the tuff is pumice poor with less than 1 percent clast content. From 57.0 to 93.0 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 15 percent of rock. Based on the occurrence of vapor phase mineralization fragments in the chips, there is a lithophysal bearing zone from 93.0 to 104.0 ft. Phenocryst content begins to decrease at 104.0 ft.

110.0 to 230.0 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, crystalized, vapor phase altered, light gray, with less than 1 percent sanidine, plagioclase, and biotite phenocrysts. Tuff has less than 1 percent, very light gray, pumice clasts and volcanic lithic fragments. Lithophysae are distinguished by vapor phase altered chips, indicating the edges of voids in the tuff.

230.0 to 267.9 ft. TIVA CANYON TUFF CRYSTAL POOR MIDDLE NON-LITHOPHYSAL ZONE (Tpcpmn)
Pyroclastic flow, densely welded, crystalized, pale red, with less than 1 percent sanidine, plagioclase, and biotite phencrysts. Tuff has up to 1 percent pumice clasts and less than 1 percent volcanic lithic clasts. Vapor phase altered chips indicate some lithophysae from 360.0 to 367.0 ft.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

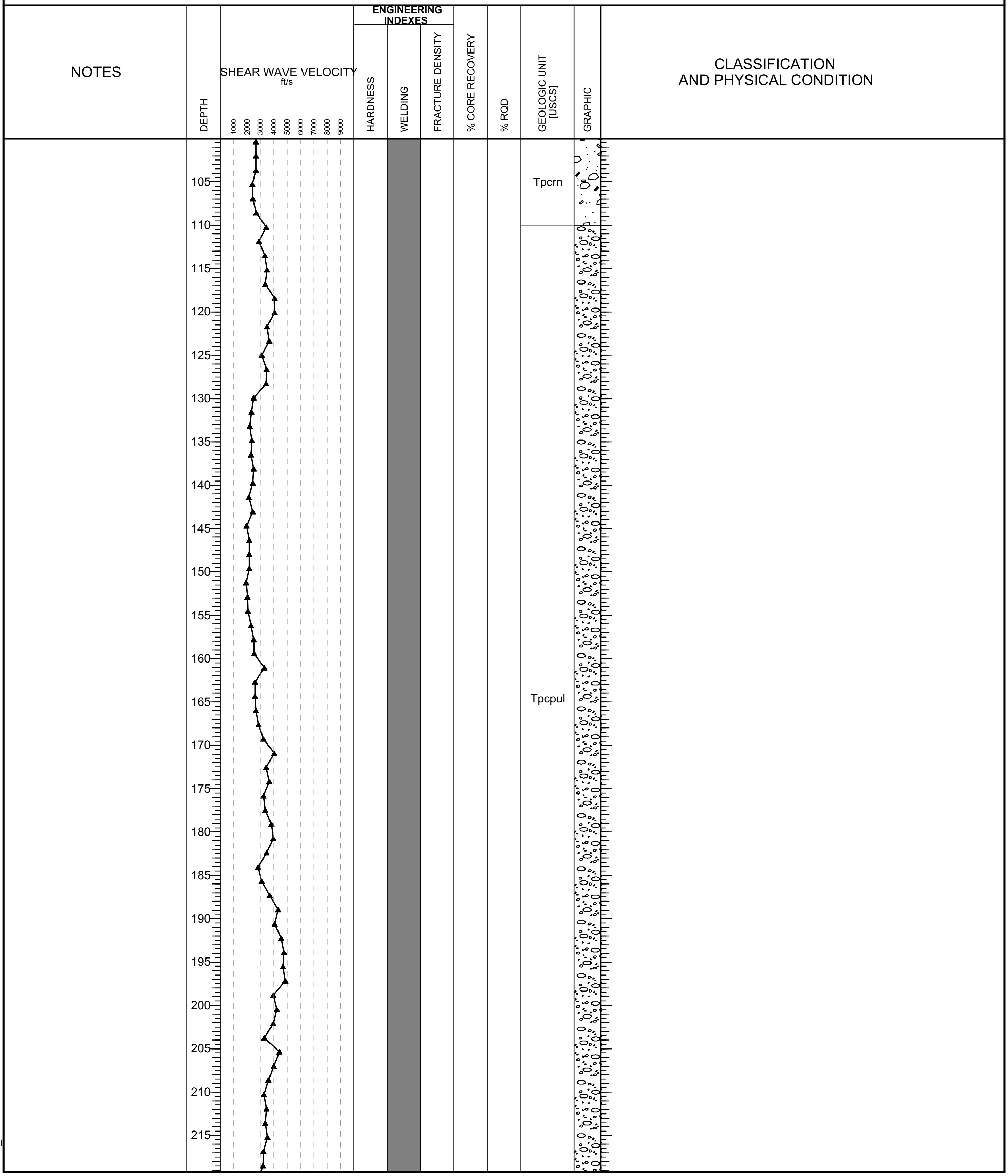
WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#24

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/15/2000 FINISHED: 8/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,344.31 E 570,542.26
TOTAL DEPTH: 268.0 ft.
DEPTH TO BEDROCK: 45.0 ft.

STATE: Nevada
GROUND ELEVATION: 3684.48
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

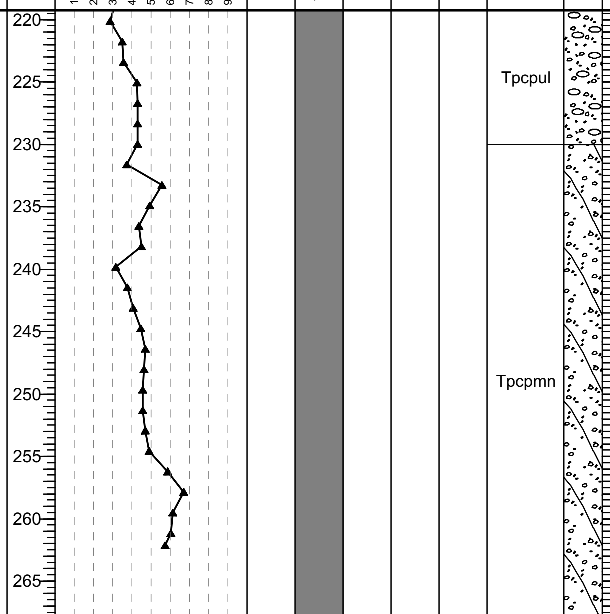
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#24

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/15/2000 FINISHED: 8/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,344.31 E 570,542.26
TOTAL DEPTH: 268.0 ft.
DEPTH TO BEDROCK: 45.0 ft.

STATE: Nevada
GROUND ELEVATION: 3684.48
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	220–230							Tpcpul		
	230–268							Tpcpmn		



BOTTOM OF HOLE

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#24

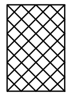
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/15/2000 FINISHED: 8/23/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,344.31 E 570,542.26
TOTAL DEPTH: 268.0 ft.
DEPTH TO BEDROCK: 45.0 ft.

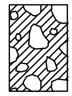
STATE: Nevada
GROUND ELEVATION: 3684.48
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

SOIL

Fill (made ground)

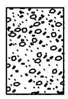


Quaternary Alluvium (Qal)

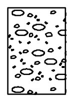


ROCK

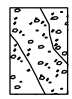
Tpcprn



Tpcpul

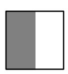


Tpcpmn

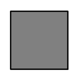


WELDING

Moderately Welded



Densely Welded



RF24_KEY WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#25

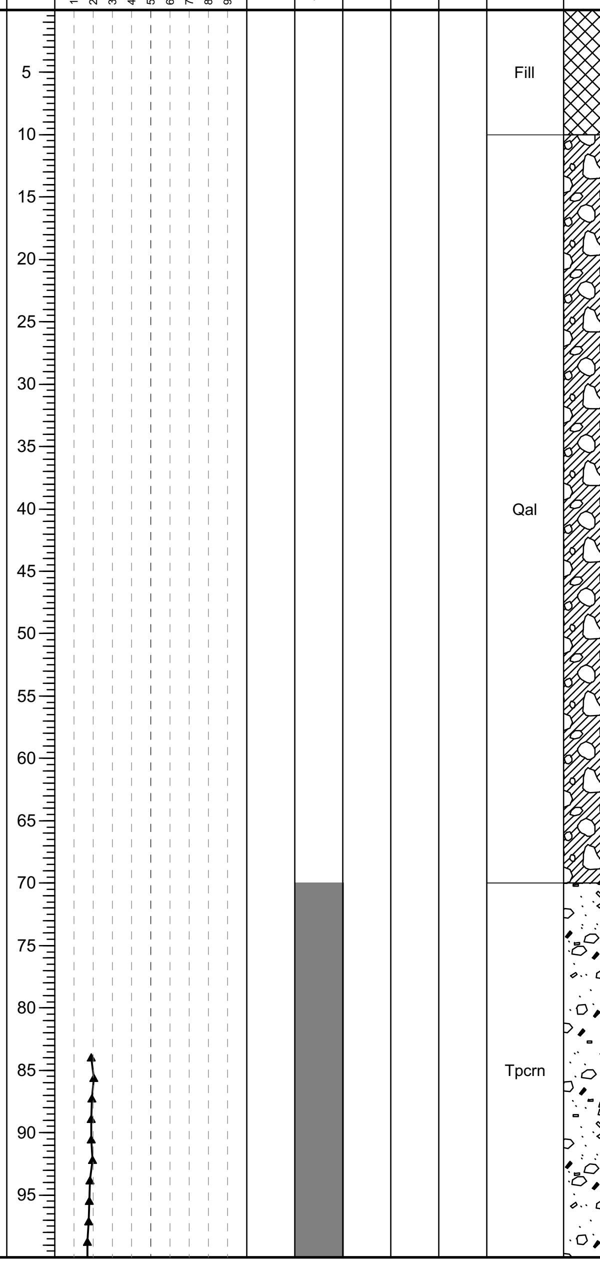
SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/21/2000 FINISHED: 9/22/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,968.15 E 570,626.38
TOTAL DEPTH: 159.0 ft.
DEPTH TO BEDROCK: 70.0 ft.

STATE: Nevada
GROUND ELEVATION: 3676.54
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



NOTES

Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 5.00. Cement 10.75 O.D. casing with 1.12 stickup. Re-enter hole on 9/22/2000 with 8.50 Tricone bit. Drill from 5.00 to total depth of 158.97.

Drilling Conditions:
1 new bit.

Drilling Fluid:
0.00 to 5.00: Non-potable water.
5.00 to 158.97: Quick Gel mud with EZ-Mud.

Loss Intervals:
None

Casing Record:
0.00 to 5.00 : 10.75 O.D. casing.
5.00 to 158.97: No casing

Hole Completion:
Set and cement 158.50 of 4.50 schedule 80 PVC casing.

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 10.0 ft. PAD FILL (Fill)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.

10.0 to 70.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material has white to light gray caliche coatings.

70.0 to 125.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystalized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 70.0 to 87.0 ft. the tuff is pumice poor with less than 1 percent clast content. From 87.0 to 115.0 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock. Based on the occurrence of vapor phase mineralization fragments in the chips, there is a lithophysal bearing zone from 115.0 to 125.0 ft.

125.0 to 159.0 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, crystalized, vapor phase altered, light gray, with less than 1 percent sanidine, plagioclase, and biotite phenocrysts. Tuff has less than 1 percent, very light gray, pumice clasts and volcanic lithic fragments. Lithophysae are distinguished by vapor phase altered chips, indicating the edges of voids in the tuff.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#25

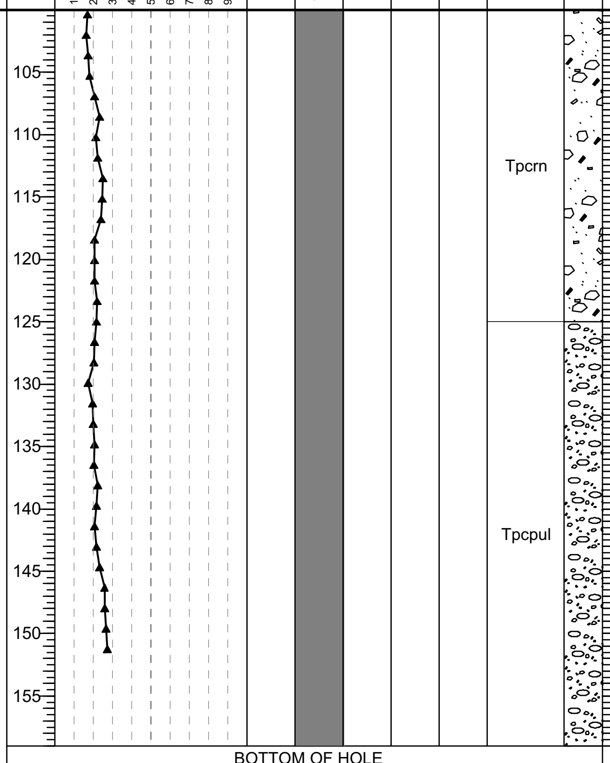
SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/21/2000 FINISHED: 9/22/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,968.15 E 570,626.38
TOTAL DEPTH: 159.0 ft.
DEPTH TO BEDROCK: 70.0 ft.

STATE: Nevada
GROUND ELEVATION: 3676.54
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#25

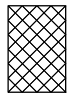
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 9/21/2000 FINISHED: 9/22/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,968.15 E 570,626.38
TOTAL DEPTH: 159.0 ft.
DEPTH TO BEDROCK: 70.0 ft.

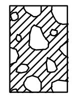
STATE: Nevada
GROUND ELEVATION: 3676.54
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

SOIL

Fill (made ground)

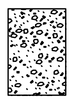


Quaternary Alluvium (Qal)

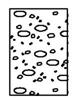


ROCK

Tpcprn

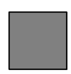


Tpcpul



WELDING

Densely Welded



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GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#26

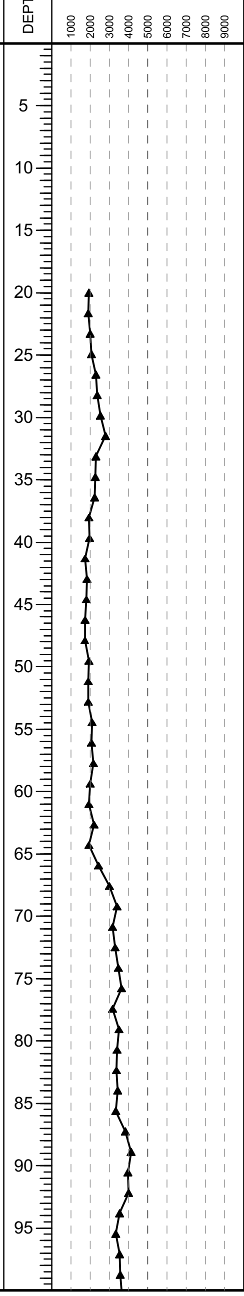
SHEET 1 OF 4

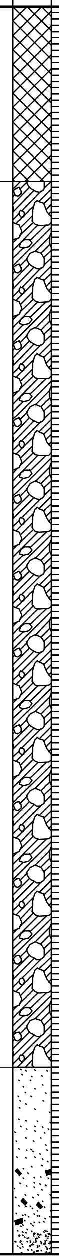
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 7/25/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,247.95 E 570,579.71
TOTAL DEPTH: 264.9 ft.
DEPTH TO BEDROCK: 85.0 ft.

STATE: Nevada
GROUND ELEVATION: 3670.79
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	0–14.0							Fill		
	14.0–85.0							Qal		
	85.0–							Tpki		





NOTES

Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 5.00. Cement 10.75 O.D. casing with 1.13 stickup. Re-enter hole on 7/7/2000 with 9 7/8 Tricone bit. Drill from 5.00 to depth of 39.39. Drill from 39.39 to total depth of 264.90 with 8.50 Tricone bit.

Drilling Conditions:
1 new bit. Loss circulation at 258.13.

Drilling Fluid:
0.00 to 5.00: Non-potable water.
5.00 to total depth of 264.90: Hydro Gel mud with EZ-Mud and LCM to re-establish circulation.

Loss Intervals:
258.13

Casing Record:
0.00 to 5.00 : 10.75 O.D. casing.
5.00 to 39.20 : 9 casing.
39.20 to 264.90: No casing.

Hole Completion:
Set and cement 259.90 of 4.50 schedule 80 PVC casing.

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 14.0 ft. PAD FILL (Fill)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.

14.0 to 85.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material have white to light gray caliche coatings.

85.0 to 204.0 ft. COMB PEAK IGNIMBRITE - TUFF X (Tpki):
Pyroclastic flow, nonwelded, crystallized, with up to 20 percent pumice clasts. Tuff contains 2 to 3 percent sanidine, plagioclase, quartz, and less than 1 percent biotite and hornblende phenocrysts. Up to 8 percent moderate red to medium dark gray, volcanic lithic clasts. Tuff is predominately grayish-orange pink with possible minor silicification.

204.0 to 211.0 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5):
Nonwelded, devitrified, reworked (?) Fallout tephra and pyroclastic flows separated by distinct paleosols. Bedded tuffs are very pale orange with 20 to 25 percent pumice clasts and up to 4 percent, pale red, volcanic lithic clasts. The tuff has up to 6 percent quartz, sanidine and lesser plagioclase, with less than 1 percent biotite and manganese oxides.

211.0 to 265.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystallized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. Possible vitrophyre from 211.0 to 220.0 ft. From 220.0 to 244.0 ft. the tuff is pumice poor with up to 3 percent clast content. From 244.0 to 264.9 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 15 percent of rock.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#26

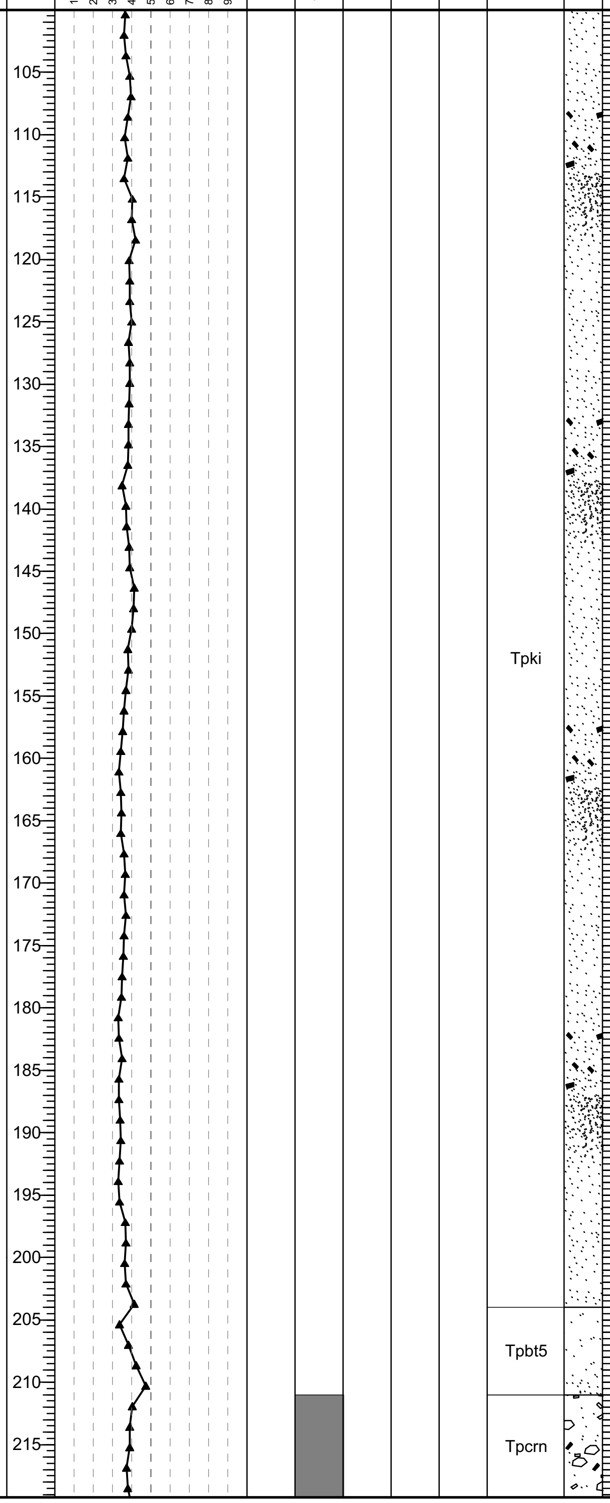
SHEET 2 OF 4

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 7/25/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,247.95 E 570,579.71
TOTAL DEPTH: 264.9 ft.
DEPTH TO BEDROCK: 85.0 ft.

STATE: Nevada
GROUND ELEVATION: 3670.79
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s (1000 2000 3000 4000 5000 6000 7000 8000 9000)	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



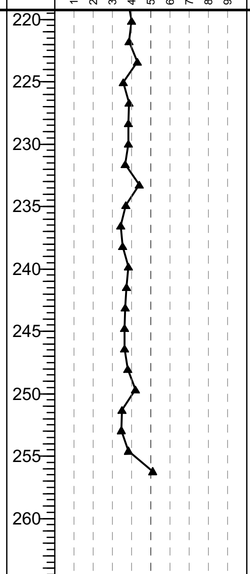
WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#26

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 7/25/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,247.95 E 570,579.71
TOTAL DEPTH: 264.9 ft.
DEPTH TO BEDROCK: 85.0 ft.

STATE: Nevada
GROUND ELEVATION: 3670.79
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	220–264.9							Tpcrn		

BOTTOM OF HOLE

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#26

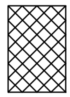
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 6/26/2000 FINISHED: 7/25/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,247.95 E 570,579.71
TOTAL DEPTH: 264.9 ft.
DEPTH TO BEDROCK: 85.0 ft.

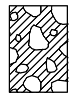
STATE: Nevada
GROUND ELEVATION: 3670.79
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

SOIL

Fill (made ground)

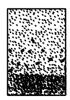


Quaternary Alluvium (Qal)

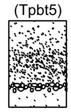


ROCK

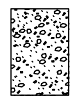
Tuff "x" (Tpki)



Post Tiva Canyon Bedded Tuff (Tpbt5)

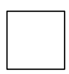


Tpcprn

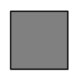


WELDING

Non-Welded



Densely Welded



RF26_KEY WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#28

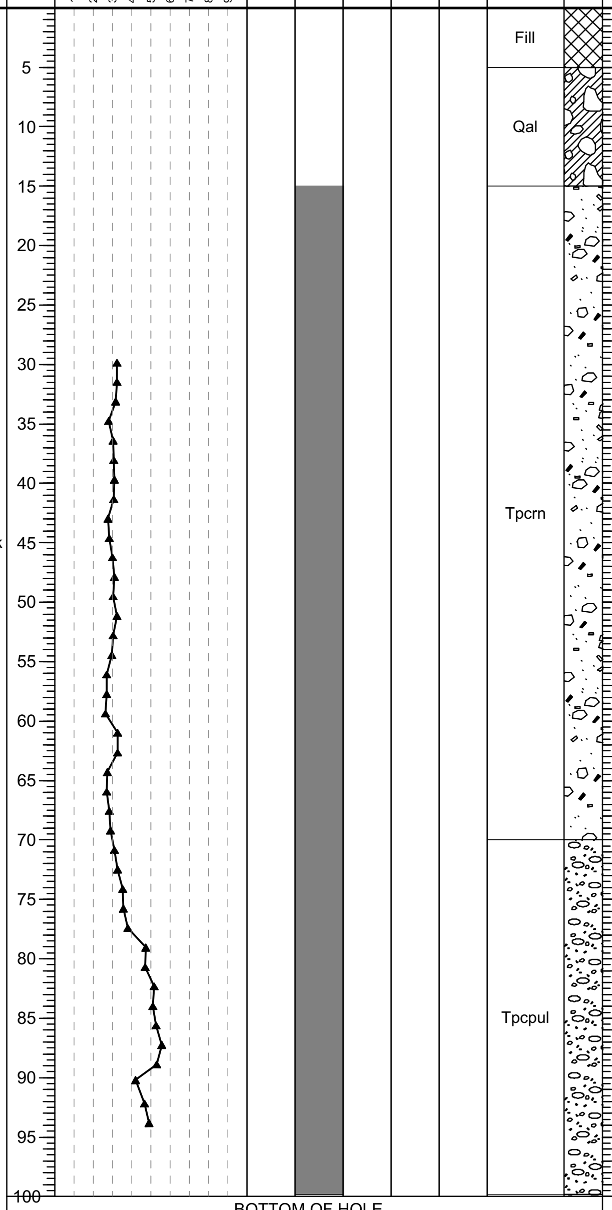
SHEET 1 OF 2

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/24/2000 FINISHED: 8/25/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,510.21 E 570,104.87
TOTAL DEPTH: 100.0 ft.
DEPTH TO BEDROCK: 15.0 ft.

STATE: Nevada
GROUND ELEVATION: 3680.63
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 4.96. Cement 10.75 O.D. casing with 1.16 stickup. Re-enter hole on 8/25/2000 with 8.50 Tricone bit. Drill from 4.96 to total depth of 99.75.

Drilling Conditions:
Smooth soft drilling to total depth of hole.

Drilling Fluid:
0.00 to 4.96: Non-potable water.
4.96 to total depth of 99.75: Quick Gel mud with EZ-Mud.

Loss Intervals:
NA

Casing Record:
0.00 to 4.96 : 10.75 O.D. casing.
4.96 to 99.75 : No casing.

Hole Completion:
Set and cement 97.98 of 4.50 schedule 80 PVC casing.

0.0 to 5.0 ft. PAD FILL (Fill)
Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.

5.0 to 15.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material has white to light gray caliche coatings.

15.0 to 70.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystallized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 15.0 to 30.0 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock. From 30.0 to 47.0 ft. the presence of vapor phase mineral coatings on the chips indicate the presence lithophysal cavities. Phenocrysts content begins to decrease at 47.0 ft.

70.0 to 99.8 ft. TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul)
Pyroclastic flow, densely welded, crystallized, vapor-phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 5 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor-phase altered chips, indicating the edges of voids in the tuff.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

WHB_LOG WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#28

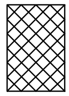
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 8/24/2000 FINISHED: 8/25/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,510.21 E 570,104.87
TOTAL DEPTH: 100.0 ft.
DEPTH TO BEDROCK: 15.0 ft.

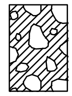
STATE: Nevada
GROUND ELEVATION: 3680.63
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

SOIL

Fill (made ground)

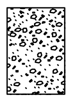


Quaternary Alluvium (Qal)

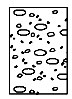


ROCK

Tpcprn

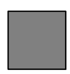


Tpcpul



WELDING

Densely Welded



RF28_KEY WHB.GPJ WHB.GDT 6/14/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#29

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 766,018.46 E 570,836.04	GROUND ELEVATION: 3672.71
BEGUN: 10/26/2000 FINISHED: 11/1/2000	TOTAL DEPTH: 430.0 ft.	ANGLE FROM HORIZONTAL: -90
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 85.0 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

Column headings: NOTES | DEPTH | SHEAR WAVE VELOCITY ft/s (1000–9000) | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION

NOTES

Purpose of Hole:
Preliminary, conceptual-level geotechnical foundation investigations for the design of the Waste Handling Building (WHB).

Drill Equipment:
Schramm T685 Drill Rig

Drillers:
G. Fox, V. Mora, M. Fyffe; Dynatec Drilling Inc.; Salt Lake City, Utah.

Drilling Method:
Install 12" hammer. Hammer to 4.50. Cement 10.75 O.D. casing with 1.51 stickup. Re-enter hole on 10/27/2000 with 8.50 Tricone bit. Drill from 4.50 to total depth of 429.92.

Drilling Conditions:
Smooth soft drilling to total depth of hole.

Drilling Fluid:
0.00 to 4.50: Non-potable water.
4.50 to total depth of 429.92: Quick Gel mud with EZ-Mud.

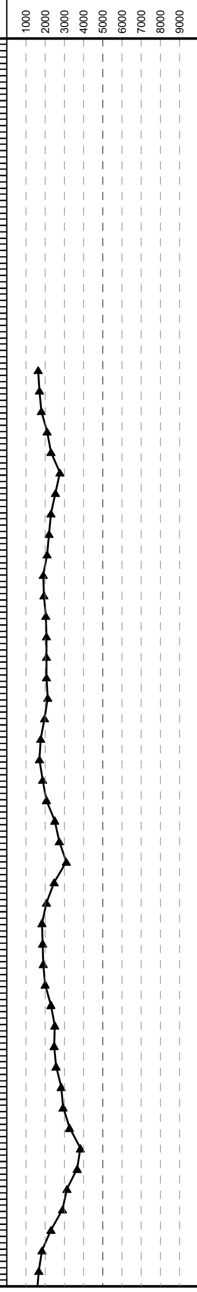
Loss Intervals:
NA

Casing Record:
0.00 to 4.50 : 10.75 O.D. casing.
4.50 to 429.92: No casing.

Hole Completion:
Set and cement 409.67 of 4.50 schedule 80 PVC casing.

DEPTH / SHEAR WAVE VELOCITY

Depth: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95



GEOLOGIC UNIT

Qal (0.0 to 85.0 ft.)

Tmbt1 (from 85.0 ft.)

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 85.0 ft. QUATERNARY ALLUVIUM (Qal)
Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material have white to light gray caliche coatings.

85.0 to 280.0 ft. BEDDED TUFF (Tmbt1)
Pre-Rainier Mesa Bedded Tuff composed of bedded and reworked tuff. Bedded tuff is nonwelded, argillic, with up to 10 percent quartz, plagioclase, and sanidine phenocrysts. Bedded tuff contains up to 10 percent argillically altered pumice clasts. Some beds have up to 15 percent volcanic lithic clasts. Tuff is predominately grayish-orange pink and drill cuttings returns are sand to silt sized.

280.0 to 370.0 ft. COMB PEAK IGNIMBRITE - TUFF X (Tpki):
Pyroclastic flow, nonwelded, crystallized, with up to 15 percent pumice clasts. Tuff contains 2 to 3 percent sanidine, plagioclase, quartz, and less than 1 percent biotite and hornblende phenocrysts. Up to 15 percent moderate red to medium dark gray, volcanic lithic clasts. Tuff is predominately grayish-orange pink with possible minor silicification.

370.0 to 380.0 ft. POST TIVA CANYON BEDDED TUFFS (Tpbt5):
Nonwelded, devitrified, reworked (?) Fallout tephra and pyroclastic flows separated by distinct paleosols. Bedded tuffs are very pale orange with 20 to 25 percent pumice clasts and up to 4 percent, pale red, volcanic lithic clasts. The tuff has up to 6 percent quartz, sanidine and lesser plagioclase, with less than 1 percent biotite and manganese oxides.

380.0 to 430.0 ft. TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn)
Pyroclastic flow, moderately to densely welded, crystallized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. Possible vitrophyre from 379.0 to 407.0 ft. From 407.0 to 427.0 ft. the tuff is pumice poor with only 3 percent Clasts content. From 427 to 429.9 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 12 percent of rock.

COMMENTS: 1. Hole logged from cuttings

2. Shear Wave Velocity data from GeoVision suspension logging. Data acquired from downhole survey conducted after PVC casing installed.

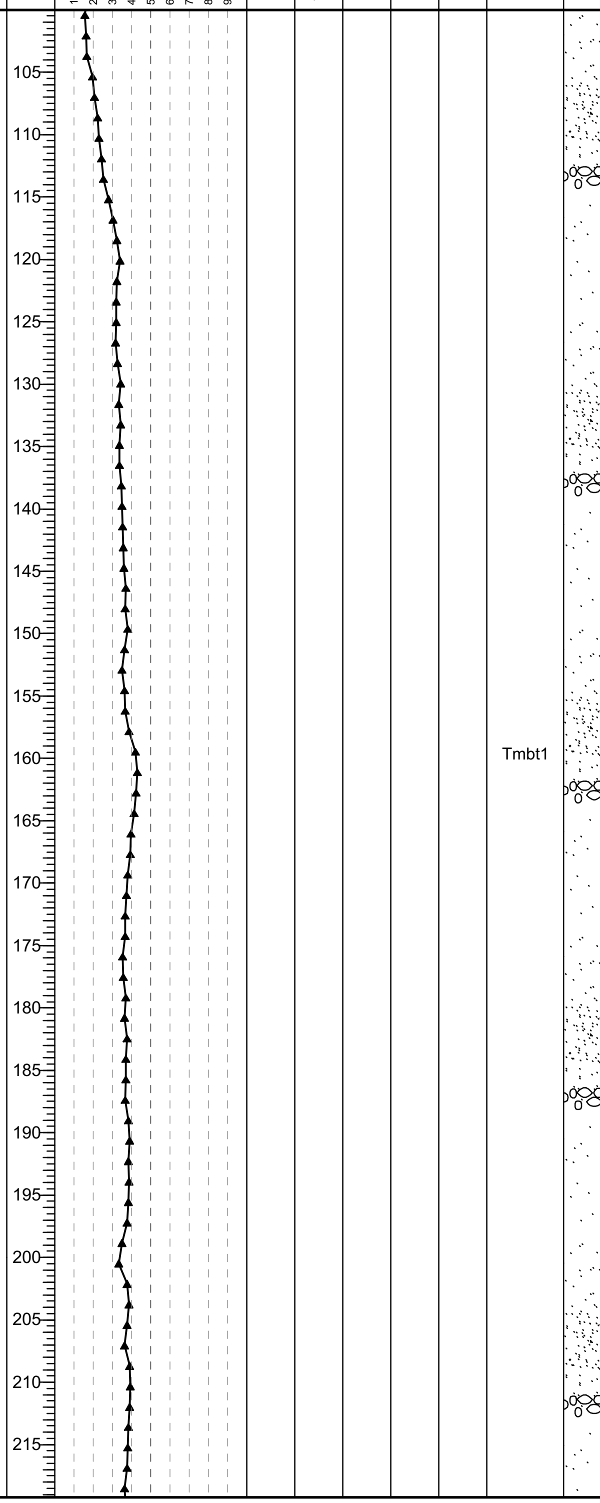
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#29

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/26/2000 FINISHED: 11/1/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,018.46 E 570,836.04
TOTAL DEPTH: 430.0 ft.
DEPTH TO BEDROCK: 85.0 ft.

STATE: Nevada
GROUND ELEVATION: 3672.71
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
			HARDNESS	WELDING	FRACTURE DENSITY					



WHB_LOG WHB.GPJ WHB.GDT 6/14/02

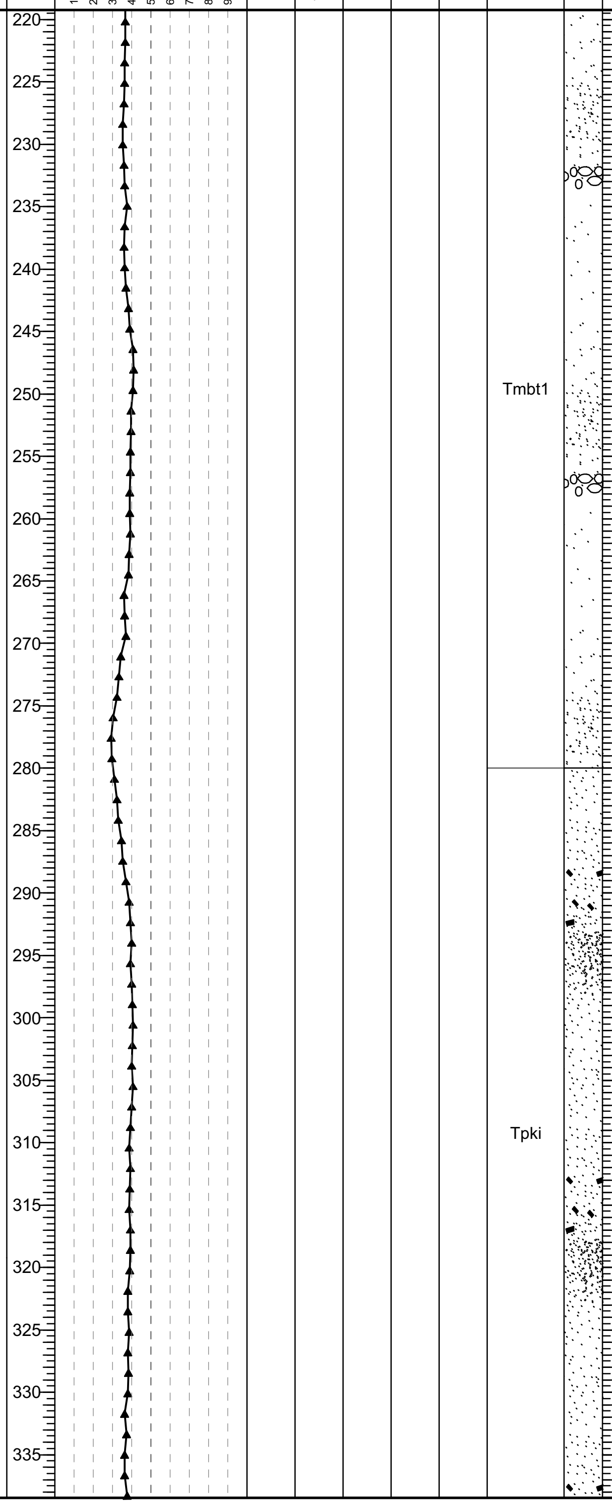
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#29

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/26/2000 FINISHED: 11/1/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,018.46 E 570,836.04
TOTAL DEPTH: 430.0 ft.
DEPTH TO BEDROCK: 85.0 ft.

STATE: Nevada
GROUND ELEVATION: 3672.71
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

NOTES	DEPTH	SHEAR WAVE VELOCITY ft/s	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		1000 2000 3000 4000 5000 6000 7000 8000 9000	HARDNESS	WELDING	FRACTURE DENSITY					

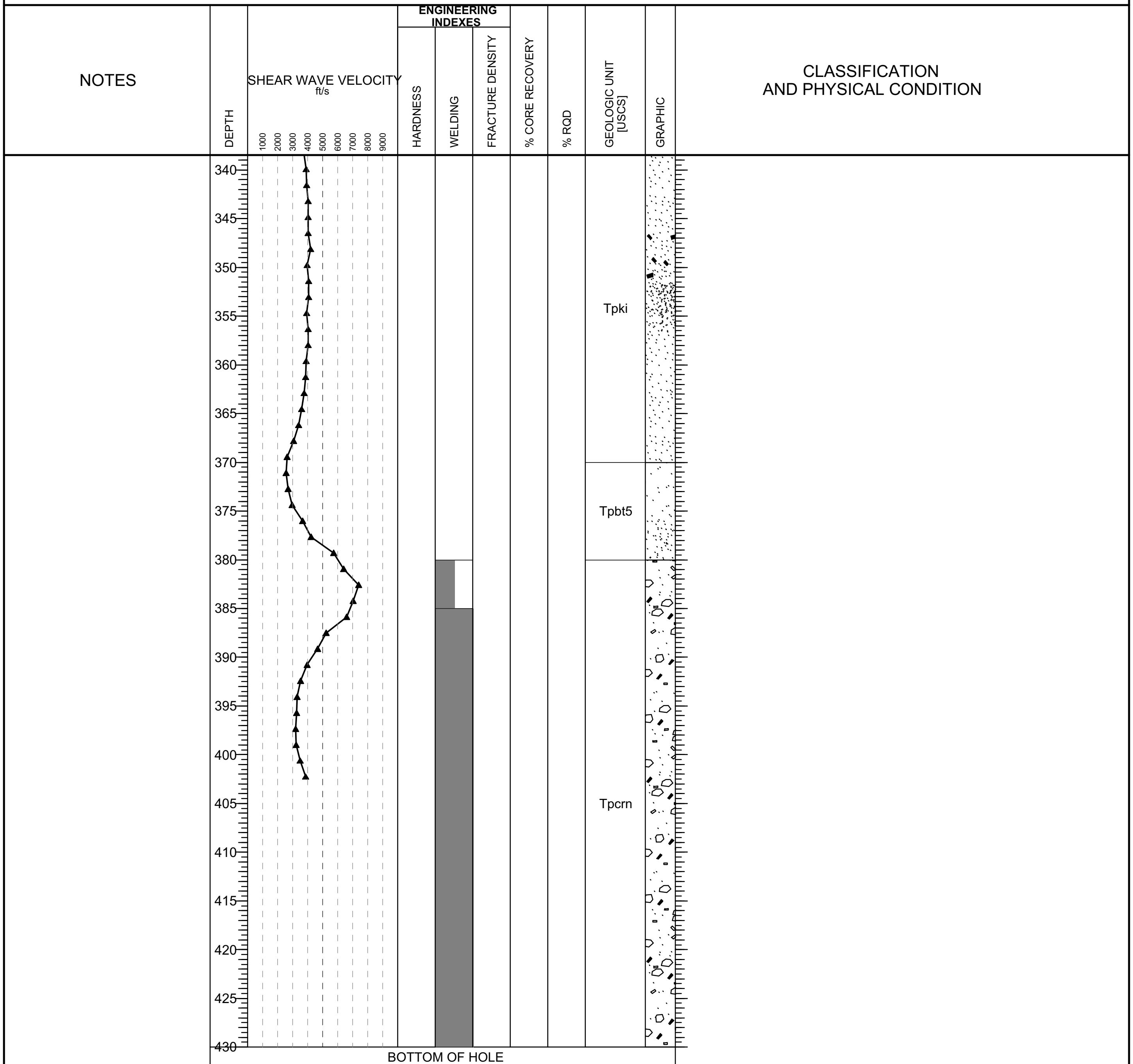


GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#29

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/26/2000 FINISHED: 11/1/2000
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,018.46 E 570,836.04
TOTAL DEPTH: 430.0 ft.
DEPTH TO BEDROCK: 85.0 ft.

STATE: Nevada
GROUND ELEVATION: 3672.71
ANGLE FROM HORIZONTAL: -90
HOLE LOGGED BY: USBR/SMF
REVIEWED BY: Mark McKeown

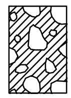


GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#29

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 766,018.46 E 570,836.04	GROUND ELEVATION: 3672.71
BEGUN: 10/26/2000 FINISHED: 11/1/2000	TOTAL DEPTH: 430.0 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 85.0 ft.	HOLE LOGGED BY: USBR/SMF
		REVIEWED BY: Mark McKeown

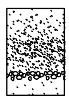
SOIL

Quarternary Alluvium (Qal)



ROCK

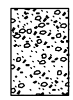
Pre-Ranier Mesa Bedded Tuff (Tmbt1)



Tuff "x" (Tpki)

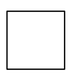
Post Tiva Canyon Bedded Tuff (Tpbt5)

Tpcrn

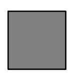


WELDING

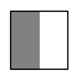
Non-Welded



Densely Welded



Moderately Welded



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ATTACHMENT II

REVISED LOG OF BOREHOLE RF#13

ATTACHMENT II

REVISED LOG OF BOREHOLE RF#13

As mentioned in Section 6.2.3, borehole RF#13 was originally drilled in 1998 at the location shown on Figure 2 in the main text. Its log was revised for this program in order to show engineering properties and shear wave velocity on the log. During the process of creating final SMF geologic logs for the current program (RF#14 to 29), the RF#13 core was reexamined. Initially, the borehole was logged with a normal fault that repeated the Tpcpmn at the bottom of the hole (CRWMS M&O 1999b, Appendix L). With further drilling it is now accepted that instead of the Tpcpmn the zone in question is the Tpcpln, which is confirmed in all the cored boreholes in the current program (DTN: GS020383114233.003). The revised log of RF#13 (DTN: GS020383114233.003) is included in this attachment. The revised log may also be found in DTN: GS020383114233.003.

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#13

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,500.04 E 570,720.12	GROUND ELEVATION: 3671.03
BEGUN: 10/6/1998 FINISHED: 12/7/1998	TOTAL DEPTH: 350.1 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 98.0 ft.	HOLE LOGGED BY: URS/SMF/USBR
		REVIEWED BY: M. Luebbers/M. McKeown

Column headings: NOTES | DEPTH | ENGINEERING PROPERTIES: SPT, FRACTURE DENSITY, HARDNESS, WEATHERING | SHEAR WAVE VELOCITY ft/s (1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000) | GEOLOGIC UNIT | CLASSIFICATION / LITHOLOGY | % CORE RECOVERY | % RQD | CLASSIFICATION AND PHYSICAL CONDITION

NOTES

PURPOSE OF HOLE:

Preliminary, conceptual-level geotechnical foundation investigations for the design of the potential Waste Handling Building (WHB).

DRILL RIG:

CME 850

DRILLER:

M. Pancake

DRILLING METHOD:

ODEX method from ground surface to 98.0'; Modified California (MC) and Pitcher tube samples collected at approximately 5' intervals from 7 - 98'; continuous HX wireline from 98.0 - 350.1'. The MC samplers were driven approximately 18 inches into the bottom of the borehole by repeatedly dropping a 140-pound hammer a distance of 30 inches. MC samples were collected in brass tubes and sealed with vinyl caps. All samples and core were transported to the Sample Management Facility.

DRILLING CONDITION & DRILLER'S REMARKS:

CASING RECORD:

DRILLING FLUID:

Air.

DRILL FLUID LOSSES:

Not Applicable.

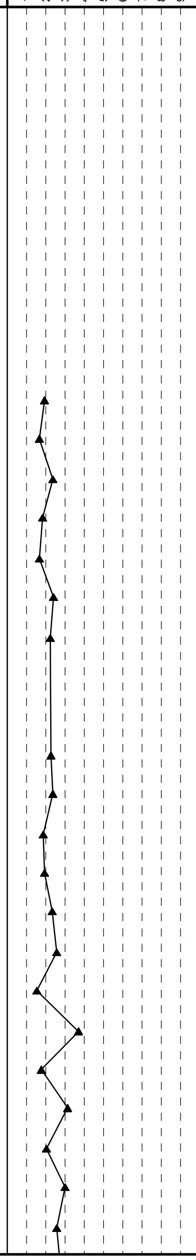
HOLE COMPLETION:

3.5-inch O. D. schedule 80 PVC with flush threads sealed by O-rings installed from ground surface to 350.1' to enable downhole seismic and suspension seismic measurements; neat cement grout with 2 - 5% bentonite added to prevent shrinkage used to fill the annulus was pumped through a tremie pipe that was pulled up as the grout was added; the grout was added in 30 - 50' lifts and allowed to cure for at least 8 hours between lifts.

DEPTH / SPT / GEOLOGIC UNIT / LITHOLOGY

DEPTH	SPT	GEOLOGIC UNIT	LITHOLOGY
0–5.5		Fill	GP
5.5–12.5	167	Fill	SW-SM
12.5–16.0		Qal	SW-SM
16.0–20.0	178 9"	Qal	GP-GM
20.0–32.0	103; 117	Qal	SP-SM
32.0–35.0		Qal	ML
35.0–37.0		Qal	SP-SM
37.0–42.0	24	Qal	GP
42.0–52.0	140 7"; 38 3"	Qal	SM-GP

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50



CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 12.5' **PAD FILL (machine place fill material)**

0.0 to 5.5': GRAVEL WITH SAND (GP); moist

5.5 to 12.5': WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM); Medium dense, moist, brown, red, and white.

Laboratory Classification: 11.3 - 12.8' WELL-GRADED GRAVEL WITH SILT AND SAND (GW-GM)

12.5 to 98.0' **QUATERNARY ALLUVIUM (surficial deposits) Qal**

12.5 to 16.0': WELL-GRADED SAND WITH SILT AND GRAVEL (SW-SM); Very dense, moist, gray, and white.

16.0 to 20.0': POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM); Very dense, moist, brown.

Laboratory Classification: 16.3 - 17.55' POORLY-GRADED GRAVEL WITH SILT AND SAND (GP-GM)

20.0 to 32.0': POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM); Very dense, moist ,brown.

Laboratory Classification: 21.2 - 22.7' POORLY-GRADED SAND WITH SILT AND GRAVEL (SP-SM)
Laboratory Classification: 26.2 - 27.7' POORLY-GRADED SAND WITH SILT AND GRAVEL (SP-SM)

32.0 to 35.0': SILT WITH LESS THAN 10% GRAVEL (ML); Medium stiff, dry, tan, sandy.

35.0 to 37.0': POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM); Medium dense, dry, beige and gray.

37.0 to 42.0': POORLY GRADED GRAVEL (GP); Medium dense, moist, gray and purple.

42.0 to 52.0': INTERBEDDED SILTY SAND WITH GRAVEL (SM) AND POORLY GRADED GRAVEL (GP); Very dense, moist, light brown.

Laboratory Classification: 51.8 - 52.3' WELL-GRADED GRAVEL WITH SAND (GW)

52.0 to 56.5': POORLY GRADED SAND (SP); Very dense, dry, pale brown,

56.5 to 71.5': POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM); Very dense, dry, brown.

Laboratory Classification: 56.7 - 57.9' POORLY-GRADED SAND WITH SILT AND GRAVEL(SP-SM)

71.5 to 87.0': SILTY SAND WITH GRAVEL (SM); Very dense, dry, purple and brown.

Laboratory Classification: 71.5 - 72.8' SILTY SAND WITH GRAVEL (SM)
Laboratory Classification: 76.4 - 76.9' SILTY SAND WITH GRAVEL (SM)
Laboratory Classification: 81.4 - 82.15' SILTY SAND WITH GRAVEL (SM)
Laboratory Classification: 86.4 - 87.15' SILTY SAND WITH GRAVEL (SM)

87.0 to 98.0': SILTY SAND (SM); Very dense, moist, white to beige,, fine grained, trace gravel, transition to bedded tuff; contact with underlying unit (Tpki) is unconformable

Laboratory Classification: 91.4 - 91.8' SILTY SAND WITH GRAVEL (SM)

COMMENTS

1. Based on measurements by the drilling engineer, 12 inches of slough material was in the bottom of the borehole when Sample MC-1 was driven. A blow count of 7 was recorded for these12 inches and a blow count of 15 was recorded for the final 4 inches of the drive. ODEX 165 pipe was used as the rod, rather than the AW rod that was used inthe remaining drive samples in this boring. The sampler was not driven the full 18 inches. The blow count is not to be used.

2. In driving MC-3 from 15 to 18 inches, the hammer drop exceeded a 30-inch drop. The recorded blow count of 167 is consequently too low.

3. All of the samples on which a sieve analysis was performed were tested for reaction with dilute hydrochloric acid. A reaction was noted in all of the samples. The reaction was moderate for the two samples from 76.4 - 76.7' and 81.5 - 81.8'. The reaction was strong for the remaining samples.

4. Two Pitcher tube samples were attempted from 7 - 9' and 13 - 14'.

WHB13_LOG WHB13.GPJ WHB13.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#13

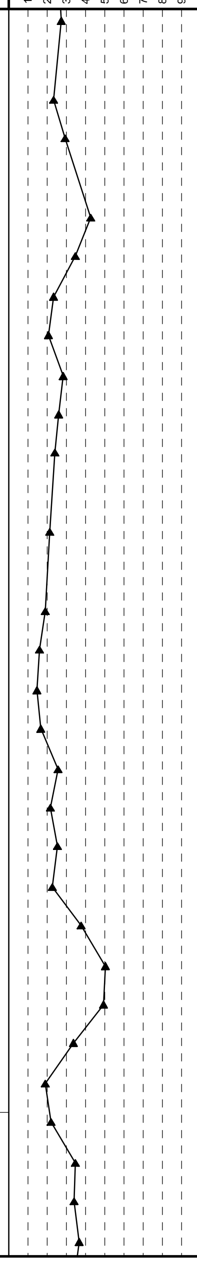
FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/6/1998 FINISHED: 12/7/1998
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,500.04 E 570,720.12
TOTAL DEPTH: 350.1 ft.
DEPTH TO BEDROCK: 98.0 ft.

STATE: Nevada
GROUND ELEVATION: 3671.03
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: URS/SMF/USBR
REVIEWED BY: M. Luebbers/M. McKeown

NOTES	DEPTH	SPT	FRACTURE DENSITY	HARDNESS	WEATHERING	GEOLOGIC UNIT	CLASSIFICATION / LITHOLOGY	% CORE RECOVERY	% RQD
	55	91 6"				Qal	SP		
		108 8"					SP-SM		
	60	113 8"							
	65	119 5"							
	70	167 10"					SM		
	75	100 6"							
	80	66 3"							
	85	88 3"					SM		
	90	125 5"							
	95	73 4"							
	100		FD7	H4	W2	Tuff "x" (Tpki)		100	43
			FD0					100	68
			FD7					100	65

SHEAR WAVE VELOCITY ft/s



CLASSIFICATION AND PHYSICAL CONDITION

Laboratory Classification: 97.8 - 98.1'

98.0 to 164.4': **COMB PEAK IGNIMBRITE - Tuff "X" (Tpki)**

98.0 to 98.5': Very light grey; well indurated (silicified) matrix showing oriented pumice; approximately 40% pumice; 5 - 7% lithic fragments, subrounded to angular, 1 - 2% phenocrysts of quartz(?), felsics, and mafics (biotite(?).

98.5 to 98.7': Thin bed; white; very fine grained; partly silicified; no distinct pumice.

98.7 to 160.0': White; non-welded; devitrified; 25 - 30% pumice; 1 - 2% phenocrysts of feldspar, quartz, rare mafics including biotite(?); approximately 5% lithic fragments.

160.0 to 162.2': White; non-welded; devitrified; 20 - 30% pumice; 2% phenocrysts; 1% lithic fragments.

162.4 to 162.6': Pinkish gray; very fine grained; 1 - 2% small (<1mm) phenocrysts and 2% very fine grained lithic fragments.

162.6 to 164.4': White; non-welded; devitrified; approximately 25 up to 50% pumice at base; 2% phenocrysts; 2% lithic fragments.

Intensely fractured from 98.0 - 100.5'; unfractured from 100.5 - 102.5'; intensely fractured from 102.5 - 105.8'; slightly fractured from 105.8 - 108.1'; intensely to moderately fractured from 108.1 - 115.8'; very intensely to intensely fractured from 115.8 - 121.1'; moderately fractured from 121.1 - 122.8'; intensely to moderately fractured from 122.8 - 145.3'; slightly fractured from 145.3 - 161.8'; and intensely to moderately fractured from 161.8 - 164.4'.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
99.5	40	R2-R3	trace to paper thin light brown coating
102.9	20	R3	trace to paper thin light brown coating
104.6	60	R2	trace to paper thin light brown coating
109.0	35	R2	trace to paper thin light brown coating
120.9	30	R3	trace to paper thin light brown coating
121.7	50	R2	trace to paper thin light brown coating
125.8	40	R2	trace to paper thin light brown coating
126.0	40	R2	trace to paper thin light brown coating
136.0	45	R3	clean
145.0	30	R2-R3	clean
152.6	40	R1	paper thin light brown coating
154.9	55	R2	trace to paper thin light brown coating

164.4 - 169.3 **TIVA CANYON ASHFALL TUFF (nonwelded) Tpbt5**
Fallout tephra (?); grayish-orange pink to pale brown; argilic alteration (core damp, sticky, surface smeared by core catcher); approximately 10% white pumice; 10% variably colored, altered lithic fragments; a thin (16 mm) layer of pale to moderate red, very well sorted fallout tephra occurs at 166.8'; moderate red to moderate reddish orange and grayish-orange pink, heavily altered from 166.8 - 169.3'; moderately soft from 164.4 - 166.8'; moderately weathered from 164.4 - 166.8'; intensely to moderately fractured from 164.4 - 166.8'; contact with underlying unit (Tpcrn4d) dips 30o below horizontal and is distinct and separated.

Discontinuity Measurements:
No discontinuities

COMMENTS:

WHB13_LOG WHB13.GPJ WHB13.GDT 6/13/02

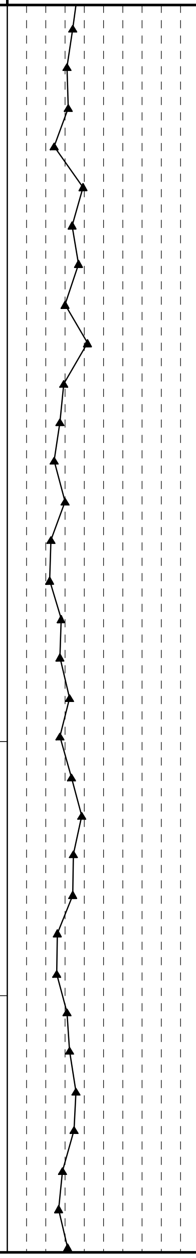
GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#13

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/6/1998 FINISHED: 12/7/1998
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,500.04 E 570,720.12
TOTAL DEPTH: 350.1 ft.
DEPTH TO BEDROCK: 98.0 ft.

STATE: Nevada
GROUND ELEVATION: 3671.03
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: URS/SMF/USBR
REVIEWED BY: M. Luebbers/M. McKeown

NOTES	DEPTH	ENGINEERING PROPERTIES: SPT	FRACTURE DENSITY	HARDNESS	WEATHERING	SHEAR WAVE VELOCITY ft/s	GEOLOGIC UNIT	CLASSIFICATION / LITHOLOGY	% CORE RECOVERY	% RQD
	105		FD7						100	65
			FD3							
	110		FD6						100	42
	115								98	52
			FD8		W2					
	120		FD5						72	32
	125								94	30
	130			H4			Tuff "x" (Tpki)		16	0
	135		FD6						68	42
	140				W3				100	43
	145								96	38
	150		FD3		W1				100	24
	155								100	34



CLASSIFICATION AND PHYSICAL CONDITION

169.3 - 175.9 **TIVA CANYON CRYSTAL RICH NONLITHOPHYSAL TUFF (moderately to strongly welded tuff) Tpcrn4d**
Pale red; moderately welded, devitrified; 7 - 10% vesicular pumice; 7% phenocrysts of feldspar, rare quartz, altered biotite and other mafics; lithic fragments rare to absent; moderately hard; moderately to slightly weathered; very intensely fractured; contact with underlying unit (Tpcrn3) is gradational and broken, with significant change in alteration.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
169.3-170.2	85	R2	trace to paper thin light tan coating
175.0-176.0	intersecting 75-85	R3	trace to paper thin white non-crystalline coating

175.9 - 186.6 **TIVA CANYON CRYSTAL-RICH NONLITHOPHYSAL TUFF (moderately to strongly welded tuff) Tpcrn3**
Pale red; matrix is highly porous; 10% phenocrysts; pumice and lithic fragments absent; clay-altered, soft, greenish fragments, not aligned, waxy textured, approximately 1 cm; large (2 cm) vesiculated pumice mixed with small flattened cavities (eroded out pumice?); moderately hard; slightly weathered to fresh; very intensely fractured; contact with underlying unit (Tpcrn2) is gradational and broken.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
179.1	70	R4	trace light brown
181.2	70	R4	healed with sand-size fragments; 0-1mm white mineral
182.0	intersecting 70 and 85	R4	clean
186.5	70	R2-R3	trace white mineral

186.6 - 202.0 **TIVA CANYON CRYSTAL RICH NONLITHOPHYSAL TUFF (moderately to strongly welded tuff) Tpcrn2**
Pale red; same as overlying unit except at 191.5' alteration becomes intense, pumice very soft, matrix rough; matrix waxy, friable, plastic, and sticky from 195.5 - 196.5' with splotches of blue/white mineral (opal?); 10 - 12% phenocrysts at 200.3'; moderately hard; slightly weathered to fresh 186.6 - 191.4', slightly weathered 191.4 - 202.0'; very intensely fractured; contact with underlying unit (Tpcrn1) is gradational and broken.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
187.4	30	R3	clean
188.0	50	R3	bluish drusy quartz and white noncrystalline coating
191.5	30	R3	trace white noncrystalline material
192.4	40	R2	trace white noncrystalline material
194.2	30	R3	local brown stain
195.2	35	R4	caliche cemented breccia
196.9	25	R3	patches of white mineral
198.3	30	R2 - R3	patches of white mineral
198.8	40	R2 - R3	patches of white mineral
200.6	45	R2	patches of white mineral

202.0 - 219.1 **TIVA CANYON CRYSTAL RICH NONLITHOPHYSAL TUFF (strongly welded tuff) Tpcrn1**
Light brownish gray, moderately welded, devitrified; 10 - 15% pumice, up to 25 - 35% locally, moderately to highly flattened, up to core diameter; 10% phenocrysts of feldspar and rare quartz(?); some vapor phase

COMMENTS:

WHB13_LOG WHB13.GPJ WHB13.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#13

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/6/1998 FINISHED: 12/7/1998
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,500.04 E 570,720.12
TOTAL DEPTH: 350.1 ft.
DEPTH TO BEDROCK: 98.0 ft.

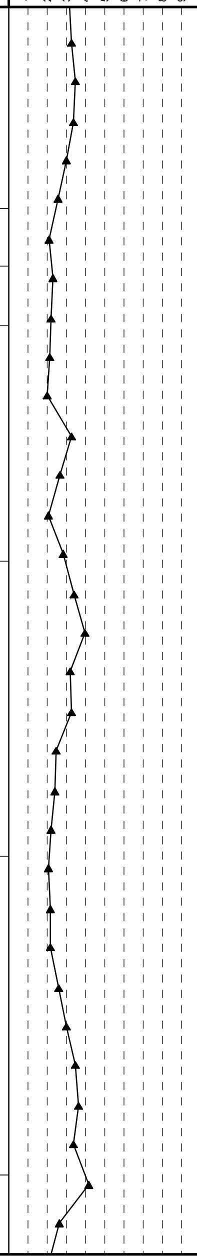
STATE: Nevada
GROUND ELEVATION: 3671.03
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: URS/SMF/USBR
REVIEWED BY: M. Luebbers/M. McKeown

NOTES | DEPTH | SPT | ENGINEERING PROPERTIES: FRACTURE DENSITY, HARDNESS, WEATHERING | SHEAR WAVE VELOCITY ft/s | GEOLOGIC UNIT | CLASSIFICATION / LITHOLOGY | % CORE RECOVERY | % RQD | CLASSIFICATION AND PHYSICAL CONDITION

Depth scale: 160, 165, 170, 175, 180, 185, 190, 195, 200, 205

Fracture Density	Hardness
FD3	H4
FD6	H5
NR	NR
FD9	H4

Weathering
W1
W5
NR
W4
W2
W3
W2



Geologic Unit
Tuff "x" (Tpki)
Tpbt5
Tpcrn4d
Tpcrn3
Tpcrn2
Tpcrn1

% Core Recovery	% RQD
100	34
100	82
100	73
NR	NR
23	0
0	NR
62	0
70	0
82	0
72	0
91	0
66	0
77	0
82	0

alteration of matrix; moderately hard; slightly weathered from 202.0 - 204.7', slightly weathered to fresh from 204.7 - 219.1'; contact with underlying unit (Tpcpul) is a possible fault(?) contact, broken; material from 215.4 to 219.1 feet not recovered.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
207.1	40	R3	trace light brown stain
212.8	80	R3	trace white mineral
212.8	50	R3	clean

219.1 - 231.5 TIVA CANYON CRYSTAL POOR UPPER LITHOPHYSAL TUFF (strongly welded tuff) Tpcpul

Densely welded; pale reddish-brown to grayish-orange pink; 2% pumice; 2 - 3% phenocrysts of feldspar, rare mafics; lithic fragments absent; 1% or less oblate lithophysal cavities with vapor phase minerals and light gray alteration rims, flattened and approximately 20 degrees to near-perpendicular to core axis; at 231.0' first concentration of well developed spherulites; moderately hard from 219.1 - 225.6', hard from 225.6 - 231.5'; slightly weathered to fresh; very intensely fractured; contact with underlying unit (Tpcpmn) is distinct; broken.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
220-223	multiple 70 - 80	R3	trace to paper thin white and light brown coating
224.8	15	R5	clean
229.0	30	R3	trace tan and light brown stain

231.5 - 286.7 TIVA CANYON MIDDLE NONLITHOPHYSAL TUFF (densely welded) Tpcpmn

Pale reddish-brown; densely welded; devitrified; less than 1% pumice, vapor phase altered and eroded out, up to greater than core diameter, locally occur in swarms up to 50%; approximately 5% pumice below 260'; 2 - 3% phenocrysts of feldspar, hornblende (?); hard from 231.5 - 271.0', moderately hard from 271.0 - 271.5', very hard from 271.5 - 286.7'; fresh from 231.5 - 271.0', slightly weathered from 271.0 - 271.5', slightly weathered to fresh from 271.5 - 286.7'; very intensely fractured from 231.5 - 231.7', slightly to very slightly fractured from 231.7 - 270.5', intensely to moderately fractured from 270.5 - 286.7'; contact with underlying unit (Tpcpmn2) is gradational.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
233.8	70	R2	trace tan and light brown stain
236.0	80	R4	clean
237.0	35	R4	trace tan, light brown, and white stain
237.5	40	R3	paper thin tan, light brown, and white coating
237.7	45	R3	paper thin tan, light brown, and white coating
239.0	45	R2	paper thin tan coating
241.9	20	R2	paper thin tan and white coating
242.1	40	R3	trace white mineral
242.4	40	R3	trace tan and white mineral
249.6	50	R3	trace tan and white mineral
250.5-250.7	20	R4	4 to 6cm yellowish-orange crystalline infilling
251.6	30	R5	white crystalline infilling
256.4	15	R3	paper thin tan and white coating
257.2	70	R3	paper thin tan and white coating
261.7	30	R4	clean

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#13

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/6/1998 FINISHED: 12/7/1998
DEPTH TO WATER: Not Encountered

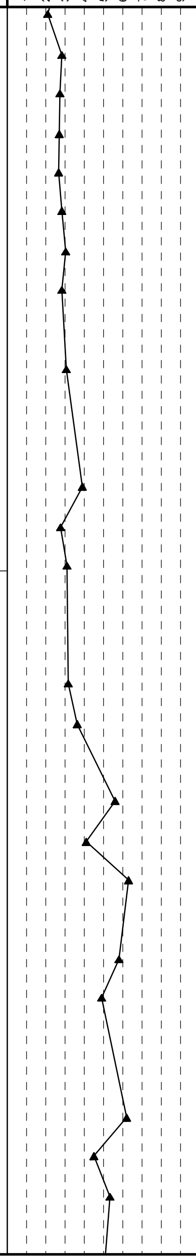
PROJECT: Yucca Mountain Project
COORDINATES: N 765,500.04 E 570,720.12
TOTAL DEPTH: 350.1 ft.
DEPTH TO BEDROCK: 98.0 ft.

STATE: Nevada
GROUND ELEVATION: 3671.03
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: URS/SMF/USBR
REVIEWED BY: M. Luebbers/M. McKeown

NOTES	DEPTH	SPT	FRACTURE DENSITY	HARDNESS	WEATHERING	GEOLOGIC UNIT	CLASSIFICATION / LITHOLOGY	% CORE RECOVERY	% RQD
	210–219		FD9	H4	W2	Tpcrn1		82	0
								92	6
								96	0
	219–225.5		FD9	H4	W2	Tpcpul		82	0
	225.5–231.5		FD9	H3	W2	Tpcpul		34	0
	231.5–260		FD2	H3	W1	Tpcpmn		72	50
								100	63
								100	81
								100	100
								100	76
								100	83
								100	82

Depth marks: 210, 215, 220, 225, 230, 235, 240, 245, 250, 255

SHEAR WAVE VELOCITY ft/s



CLASSIFICATION AND PHYSICAL CONDITION

263.0	20	R4	clean
263.2	20	R4	1mm tan and white infilling
267.2	70	R2	trace tan and white mineral
269.1	60	R2	trace to 1mm light brown mineral
270.6	30	R5	paper thin white and light brown coating
271.7	20	R5	4 to 6cm very pale orange, very fine grained well sorted fallout tephra
272.0	20	R5	patches of white mineral
273.0	10	R3	1mm white mineral
274.2	40	R5	paper thin white mineral
275.0	30	R5	paper thin white mineral
275.4	45	R2	paper thin white mineral
276.7	40	R4	trace white mineral
277.2	20	R4	paper thin white mineral
278.5	55	R2	paper thin white mineral
278.7	25	R5	paper thin white and tan mineral
279.5	60	R5	paper thin white mineral
280.5	25	R5	paper thin white mineral
281.0	25	R5	paper thin white and tan mineral
282.5	15	R5	trace of white mineral
283.5	10	R5	trace to paper thin white mineral
281.4-285.7	20	R4	trace to paper thin white mineral

286.7 - 300.9 TIVA CANYON LOWER LITHOPHYSAL TUFF (densely welded) Tpcpll

Ignimbrite; pale red to moderate orange-pink; densely welded, devitrified; less than 5% pumice; 2 - 3% feldspar phenocrysts, rare mafics; rare lithic fragments; 1 - 2% lithophysae, moderately flattened with vapor phase mineral coating and alteration rims , up to core diameter; very hard; slightly weathered to fresh; intensely to moderately fractured from 286.7 - 293.0', very intensely fractured from 293.0 - 300.9'; contact with underlying unit (Tpcpmn) is broken.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
287.7	20	R3	trace to paper thin white mineral
289.3	30	R2	paper thin white and yellowish brown mineral
290.3	30	R4	paper thin white mineral
291.7	25	R2	trace tan mineral
294.6-301.0	20	R3	paper thin white mineral

300.9 - 350.1 TIVA CANYON LOWER NONLITHOPHYSAL TUFF (densely welded) Tpcpln

Ignimbrite; light brownish gray with grayish orange pink mottling (1- 2 mm alteration spots usually around phenocrysts); densely welded, devitrified; 2 -3% pumice, slightly altered/eroded; 2% phenocrysts, primarily feldspar, rare mafics; rare lithic fragments; very hard; fresh from 300.9 - 316.2', slightly weathered from 316.2 - 317.0', fresh from 317.0 - 350.1'; moderately fractured.

Discontinuity Measurements:

Depth (ft.)	Inclination from Core Axis (o)	Rough	Infilling
294.6-301.0	20	R3	paper thin white mineral
302.2	50	R3	trace white mineral
302.6	60	R2	paper thin white mineral

COMMENTS:

WHB13_LOG WHB13.GPJ WHB13.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#13

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/6/1998 FINISHED: 12/7/1998
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,500.04 E 570,720.12
TOTAL DEPTH: 350.1 ft.
DEPTH TO BEDROCK: 98.0 ft.

STATE: Nevada
GROUND ELEVATION: 3671.03
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: URS/SMF/USBR
REVIEWED BY: M. Luebbers/M. McKeown

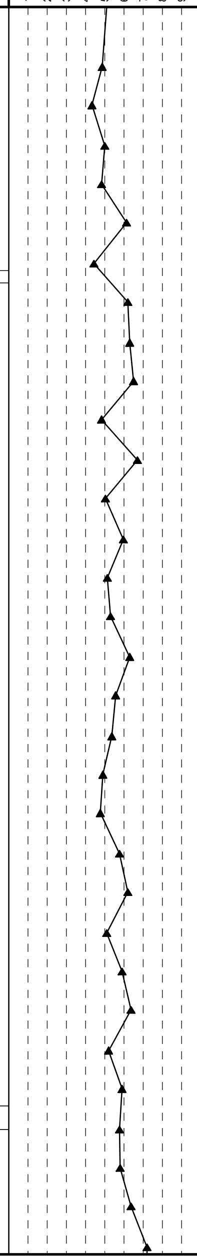
NOTES | DEPTH | ENGINEERING PROPERTIES: SPT, FRACTURE DENSITY, HARDNESS, WEATHERING | SHEAR WAVE VELOCITY ft/s | GEOLOGIC UNIT | CLASSIFICATION / LITHOLOGY | % CORE RECOVERY | % RQD | CLASSIFICATION AND PHYSICAL CONDITION

Depth scale: 265, 270, 275, 280, 285, 290, 295, 300, 305, 310

Fracture density: FD2, FD6, FD9, FD5

Hardness: H3, H4, H2

Weathering: W1, W3, W2, W3, W1



Geologic unit: Tpcpmn, Tpcpll, Tpcpln

% CORE RECOVERY	% RQD
100	82
100	100
94	34
94	45
100	62
100	48
96	61
96	32
33	0
94	71
100	46
100	34

CLASSIFICATION AND PHYSICAL CONDITION

302.6	10	R5	healed with paper thin white mineral
303.1	45	R5	paper thin white mineral
303.4	70	R3	paper thin white mineral
303.7	20	R4	clean
305.3	25	R2	1 mm white mineral
306.5	15	R3	1 mm white mineral
307.2	40	R2	1 mm white mineral
307.7	05	R4	1 mm white mineral
308.7	30	R5	partially healed with trace white mineral
309.3	30	R4	clean
309.5	25	R4	trace tan mineral
310.1	35	R5	clean
311.2	50	R3	paper thin white mineral
311.3	50	R4	patches of white mineral
311.5	40	R3	trace of white mineral
312.1	35	R4	paper thin white mineral
314.3	70	R2	healed with 3mm white to grey mineral (vapor phase mineral?)
314.9	35	R4	paper thin white mineral
315.3	25	R3	clean
315.7	45	R3	paper thin white mineral
316-319	20	R2	paper thin white mineral
319.3	25	R2	paper thin white mineral
320.0	30	R3	paper thin white mineral
320.9	65	R2	1mm white mineral
325.8	60	R3	clean
326.5	40	R4	clean
327.6	60	R3	1 - 2mm white mineral
328.3	30	R3	healed with a trace of white mineral
329.6	30	R2	3mm cemented sand and tan and white mineral
330.2	35	R3	1mm white mineral
330.9	20	R4	paper thin white mineral
330.95	65	R4	paper thin white mineral
331.9	70	R4	paper thin white mineral
332.2	35	R4	clean
332.5	25	R4	paper thin white mineral
332.9	45	R4	4mm white mineral
334.6	40	R4	paper thin white mineral
335.3	60	R4	paper thin white mineral
335.6	60	R2	paper thin white mineral
336.2	25	R4	tight; clean
337.0	70	R4	paper thin white mineral
337.1	40	R4	clean
337.7	45	R4	trace white mineral
337.8	50	R4	patches of white mineral
338.0	40	R4	patches of white mineral
338.4	60	R3	patches of white mineral
339.8	40	R2	patches of white mineral
340.3	45	R3	trace white mineral
340.8	35	R4	patches of white mineral
340.9	30	R4	patches of white mineral
341.5	50	R4	paper thin white mineral
342.3	20	R3	healed; 2mm grey mineral
343.5	30	R4	patches of white mineral
343.6	25	R4	patches of white mineral
343.8	60	R2	patches of white mineral
344.1	30	R3	patches of white mineral
345.3	30	R4	1mm white mineral
345.5	25	R4	1mm white mineral
349.3	65	R3	1mm white mineral

COMMENTS:

WHB13_LOG WHB13.GPJ WHB13.GDT 6/13/02

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#13

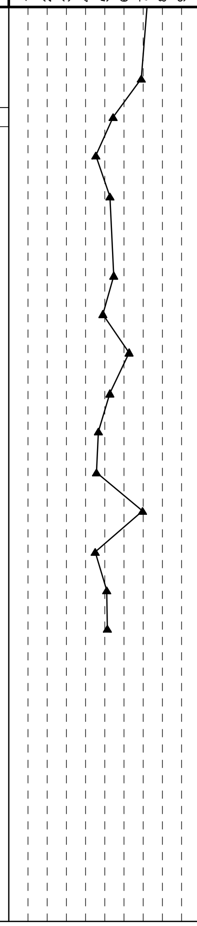
SHEET 7 OF 8

FEATURE: Waste Handling Building
LOCATION: ESF North Portal Pad
BEGUN: 10/6/1998 FINISHED: 12/7/1998
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,500.04 E 570,720.12
TOTAL DEPTH: 350.1 ft.
DEPTH TO BEDROCK: 98.0 ft.

STATE: Nevada
GROUND ELEVATION: 3671.03
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: URS/SMF/USBR
REVIEWED BY: M. Luebbers/M. McKeown

NOTES	DEPTH	SPT	FRACTURE DENSITY	HARDNESS	WEATHERING	SHEAR WAVE VELOCITY ft/s	GEOLOGIC UNIT	CLASSIFICATION / LITHOLOGY	% CORE RECOVERY	% RQD	CLASSIFICATION AND PHYSICAL CONDITION
					W1				100	34	
	315				W3				88	26	
	320								100	60	
	325								92	63	
	330		FD5	H2			Tpcpln		88	30	
	335				W1						
	340								68 96 100	27 63 72	
	345										
	350								100	70	



BOTTOM OF HOLE

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. UE-25 RF#13

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: ESF North Portal Pad	COORDINATES: N 765,500.04 E 570,720.12	GROUND ELEVATION: 3671.03
BEGUN: 10/6/1998 FINISHED: 12/7/1998	TOTAL DEPTH: 350.1 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 98.0 ft.	HOLE LOGGED BY: URS/SMF/USBR
		REVIEWED BY: M. Luebbers/M. McKeown

HARDNESS

Alpha-numeric descriptor	Descriptor	Criteria
H1	Extremely	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very Hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately Hard	Can be scratched with knife or sharp pick with light pressure. Core or fragment breaks with moderate hammer blow.
H5	Moderately Soft	Can be grooved 1/16 inch (2mm) deep by sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very Soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

WEATHERING

Alpha-numeric descriptor	Descriptor	General characteristics (strength, excavation, etc.)
W1	Fresh	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as Siltstones or shales.
W2	Slightly weathered to fresh	
W3	Slightly weathered	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classified as rock excavation.
W4	Moderately to slightly weathered	
W5	Moderately weathered	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstones or shales.
W6	Intensely to moderately weathered	
W7	Intensely weathered	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very intensely weathered	
W9	Decomposed	Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes".

FRACTURE DENSITY

Alpha-numeric descriptor	Descriptor	Criteria (Excludes mechanical breaks)
FD0	Unfractured	No observed fractures.
FD1	Very slightly fractured	Core recovered mostly in lengths greater than 3 feet (1 m).
FD2	Slightly to very slightly fractured	
FD3	Slightly fractured	Core recovered mostly in lengths from 1 to 3 feet (300 to 1,000 mm) with few scattered lengths less than 1 foot (300 mm) or greated than 3 feet (1,000 mm).
FD4	Moderately to slightly fractured	
FD5	Moderately fractured	Core recovered mostly in lengths from 0.33 to 1.0 foot (100 to 300 mm) with most lengths about 0.67 foot (200 mm).
FD6	Moderately to intensely fractured	
FD7	Intensely fractured	Lengths average from 0.1 to 0.33 foot (30 to 100 mm) with fragemented intervals. Core recovered mostly in lengths less than 0.33 foot (100 mm).
FD8	Very intensely to intensely fractured	
FD9	Very intenesely fractured	Core recovered mostly as chips and fragments with a few scattered short core lengths.

RF13_KEY WHB13.GPJ WHB.GDT 6/14/02

ATTACHMENT III

LOGS OF TEST PITS TP-WHB-1 TO TP-WHB-4

As mentioned in Section 6.2.4, this attachment presents the geologic logs (DTN: GS020383114233.001) of the four test pits, TP-WHB-1 to -4, that were excavated in the WHB Area. See Attachment IV for Photomosaic Maps of the test pits.

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	SHEET 1 OF 3 HOLE NO. TP-WHB-1

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project
LOCATION: TP-WHB-1	GROUND ELEVATION: 3682.0
COORDINATES: N 766,304 E 570,772	METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 21 ft. deep	HOLE LOGGED BY: Russell Schreiner, 8/28/00
TOTAL DEPTH: 21.0 ft. DEPTH TO WATER: N/A	DATE EXCAVATED: 07/13/2000 to 07/27/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(GP-GM)scb	0.0-9.0 ft. POORLY GRADED GRAVEL WITH SILT AND SAND, COBBLES AND BOULDERS - SU1 - (GP-GM)scb: About 60% fine to coarse, hard, subrounded to subangular gravel;about 30% fine to coarse, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength and rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 15% hard, subrounded to subangular cobbles; about 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 600 mm. IN-PLACE CONDITION: Moderate to strong caliche cementation (breaks through rock, not cementation), has thin lens (4 to 6 ") of fine gravel and sand, heavy white calcium carbonate caliche coating on gravel, cobbles, and boulders, dry, pinkish gray to pale yellowish brown to light brown.
(GP-GM)s	3.0-4.0 ft. POORLY GRADED GRAVEL WITH SILT AND SAND - SU2 - (GP-GM)s: About 70% predominantly fine, hard, subrounded to subangular gravel; about 20% fine to coarse, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; max. size 20 mm; strong reaction with HCl. IN-PLACE CONDITION: Weak to moderate caliche cementation, dry, pale yellowish brown.
(GP)sc	8.0 to 10.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES - SU3 - (GP)sc: About 80% predominantly fine, hard, subrounded to subangular gravel; about 15% fine to coarse, hard, subrounded to subangular sand; about 5% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): Less than 5% hard, subrounded to subangular cobbles; remainder minus 75 mm; max. dimension 170 mm. IN-PLACE CONDITION: Weak to moderate caliche cementation, dry, pale yellowish brown.

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 21 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	SHEET 2 OF 3 HOLE NO. TP-WHB-1

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: TP-WHB-1
GROUND ELEVATION: 3682.0
COORDINATES: N 766,304 E 570,772
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 21 ft. deep
HOLE LOGGED BY: Russell Schreiner, 8/28/00
TOTAL DEPTH: 21.0 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 07/13/2000 to 07/27/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(GP-GM)scb	4.0 to 15.5 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU4 - (GP-GM)scb: About 70% fine to coarse, hard, subrounded to subangular gravel; about 20% fine to coarse, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 20% hard, subrounded to subangular cobbles; less than 5% hard, subrounded to subangular boulders, remainder minus 75 mm, max. dimension 600 mm. IN-PLACE CONDITION: Moderate to strong caliche cementation (breaks through rocks, not cementation), heavy white calcium carbonate caliche coating on gravel, cobbles, and boulders, dry, pinkish gray to light brown.
(GP-GM)sc	13.0 to 16.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES - SU6 - (GP-GM)sc: About 60% predominantly fine to medium, hard, subrounded to subangular gravel; about 30% fine to coarse, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): Less than 5% hard, subrounded to subangular cobbles; remainder minus 75 mm; max. dimension 230 mm IN-PLACE CONDITION: Moderate to strong caliche cementation (breaks through rocks, not cementation), lensed material with lenses of fine gravels to 4 inches thick, lenses of heavy white caliche cementation, and pockets of fine gravel and sand, heavy white calcium carbonate caliche coating on gravel, and cobbles, dry, pale yellowish brown.

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 21 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	SHEET 3 OF 3 HOLE NO. TP-WHB-1

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: TP-WHB-1
GROUND ELEVATION: 3682.0
COORDINATES: N 766,304 E 570,772
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 21 ft. deep
HOLE LOGGED BY: Russell Schreiner, 8/28/00
TOTAL DEPTH: 21.0 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 07/13/2000 to 07/27/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(GM)scb	15.5 to 17.0 ft. SILTY GRAVEL WITH SAND, COBBLES, AND BOULDERS - SU7 - (GM)scb: About 50% fine to coarse, hard, subrounded to subangular gravel; about 30% predominantly fine, hard, subrounded to subangular sand; about 20% nonplastic fines with no dry strength, rapid dilatancy; weak to strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10% hard, subrounded to subangular, cobbles; about 10% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 370 mm. IN-PLACE CONDITION: Moderate to strong caliche cementation, layers of medium to fine gravel up to 6 inches thick; fine gravel lens had weak reaction with HCl, heavy white calcium carbonate caliche coating on gravel, cobbles, and boulders, dry, pinkish gray to light brown.
(GP)scb	17.0 to 21.0 ft. POORLY GRADED GRAVEL WITH SAND, COBBLES, AND BOULDERS - SU8 - (GP)scb: About 70% fine to coarse, hard, subrounded to subangular gravel; about 25% fine to coarse, hard, subrounded to subangular sand; about 5% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 15% hard, subrounded to subangular cobbles; about 25% hard, subrounded to subangular boulders, max. dimension 350 mm. IN-PLACE CONDITION: Moderate to strong caliche cementation, stratification near floor of pit consists of a few fine to medium (<0.5 mm) grained sand and coarse gravel/cobble (> 20 mm) lenses up to 4 ft long and 0.5 ft wide, heavy white calcium carbonate caliche coating on gravel, cobbles, and boulders, dry, pale yellowish brown.

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 21 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	SHEET 1 OF 3 HOLE NO. TP-WHB-2

FEATURE: Waste Handling Building
LOCATION: TP-WHB-2
COORDINATES: N 756,595 E 571,106
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 19 ft. deep
TOTAL DEPTH: 19.0 ft. DEPTH TO WATER: N/A

PROJECT: Yucca Mountain Project
GROUND ELEVATION: 3658.0
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
HOLE LOGGED BY: Russell Schreiner, 9/5/00
DATE EXCAVATED: 07/31/2000 to 08/23/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(GP-GM)scb	0.0 to 16.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU1 - (GP-GM)scb: About 65% predominantly medium to coarse, subrounded to subangular gravel; about 25% predominantly fine to medium, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 15% hard, subrounded to subangular cobbles; about 5% hard, subrounded to subangular boulders, max. dimension 900 mm. IN-PLACE CONDITION: Predominantly strong caliche cementation on the west side of the test pit, pockets of strongly cemented coarse gravels to 4 inches thick, pinkish gray to pale yellowish brown, to light brown.
(GP-GM)scb	0.0 to 14.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU4 - (GP-GM)scb: About 60% predominantly fine to coarse, hard, subrounded to subangular gravel; about 30% predominantly fine to medium, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 15% hard, subrounded to subangular cobbles; about 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max.dimension 900 mm. IN-PLACE CONDITION: Predominantly weak to moderate caliche cementation on the east side of the test pit, caliche coatings on gravels, lenses of fine gravel to 4 inches thick, dry, pale yellowish brown to light brown.
(GP-GM)sc	4.0 to 6.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, AND COBBLES - SU5 - (GP-GM)sc: About 70% predominantly fine, to medium, subrounded to subangular gravel; about 20% predominantly medium to

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 19 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

LOG OF TEST PIT OR AUGER HOLE

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: TP-WHB-2
GROUND ELEVATION: 3658.0
COORDINATES: N 756,595 E 571,106
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 19 ft. deep
HOLE LOGGED BY: Russell Schreiner, 9/5/00
TOTAL DEPTH: 19.0 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 07/31/2000 to 08/23/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
	coarse, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10% hard subrounded to subangular cobbles; less than 5% hard, subrounded to subangular boulders; remainder minus 75 mm, max. dimension 450 mm. IN-PLACE CONDITION: Weak to moderate caliche cementation, thin lenses of fine gravels to 4 inches thick, pockets of sand to 6 inches thick, thin lenses of caliche coated fine gravels to 2 inches thick, dry, pale yellowish brown to pinkish gray where caliche cementation is moderate.
(GM)scb	6.0 to 12.0 ft. SILTY GRAVEL WITH SAND, COBBLES AND BOULDERS - SU3 - (GM)scb: About 70% fine to medium, hard, subrounded to angular gravel; about 15% fine to medium, hard, subrounded to subangular sand; about 15% nonplastic fines with no dry strength, rapid dilatancy. TOTAL SAMPLE (BY VOLUME): About 5 to 10% hard, subrounded to subangular cobbles; less than 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 150 mm. IN-PLACE CONDITIONS: Moderate to strong caliche cementation, dry, pinkish gray to pale yellowish brown.
(GP-GM)s	9.0 to 19.0 ft. POORLY GRADED GRAVEL WITH SILT AND SAND - SU2 - (GP-GM)s: About 70% predominantly fine, hard, subrounded to subangular gravel; about 20% predominantly medium to coarse, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl.. TOTAL SAMPLE (BY VOLUME): About 5% hard, subrounded to subangular cobbles; less than 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 900 mm.

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 19 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

7-1336-A (1-86) Bureau of Reclamation	**LOG OF TEST PIT OR AUGER HOLE**	SHEET 3 OF 3 HOLE NO. TP-WHB-2

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: TP-WHB-2
GROUND ELEVATION: 3658.0
COORDINATES: N 756,595 E 571,106
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 19 ft. deep
HOLE LOGGED BY: Russell Schreiner, 9/5/00
TOTAL DEPTH: 19.0 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 07/31/2000 to 08/23/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
	IN-PLACE CONDITION: Weak to moderate caliche cementation, lenses of fine gravel to 2 inches thick, pockets of fine sand and gravel to 4 inches thick, dry, pale yellowish brown, to pinkish gray where caliche cementation is moderate.

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 19 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

LOG OF TEST PIT OR AUGER HOLE

FEATURE: Waste Handling Building
LOCATION: TP-WHB-3
COORDINATES: N 765,306 E 571,161
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 20 ft. deep
TOTAL DEPTH: 20.0 ft. DEPTH TO WATER: N/A

PROJECT: Yucca Mountain Project
GROUND ELEVATION: 3650.0
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
HOLE LOGGED BY: Russell Schreiner, 9/5/00
DATE EXCAVATED: 08/01/2000 to 08/23/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(GP)scb	0.0 to 18.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU3 - (GP)scb: About 65% predominantly fine to medium, hard, subrounded to subangular gravel; about 25% fine to coarse, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10% hard, subrounded to subangular cobbles; about 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 900 mm. IN-PLACE CONDITION: Weak to moderate caliche cementation, thin lenses of fine clean gravels and 4 to 6 inch pockets of fine sand, pockets of coarse gravels to 8 inches thick, dry, pale yellowish brown.
(GP-GM)scb	0.0 to 4.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU1 - (GP-GM)scb: About 70% predominantly coarse, hard, subrounded to subangular gravel; about 20% predominantly fine, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 20% hard, subrounded to subangular cobbles; about 5% hard, subrounded to subangular boulders; remainder 75 mm; max. dimension 600 mm. IN-PLACE CONDITION: Weak to strong caliche cementation, 2 to 4 inch thick pockets of fine sand, whitish coatings on gravel, dry, pale yellowish brown.
(GP-GM)scb	4.0 to 15.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES AND BOULDERS - SU5 - (GP-GM)scb: About 55% predominantly fine, hard, subrounded to subangular gravel; about 35% fine to coarse, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 19 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	SHEET 2 OF 3 HOLE NO. TP-WHB-3

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: TP-WHB-3
GROUND ELEVATION: 3650.0
COORDINATES: N 765,306 E 571,161
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 20 ft. deep
HOLE LOGGED BY: Russell Schreiner, 9/5/00
TOTAL DEPTH: 20.0 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 08/01/2000 to 08/23/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
	TOTAL SAMPLE (BY VOLUME): About 5% hard subrounded to subangular cobbles; less than 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 300 mm. IN-PLACE CONDITION: Weak to moderate caliche cementation, thin layers of fine clean gravels to 6 inches thick, thin layers of heavily cemented gravels to 4 inches thick, pockets of coarse caliche cemented gravels, occasional pockets of fine silty sand to 4 inches thick, dry, pale yellowish brown.
(GP-GM)sc	3.0 to 9.5 ft. POORLY GRADED GRAVEL WITH SILT, SAND, AND COBBLES - SU2 - (GP-GM)sc: About 50% predominantly fine, hard, subrounded to subangular gravel; about 40% fine to coarse, hard, subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; weak to strong reaction with HCl TOTAL SAMPLE (BY VOLUME): About 5% hard subrounded to subangular cobbles; remainder minus 75-mm. IN-PLACE CONDITION: Weak to moderate caliche cementation, thin layers of fine clean gravels to 6 inches thick, thin layers of heavily cemented gravels to 4 inches thick, pockets of coarse caliche cemented gravels, occasional pockets of fine silty sand to 4 inches thick, dry, pale yellowish brown.
(GP)scb	6.0 to 12.0 ft. POORLY GRADED GRAVEL WITH SAND, COBBLES, AND BOULDERS - SU4 - (GP)scb: About 80% predominantly coarse, hard, subrounded to subangular gravel; about 15% predominantly fine, hard, subrounded to subangular sand; about 5% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 25% hard subrounded to subangular cobbles; less than 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 300 mm.

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 19 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

LOG OF TEST PIT OR AUGER HOLE

FEATURE: Waste Handling Building
LOCATION: TP-WHB-3
COORDINATES: N 765,306 E 571,161
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 20 ft. deep
TOTAL DEPTH: 20.0 ft. DEPTH TO WATER: N/A

PROJECT: Yucca Mountain Project
GROUND ELEVATION: 3650.0
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
HOLE LOGGED BY: Russell Schreiner, 9/5/00
DATE EXCAVATED: 08/01/2000 to 08/23/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
	IN-PLACE CONDITON: Weak to moderate caliche cementation, thin layers of fine clean gravels to 6 inches thick, thin layers of heavily cemented gravels to 4 inches thick, pockets of coarse caliche cemented gravels, ocasional pockets of fine silty sand to 4 inches thick, dry, pale yellowish brown.
(GP-GM)scb	16.0 to 20.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU6 - (GP-GM)scb: About 70% predominantly coarse, hard, subrounded to subangular gravel; about 20% predominantly fine, hard subrounded to subangular sand; about 10% nonplastic fines with no dry strength, rapid dilatancy; no reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 15% hard, subrounded to subangular cobbles; remainder minus 75 mm; max. dimension 250 mm. IN-PLACE CONDITION: Strong caliche cementation, dry, pale yellowish brown.
(GM)sc	18.0 to 20.0 ft. SILTY GRAVEL WITH SAND, AND COBBLES - SU7 - (GM)sc: About 60% predominantly fine, hard subrounded to subangular gravel; about 25% predominantly fine, hard, subrounded to subangular sand; about 15% nonplastic fines with no dry strength, rapid dilatancy; strong reaction with HCl TOTAL SAMPLE (BY VOLUME): About 5% hard, subrounded to subangular cobbles; remainder 75 mm; max. dimension 90 mm. IN-PLACE CONDITION: Moderate to strong caliche cementation, dry, pale yellowish brown.

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 19 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: TP-WHB-4
GROUND ELEVATION: 3664.7
COORDINATES: N 765,950 E 571,453
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 16 ft. deep
HOLE LOGGED BY: Russell Schreiner, 9/14/00
TOTAL DEPTH: 16.0 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 08/28/2000 to 09/06/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(GP-GM)scb	0.0 to 16.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU2 - (GP-GM)scb: About 65% predominantly fine to coarse, hard, subrounded to subangular gravel; about 25% predominantly fine, subrounded to subangular sand; about 10% low plasticity fines with high dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 15% hard, subrounded to subangular cobbles; about 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 900 mm. IN-PLACE CONDITION: Strong caliche cementation, stratified, pockets of cemented fine gravels and sands, dry, very pale orange.
(SM)gc	0.0 to 2.0 ft. SILTY SAND WITH GRAVEL AND COBBLES - SU7 - (SM)gc: About 40% predominantly fine, hard, subrounded to subangular gravel; about 40% predominantly fine subrounded sand; about 20% low plasticity fines with low toughness, none to low dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 5 to 10% hard subrounded to subangular cobbles; remainder minus 75 mm; max. dimension 200 mm. IN-PLACE CONDITION: Weak to strong caliche cementation, surficial layer with abundant roots and some organic material, dry, pale yellowish brown to light brown.
(GP-GM)scb	2.0 to 8.0 ft., 12 to 16 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU1 - (GP-GM)scb: About 70% predominantly fine to medium, subrounded to subangular gravel; about 20% predominantly fine to coarse subrounded to subangular sand; about 10% low plasticity fines with low dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10% hard, subrounded to

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 16 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

7-1336-A (1-86) Bureau of Reclamation	LOG OF TEST PIT OR AUGER HOLE	SHEET 2 OF 2 HOLE NO. TP-WHB-4

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: TP-WHB-4
GROUND ELEVATION: 3664.7
COORDINATES: N 765,950 E 571,453
METHOD OF EXPLORATION: John Deere 992 D-LC track hoe
APPROXIMATE DIMENSIONS: approx. 70 x 70 ft. x 16 ft. deep
HOLE LOGGED BY: Russell Schreiner, 9/14/00
TOTAL DEPTH: 16.0 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 08/28/2000 to 09/06/2000

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
	subangular cobbles; about 5% subrounded to subangular boulders; remainder minus 75 mm; max. dimension 450 mm. IN-PLACE CONDITION: Moderate to strong caliche cementation, irregularly and weakly stratified with a few coarse gravel/cobble lenses, roots present, dry, pale yellowish brown to light brown.
(GP-GM)scb	2.0 to 4.0 ft., 6.0 to 12.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, COBBLES, AND BOULDERS - SU3 - (GP-GM)scb: About 80% predominantly coarse, hard, subrounded to subangular gravel; about 10% predominantly fine, hard, sand; about 10% low plasticity fines with low dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 30% hard, subrounded to subangular cobbles; less than 5% hard, subrounded to subangular boulders; remainder minus 75 mm; max. dimension 350 mm. IN-PLACE CONDITION: Moderate to strong caliche cementation, stratified, pockets of cemented fine gravels and sands, dry, pinkish gray to very pale orange.
(GP-GM)sc	14.0 to 16.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND, AND COBBLES - SU6 - (GP-GM)sc: About 55% predominantly fine, hard, subrounded to subangular gravel; about 35% predominantly fine, hard, subrounded to subangular sand; about 10% low plasticity fines with low toughness and low dry strength, rapid dilatancy; strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 5% hard, subrounded to subangular cobbles; remainder minus 75 mm; max. dimension 100 mm. IN-PLACE CONDITION: Moderate to strong caliche cementation, stratified, laminated, lensed, pockets of silty, cemented sands to 4 inches thick, dry, pinkish gray to pale yellowish brown.

REMARKS:
Test pits excavated using John Deere 992 D-LC track hoe with 2 cubic yard bucket and Caterpillar 966 front end loader. Site prepared using Fiat Allis dozer with a single tooth ripper. Stopped excavation at 16 ft. target depth. Depths may overlap. All 3 exposed walls of the test pit were mapped, and they vary one from the other, i.e., soil units are not continuous across the entire pit. The purpose of soil unit (SU) designations is to label specific soil units within each test pit, and not to correspond to soil units in the other test pits.

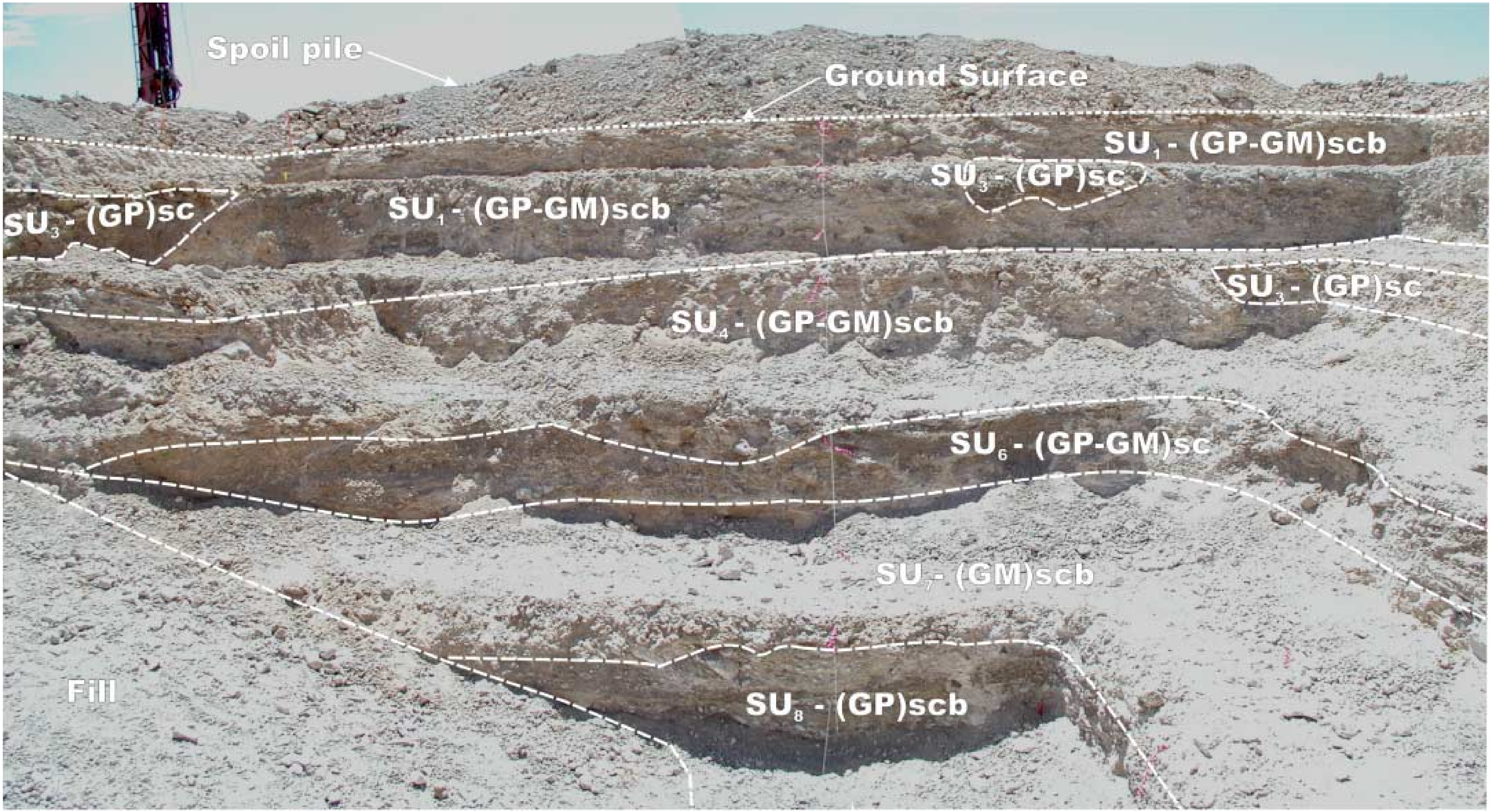
TEST_PIT_LOG YMWHBTP.GPJ WHB-TP.GDT 7/23/02

ATTACHMENT IV

PHOTOMOSAIC MAPS OF TEST PITS TP-WHB-1 TO TP-WHB-4

ATTACHMENT IV
PHOTOMOSAIC MAPS OF TEST PITS TP-WHB-1 TO TP-WHB-4

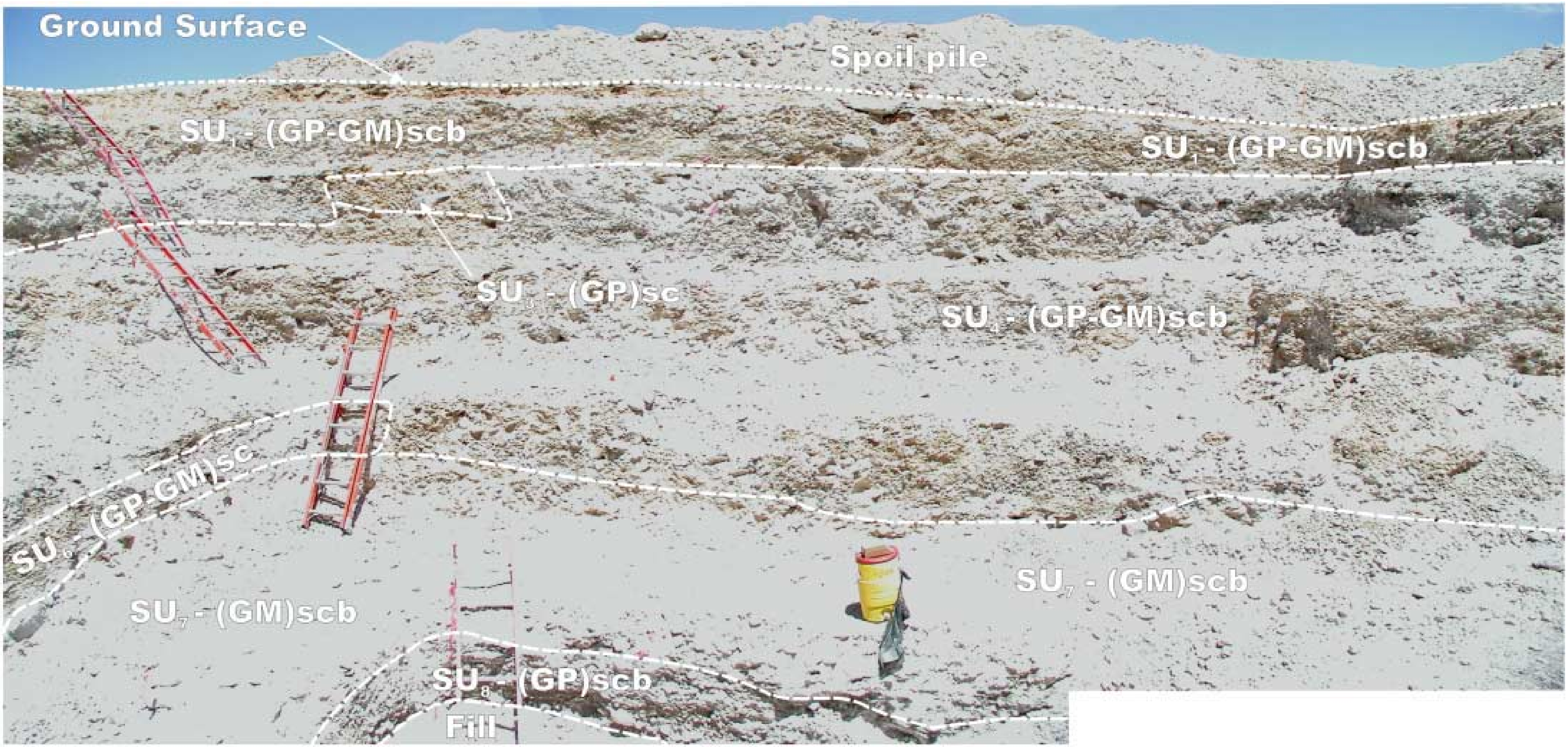
As mentioned in Section 6.2.4, this attachment presents a series of three geologic maps for each of the four test pits excavated in the WHB Area (DTN: GS020383114233.001). The geologic mapping is superimposed on a photomosaic of the test pits. Each figure covers one of the side slopes of the test pit (mapping was not performed on the bottom of the pit or on the access ramp into the pit, which occupied the fourth side of each pit).



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

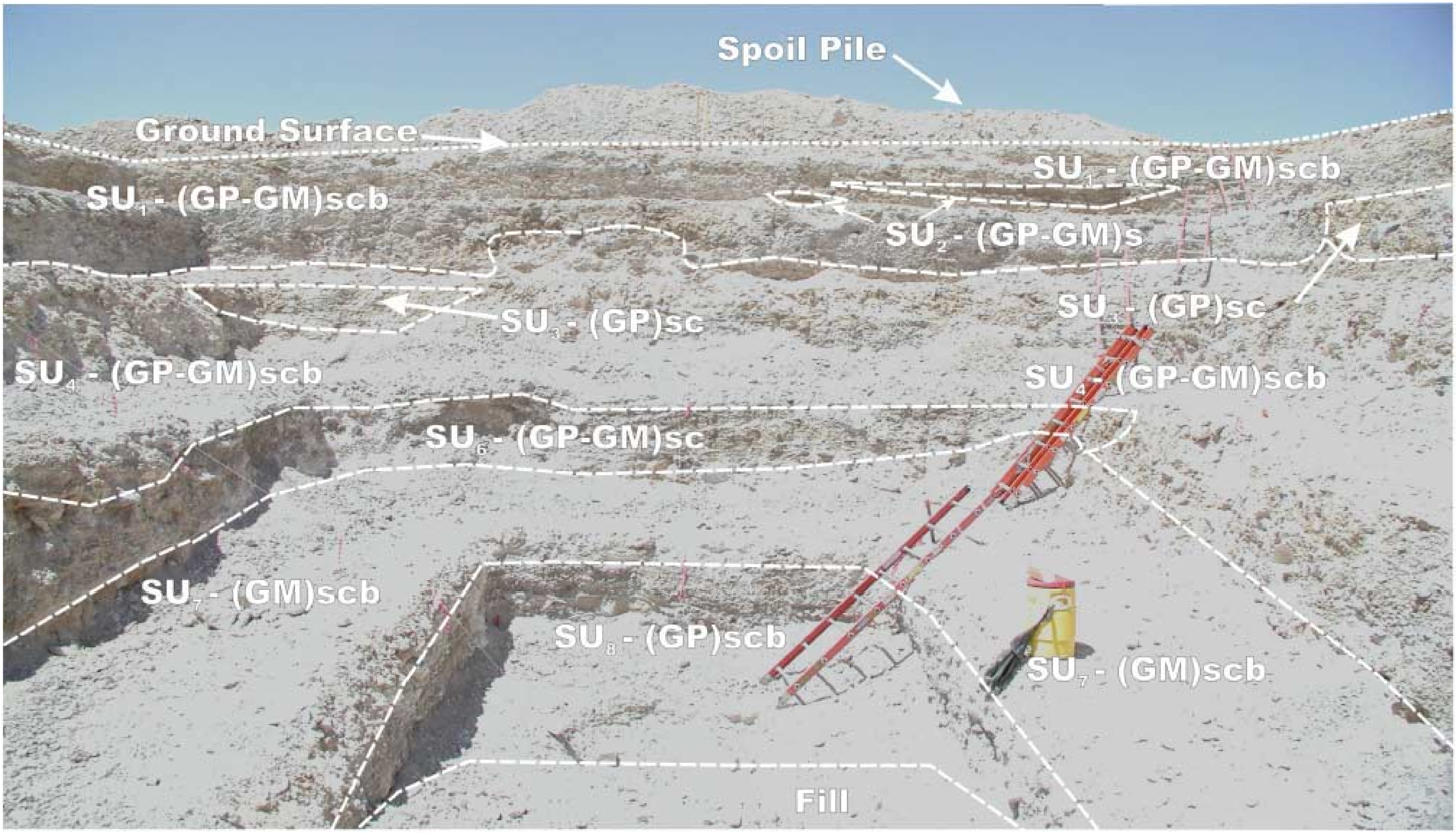
Figure IV-1. Test Pit TP-WHB-1 South Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

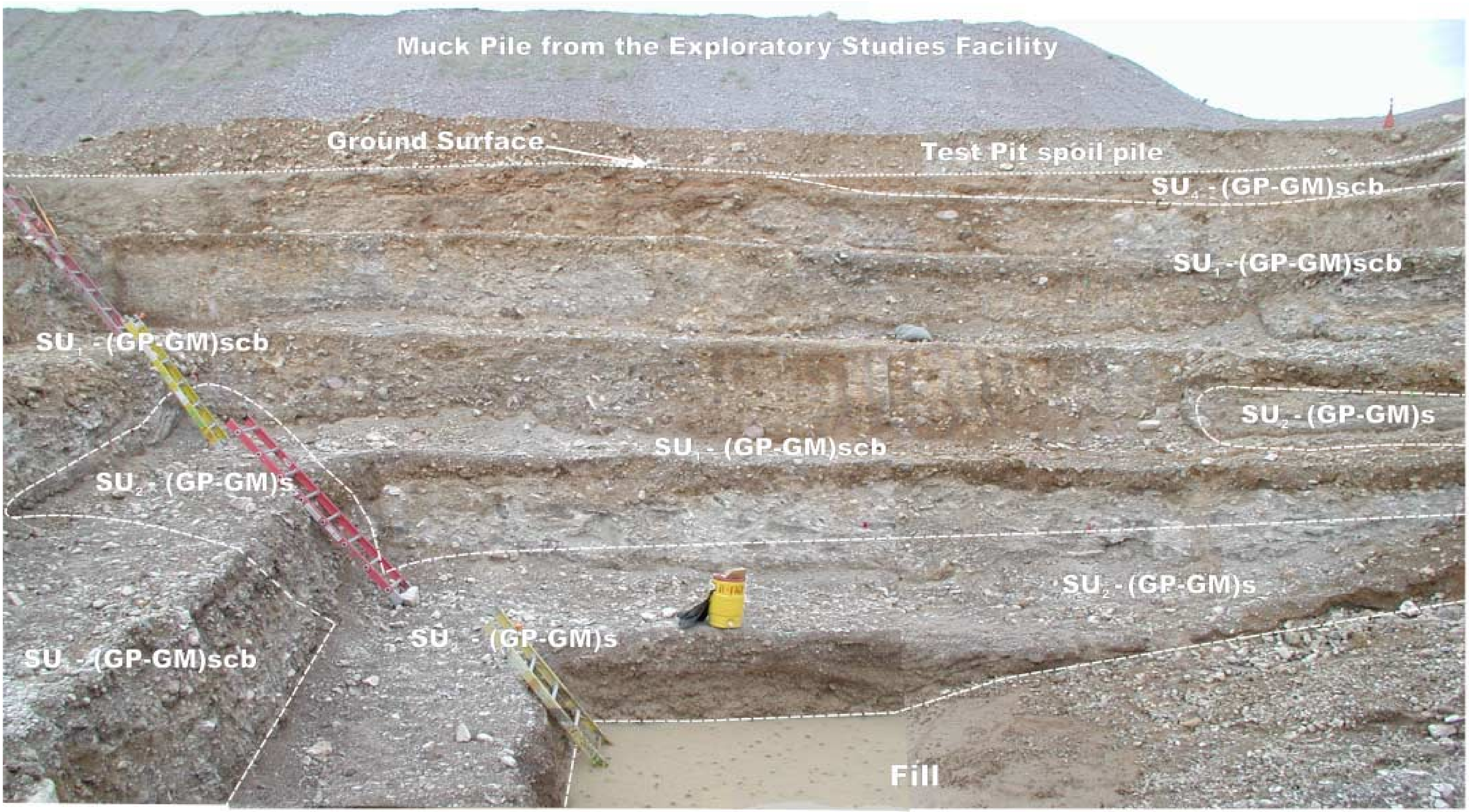
Figure IV-2. Test Pit TP-WHB-1 North Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

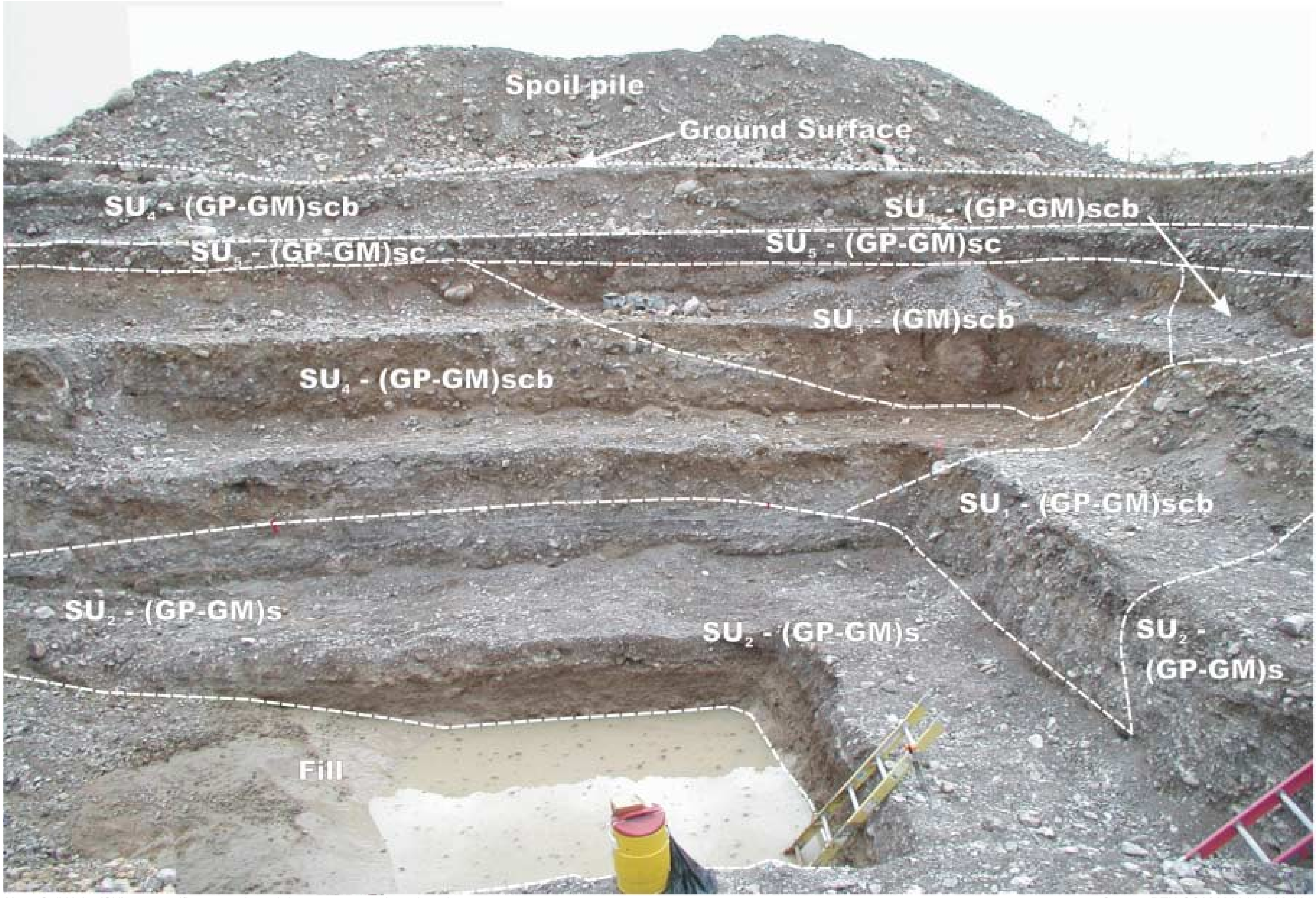
Figure IV-3. Test Pit TP-WHB-1 West Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

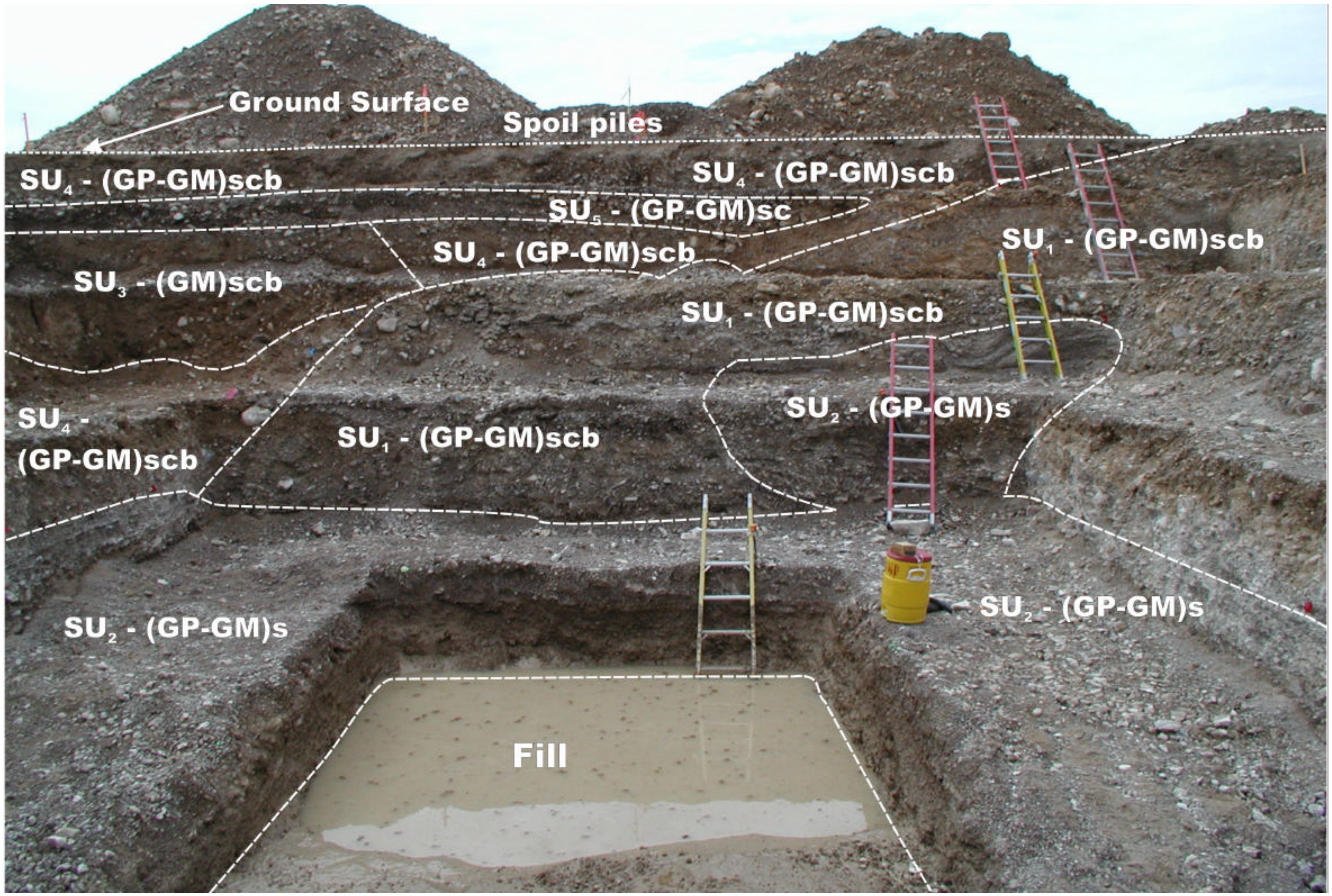
Figure IV-4. Test Pit TP-WHB-2 West Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

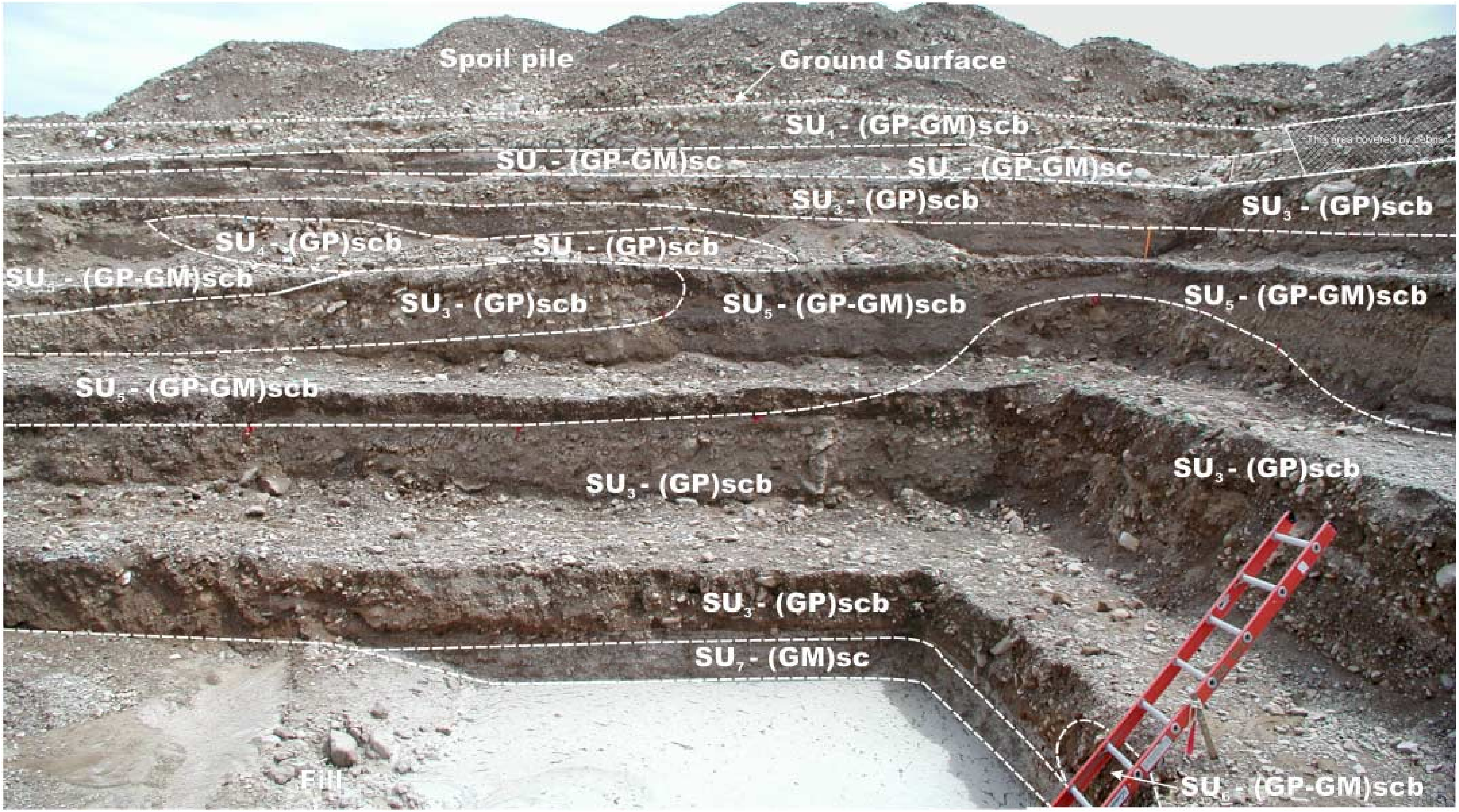
Figure IV-5. Test Pit TP-WHB-2 East Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

Figure IV-6. Test Pit TP-WHB-2 South Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

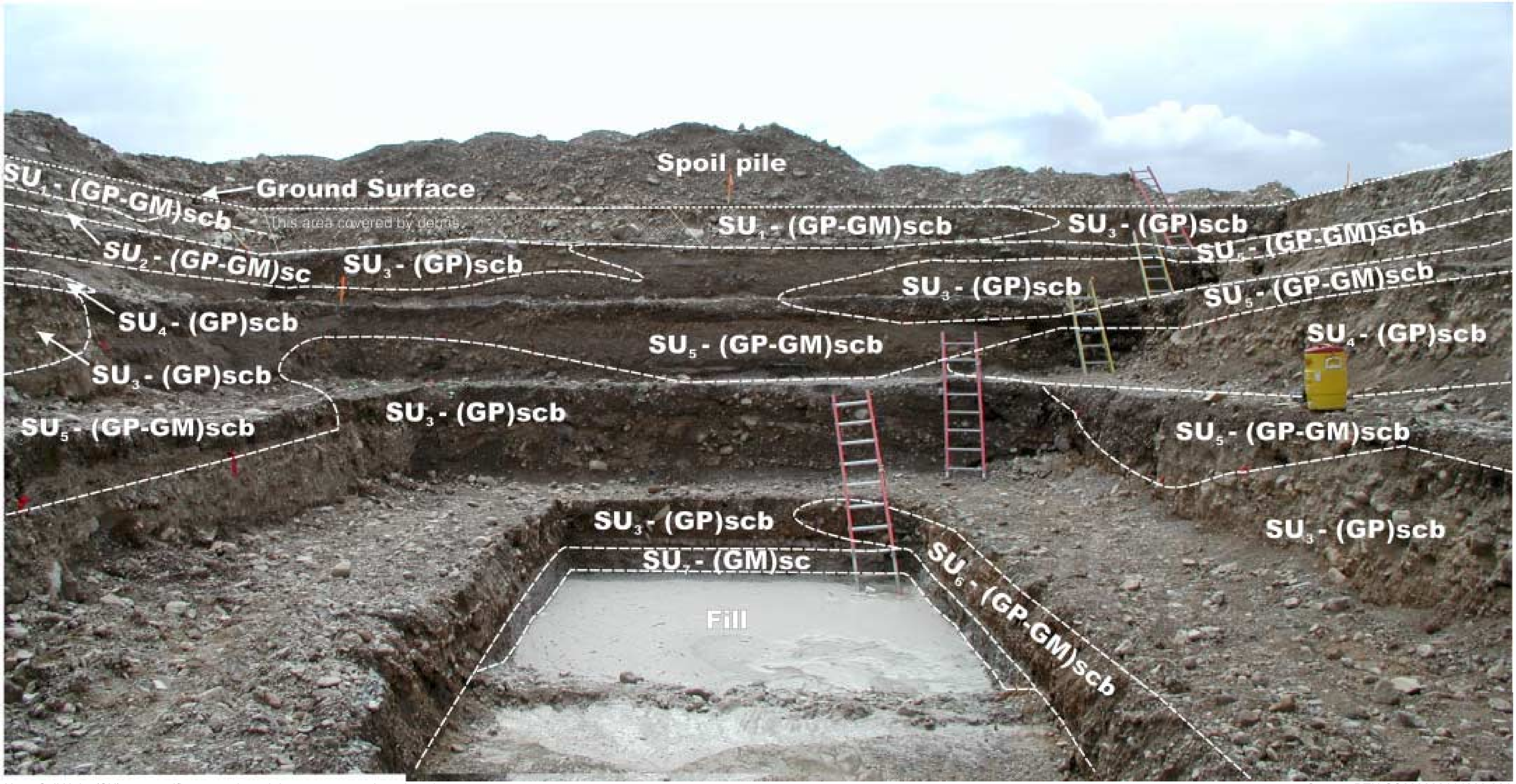
Source: DTN GS020383114233.001

Figure IV-7. Test Pit TP-WHB-3 East Wall

Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

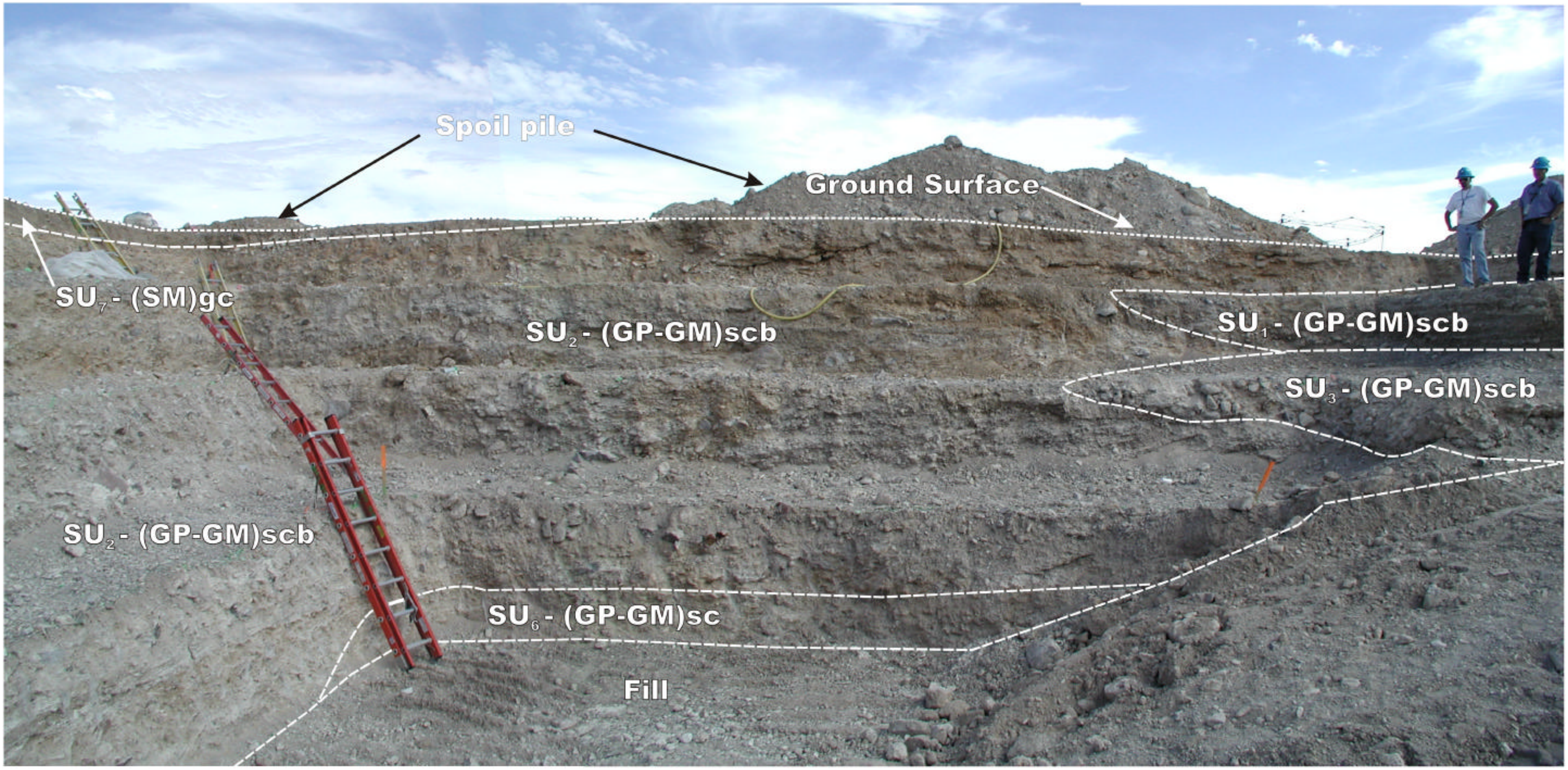
Figure IV-8. Test Pit TP-WHB-3 West Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

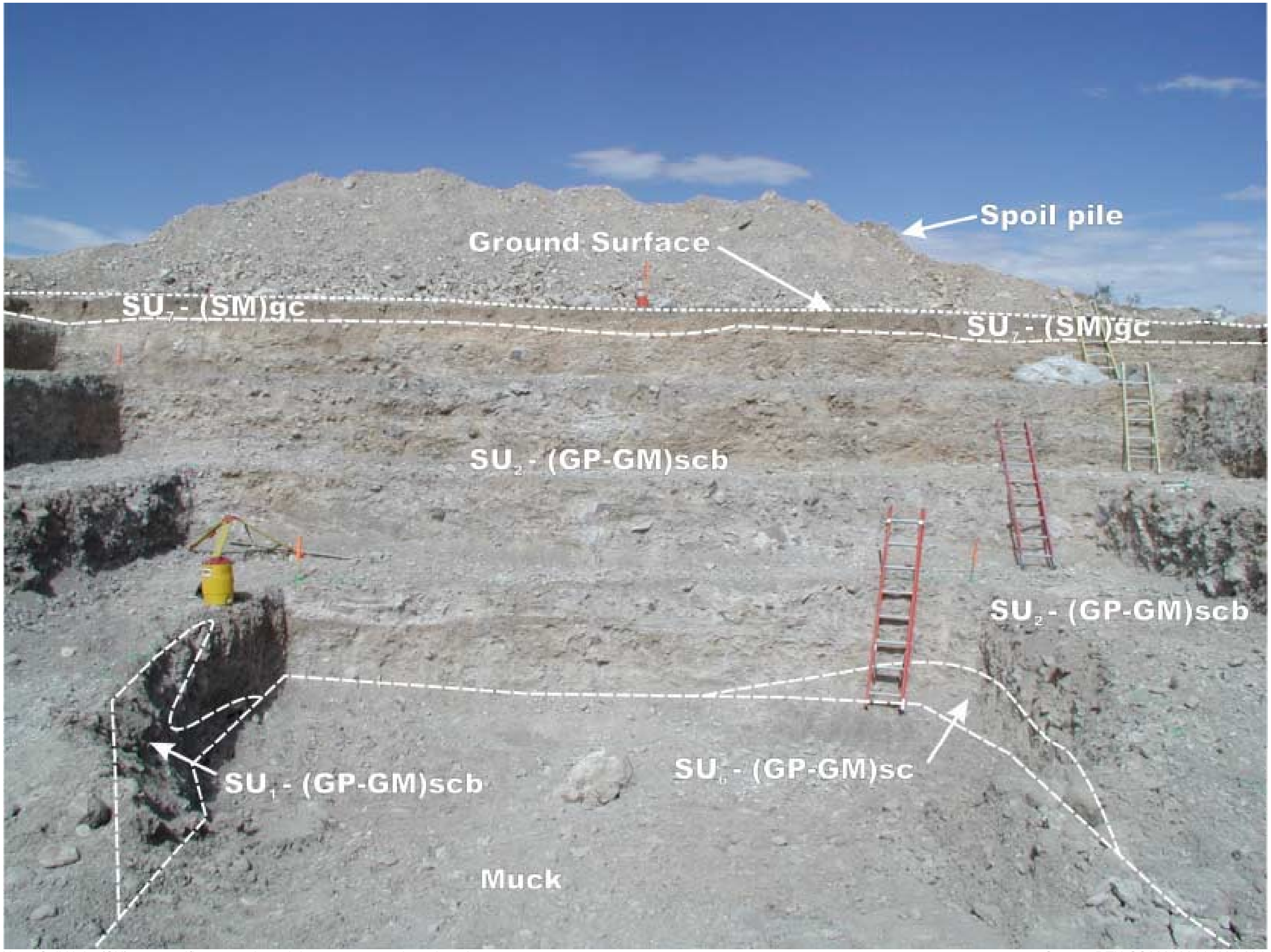
Figure IV-9. Test Pit TP-WHB-3 South Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

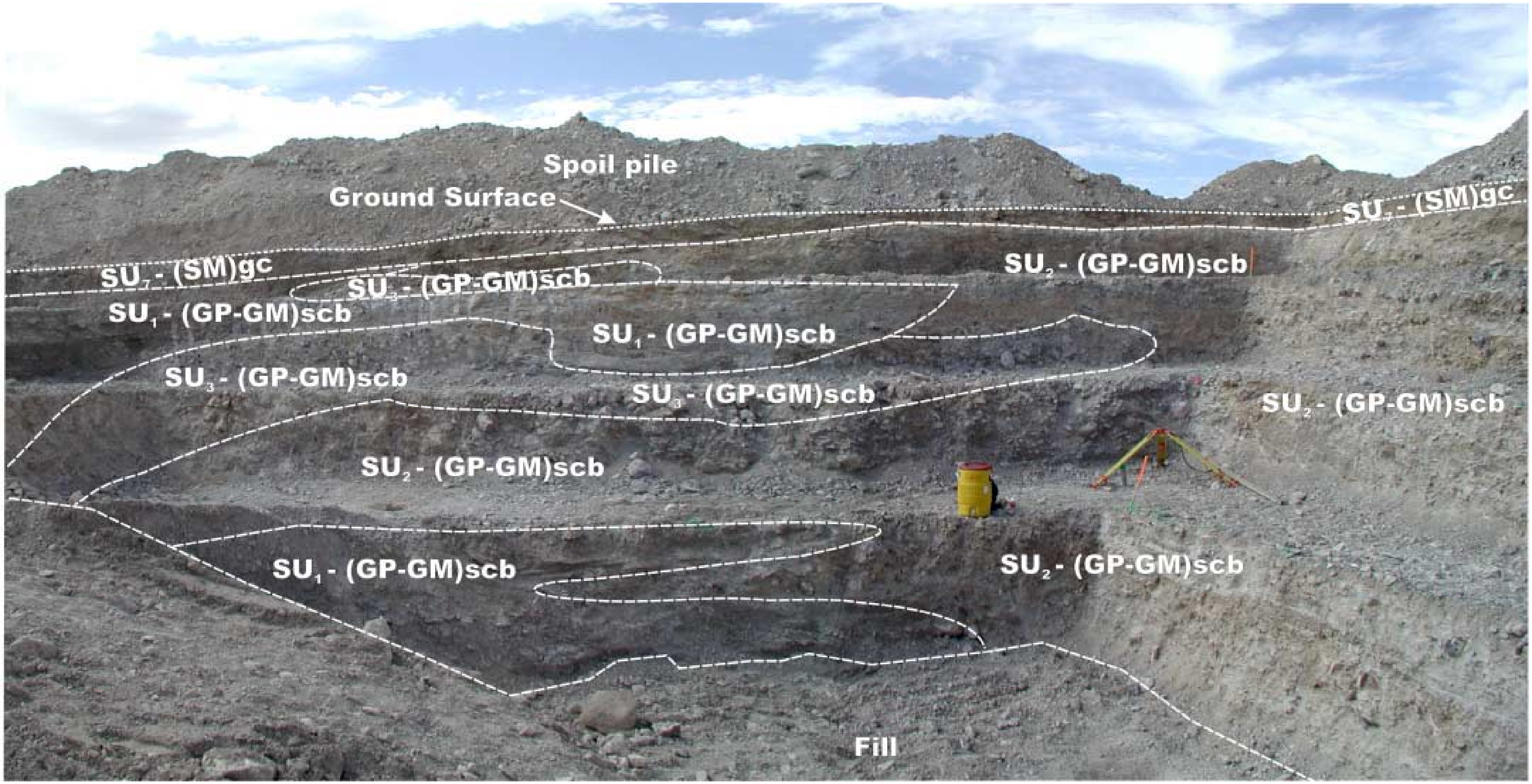
Figure IV-10. Test Pit TP-WHB-4 East Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

Source: DTN GS020383114233.001

Figure IV-11. Test Pit TP-WHB-4 North Wall



Note: Soil Units (SU) are specific to test pit and do not correspond to other pits.

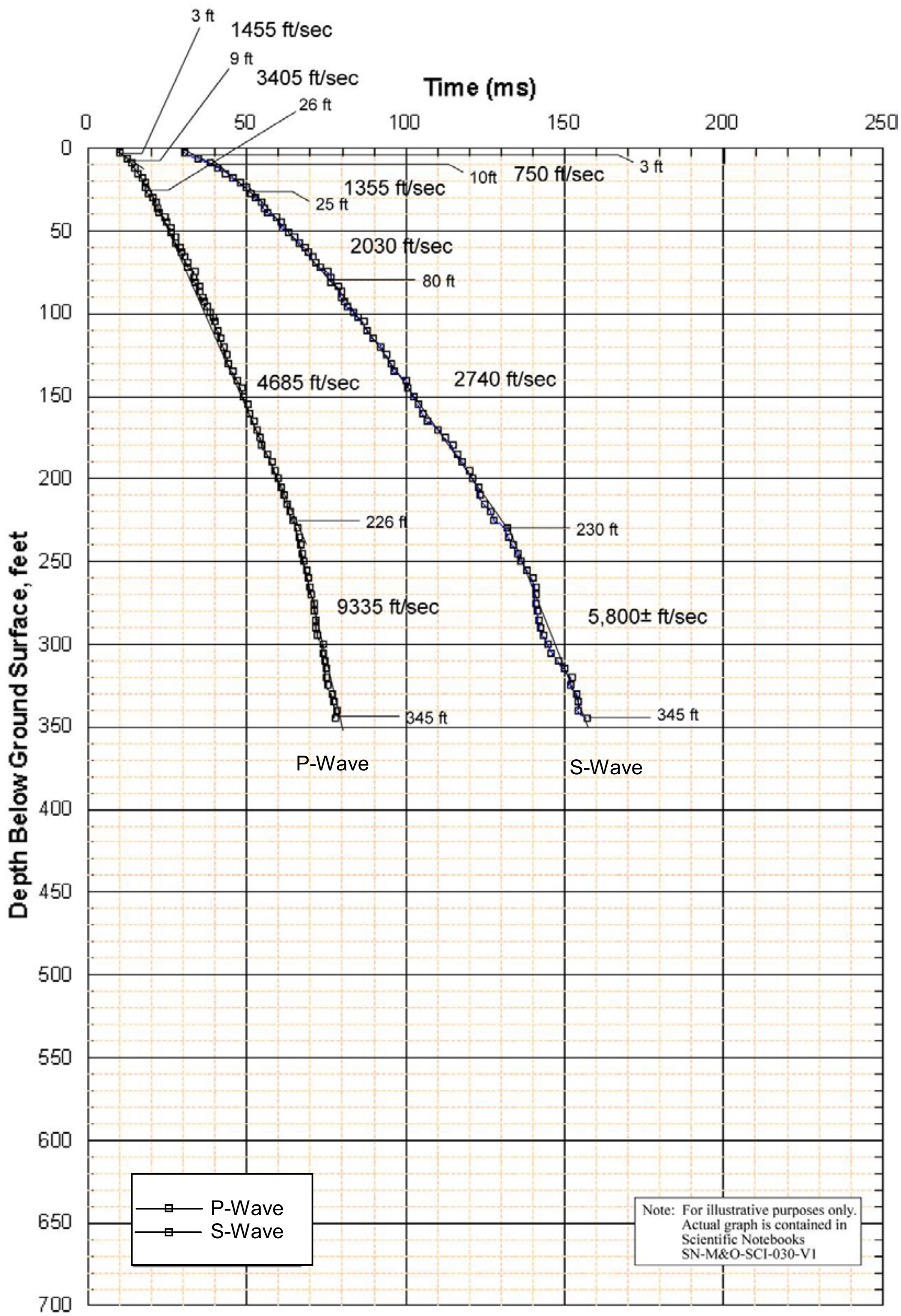
Source: DTN GS020383114233.001

Figure IV-12. Test Pit TP-WHB-4 West Wall

ATTACHMENT V

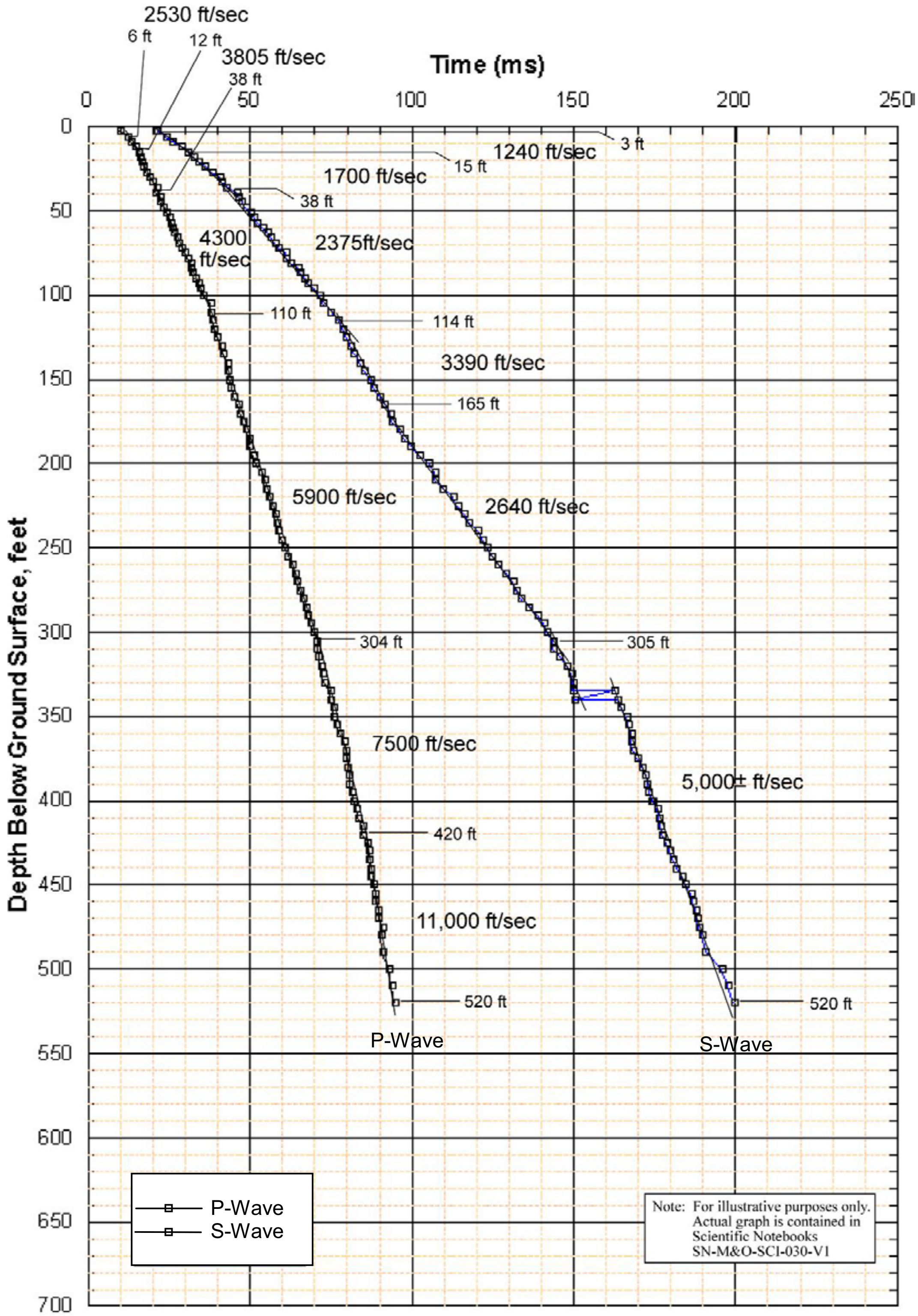
DOWNHOLE SEISMIC VELOCITY PLOTS (REDPATH) – WHB AREA

As discussed in Section 6.2.5, this attachment presents fifteen figures, one for each borehole surveyed by Redpath Geophysics, showing plots of adjusted travel time in milliseconds versus depth below ground surface in feet. The plots also show the linear fits to the data, the slope of which gives the velocity in feet per millisecond, which is converted to feet per second. Details of the surveys and data reduction can be found in scientific notebook SN-M&O-SCI-030-V1 (Wong 2002b).



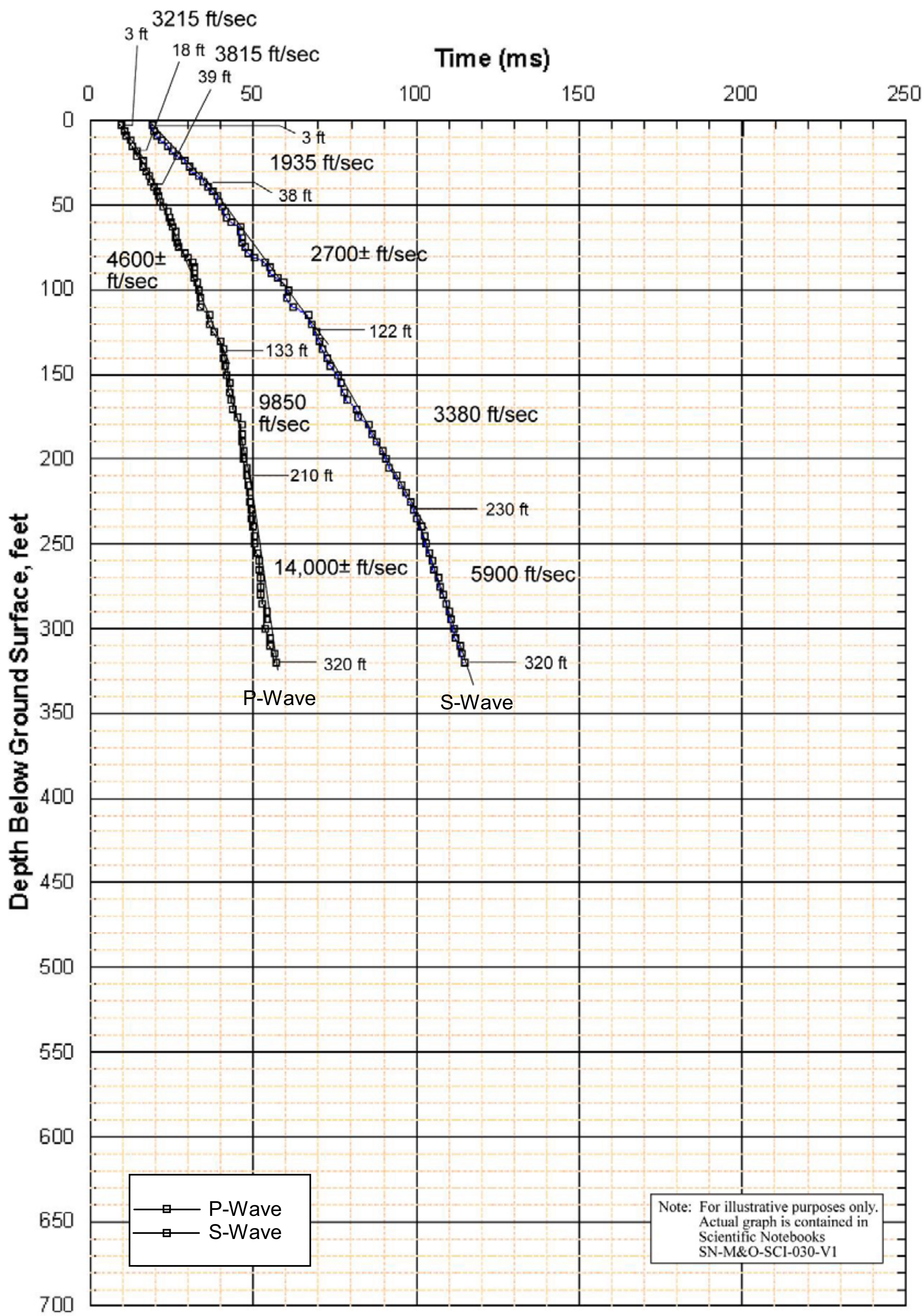
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-1. RF#13 Downhole Travel Time Versus Depth



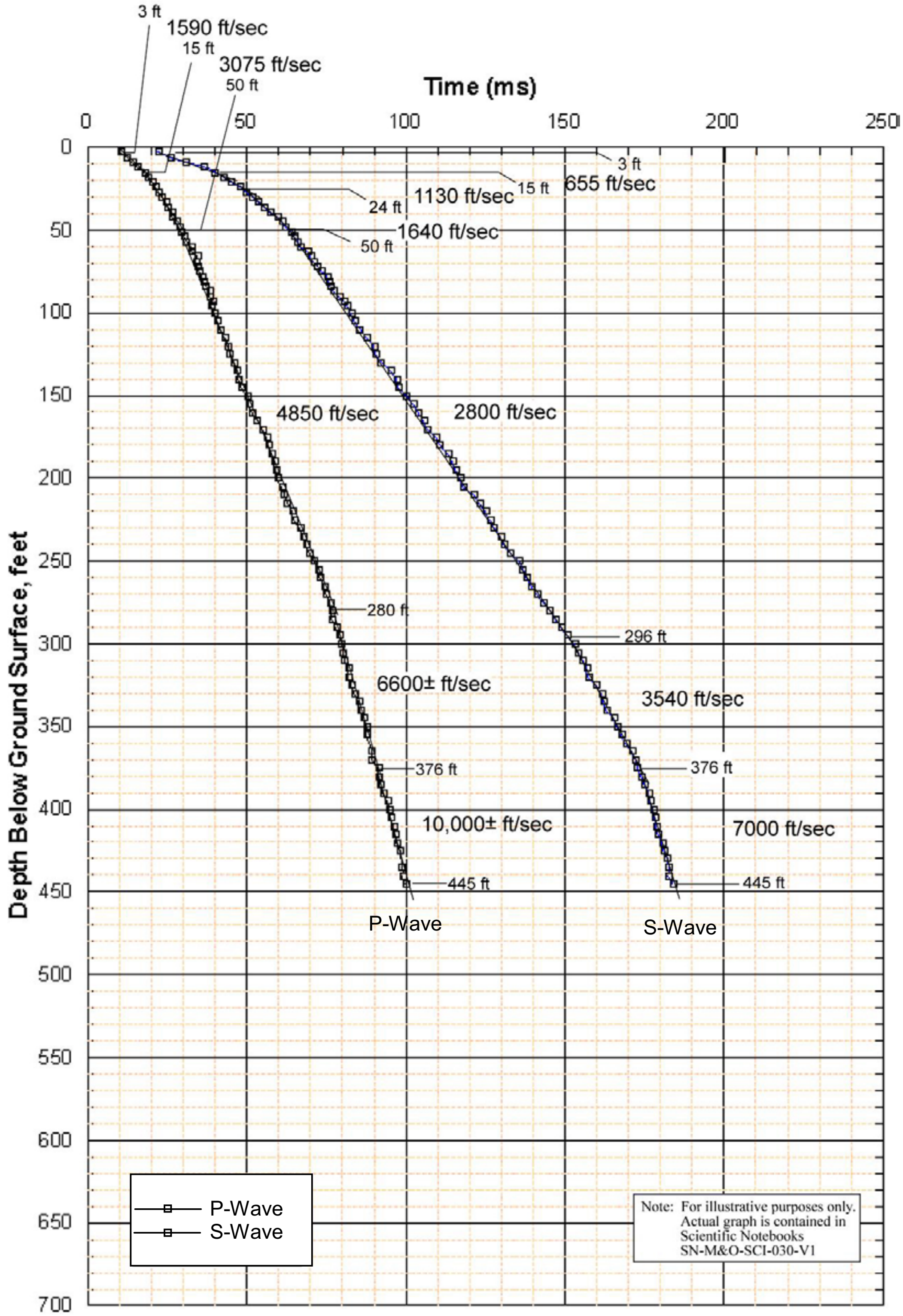
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-2. RF#14 Downhole Travel Time Versus Depth



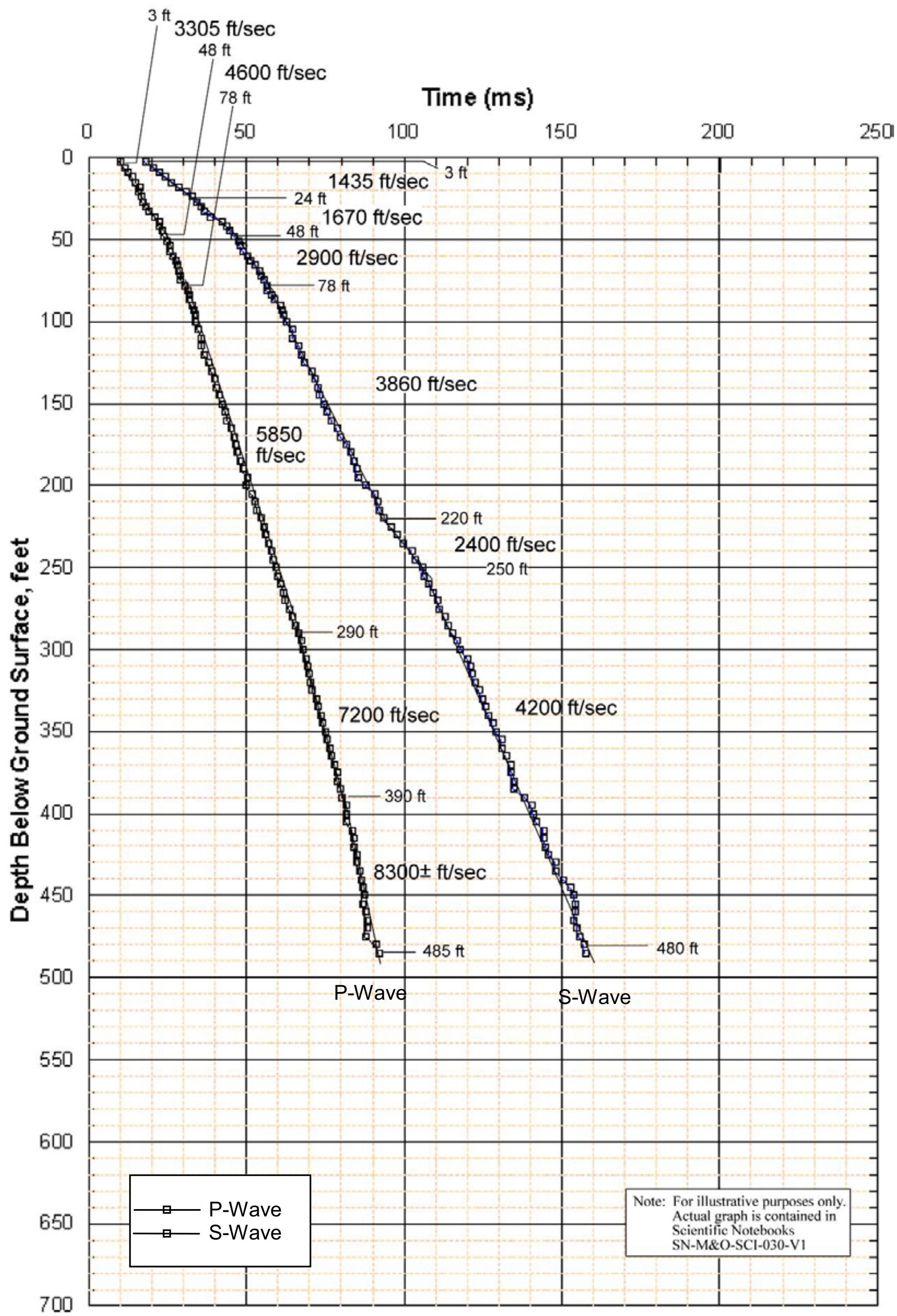
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-3. RF#15 Downhole Travel Time Versus Depth



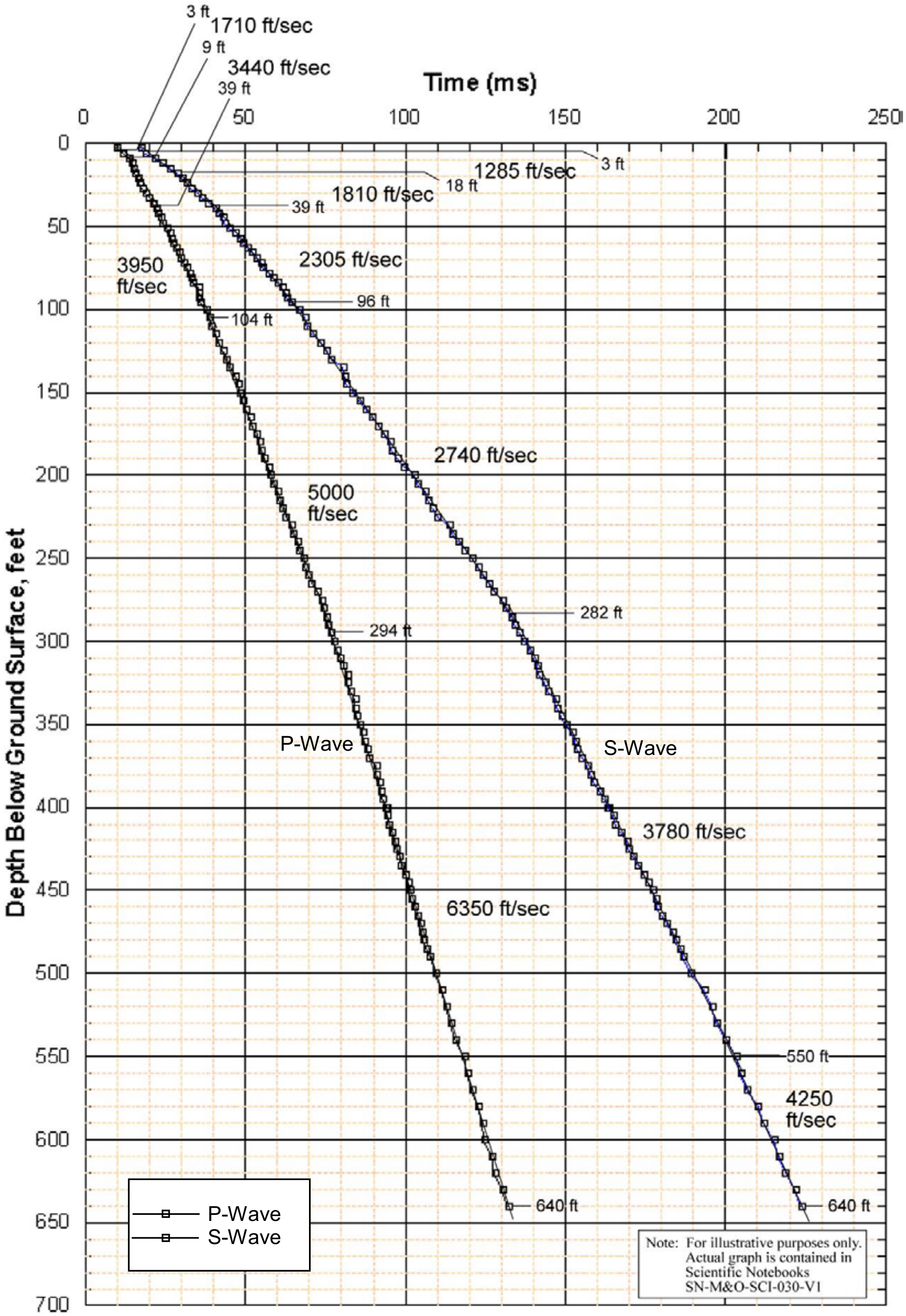
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-4. RF#16 Downhole Travel Time Versus Depth



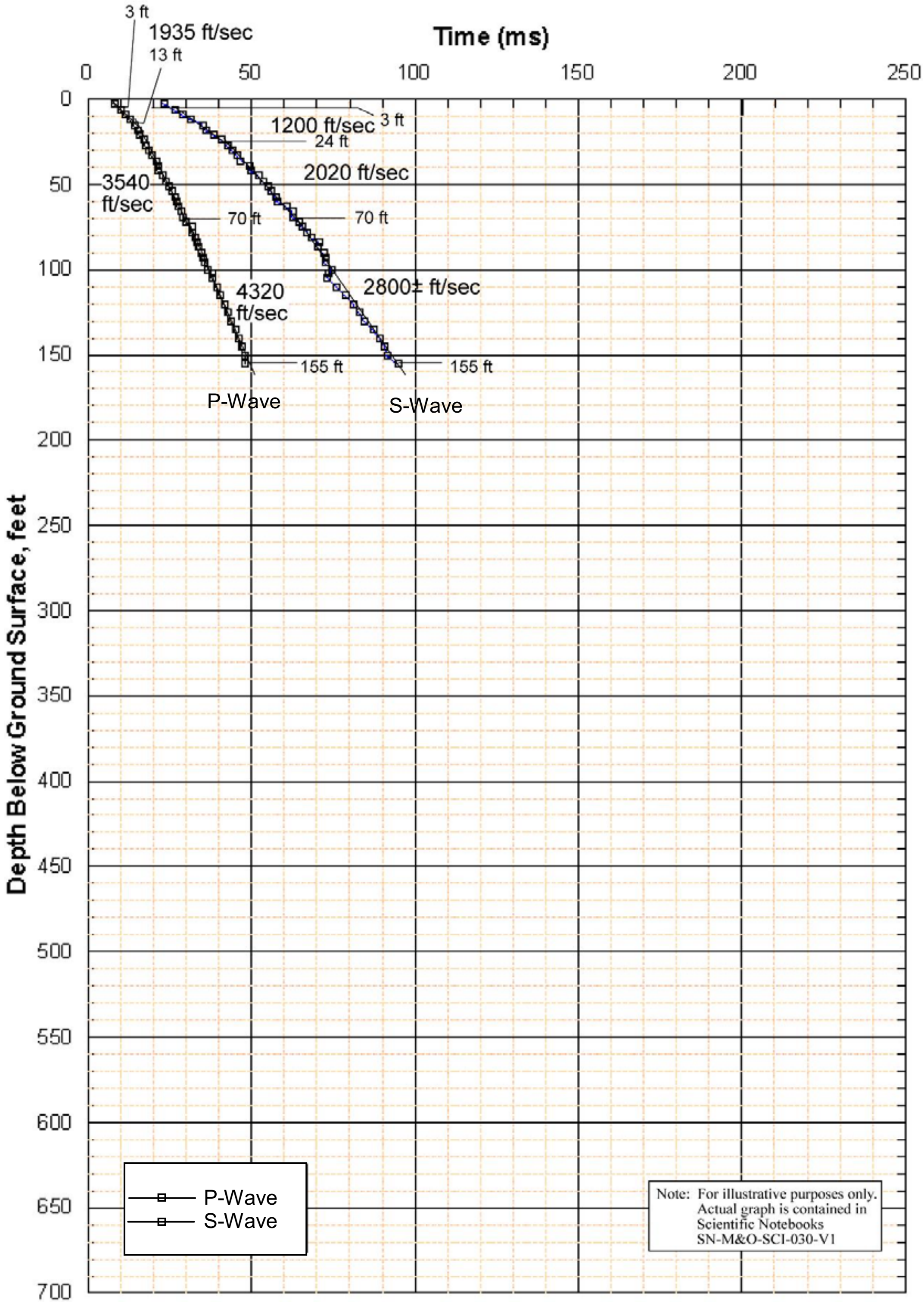
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-5. RF#18 Downhole Travel Time Versus Depth



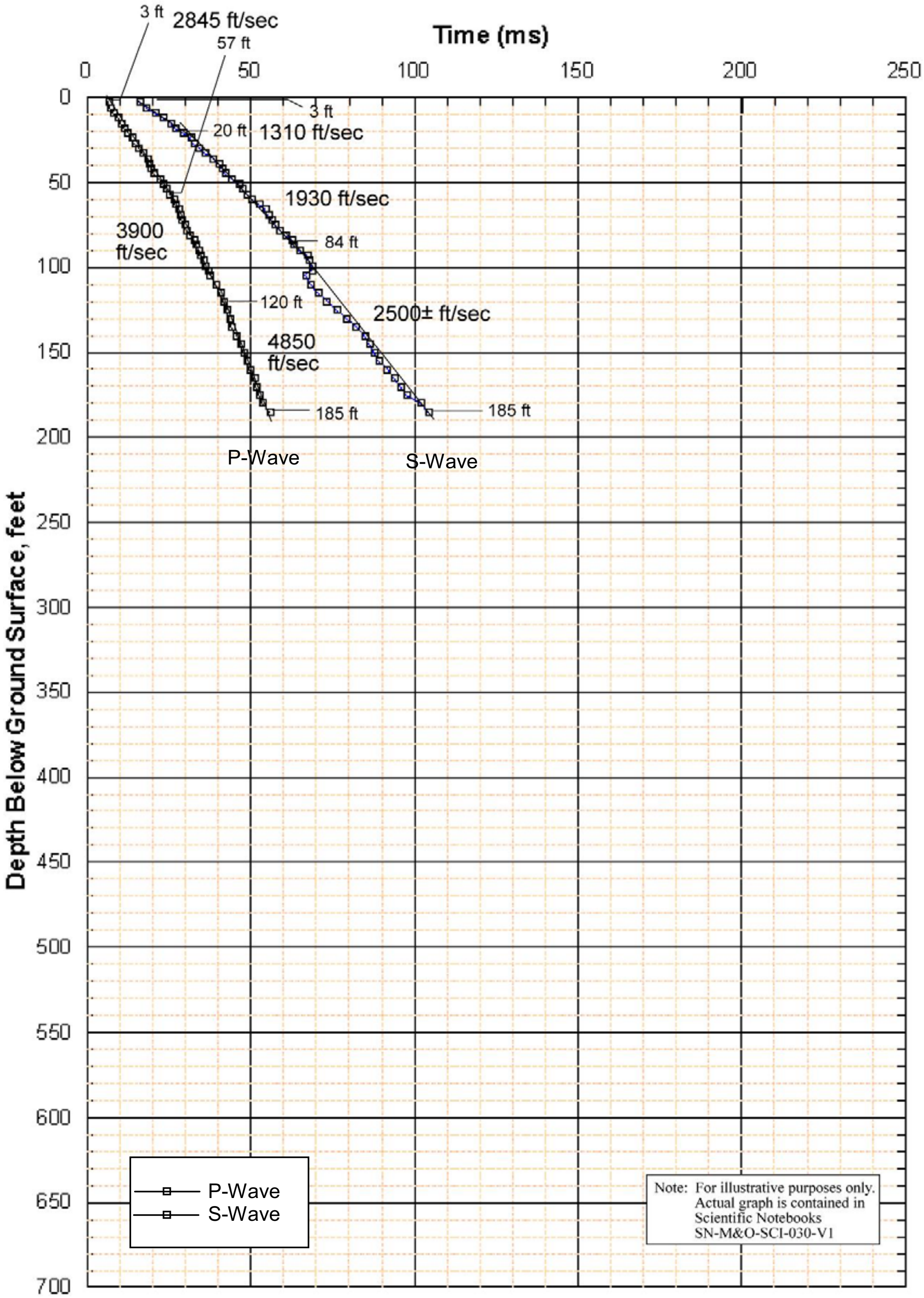
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-6. RF#19 Downhole Travel Time Versus Depth



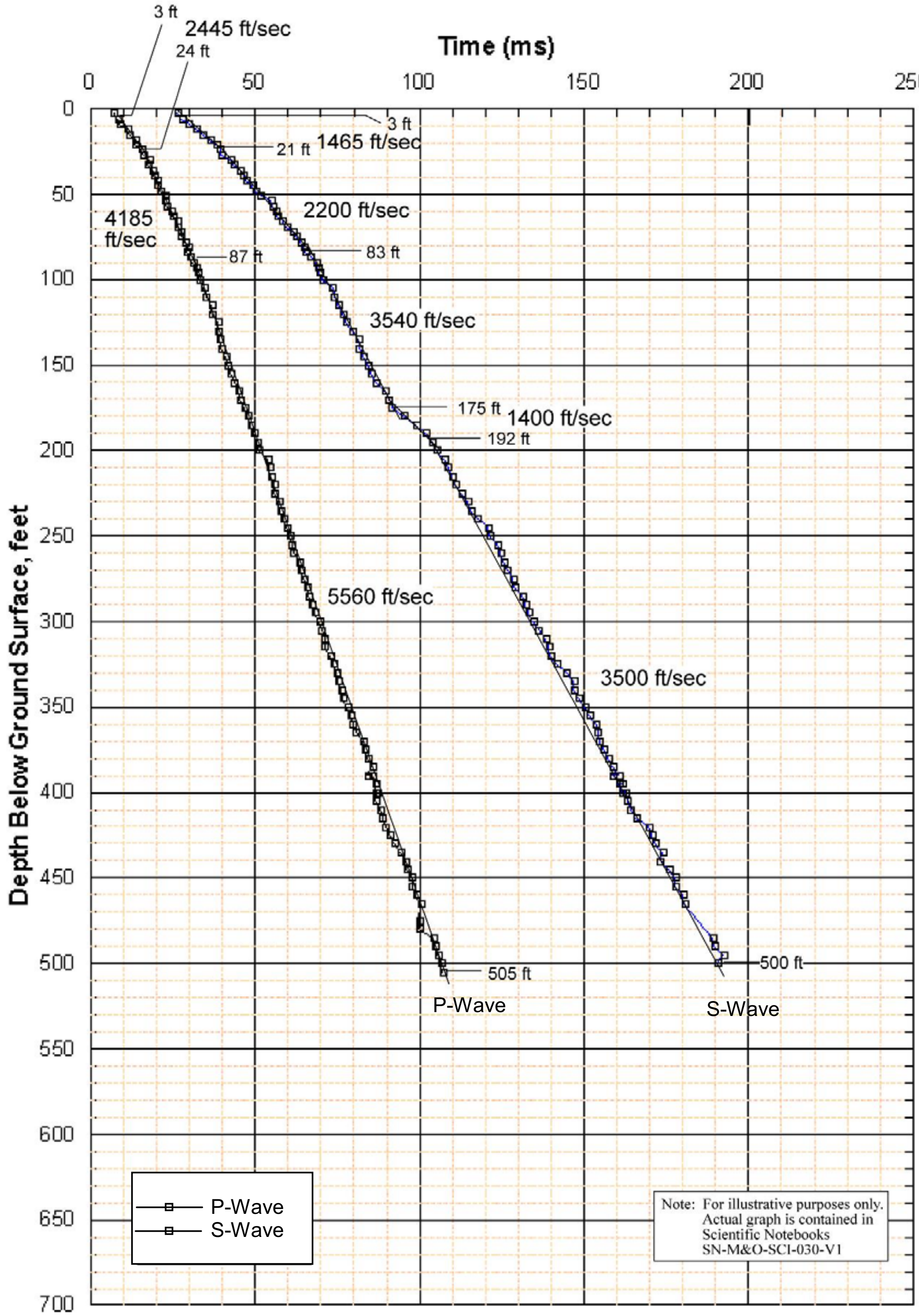
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-7. RF#20 Downhole Travel Time Versus Depth



DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-8. RF#21 Downhole Travel Time Versus Depth



DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-9. RF#22 Downhole Travel Time Versus Depth

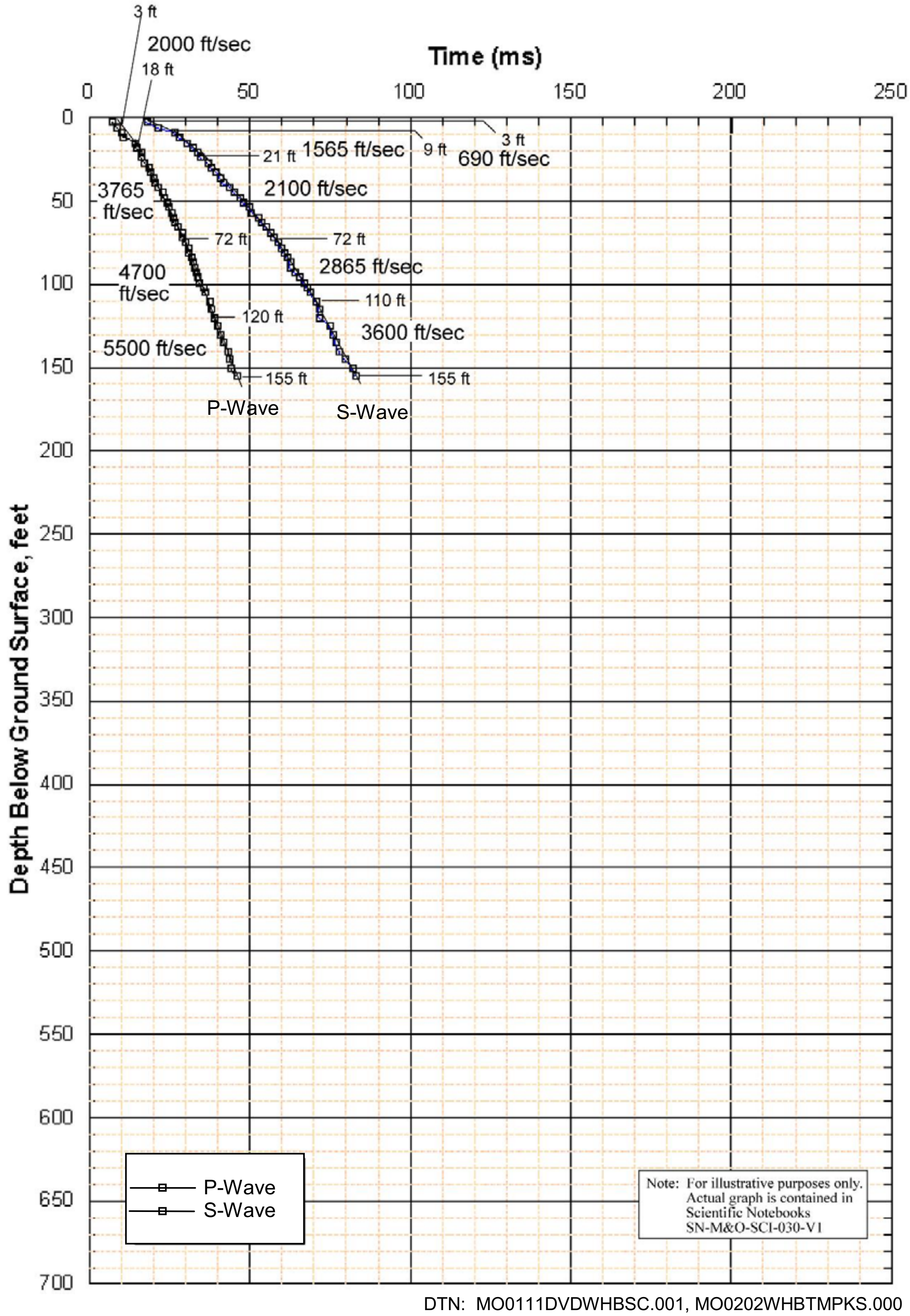
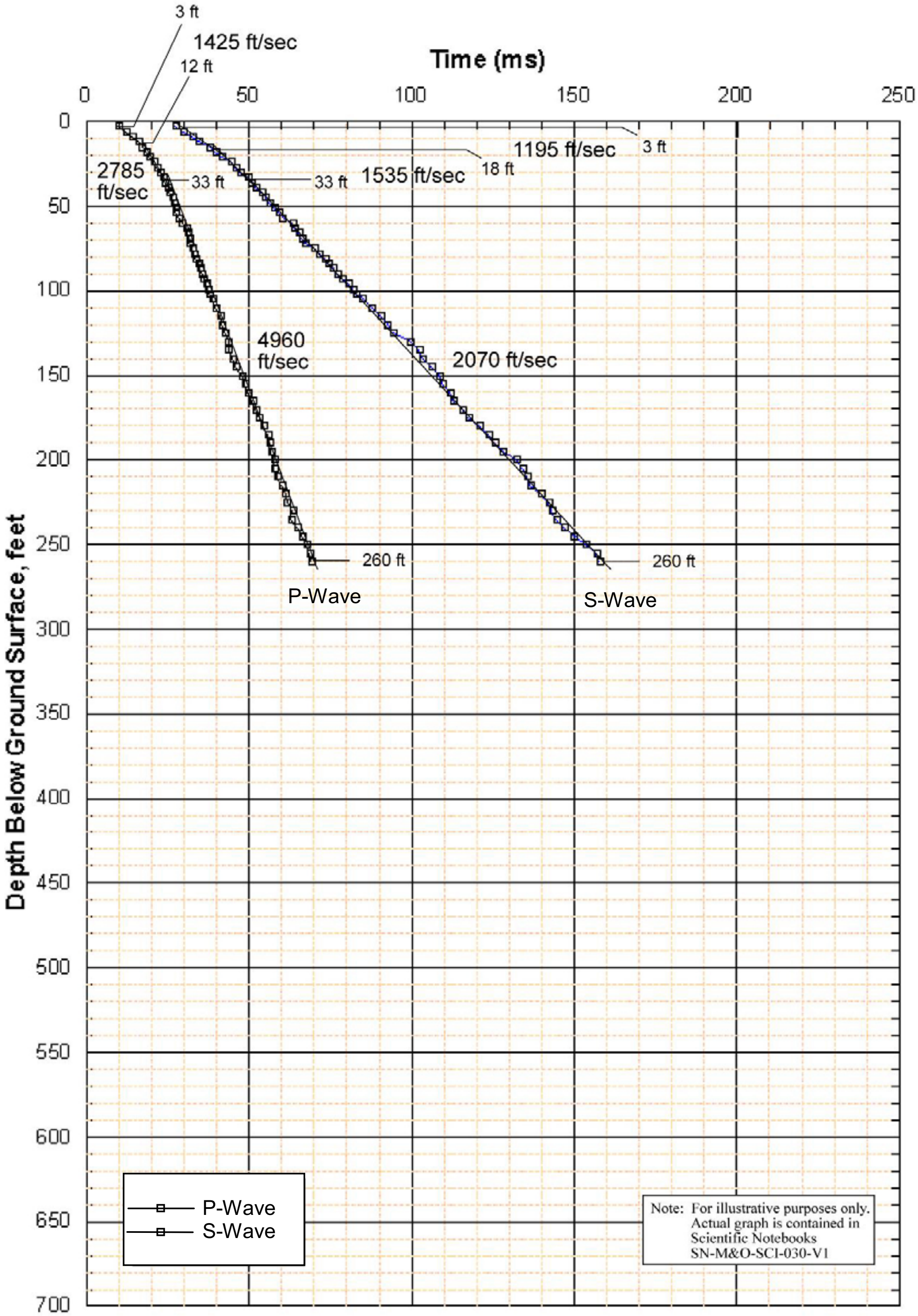
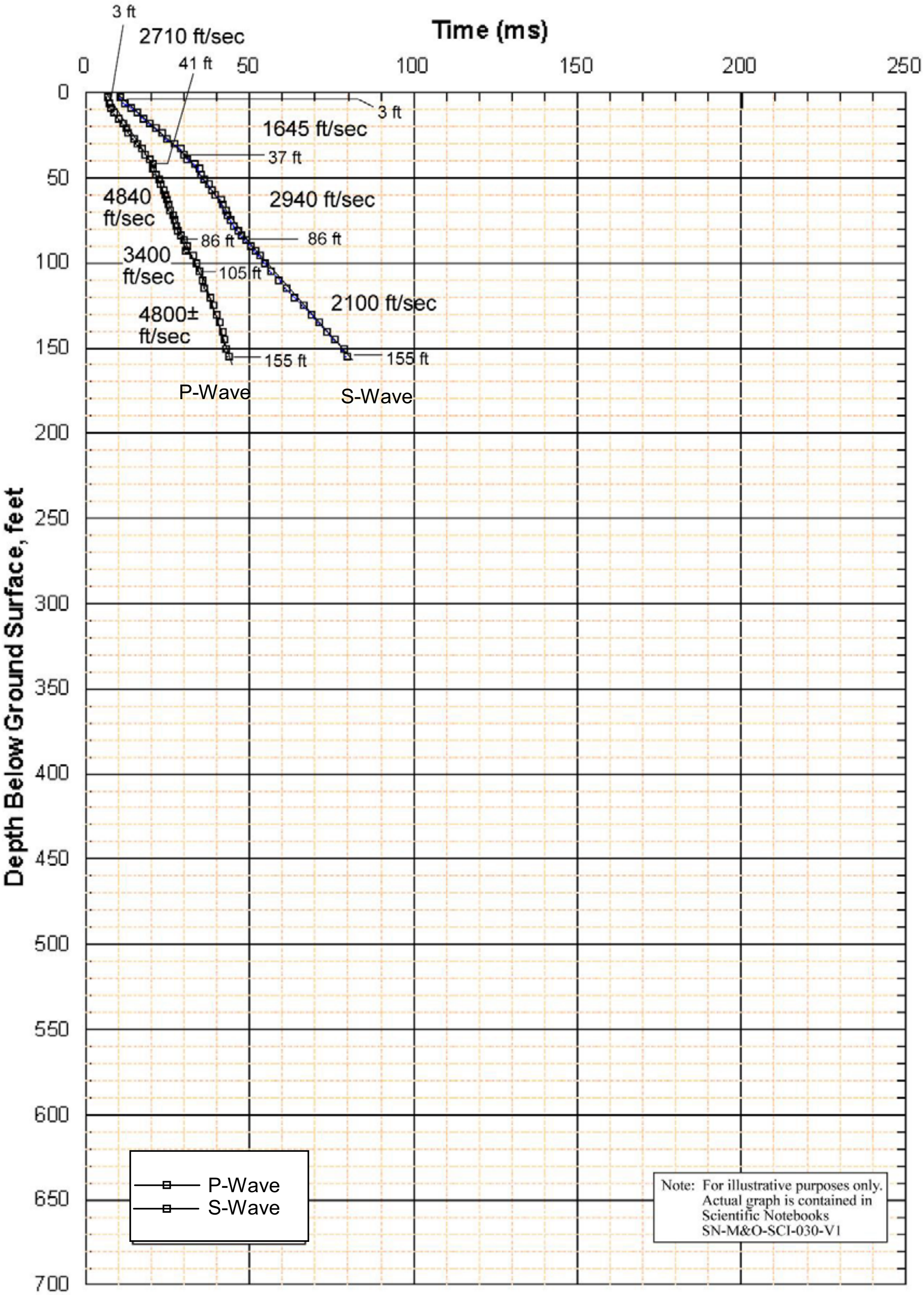


Figure V-10. RF#23 Downhole Travel Time Versus Depth



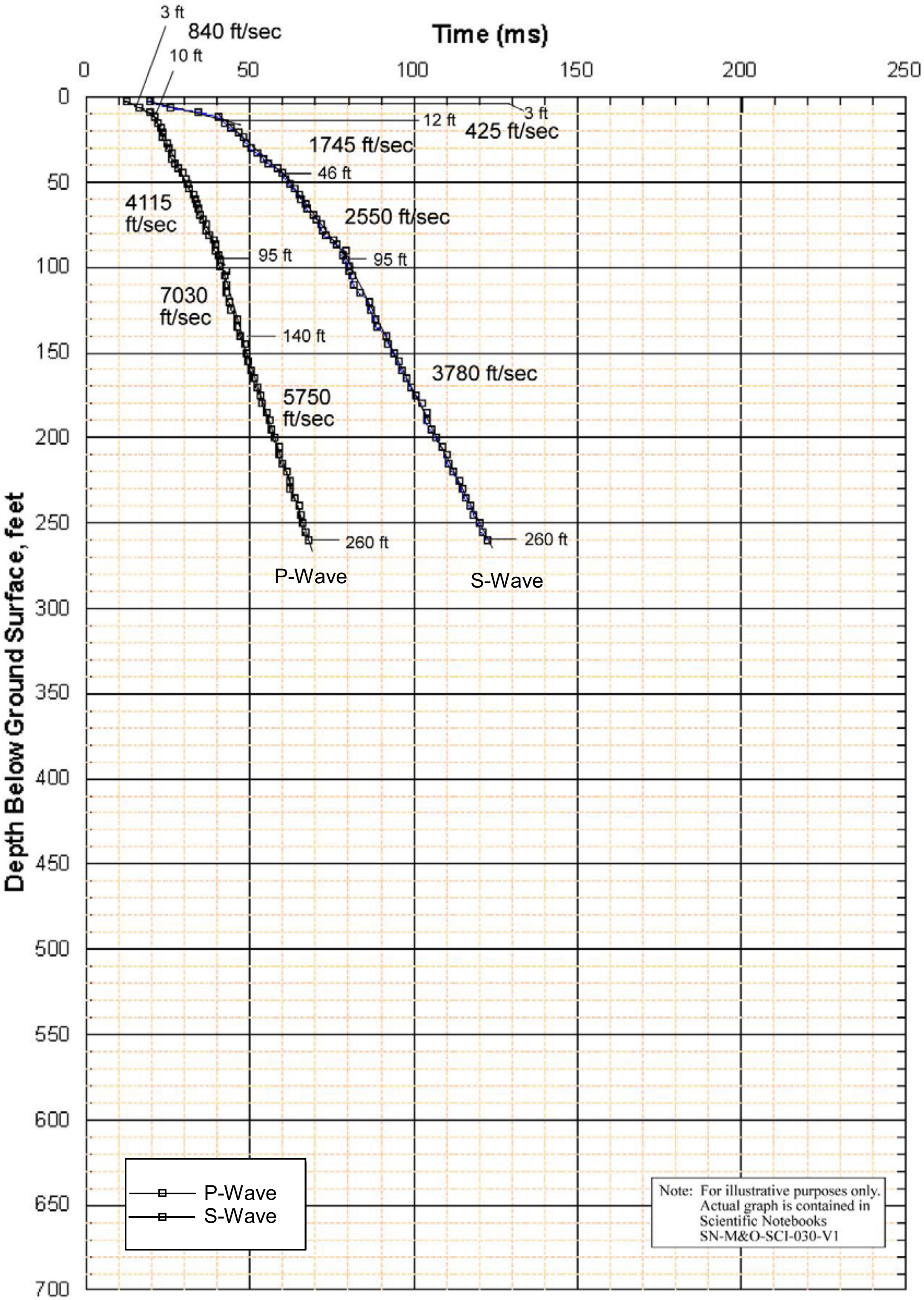
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-11. RF#24 Downhole Travel Time Versus Depth



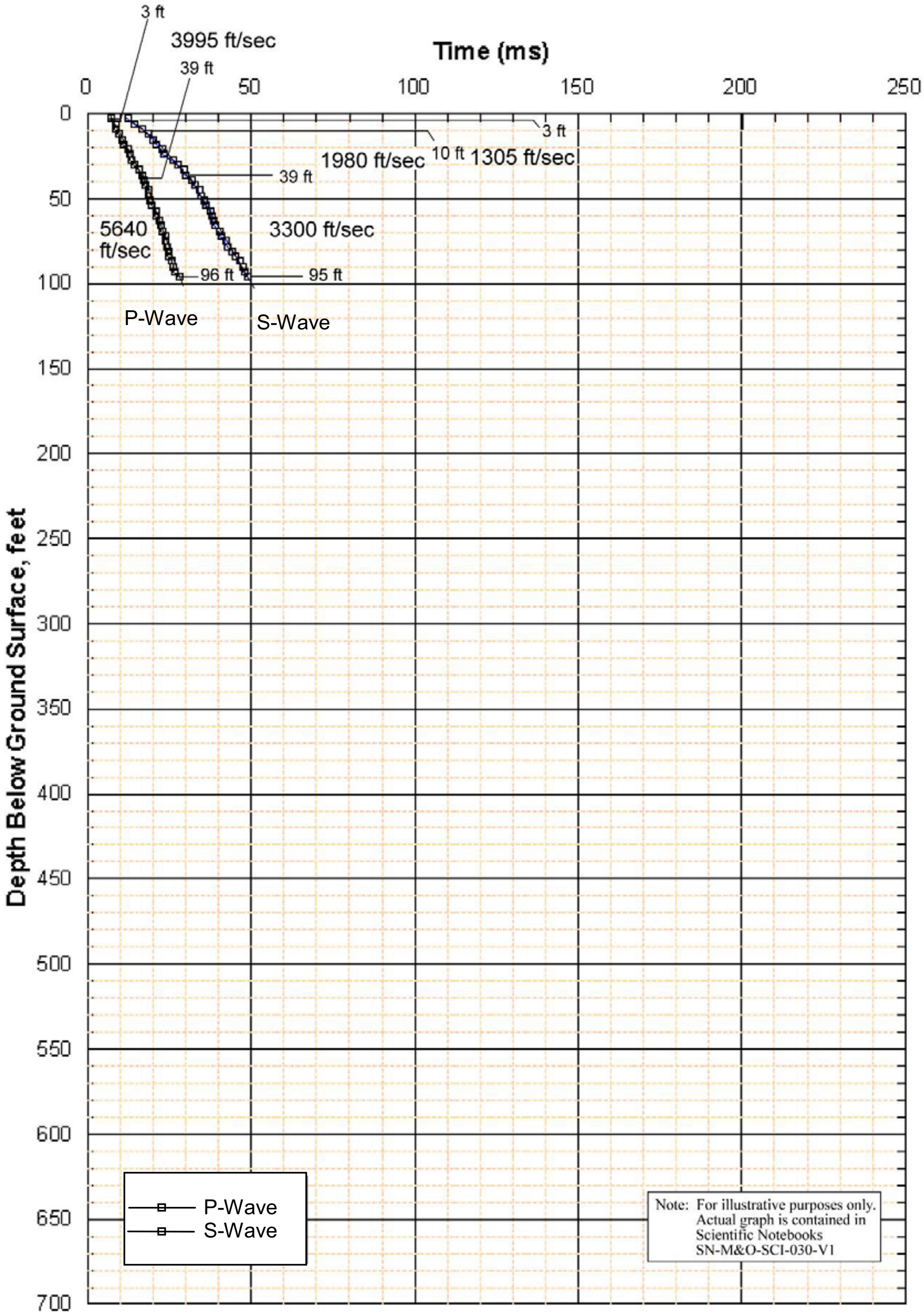
DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-12. RF#25 Downhole Travel Time Versus Depth



DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-13. RF#26 Downhole Travel Time Versus Depth



DTN: MO0111DVDWHBSC.001, MO0202WHBTMPKS.000

Figure V-14. RF#28 Downhole Travel Time Versus Depth

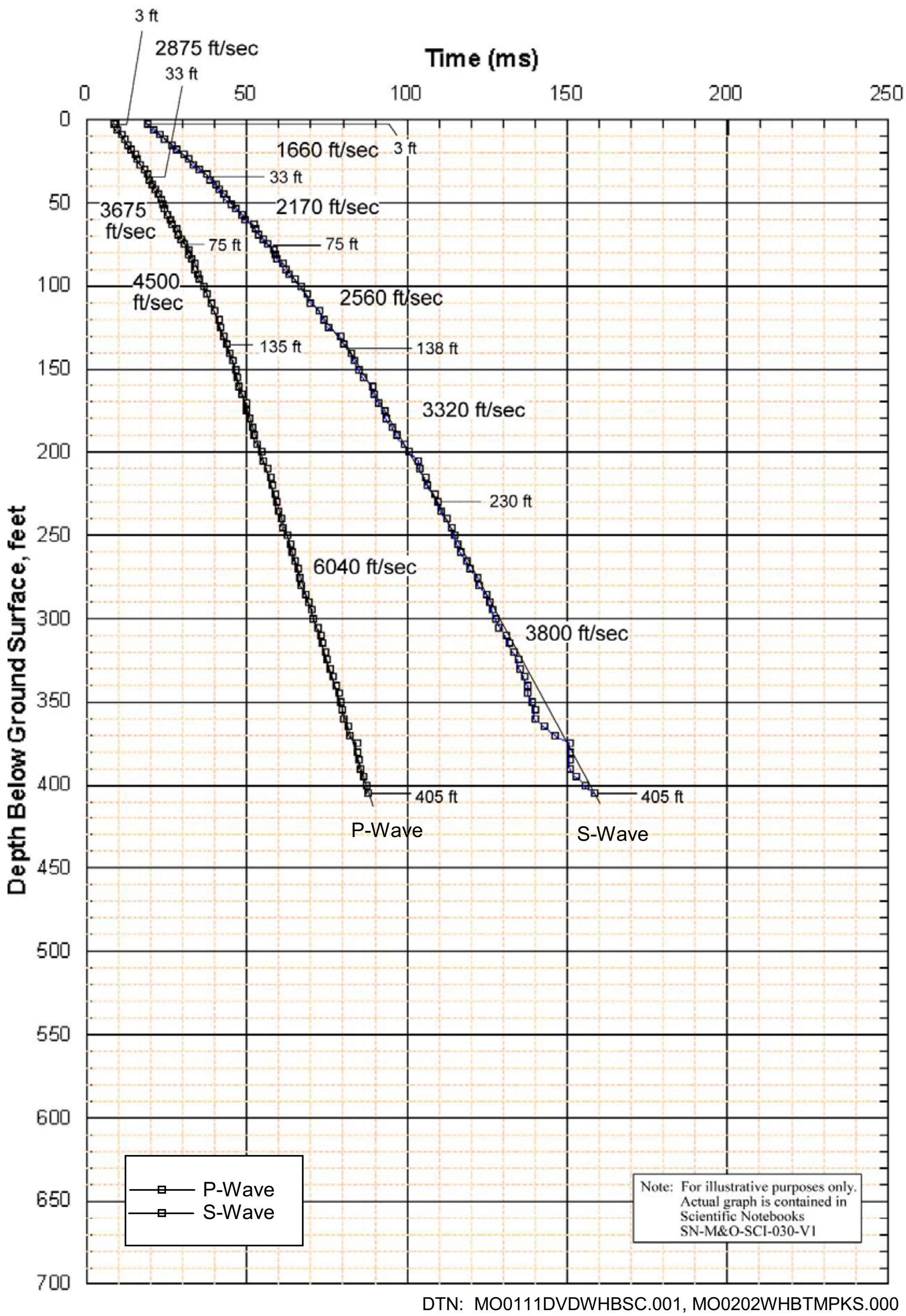


Figure V-15. RF#29 Downhole Travel Time Versus Depth

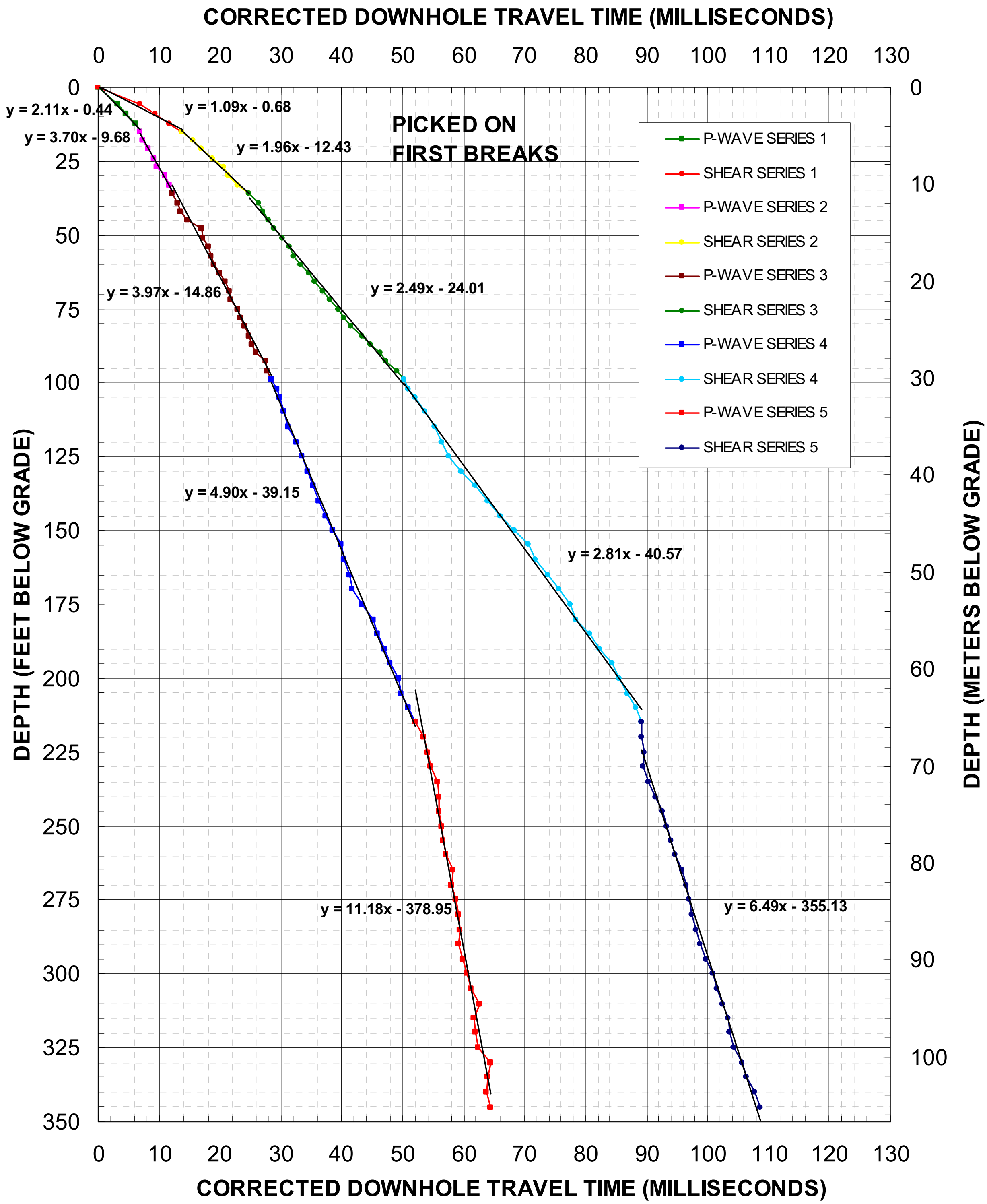
ATTACHMENT VI

DOWNHOLE SEISMIC VELOCITY PLOTS (GEOVISION) – WHB AREA

ATTACHMENT VI

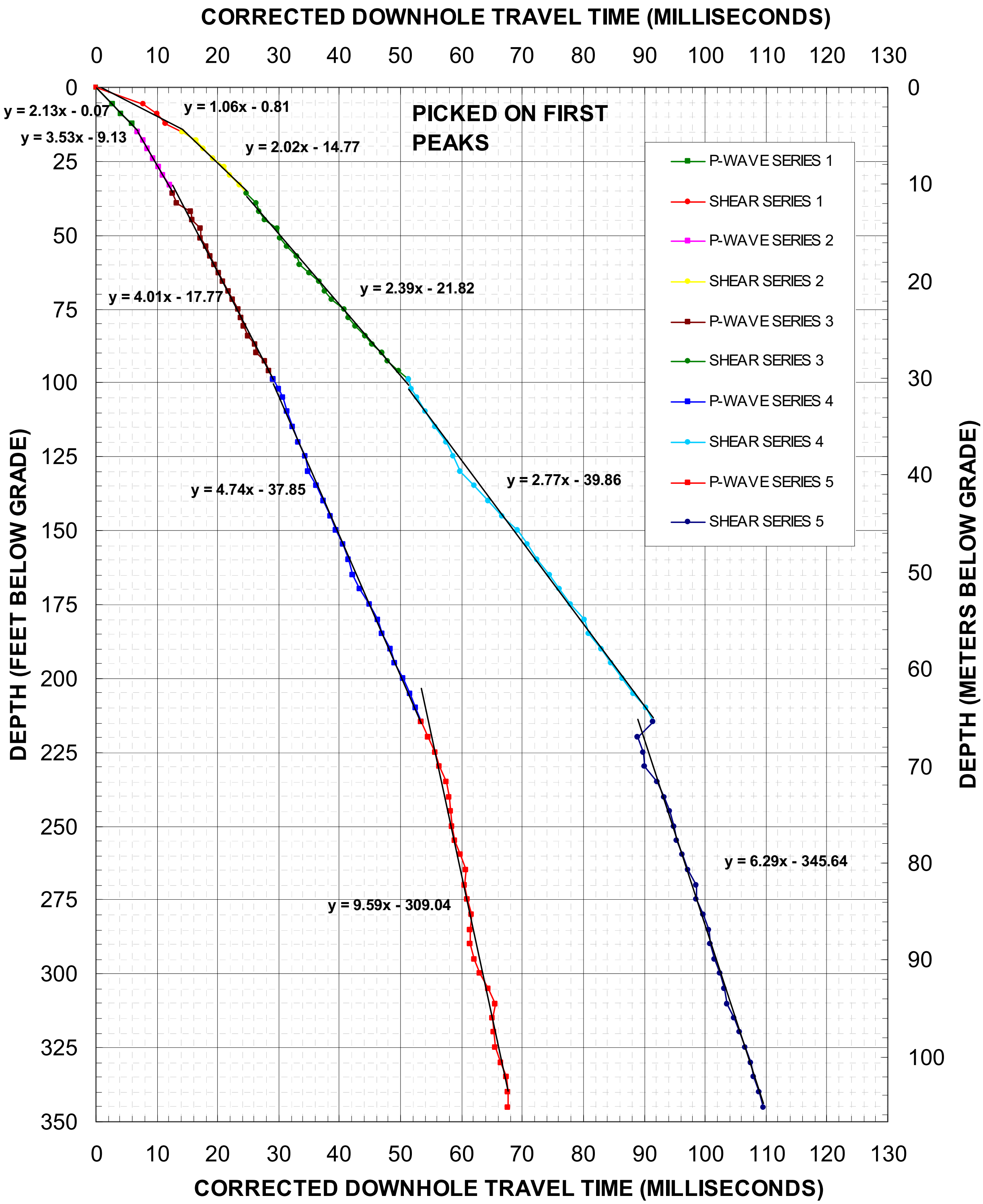
DOWNHOLE SEISMIC VELOCITY PLOTS (GEOVISION) – WHB AREA

As discussed in Section 6.2.5, this attachment presents four figures, two for each of boreholes RF#13 and #17 surveyed by GEOVision, Inc., showing plots of adjusted travel time in milliseconds versus depth below ground surface in feet. The plots also show the linear fits to the data, the slope of which gives the velocity in feet per millisecond, which is converted to feet per second. One interpretation was made by picking the first break (initial arrival) of the shear or compression wave for records at all depths, and a second interpretation was made by picking the peak of the first appearance of the shear or compression wave. GEOVision prefers the first break approach, but also provided the first peak interpretation for comparison purposes. Comparisons of Figures VI-1 and VI-2 and of Figures VI-3 and VI-4 show that the two interpretations agree very well. Details of the surveys and data reduction can be found in scientific notebook SN-M&O-SCI-025-V1 (Luebbers 2002c).



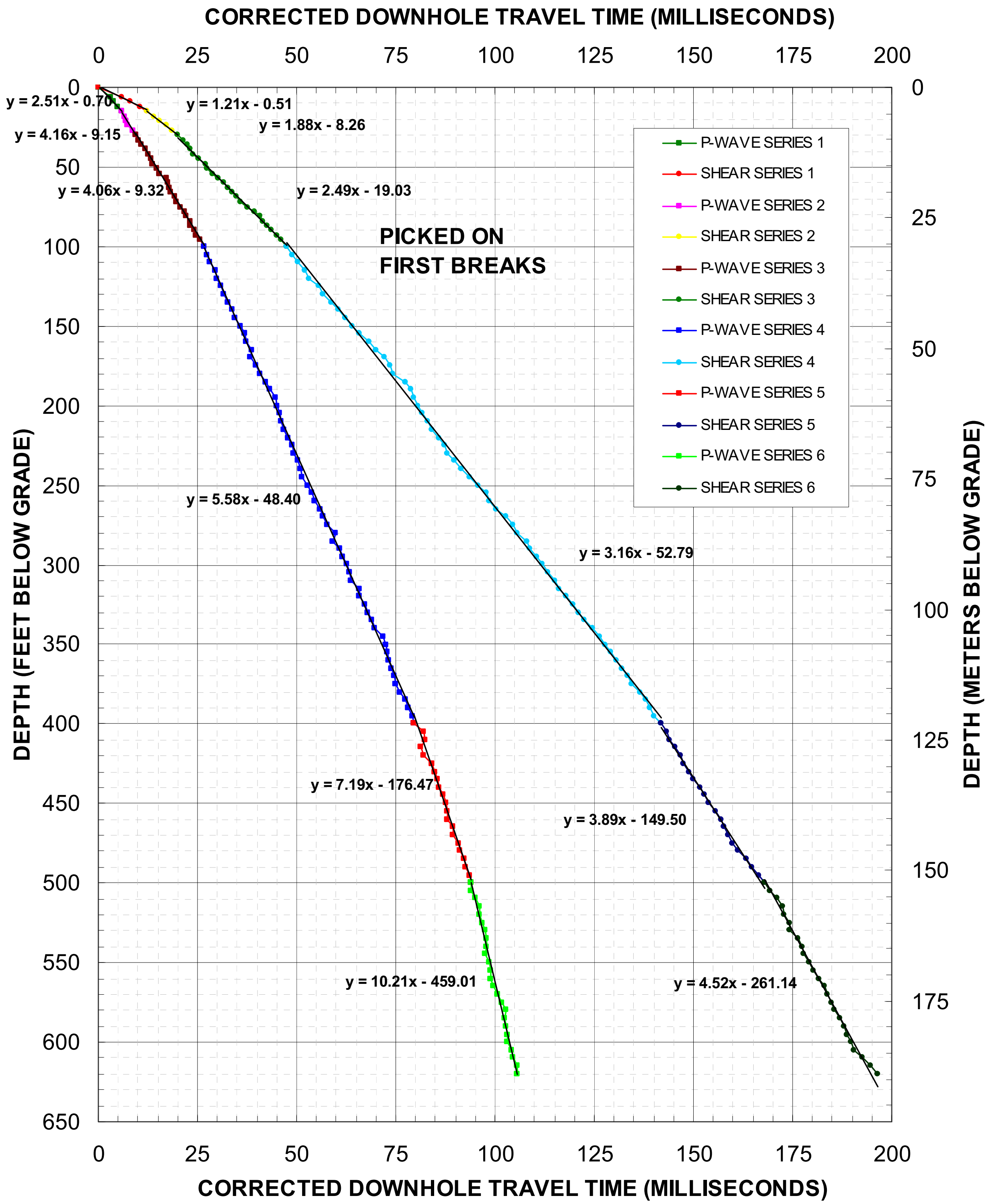
DTN: MO0110DVDBOREH.000, MO0202DWAVEATD.000

Figure VI-1. RF#13 Downhole Travel Time Versus Depth Plots (First Break Picks)



DTN: MO0110DVDBOREH.000, MO0202DWAVEATD.000

Figure VI-2. RF#13 Downhole Travel Time Versus Depth Plots (Peak Picks)



DTN: MO0110DVDBOREH.000, MO0202DWAVEATD.000

Figure VI-3. RF#17 Downhole Travel Time Versus Depth Plots (First Break Picks)

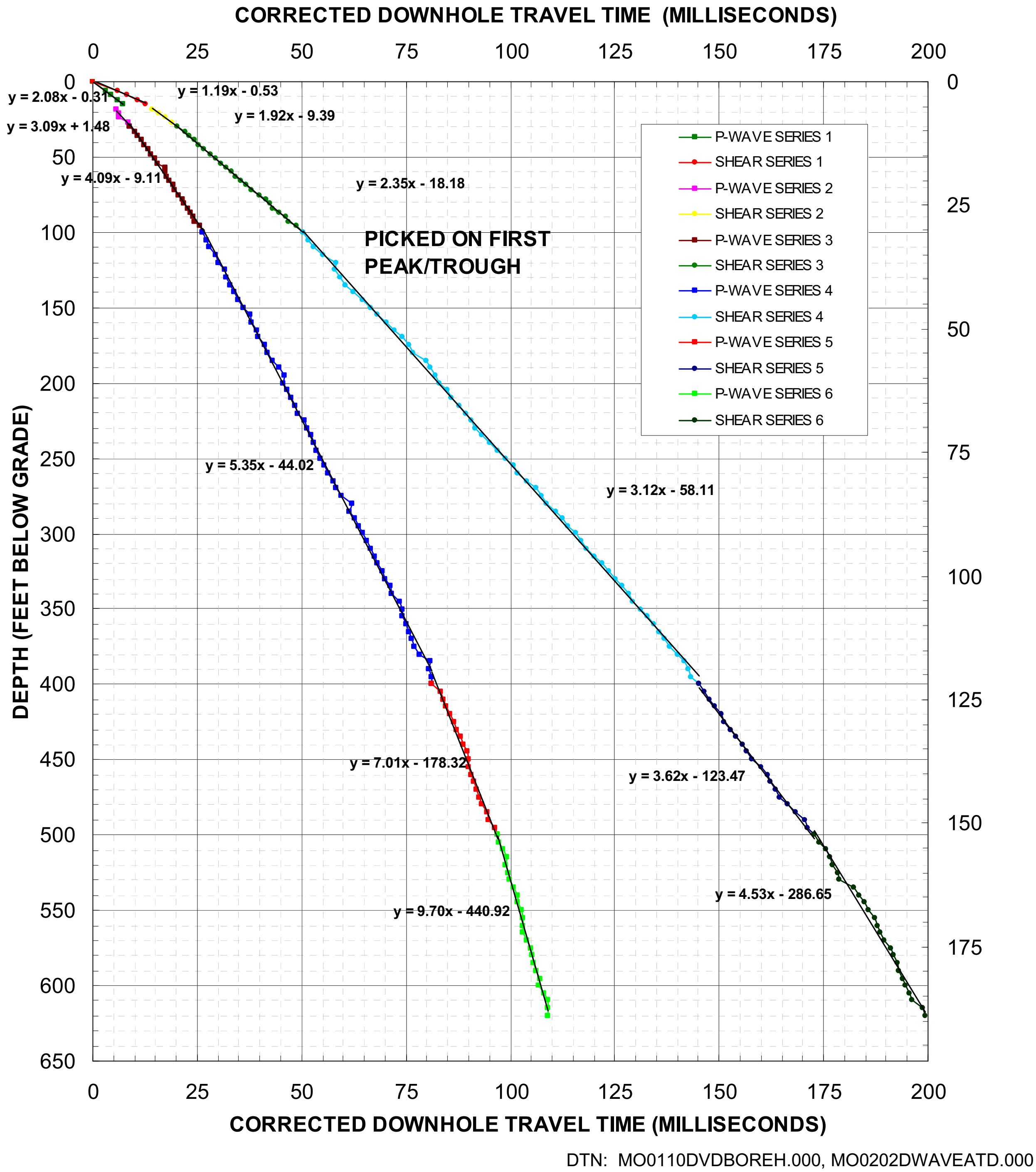


Figure VI-4. RF#17 Downhole Travel Time Versus Depth Plots (Peak Picks)

ATTACHMENT VII

SUSPENSION SEISMIC INTERVAL VELOCITY PLOTS

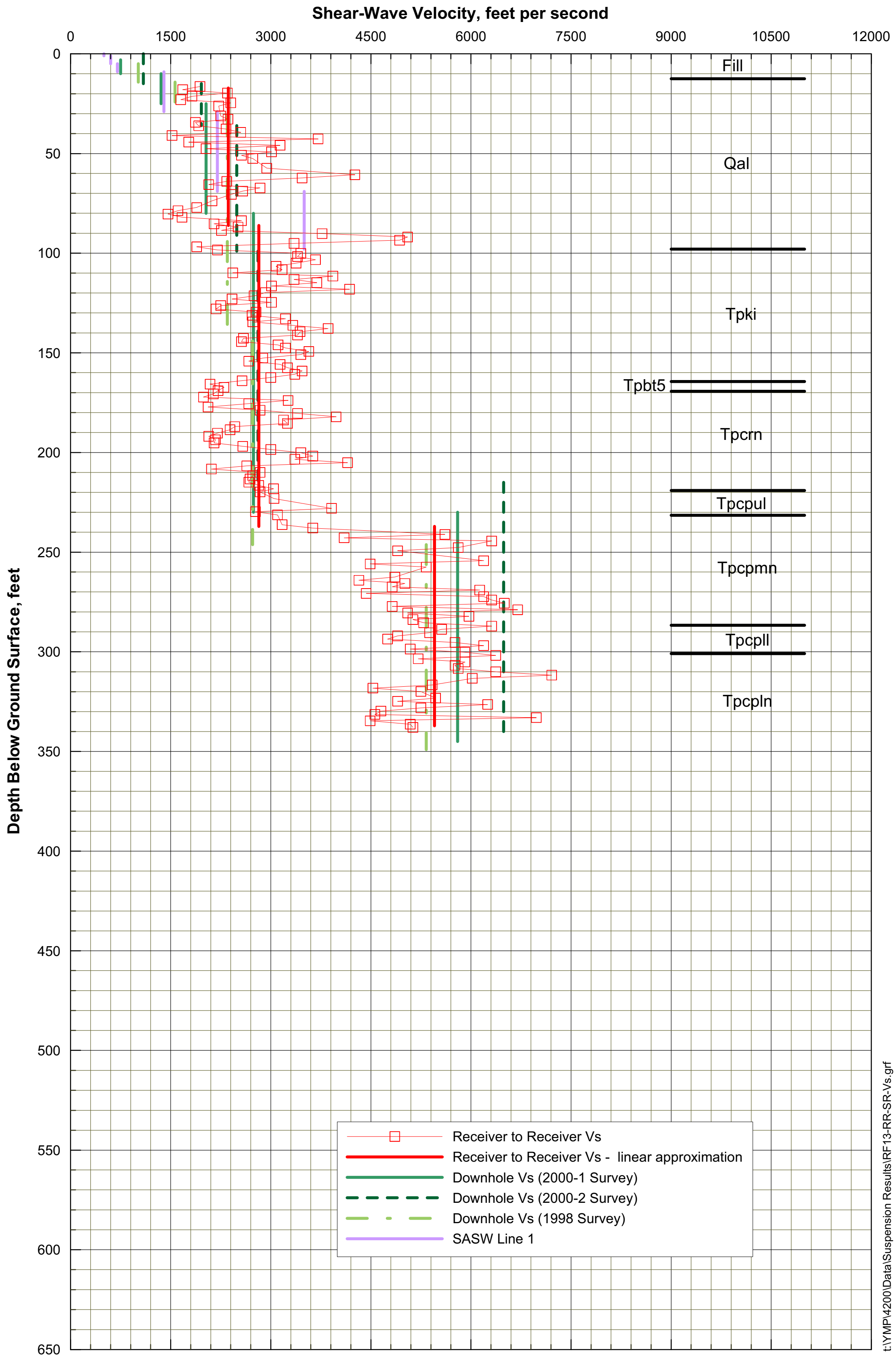
ATTACHMENT VII

SUSPENSION SEISMIC INTERVAL VELOCITY PLOTS

As mentioned in Section 6.2.6.4, this attachment presents plots and tables of interpreted suspension seismic measurements as follows:

- Figures VII-1 through VII-16, plots of shear-wave interval velocity vs. depth bgs at boreholes RF#13 through RF#29, respectively.
- Figures VII-17 through VII-32, plots of compression-wave interval velocity vs. depth bgs at boreholes RF#13 through RF#29, respectively.
- Figures VII-33 through VII-48, plots of Poisson's ratio derived from interval velocity measurements vs. depth bgs at boreholes RF#13 through RF#29, respectively.
- Figures VII-49 and VII-50 plot the averaged shear-wave velocity for individual boreholes together with the median and median ± one standard deviation for the entire data set.
- Figure VII-51 plots the averaged compression-wave velocity for individual boreholes together with the median and median ± one standard deviation for the entire data set.
- Figure VII-52 plots the values of Poisson's ratio calculated from the averaged shear- and compression-wave velocity for individual boreholes together with the median and median ± one standard deviation for the entire data set.
- Tables VII-1 and VII-2 present values of mean, median, standard deviation, and coefficient of variation and count (number of measurements in the data set) by lithostratigraphic unit for receiver-to-receiver and source-to-receiver measurements, respectively.
- Table VII-3 summarizes mean, median, standard deviation, and coefficient of variation and count by lithostratigraphic unit for the compression-wave velocity values.
- Table VII-4 summarizes mean, median, standard deviation, and coefficient of variation and count by lithostratigraphic unit for the Poisson's ratio values.

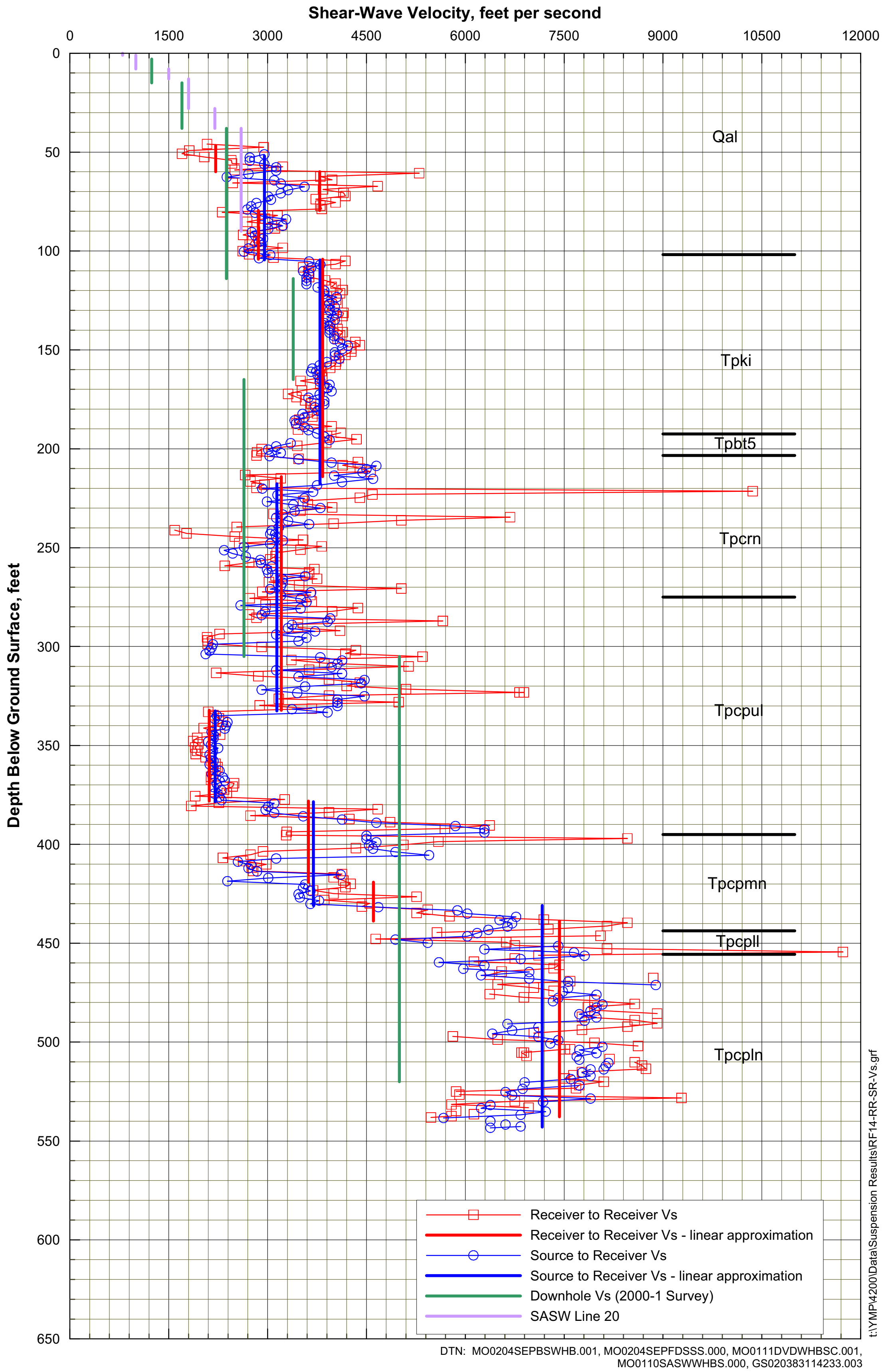
As a reminder, the 2000-1 downhole seismic survey was performed by Redpath Geophysics and the 2000-1 downhole seismic survey was performed by GEOVision.



DTN: MO0204SEISDWHB.001, MO204SEPSWSSS.000, MO0111DVDWHBSC.001, MO0110DVDBOREH.000, MO020498DNHOLE.000, MO0110SASWWHBS.000, GS020383114233.003

NOTE: Downhole and SASW velocities are shown for comparison.

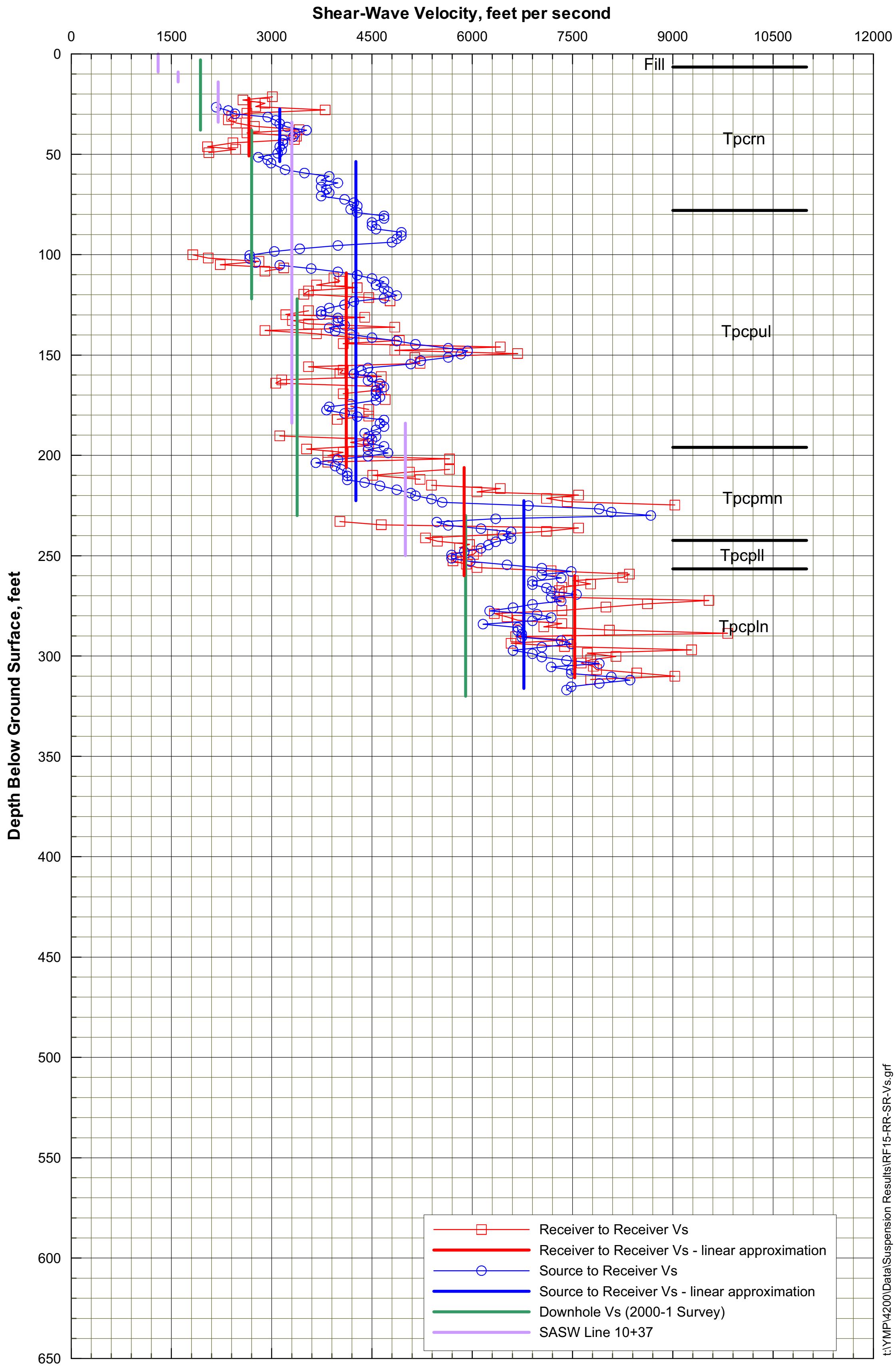
Figure VII-1. Shear-Wave Velocity (v_S) from Suspension Seismic Receiver-to-Receiver Data at Borehole RF#13.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, MO0110SASWWHBS.000, GS020383114233.003

NOTE: Downhole and SASW velocities are shown for comparison.

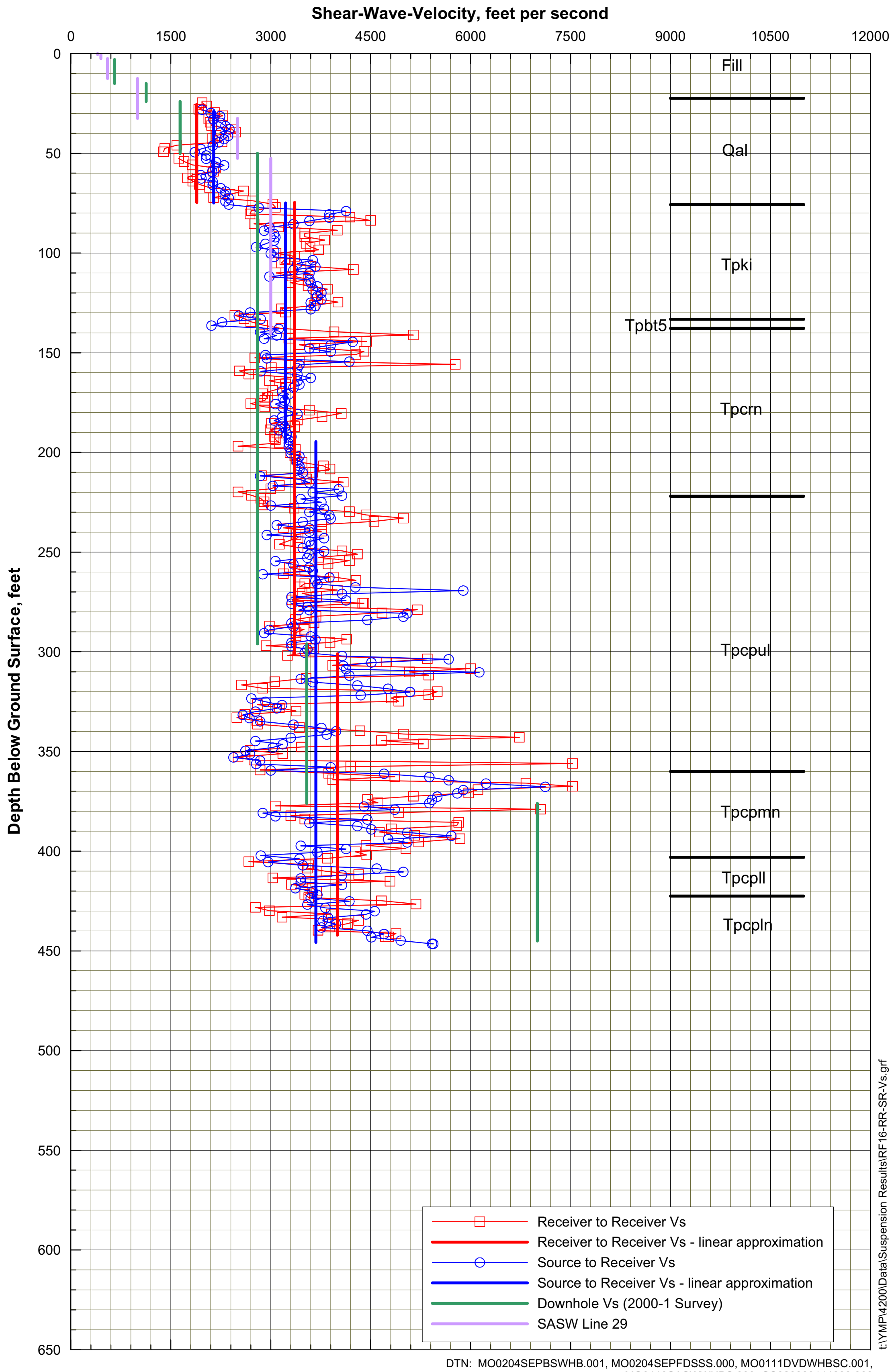
Figure VII-2. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#14.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, MO0110SASWWHBS.000, GS020383114233.003

NOTE: Downhole and SASW velocities are shown for comparison.

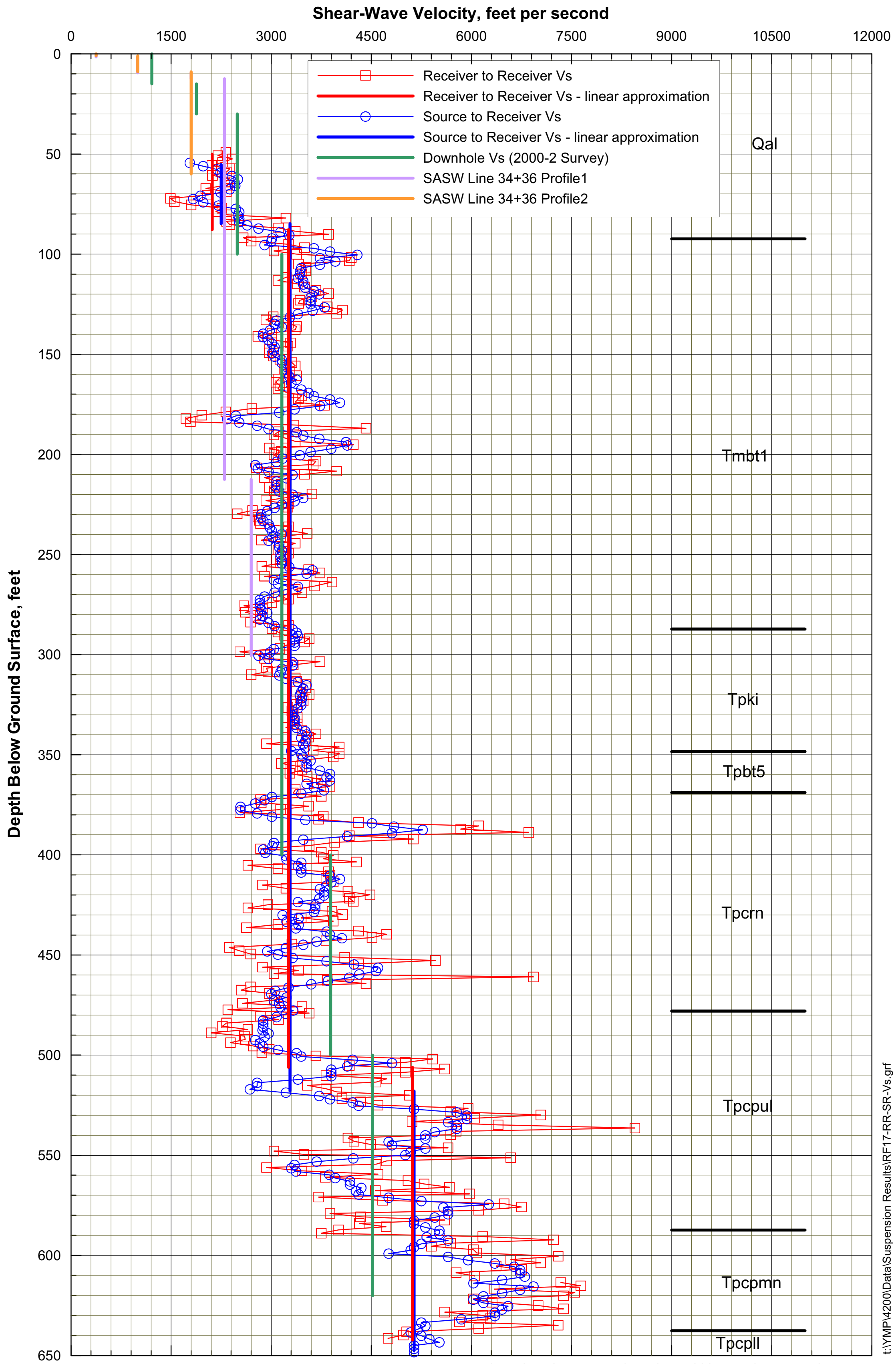
Figure VII-3. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#15.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, MO0110SASWWHBS.000, GS020383114233.003

NOTE: Downhole and SASW velocities are shown for comparison.

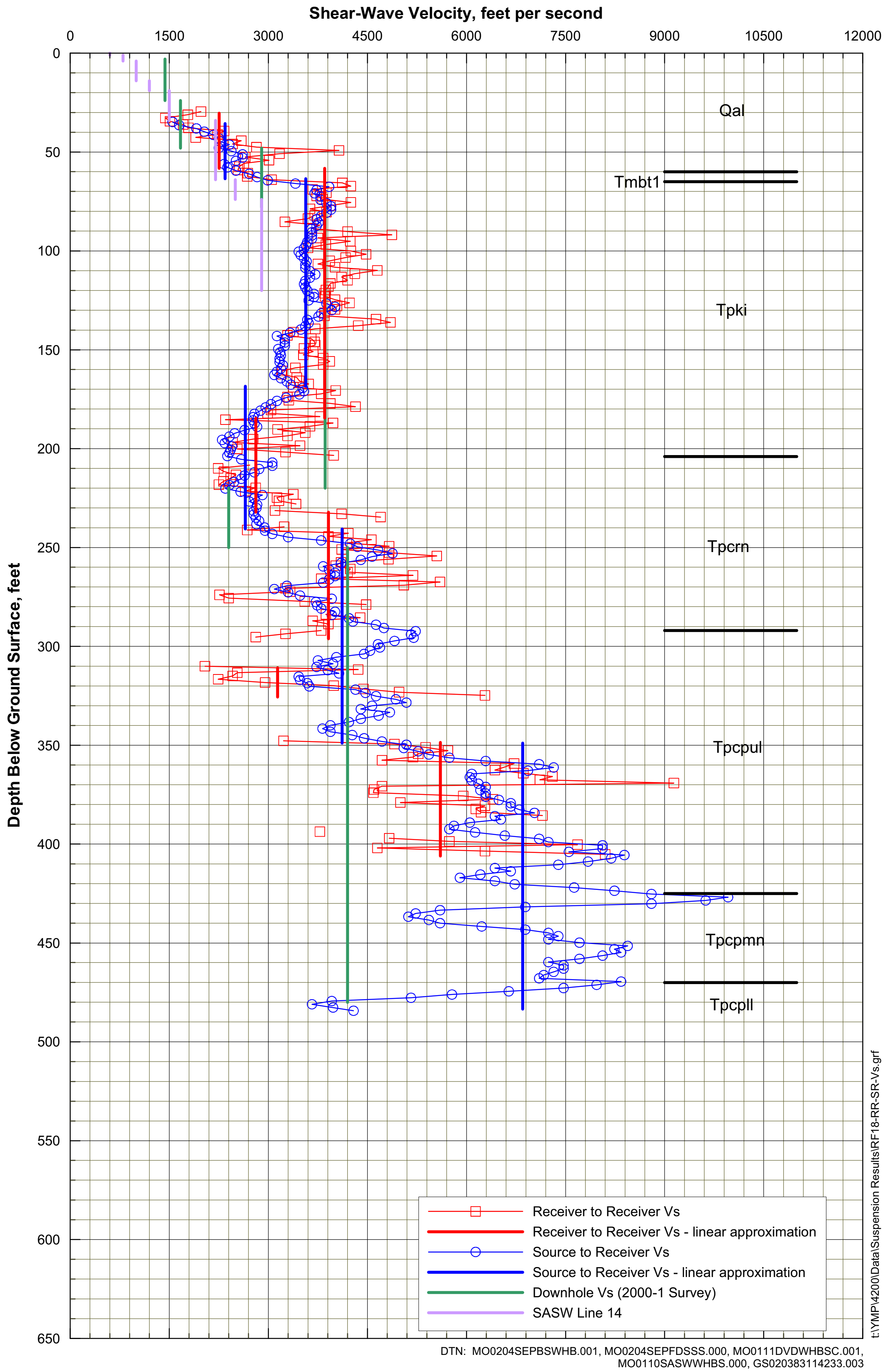
Figure VII-4. Shear Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#16.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0110DVDBOREH.000, MO0110SASWWHBS.000, GS020383114233.003

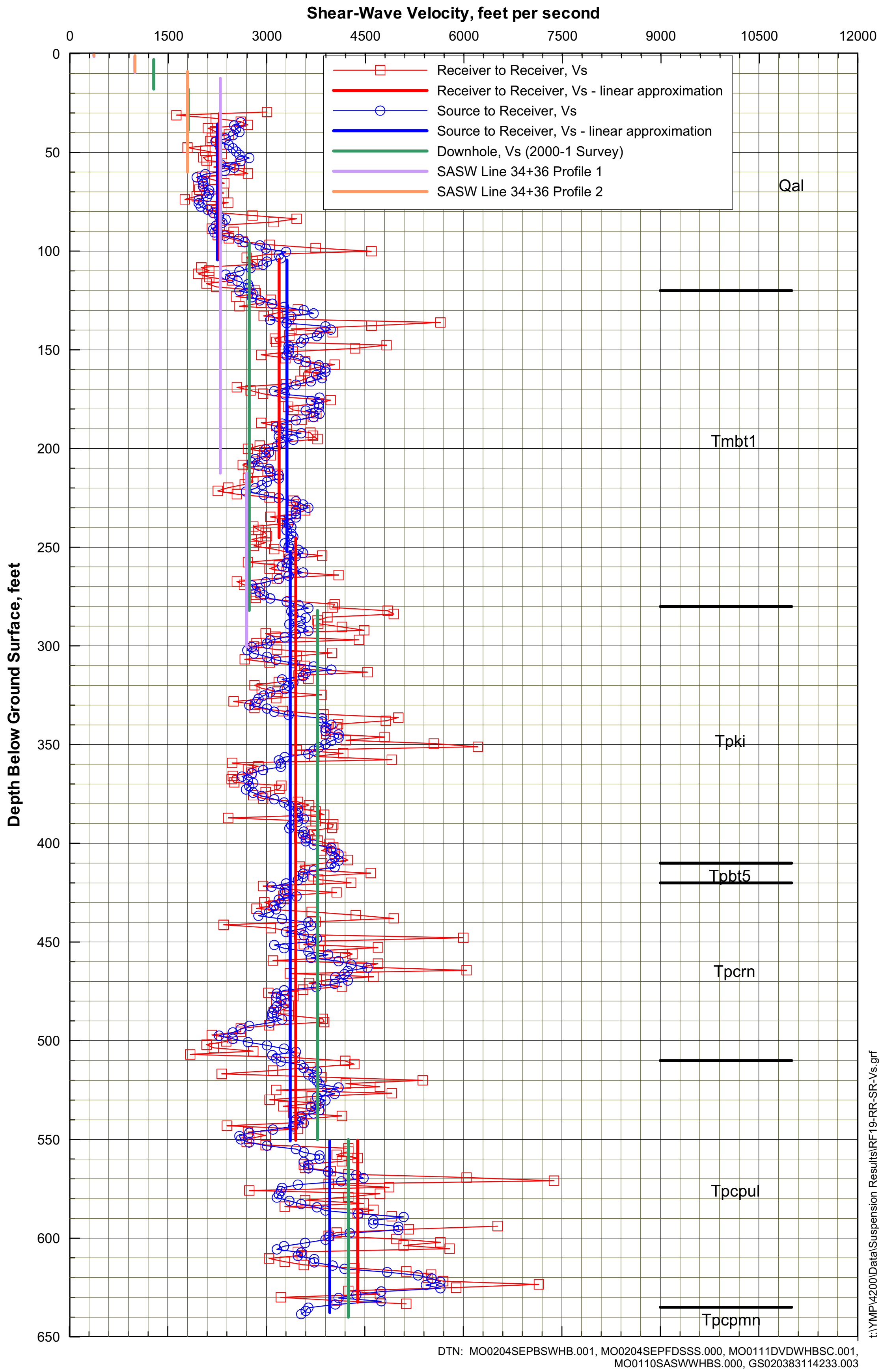
NOTE: Downhole and SASW velocities are shown for comparison.

Figure VII-5. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#17.



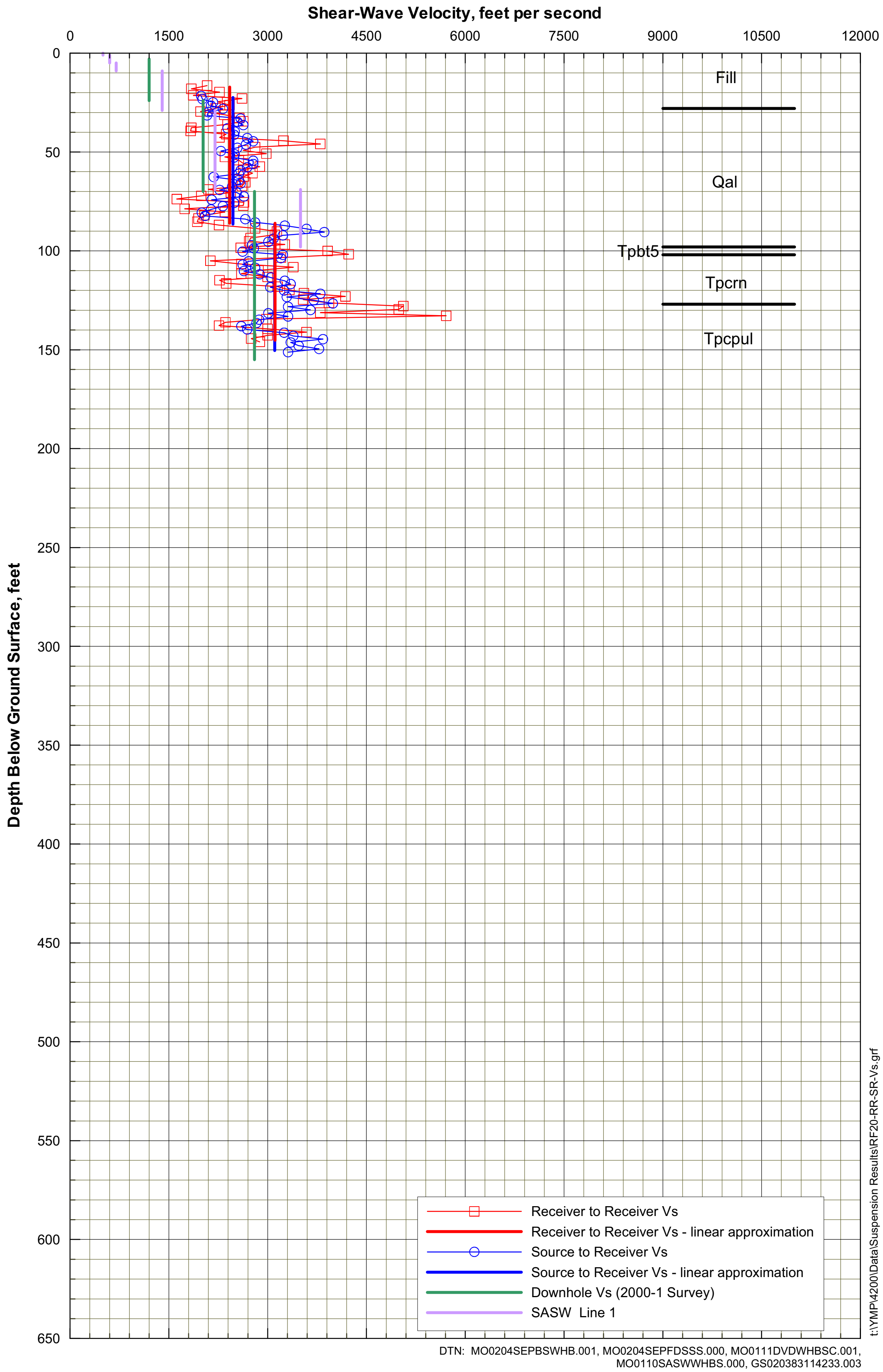
NOTE: Downhole and SASW velocities are shown for comparison.

Figure VII-6. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#18.



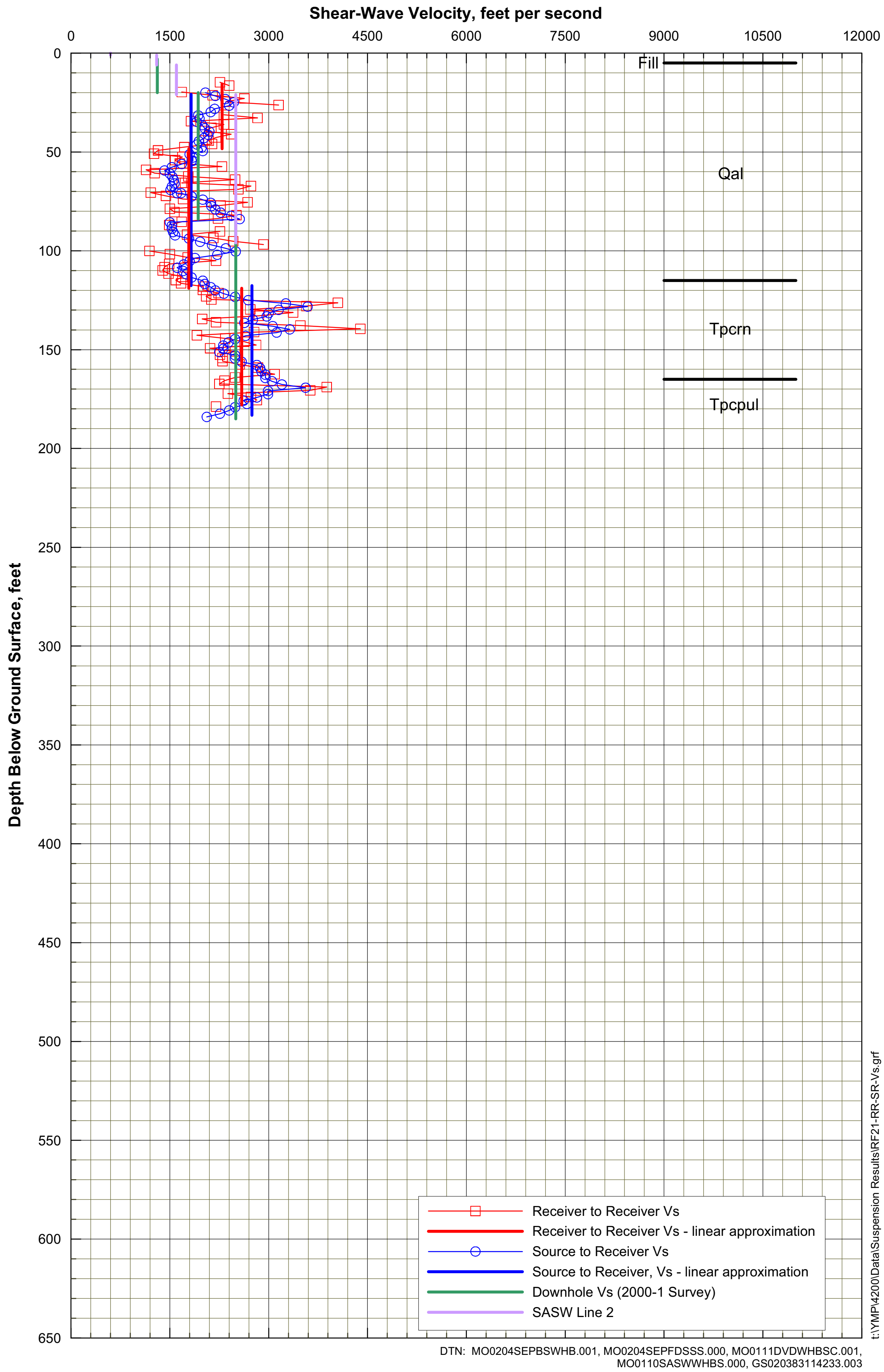
NOTE: Downhole and SASW velocities are shown for comparison.

Figure VII-7. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#19.



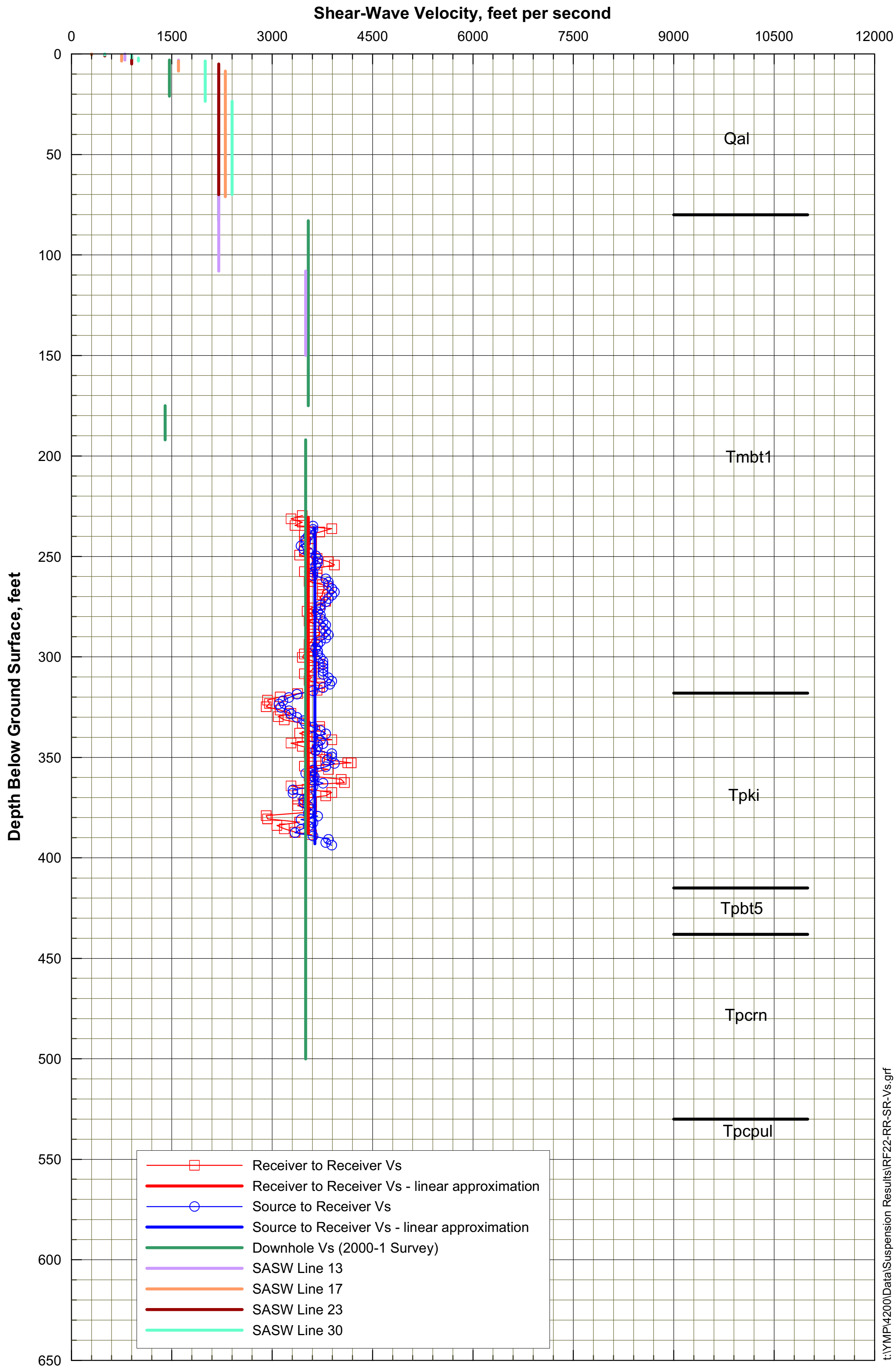
NOTE: Downhole and SASW velocities are shown for comparison.

Figure VII-8. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#20.



NOTE: Downhole and SASW velocities are shown for comparison.

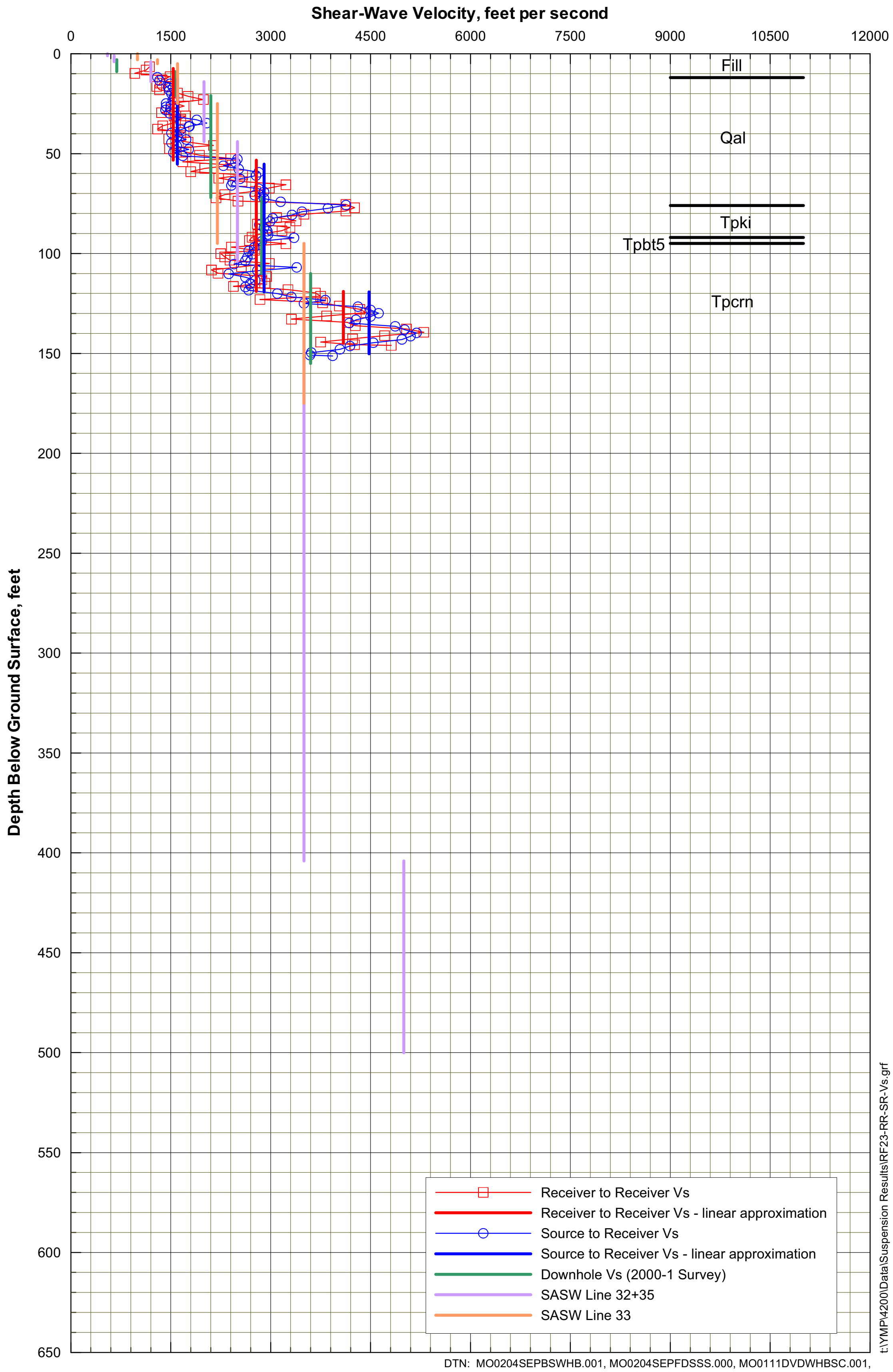
Figure VII-9. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#21.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, MO0110SASWWHBS.000, GS020383114233.003

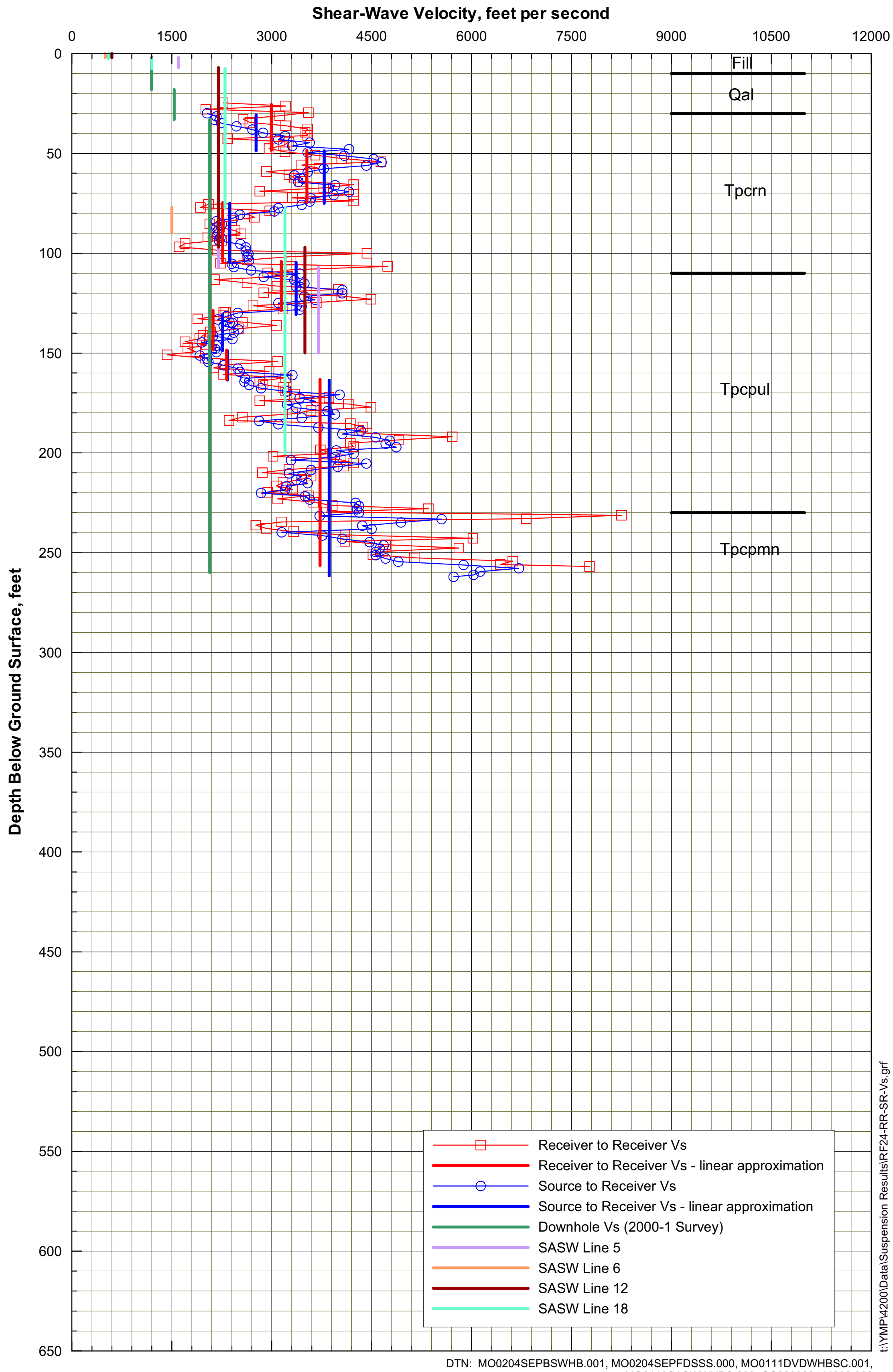
NOTE: Downhole and SASW velocities are shown for comparison.

Figure VII-10. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#22.



NOTE: Downhole and SASW velocities are shown for comparison.

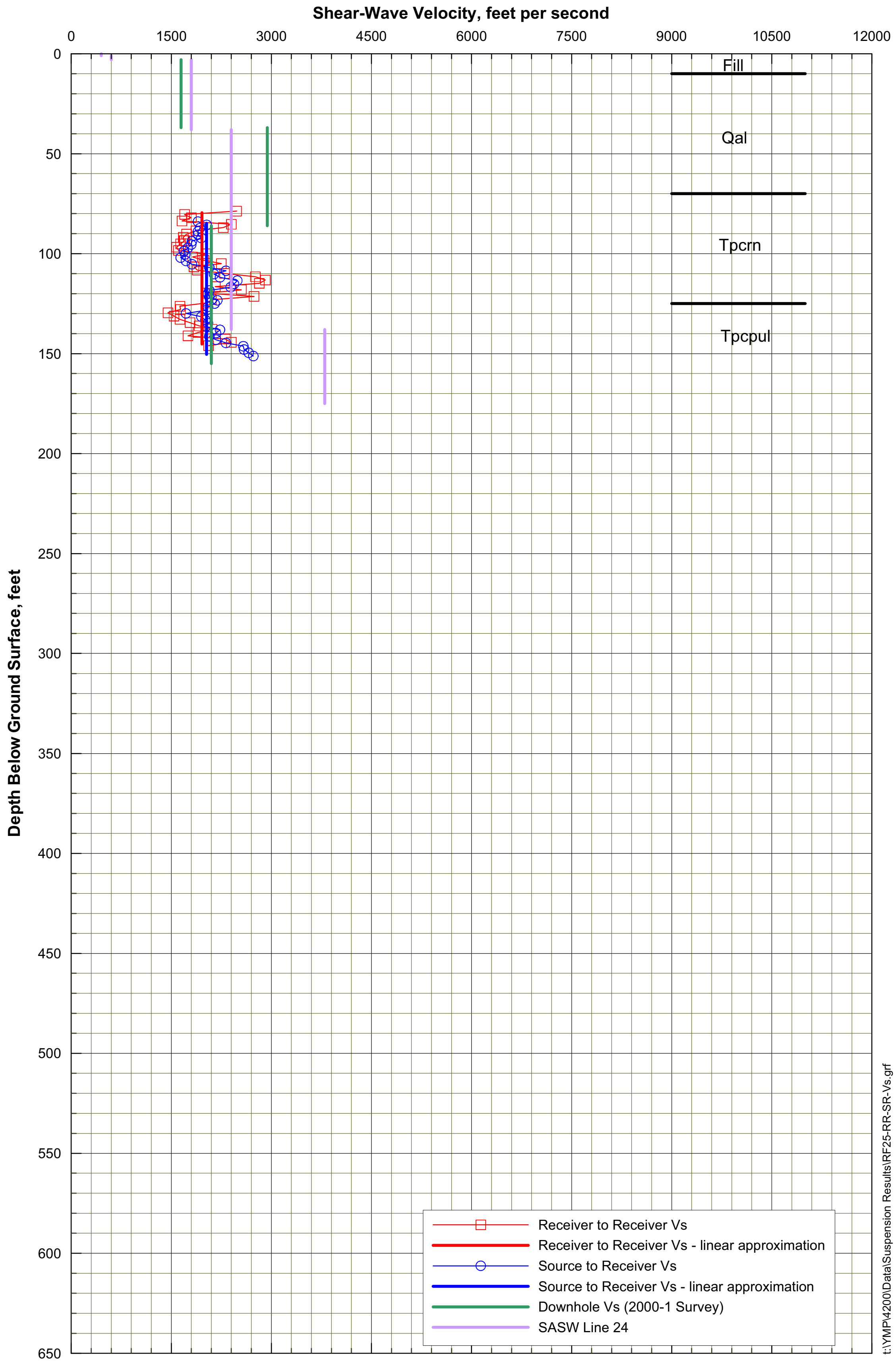
Figure VII-11. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#23.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, MO0110SASWWHBS.000, GS020383114233.003

NOTE: Downhole and SASW velocities are shown for comparison.

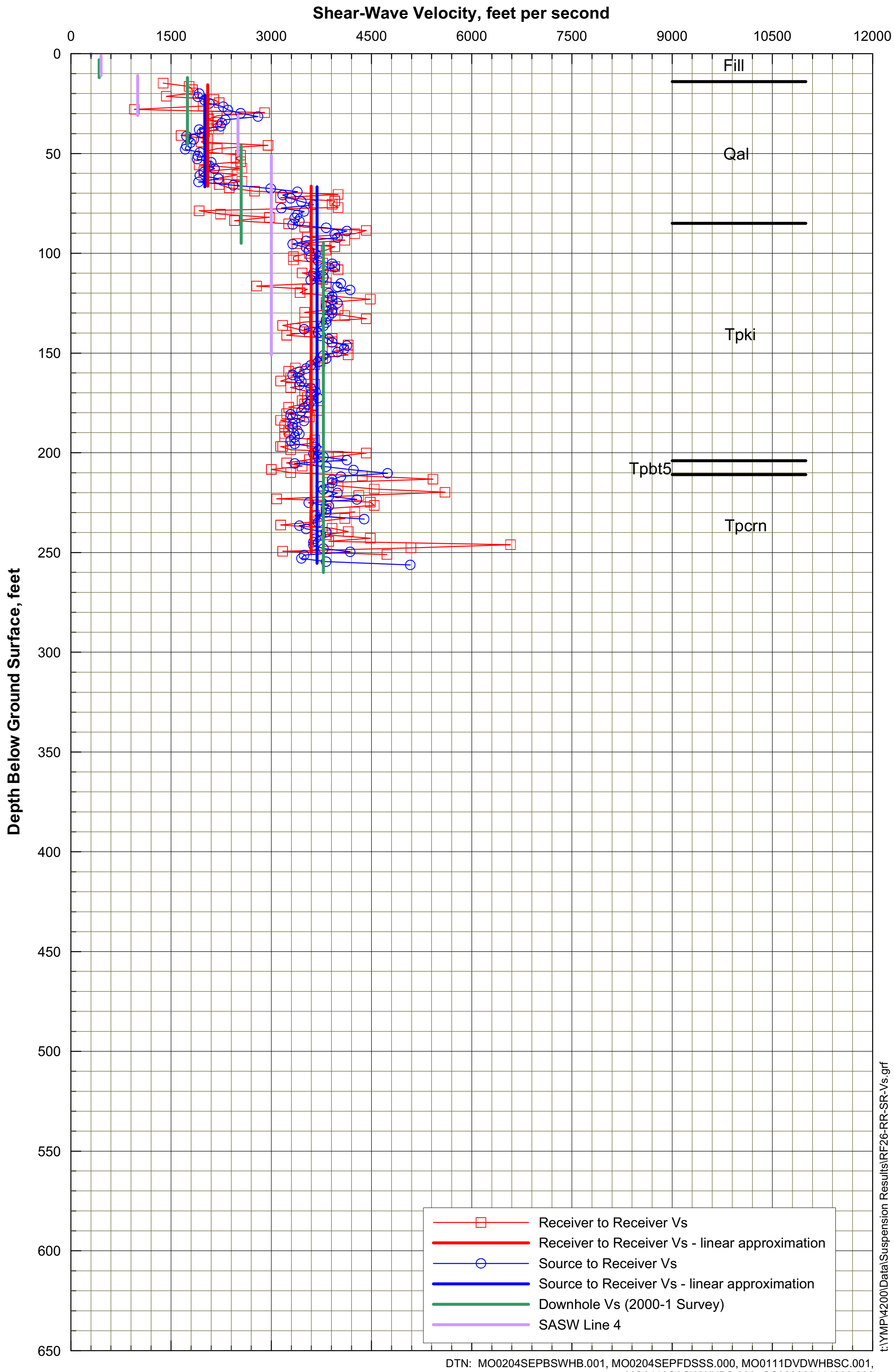
Figure VII-12. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#24.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, MO0110SASWWHBS.000, GS020383114233.003

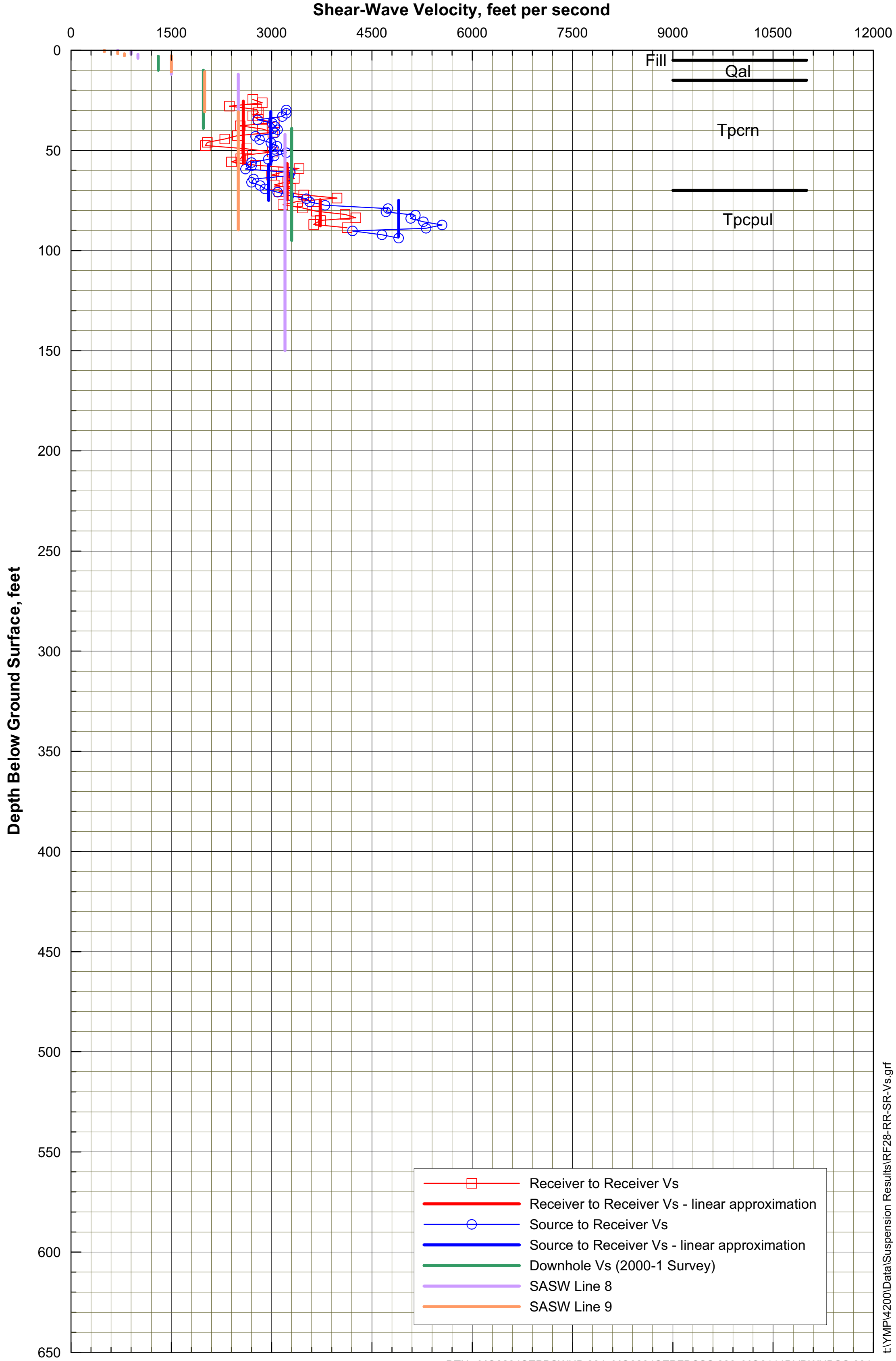
NOTE: Downhole and SASW velocities are shown for comparison.

Figure VII-13. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#25.



NOTE: Downhole and SASW velocities are shown for comparison.

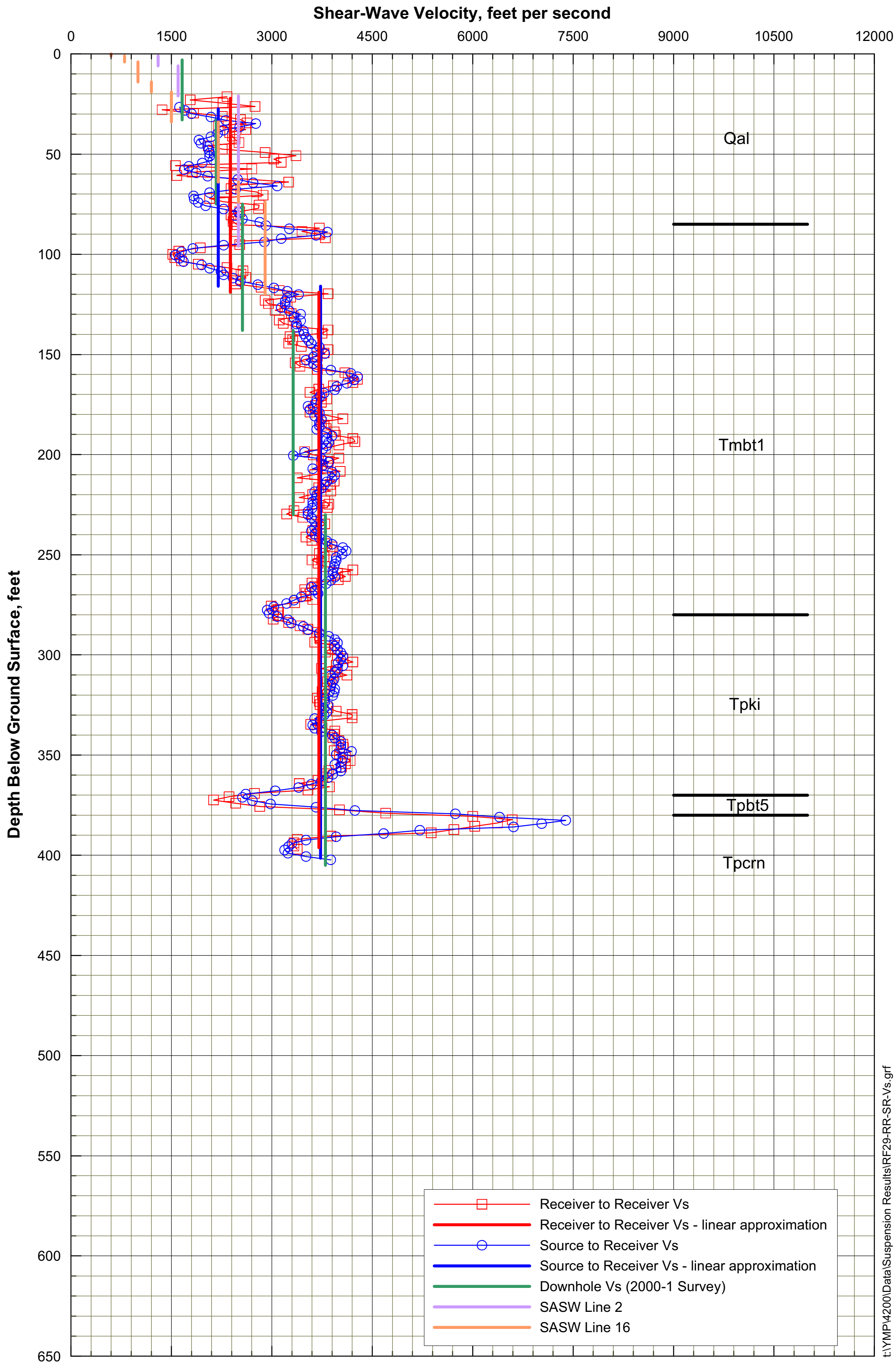
Figure VII-14. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#26.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, MO0110SASWWHBS.000, GS020383114233.003

NOTE: Downhole and SASW velocities are shown for comparison.

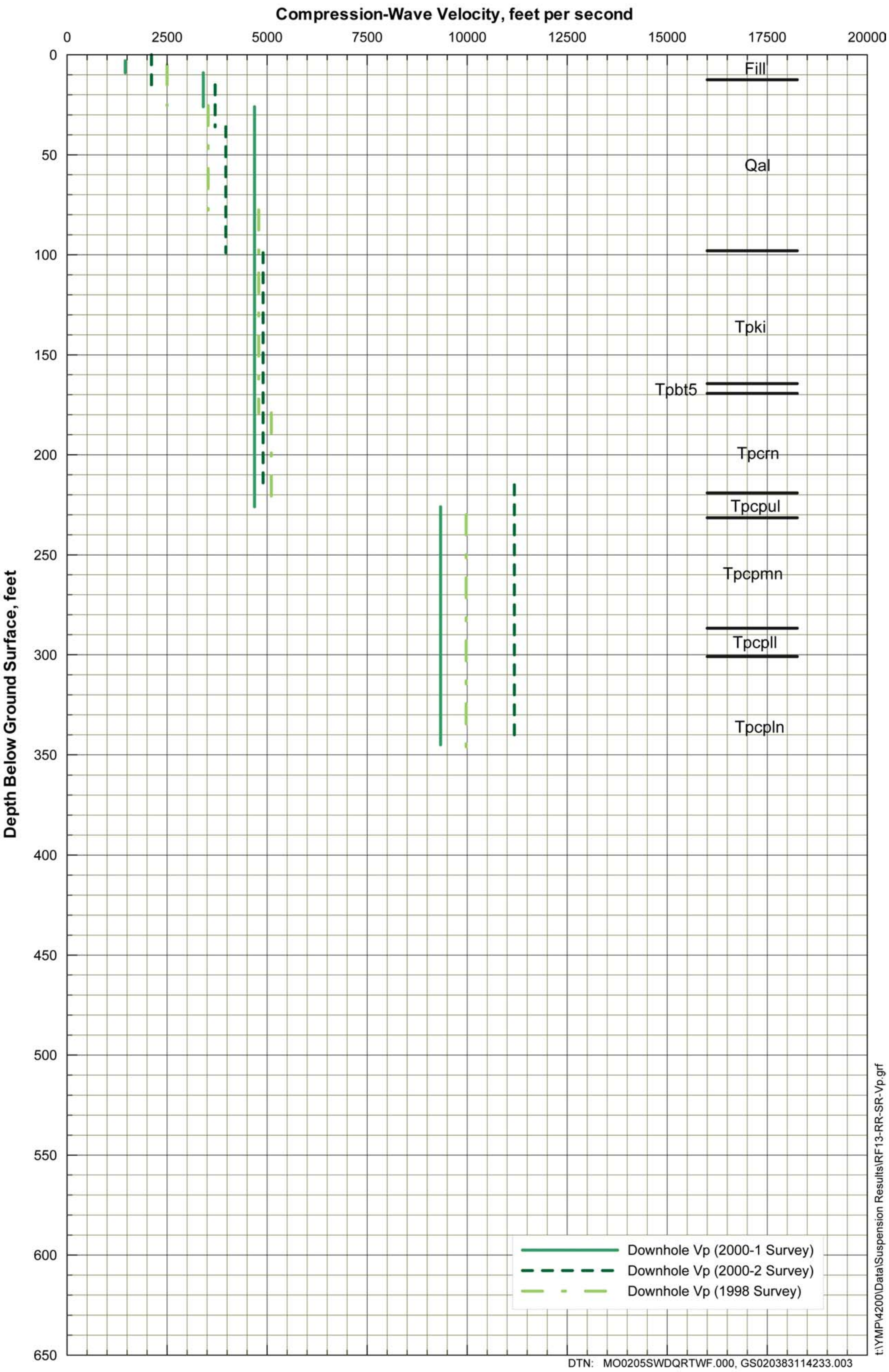
Figure VII-15. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#28.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, MO0110SASWWHBS.000, GS020383114233.003

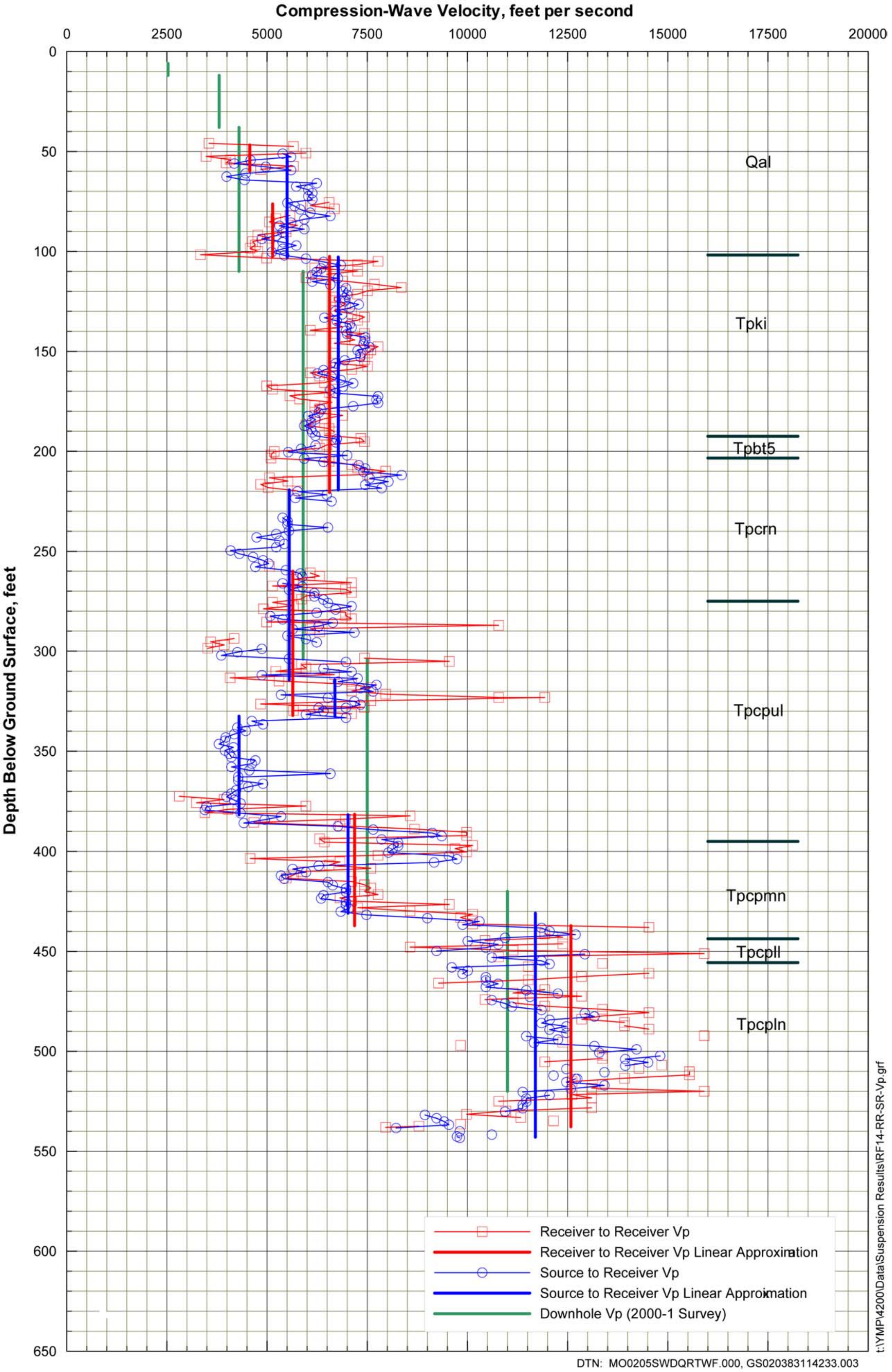
NOTE: Downhole and SASW velocities are shown for comparison.

Figure VII-16. Shear-Wave Velocity (v_S) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#29.



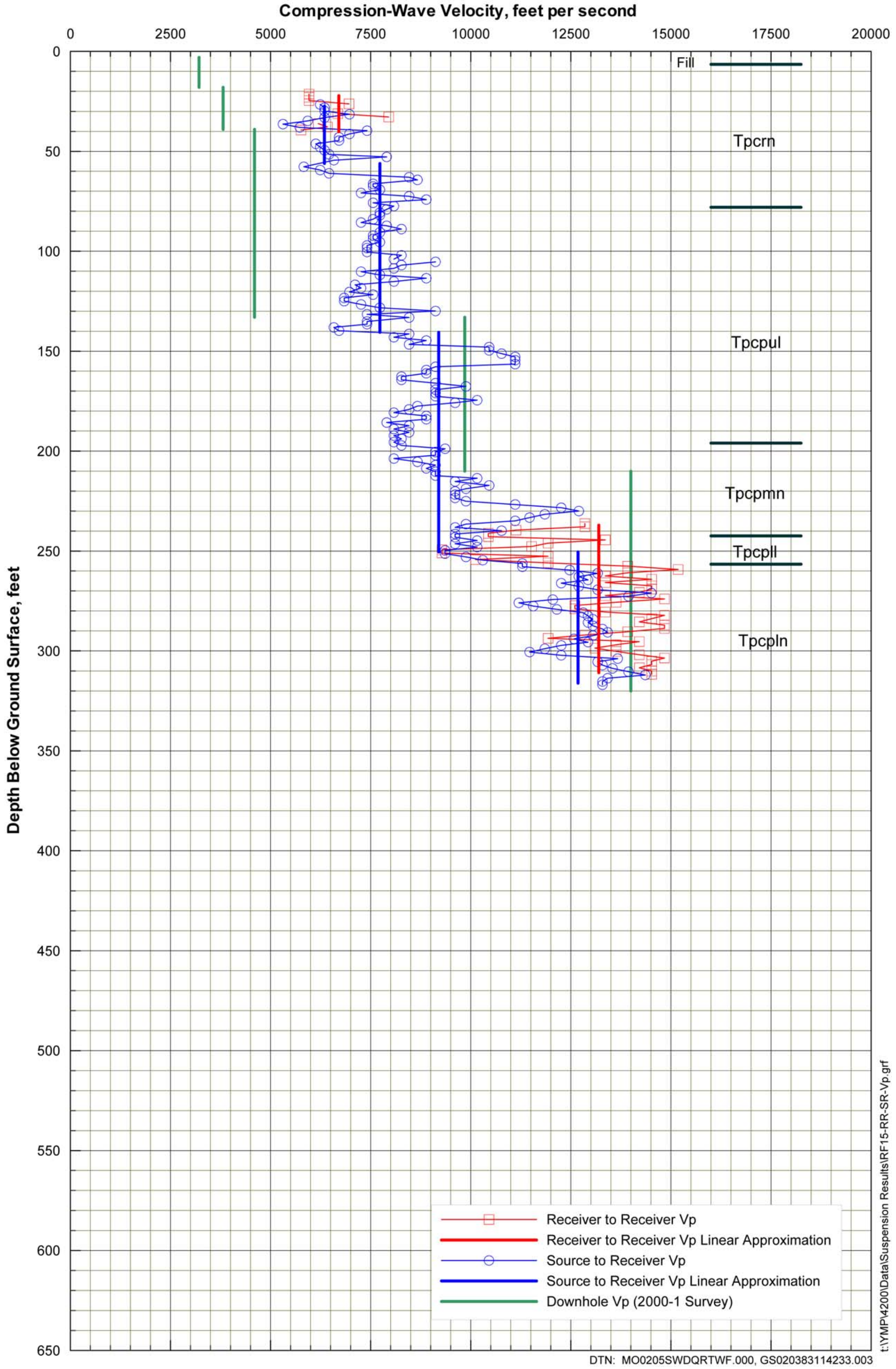
NOTE: Although no compression wave data were available from the suspension seismic survey, this plot is included to show the agreement between the three downhole velocity profiles.

Figure VII-17. Compression-Wave Velocity Profiles (v_p) from Downhole Seismic Surveys at Borehole RF#13.



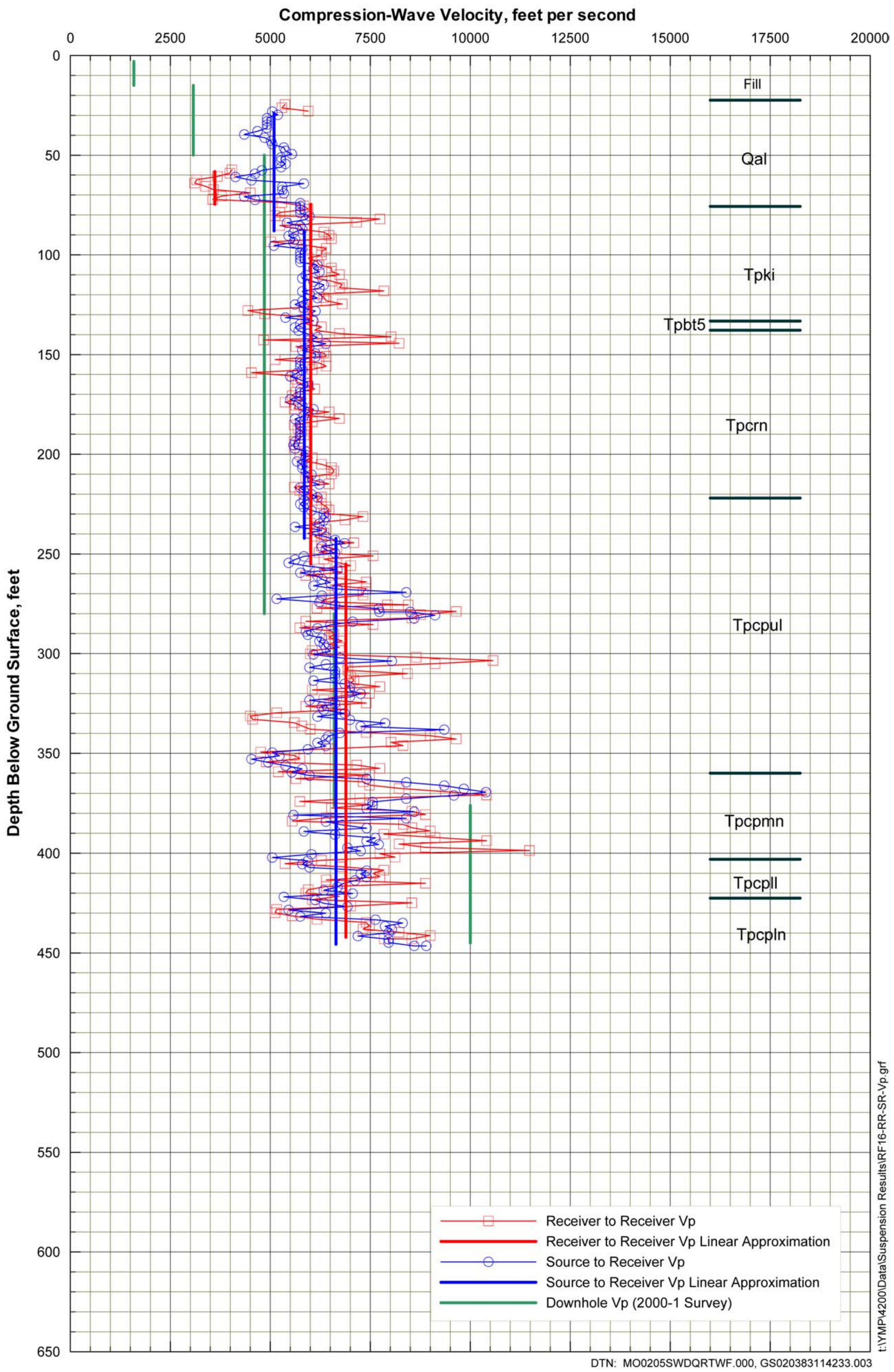
NOTE: Downhole velocities are shown for comparison.

Figure VII-18. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#14.



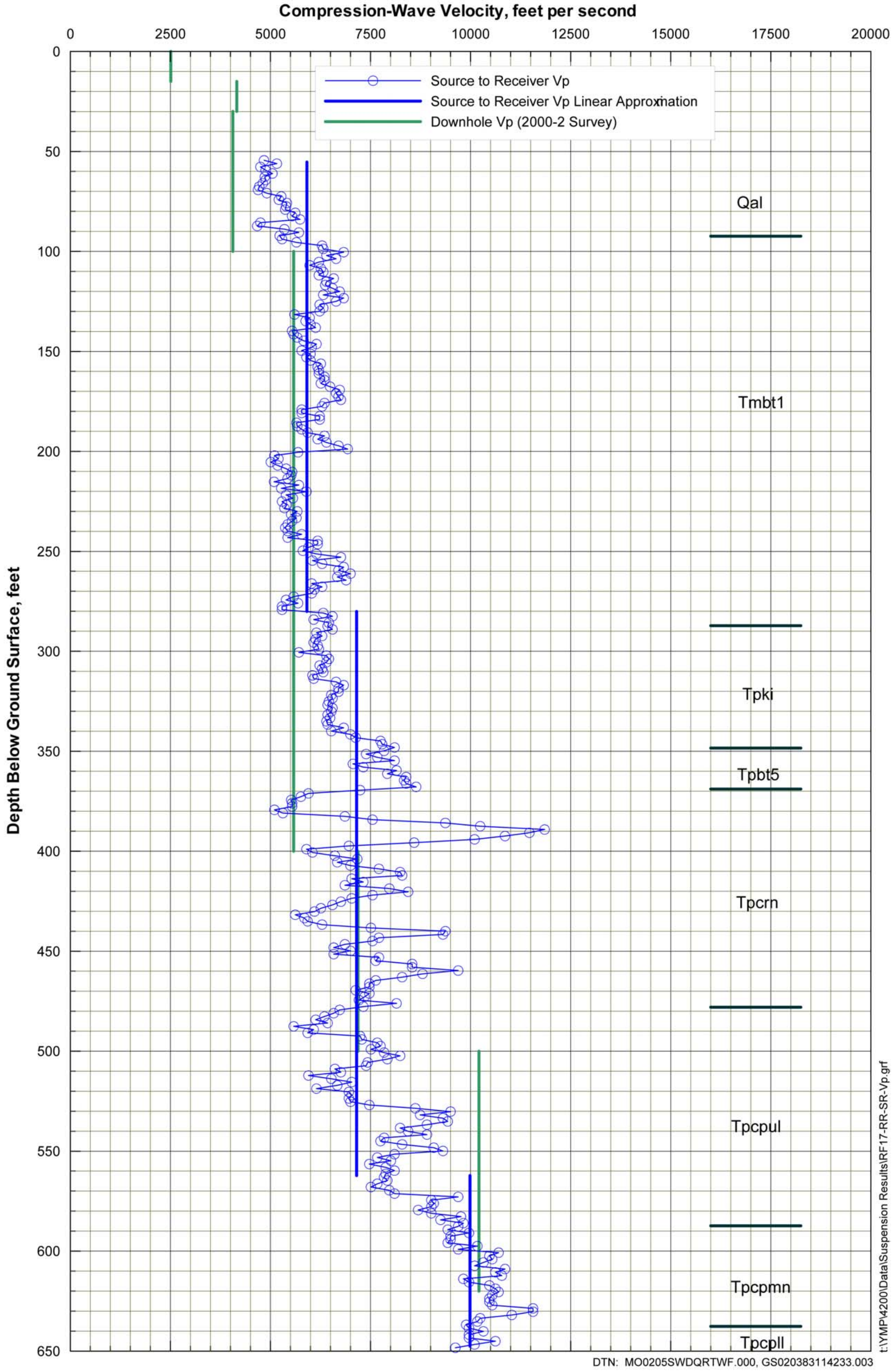
NOTE: Downhole velocities are shown for comparison.

Figure VII-19. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#15.



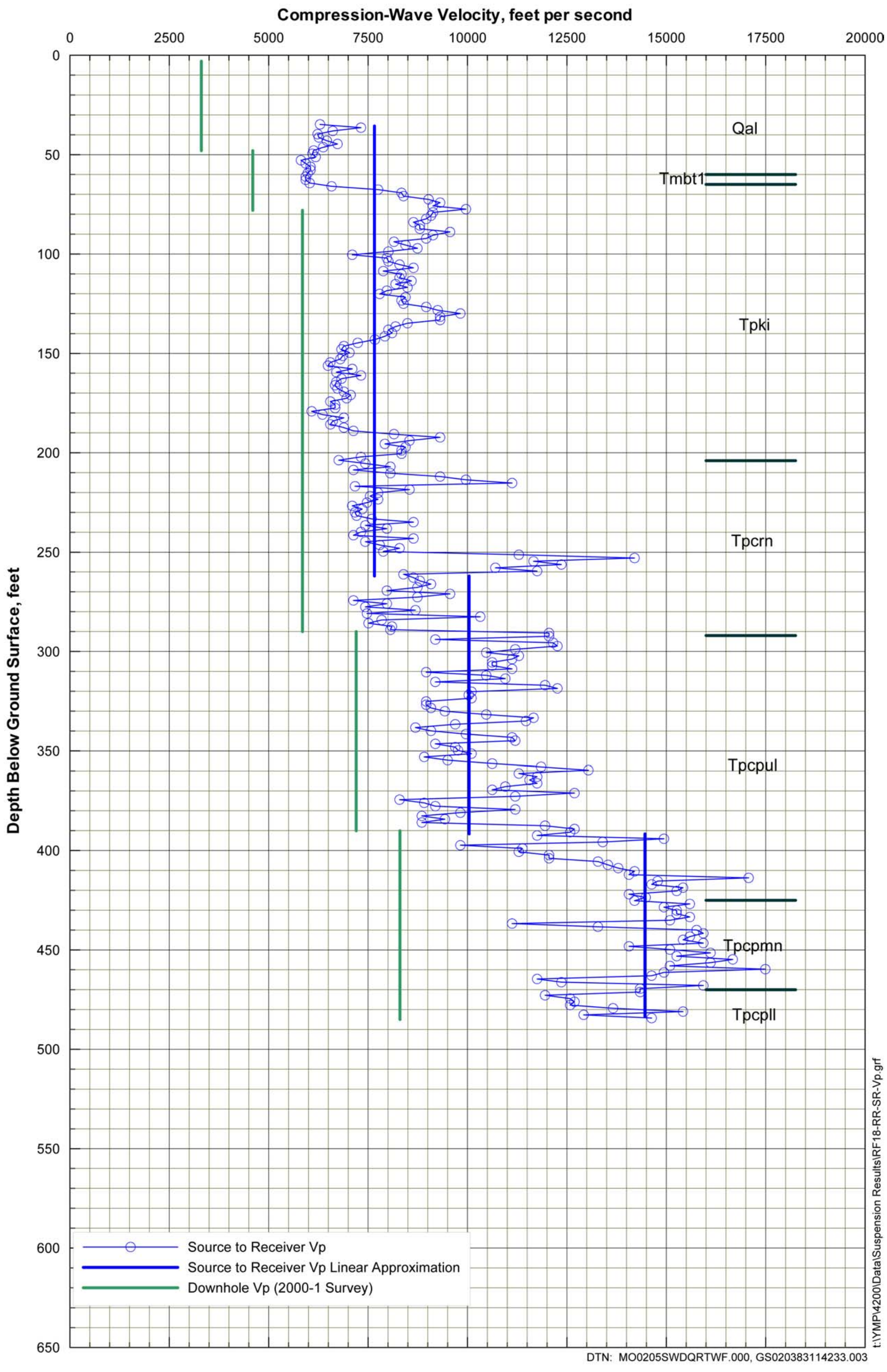
NOTE: Downhole velocities are shown for comparison.

Figure VII-20. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#16.



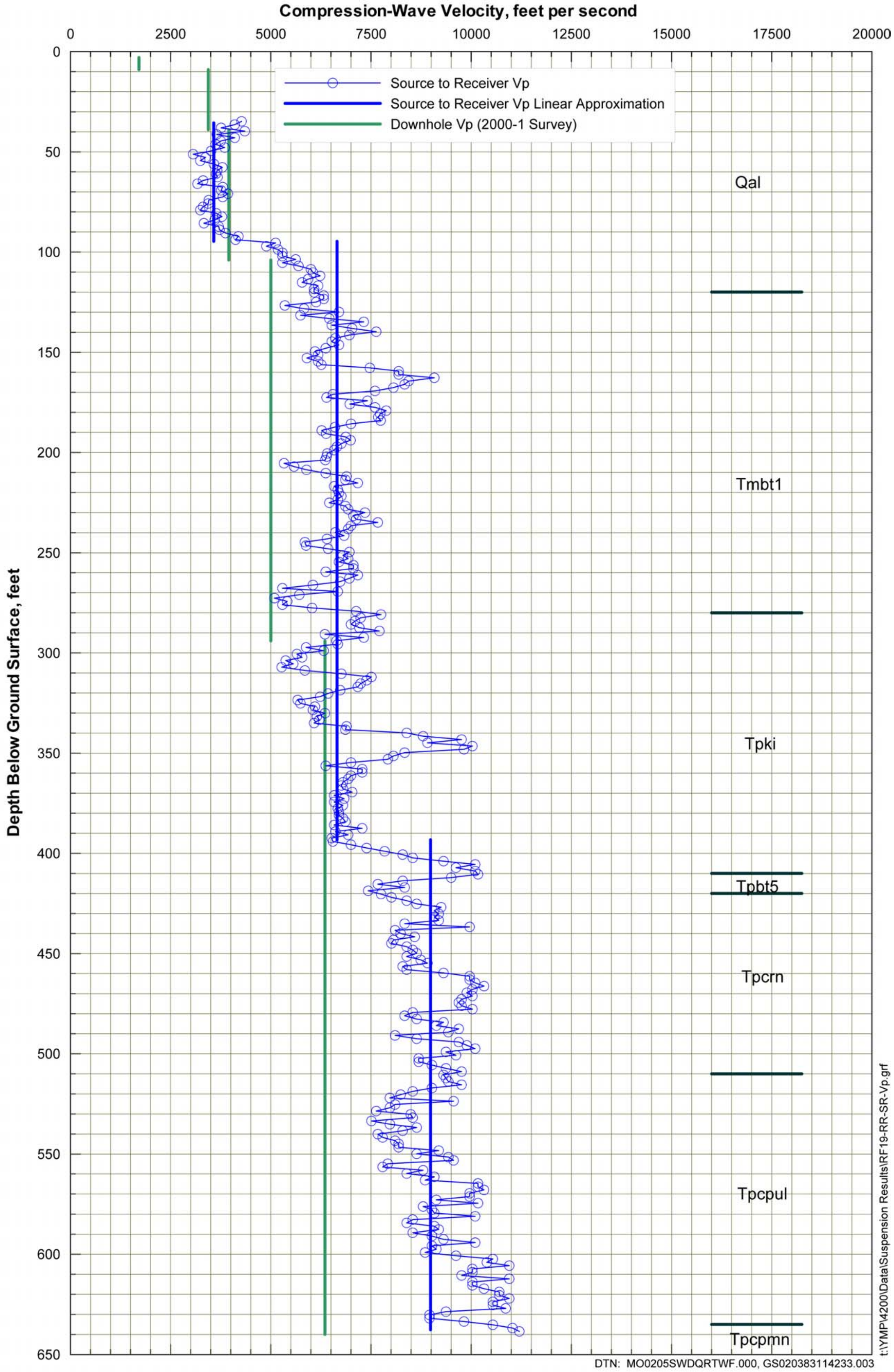
NOTE: Downhole velocities are shown for comparison.
No data for receiver-to-receiver.

Figure VII-21. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver Data at Borehole RF#17.



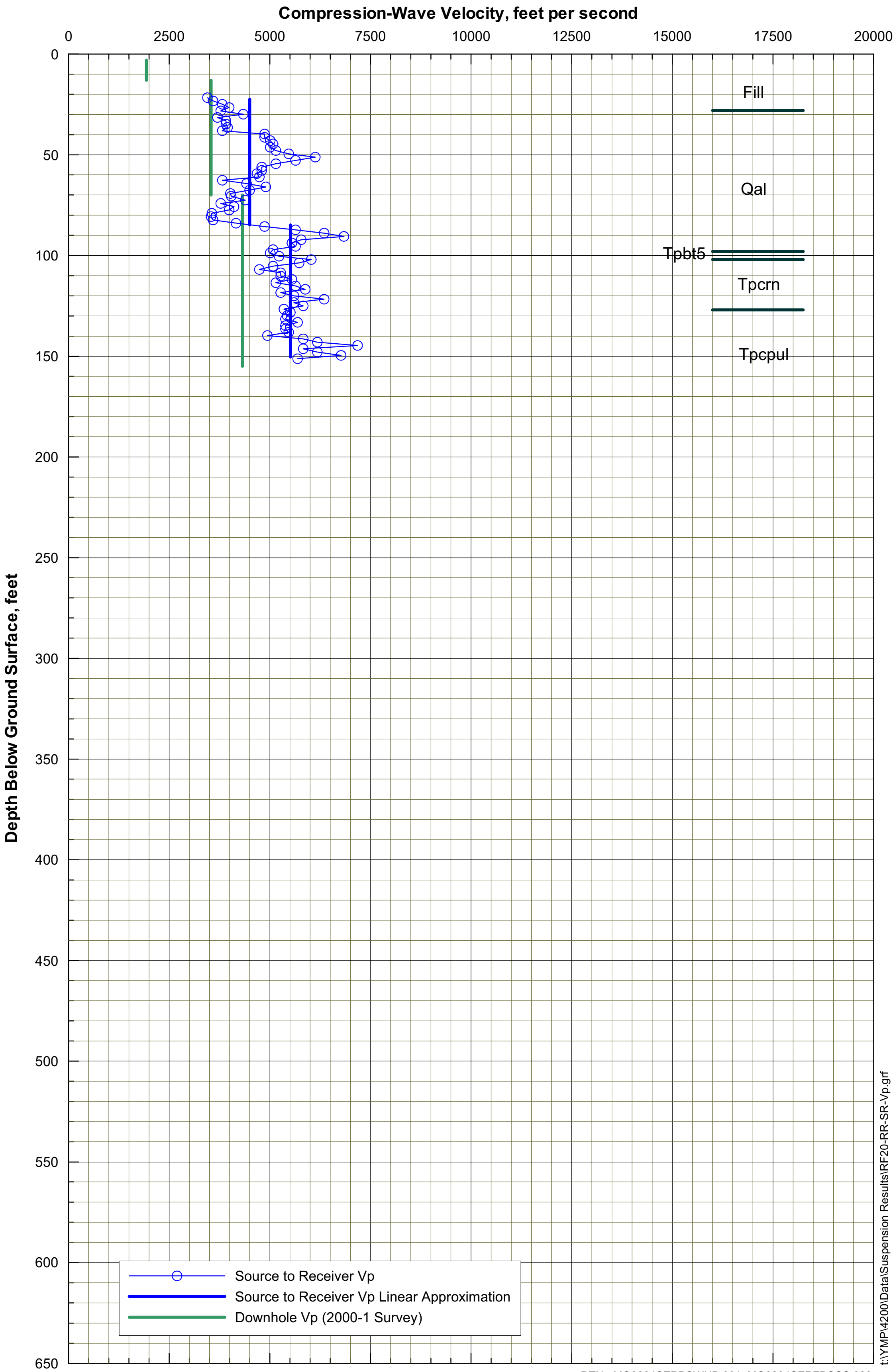
NOTE: Downhole velocities are shown for comparison.
No data for receiver-to-receiver.

Figure VII-22. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver Data at Borehole RF#18.



NOTE: Downhole velocities are shown for comparison.
No data for receiver-to-receiver.

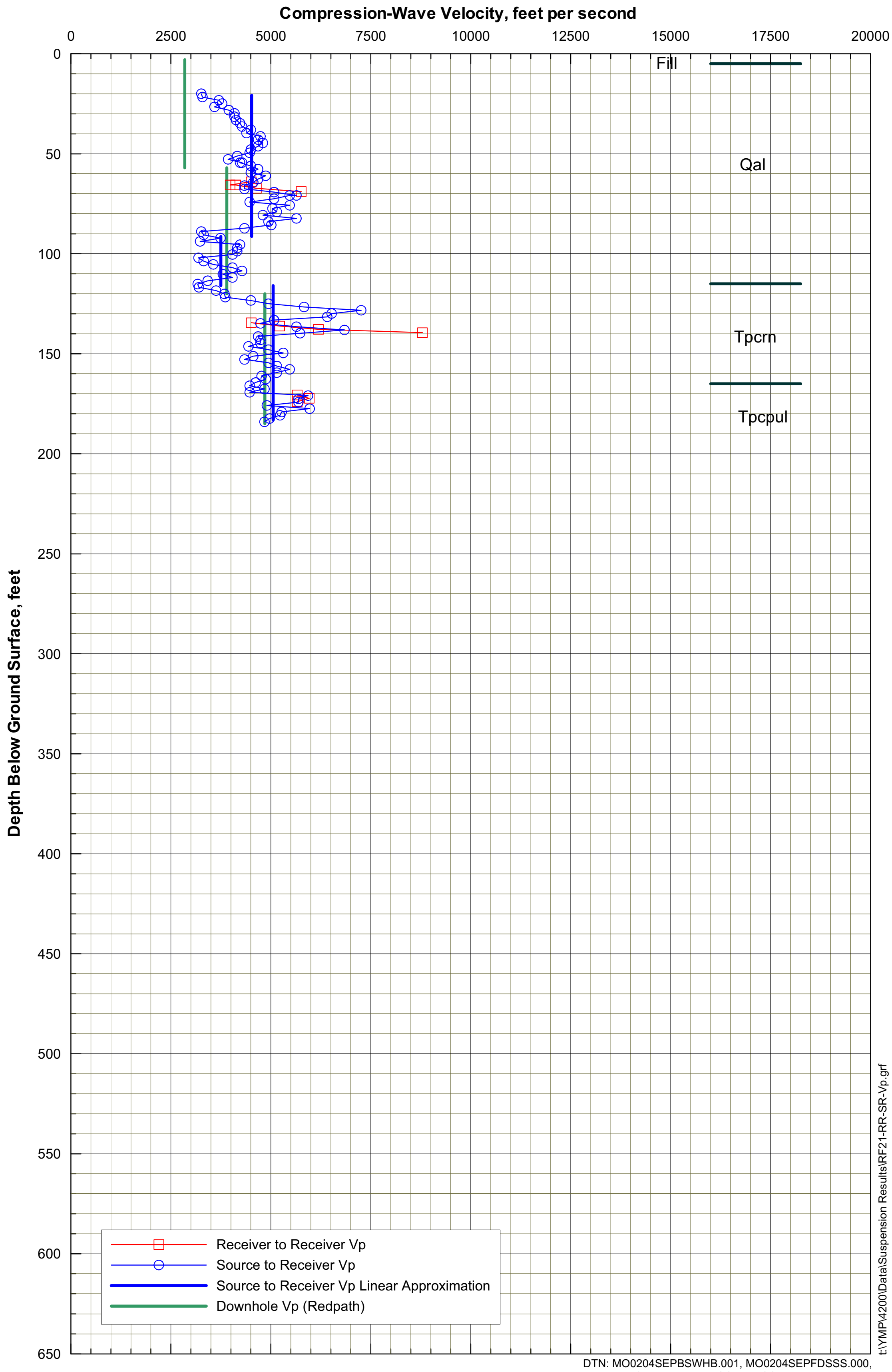
Figure VII-23. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver Data at Borehole RF#19.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, GS020383114233.003

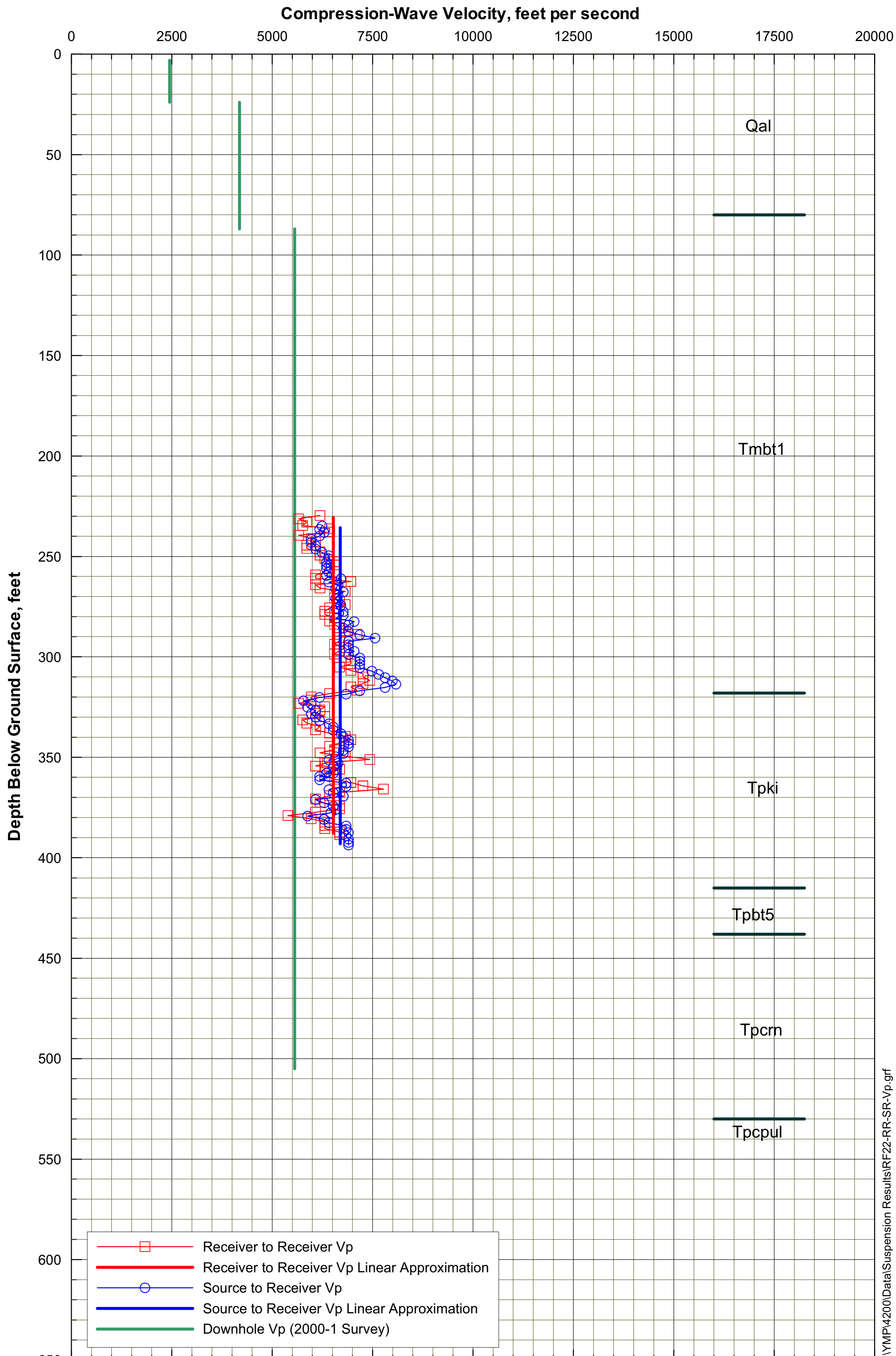
NOTE: Downhole velocities are shown for comparison.
No data for receiver-to-receiver.

Figure VII-24. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver Data at Borehole RF#20.



NOTE: Downhole velocities are shown for comparison.
Linear Approximation of receiver-to-receiver
not applicable due to insuficience of data points

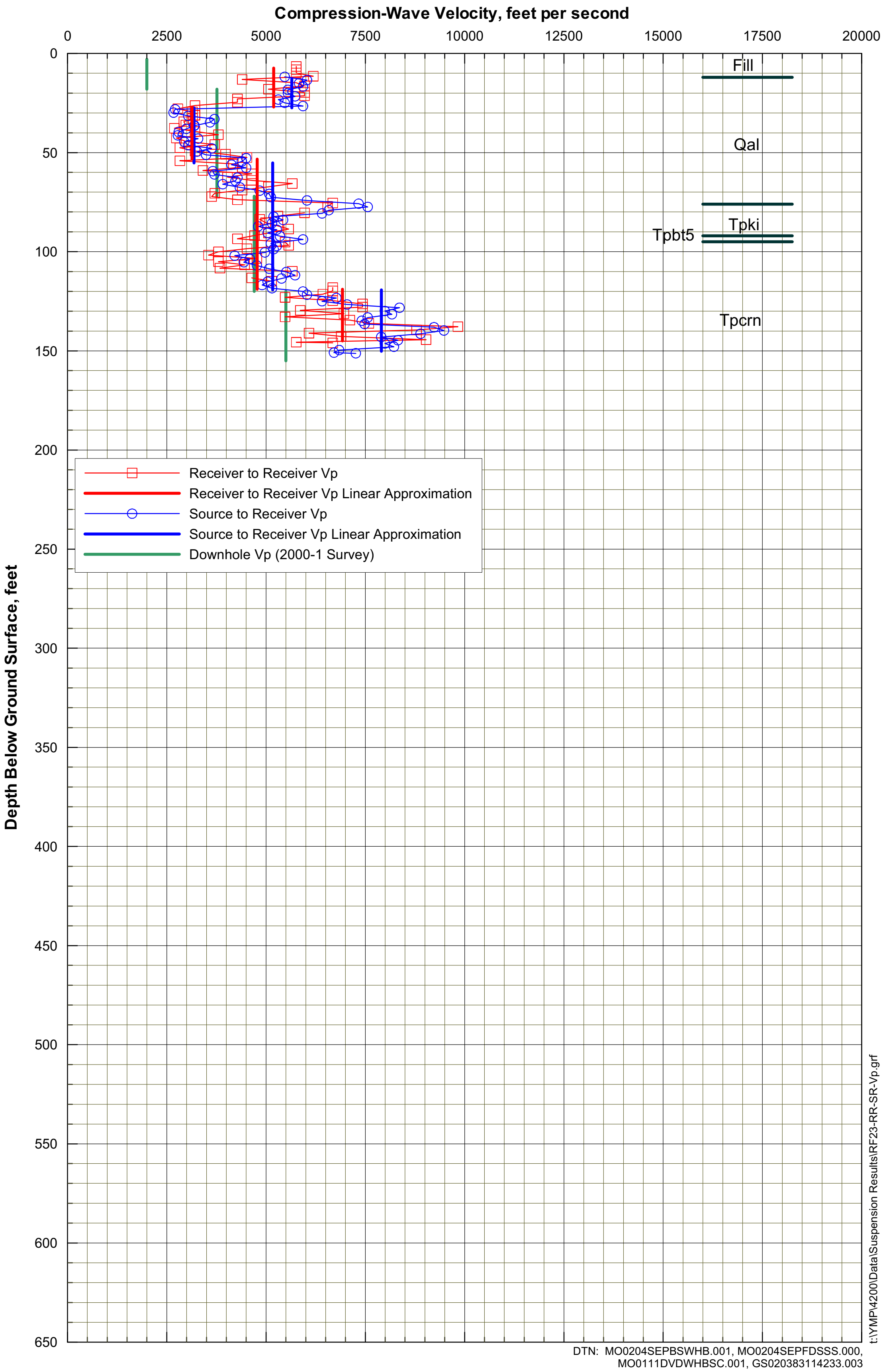
Figure VII-25. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#21.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, GS020383114233.003

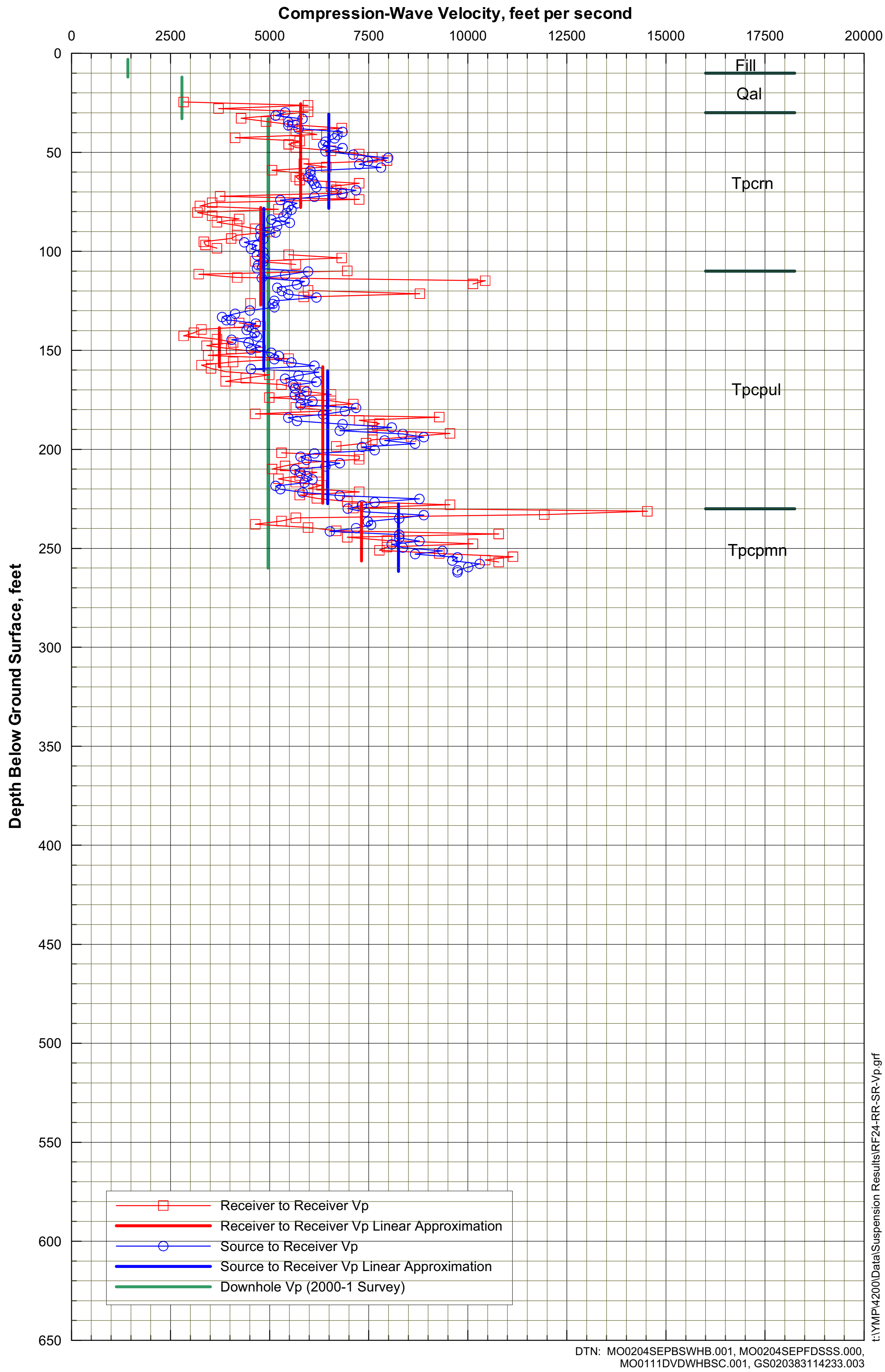
NOTE: Downhole velocities are shown for comparison.

Figure VII-26. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#22.



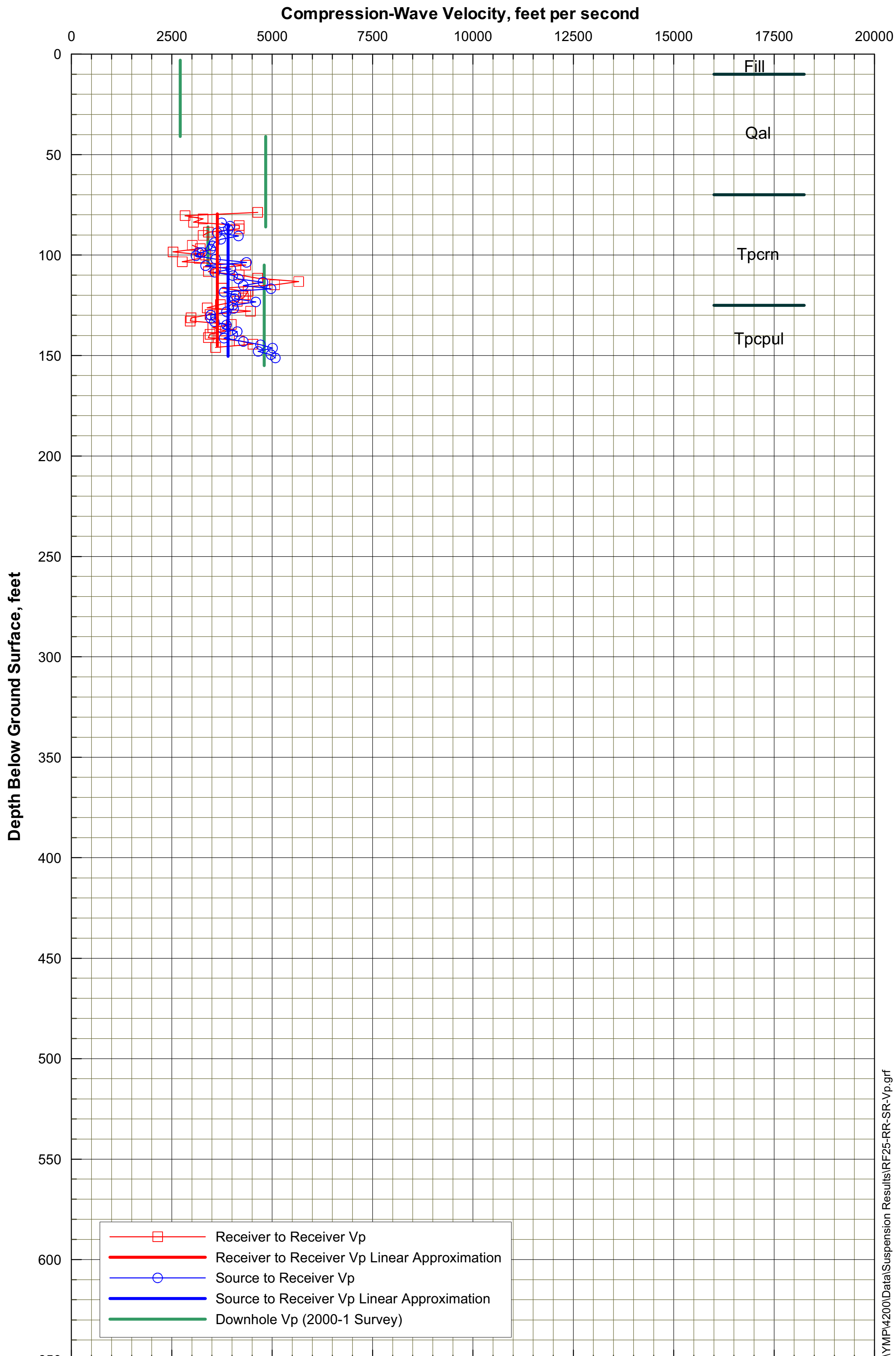
NOTE: Downhole velocities are shown for comparison.

Figure VII-27. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#23.



NOTE: Downhole velocities are shown for comparison.

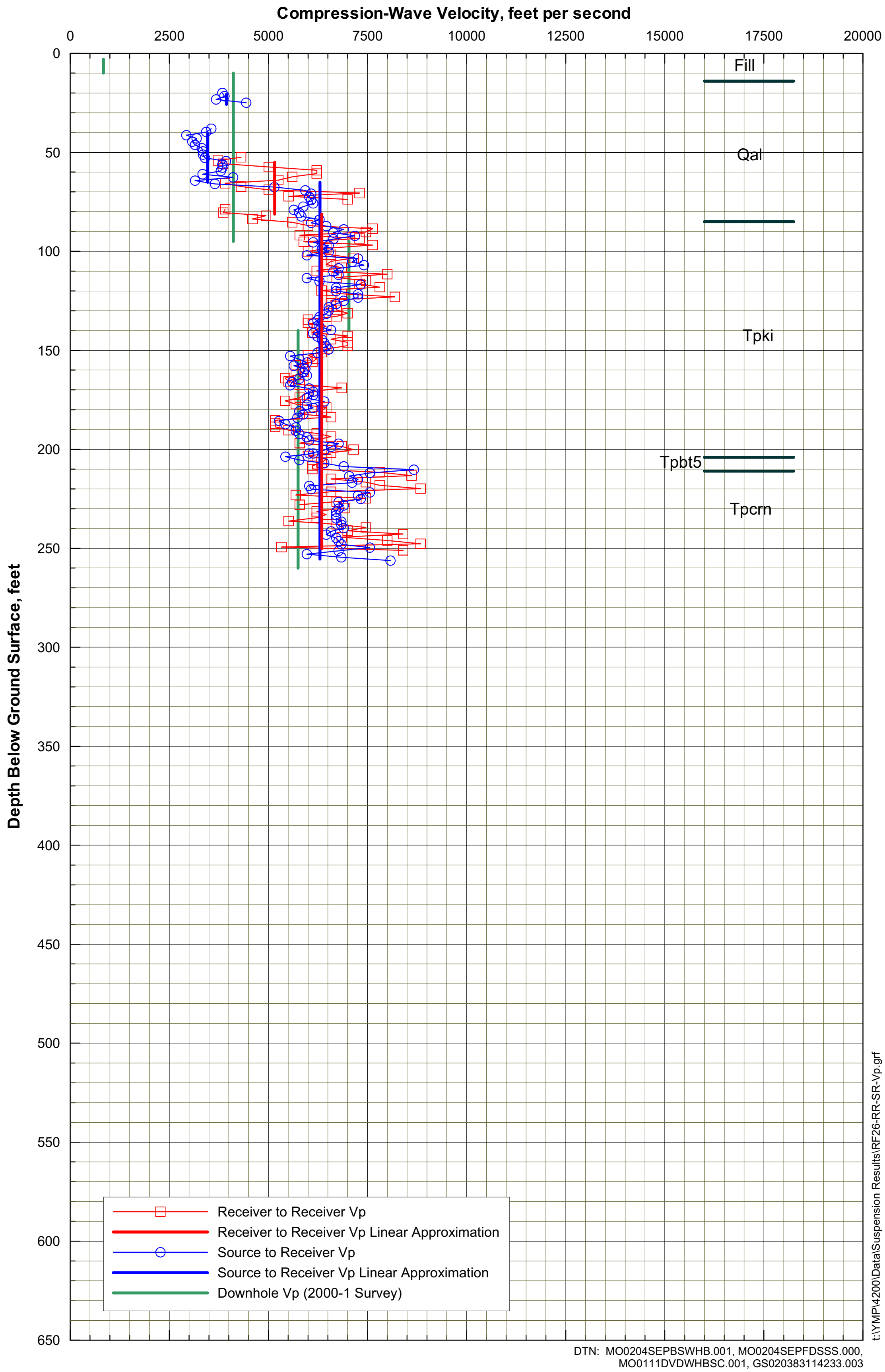
Figure VII-28. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#24.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, GS020383114233.003

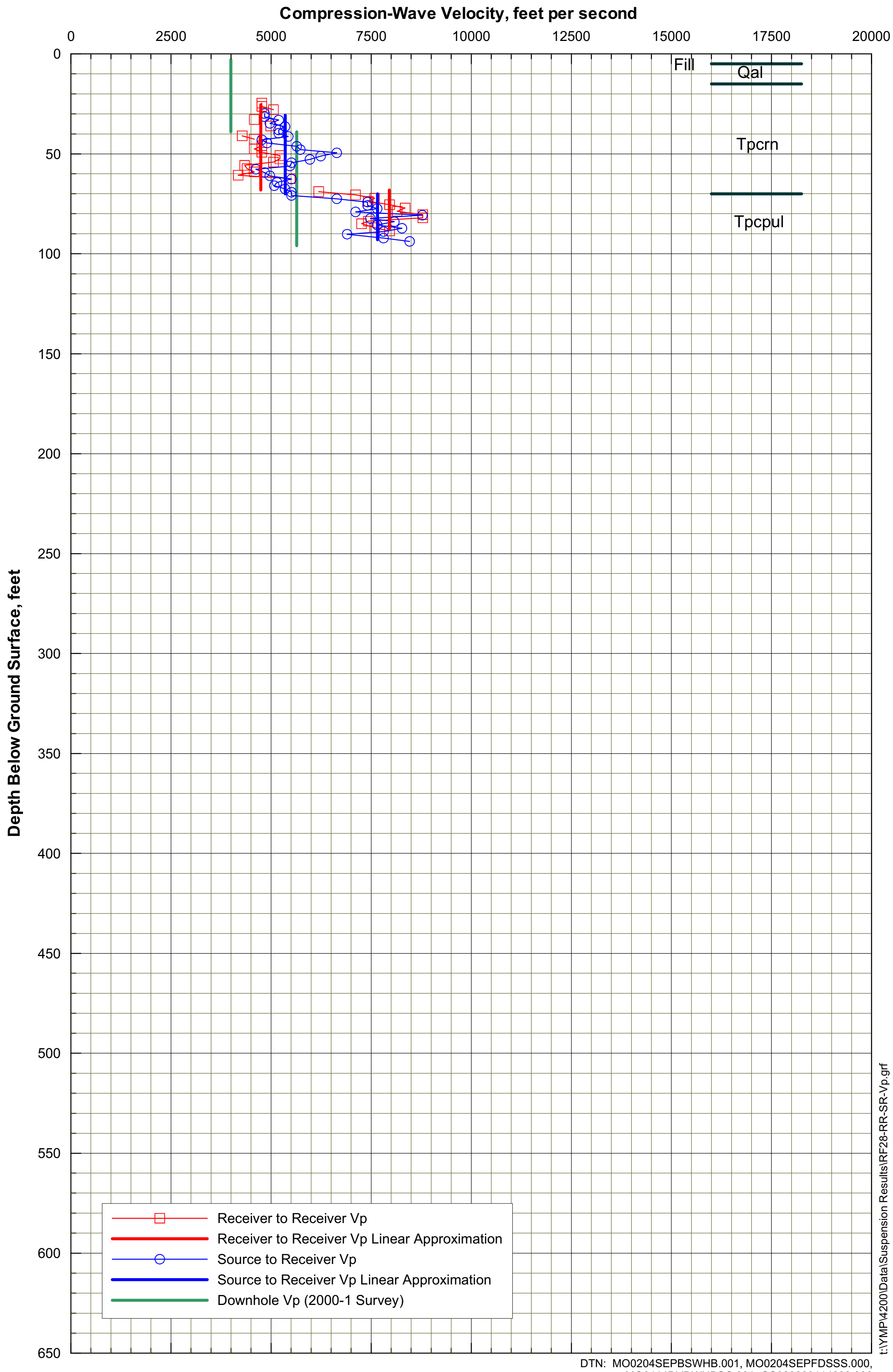
NOTE: Downhole velocities are shown for comparison.

Figure VII-29. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#25.



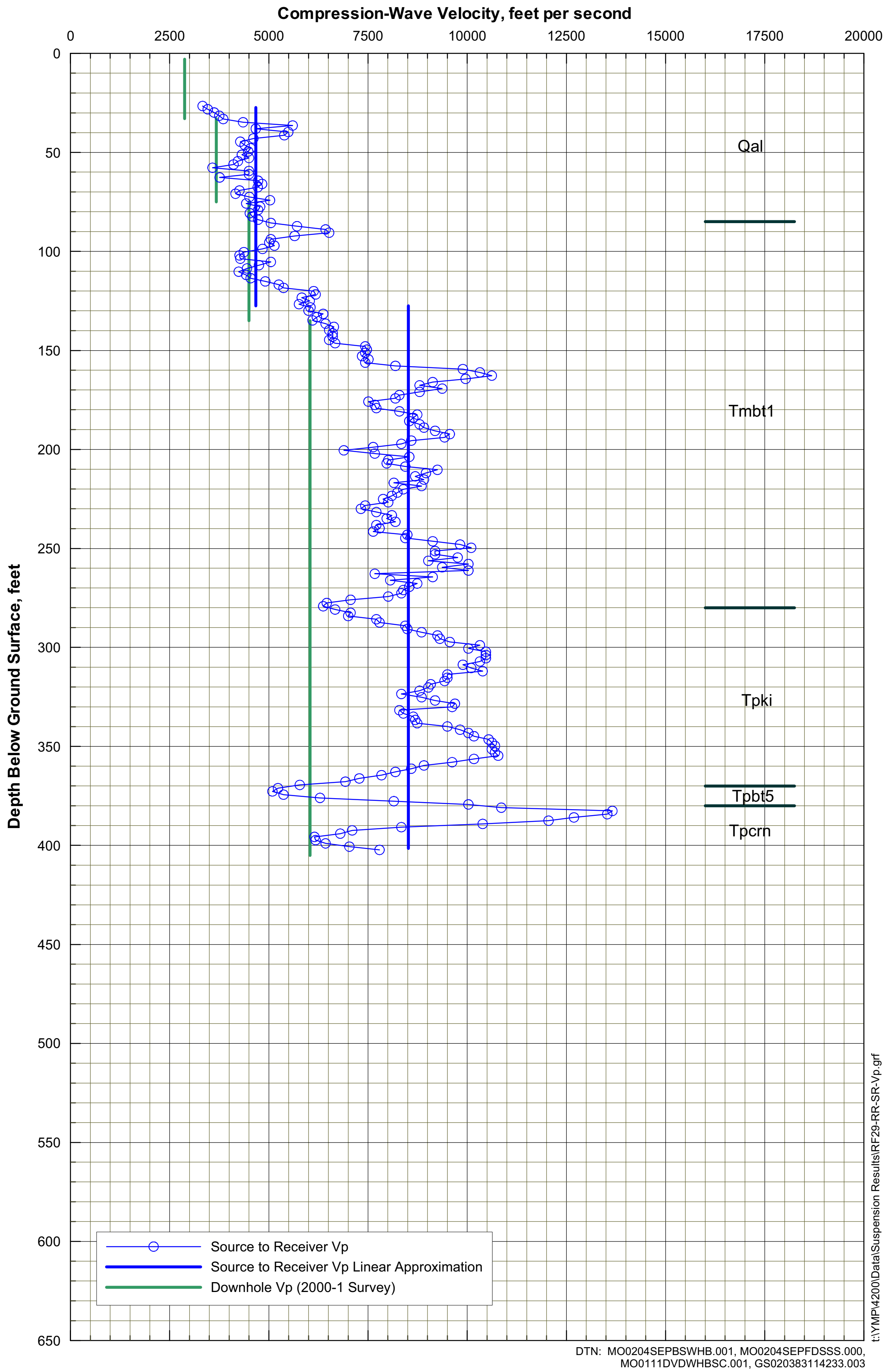
NOTE: Downhole velocities are shown for comparison.

Figure VII-30. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#26.



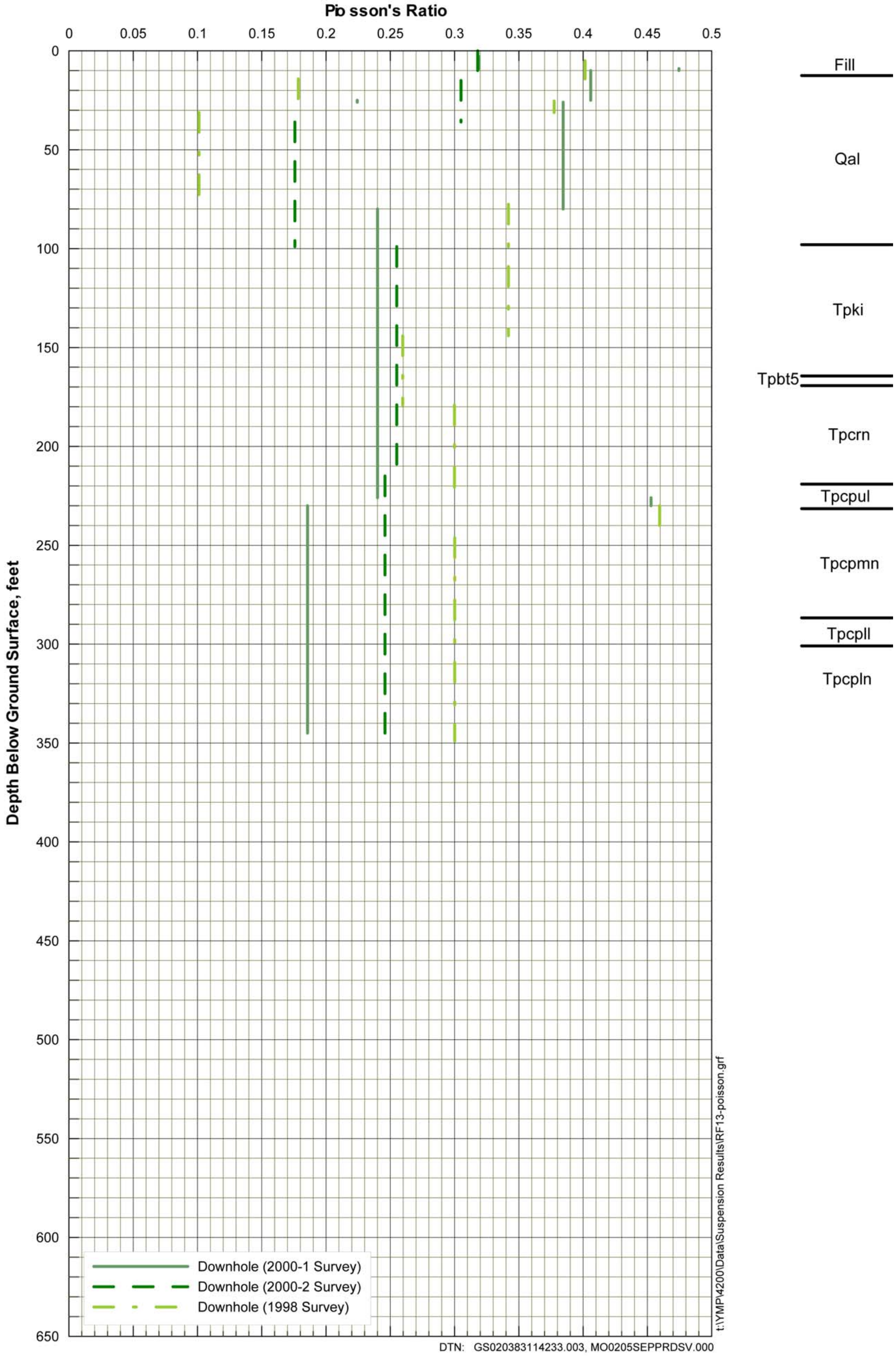
NOTE: Downhole velocities are shown for comparison.

Figure VII-31. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole UE-RF#28.



NOTE: Downhole velocities are shown for comparison.
No data for receiver-to-receiver.

Figure VII-32. Compression-Wave Velocity (v_p) from Suspension Seismic Source-to-Receiver Data at Borehole RF#29.



NOTE: Although no Poisson's ratio data were available from the suspension seismic survey, this plot is included to show the agreement between the three downhole profiles.

Figure VII-33. Poisson's Ratio from Downhole Seismic Surveys at Borehole RF#13.

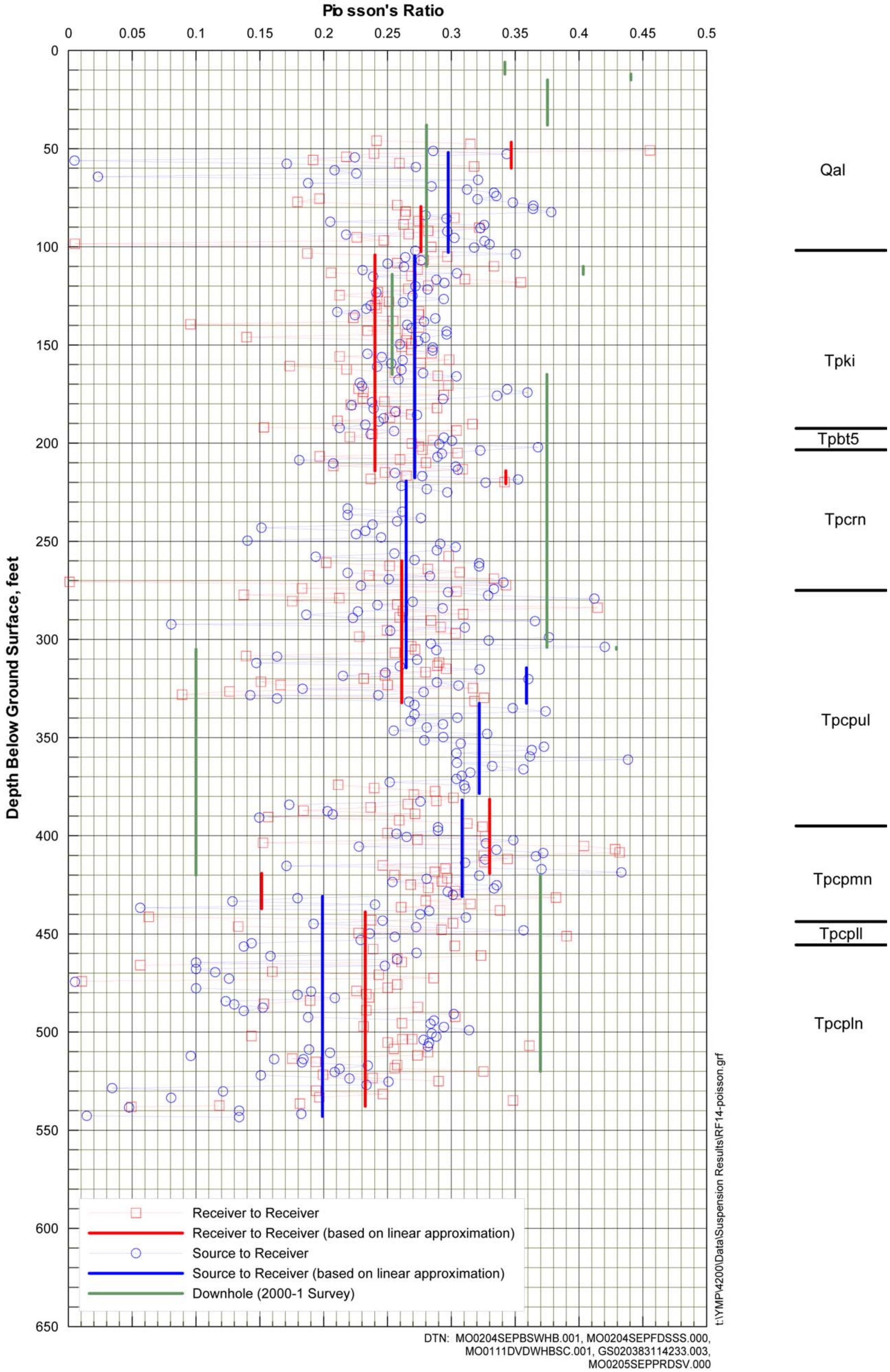
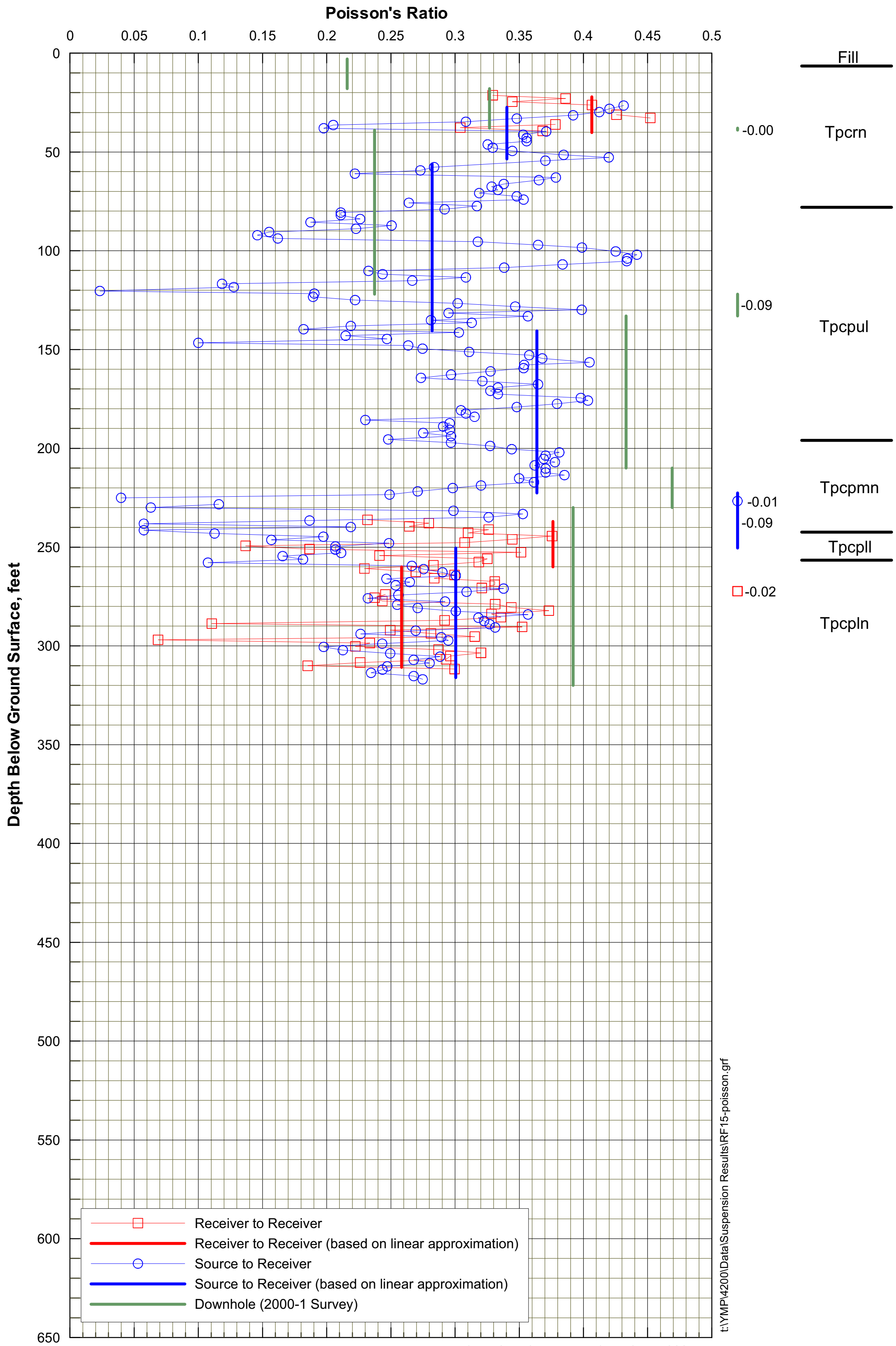


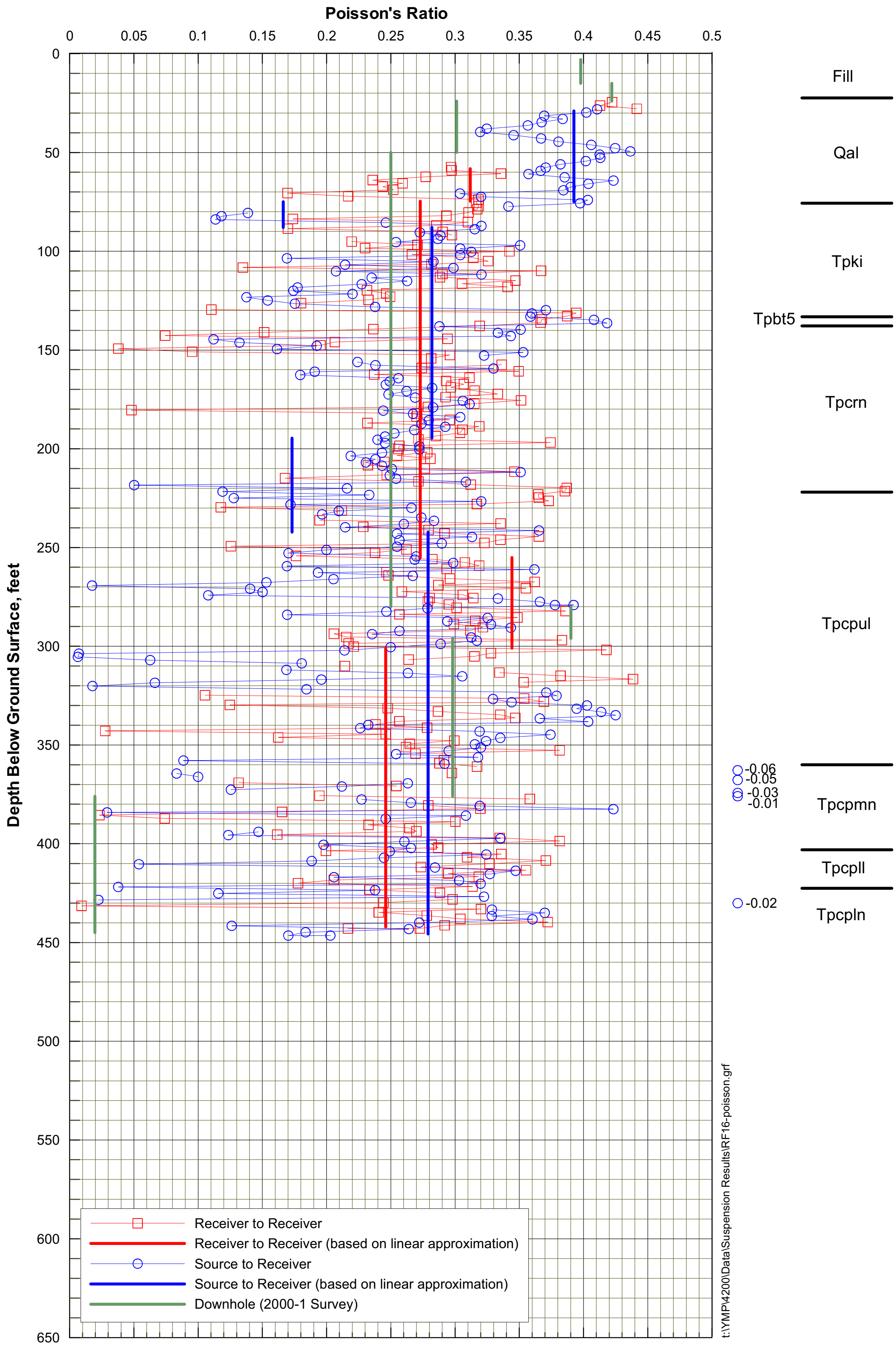
Figure VII-34. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#14.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001,GS020383114233.003, MO0205SEPPRDSV.000

NOTES: Values less than 0.0 and greater than 0.5 are indicated to the right of plot and are not plotted to scale.

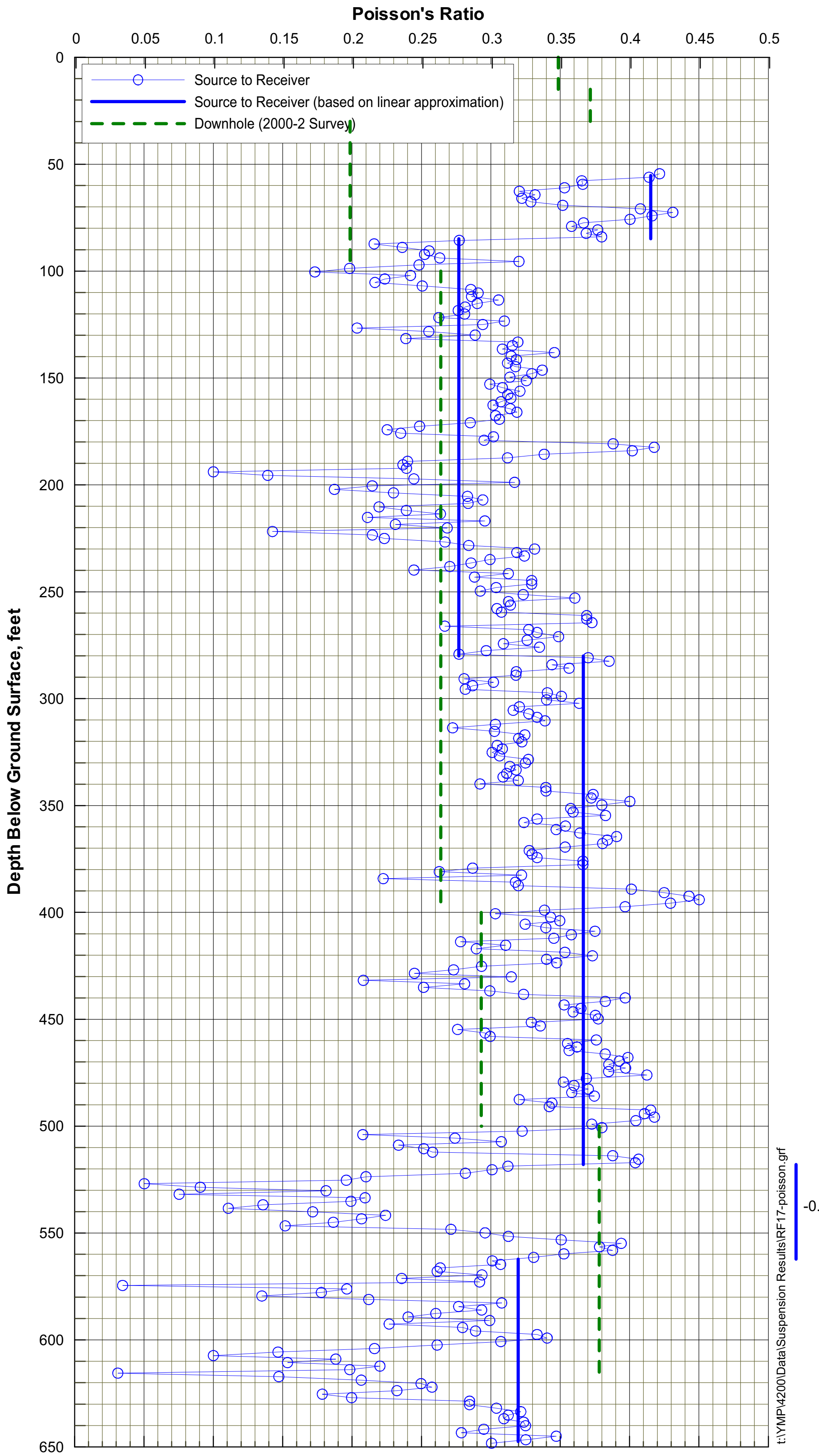
Figure VII-35. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#15.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000,
MO0111DVDWHBSC.001, GS020383114233.003
MO0205SEPPRDSV.000

NOTES: Values less than 0.0 and greater than 0.5
are indicated to the right of plot and are
not plotted to scale.

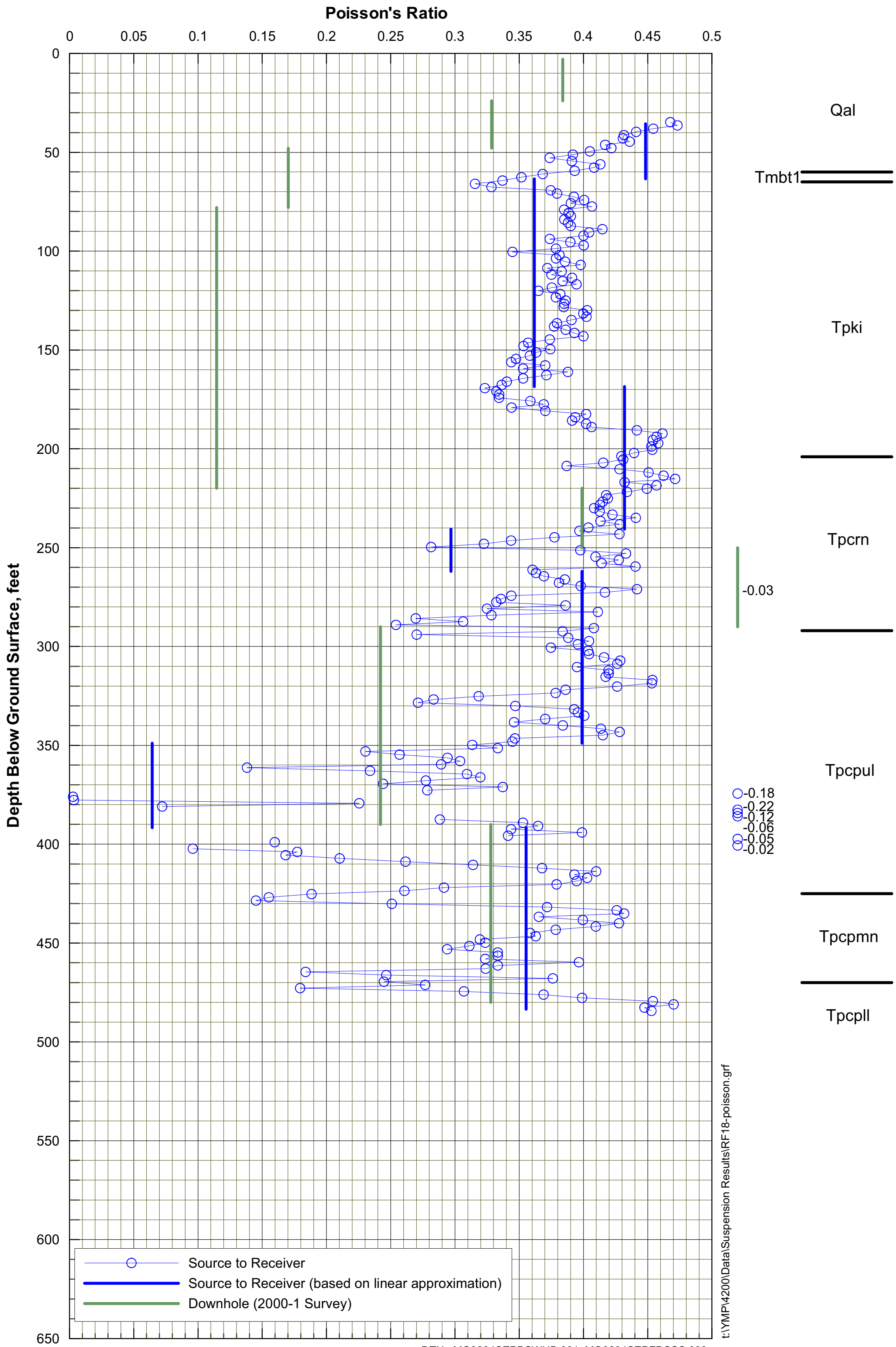
Figure VII-36. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#16.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0110DVDBOREH.000, GS020383114233.003 MO0205SEPPRDSV.000

NOTES: Values less than 0.0 and greater than 0.5 are indicated to the right of plot and are not plotted to scale. No receiver to receiver data.

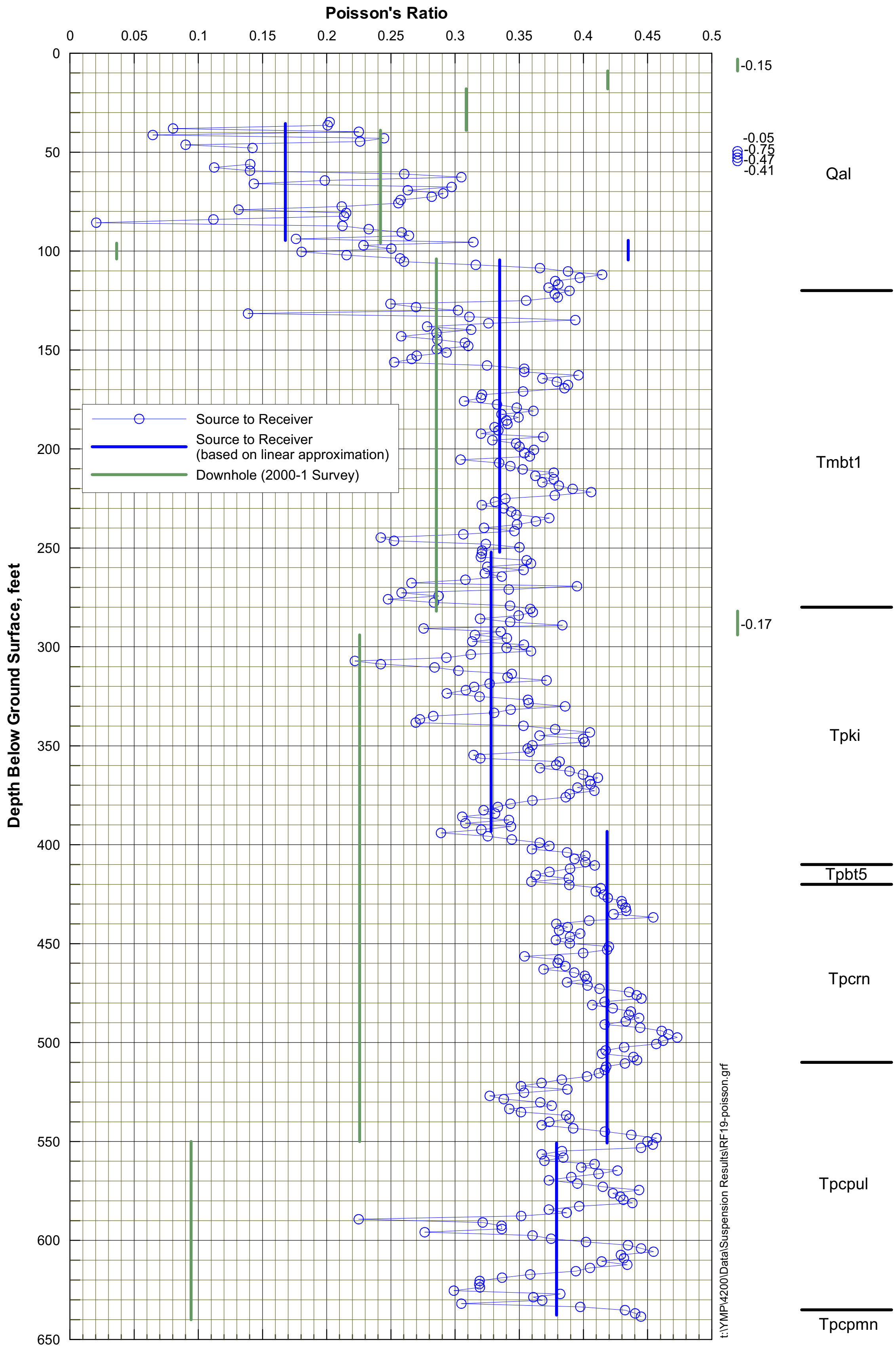
Figure VII-37. Poisson's Ratio from Suspension Seismic Source-to-Receiver Data at Borehole RF#17.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, GS020383114233.003 MO0205SEPPRDSV.000

NOTES: Values less than 0.0 and greater than 0.5 are indicated to the right of plot and are not plotted to scale.
No receiver to receiver data.

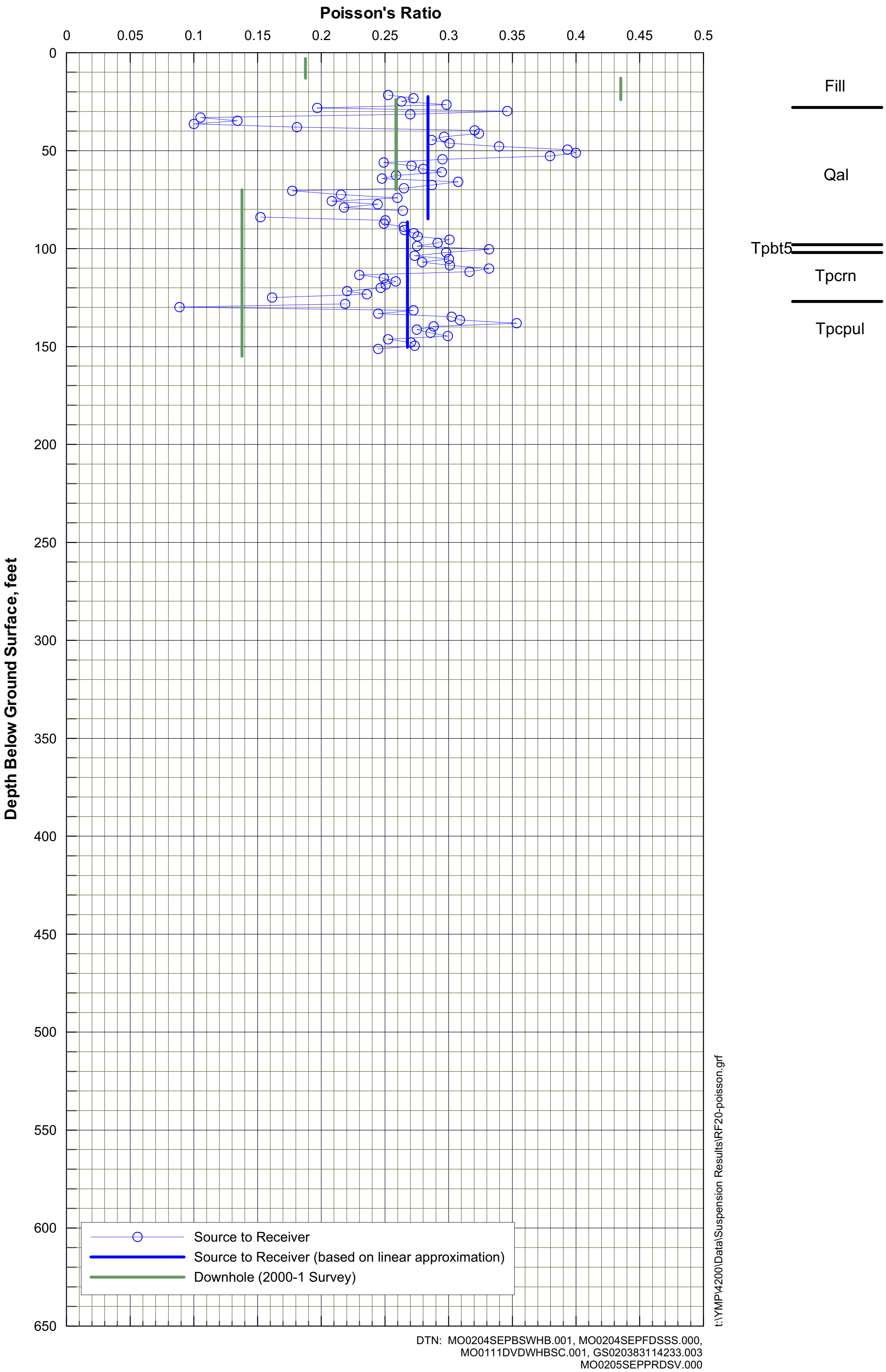
Figure VII-38. Poisson's Ratio from Suspension Seismic Source-to-Receiver Data at Borehole RF#18.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000,
MO0111DVDWHBSC.001, GS020383114233.003
MO0205SEPPRDSV.000

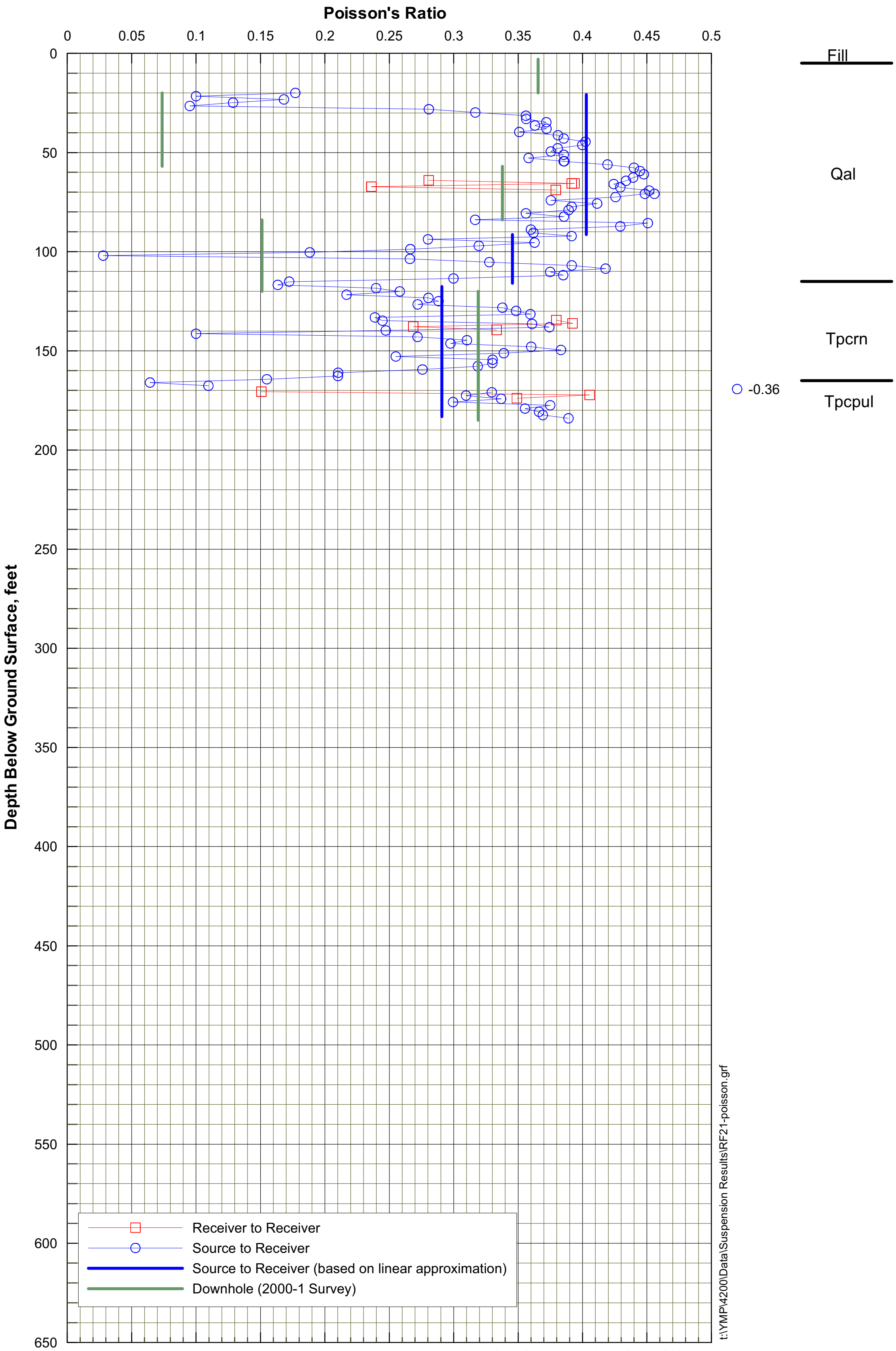
NOTES: Values less than 0.0 and greater than 0.5
are indicated to the right of plot and are
not plotted to scale.
No receiver to receiver data.

Figure VII-39. Poisson's Ratio from Suspension Seismic Source-to-Receiver Data at Borehole RF#19.



NOTES: No receiver to receiver data.

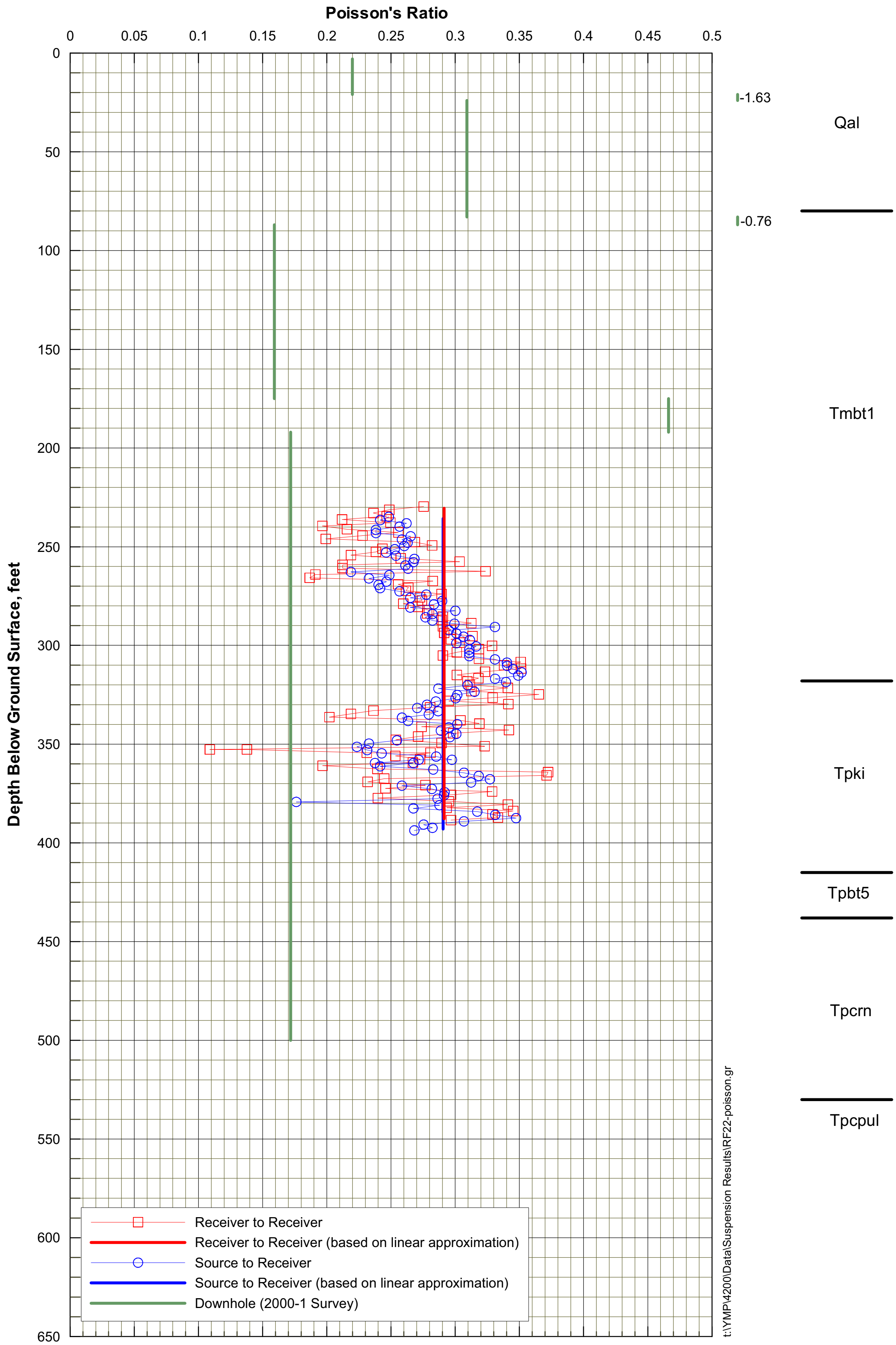
Figure VII-40. Poisson's Ratio from Suspension Seismic Source-to-Receiver Data at Borehole RF#20.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, GS020383114233.003 MO0205SEPPRDSV.000

NOTES: Values less than 0.0 and greater than 0.5 are indicated to the right of plot and are not plotted to scale.

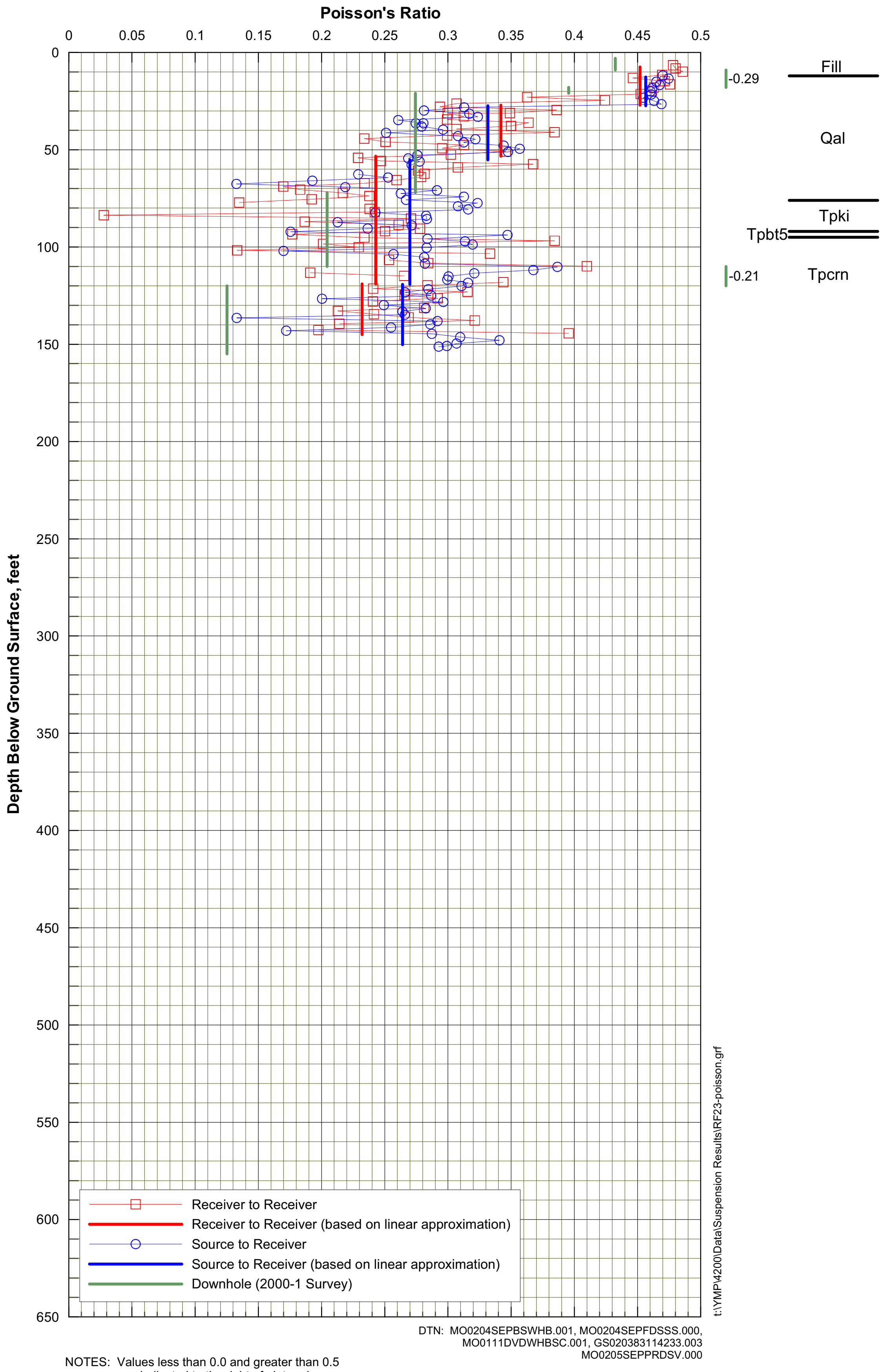
Figure VII-41. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#21.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, GS020383114233.003 MO0205SEPPRDSV.000

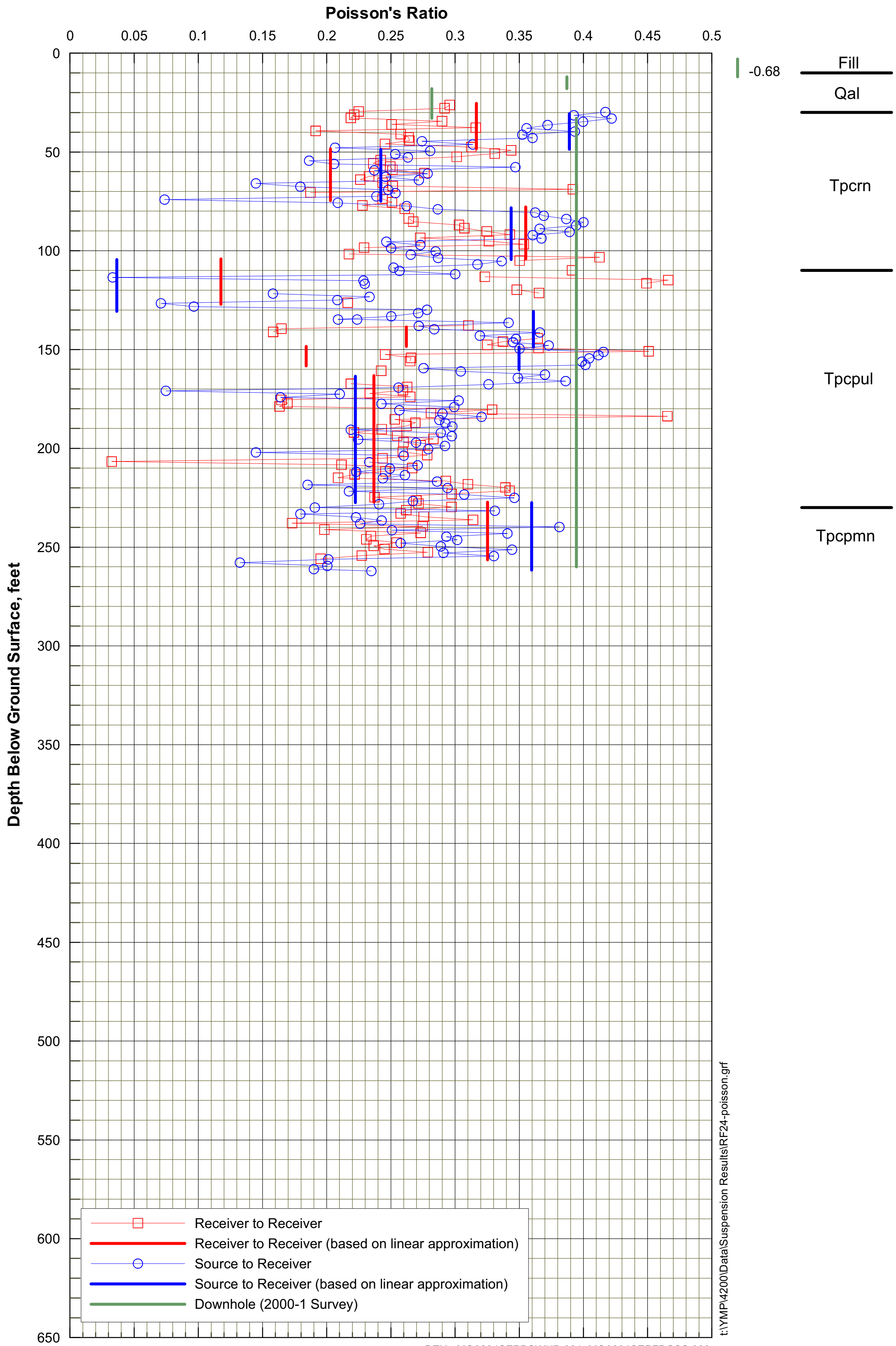
NOTES: Values less than 0.0 and greater than 0.5 are indicated to the right of plot and are not plotted to scale.

Figure VII-42. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#22.



NOTES: Values less than 0.0 and greater than 0.5 are indicated to the right of plot and are not plotted to scale.

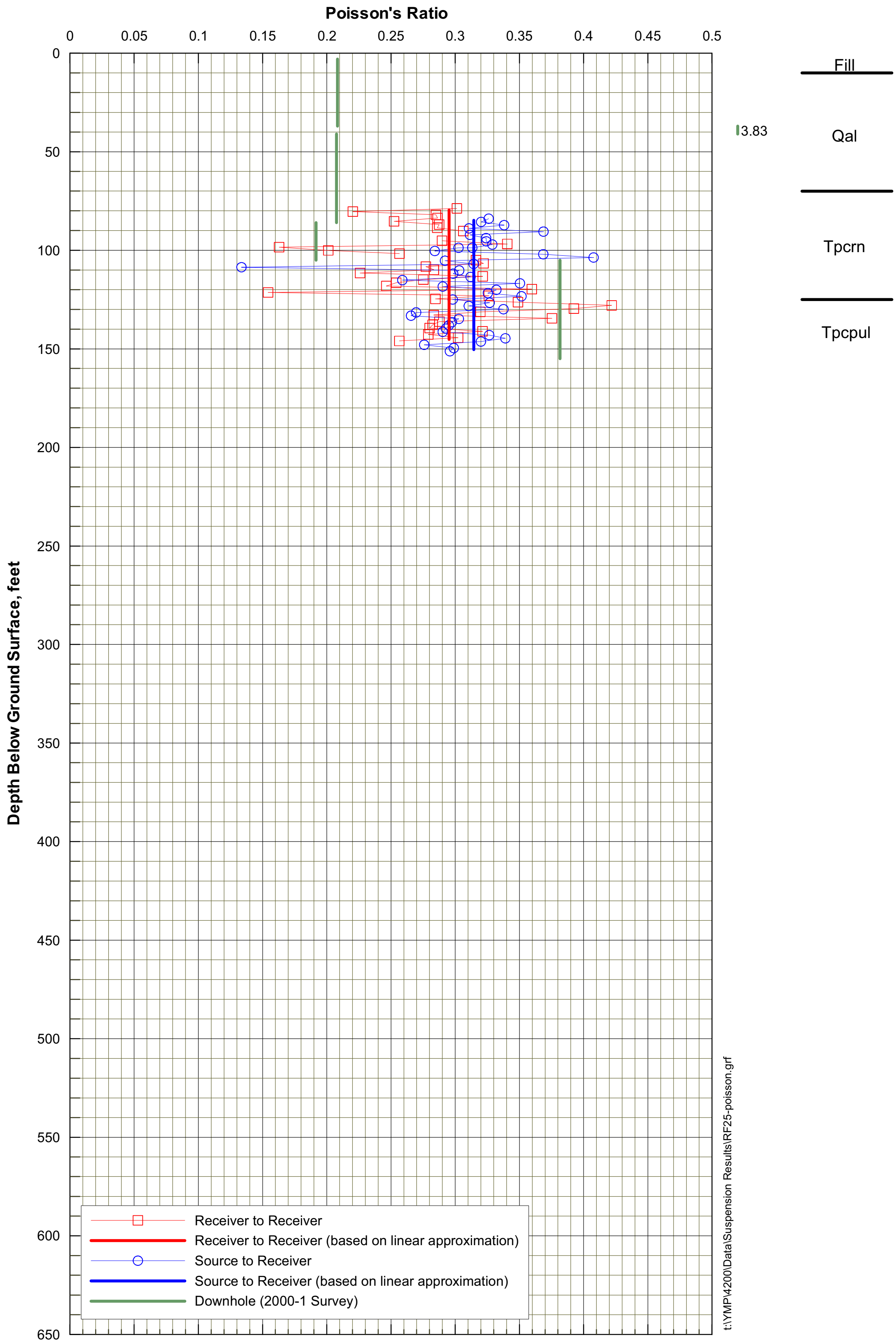
Figure VII-43. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#23.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, GS020383114233.003 MO0205SEPPRDSV.000

NOTES: Values less than 0.0 and greater than 0.5 are indicated to the right of plot and are not plotted to scale.

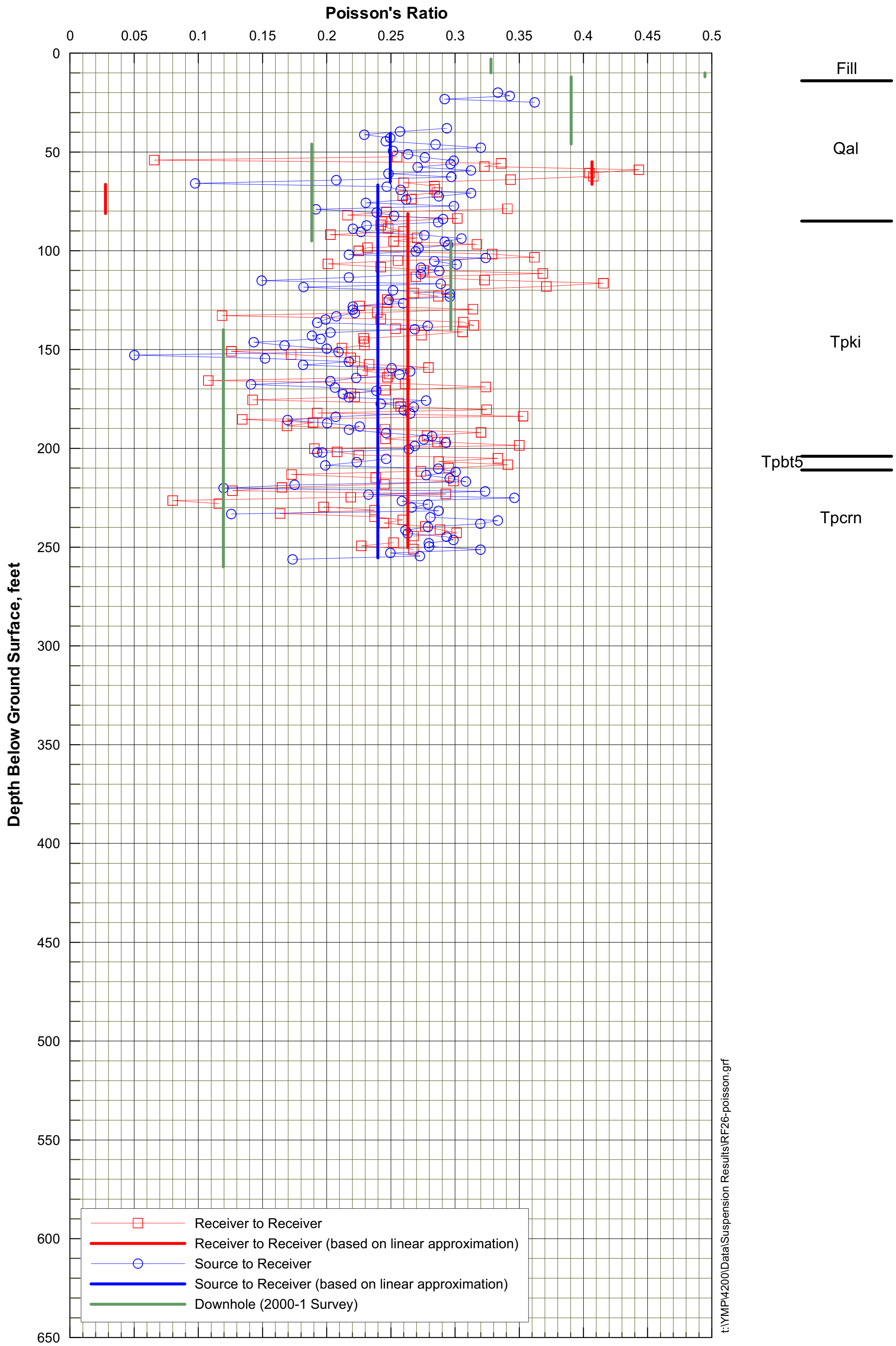
Figure VII-44. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#24.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000, MO0111DVDWHBSC.001, GS020383114233.003 MO0205SEPPRDSV.000

NOTES: Values less than 0.0 and greater than 0.5 are indicated to the right of plot and are not plotted to scale.

Figure VII-45. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#25.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000,
MO0111DVDWHBSC.001, GS020383114233.003
MO0205SEPPRDSV.000

Figure VII-46. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#26.

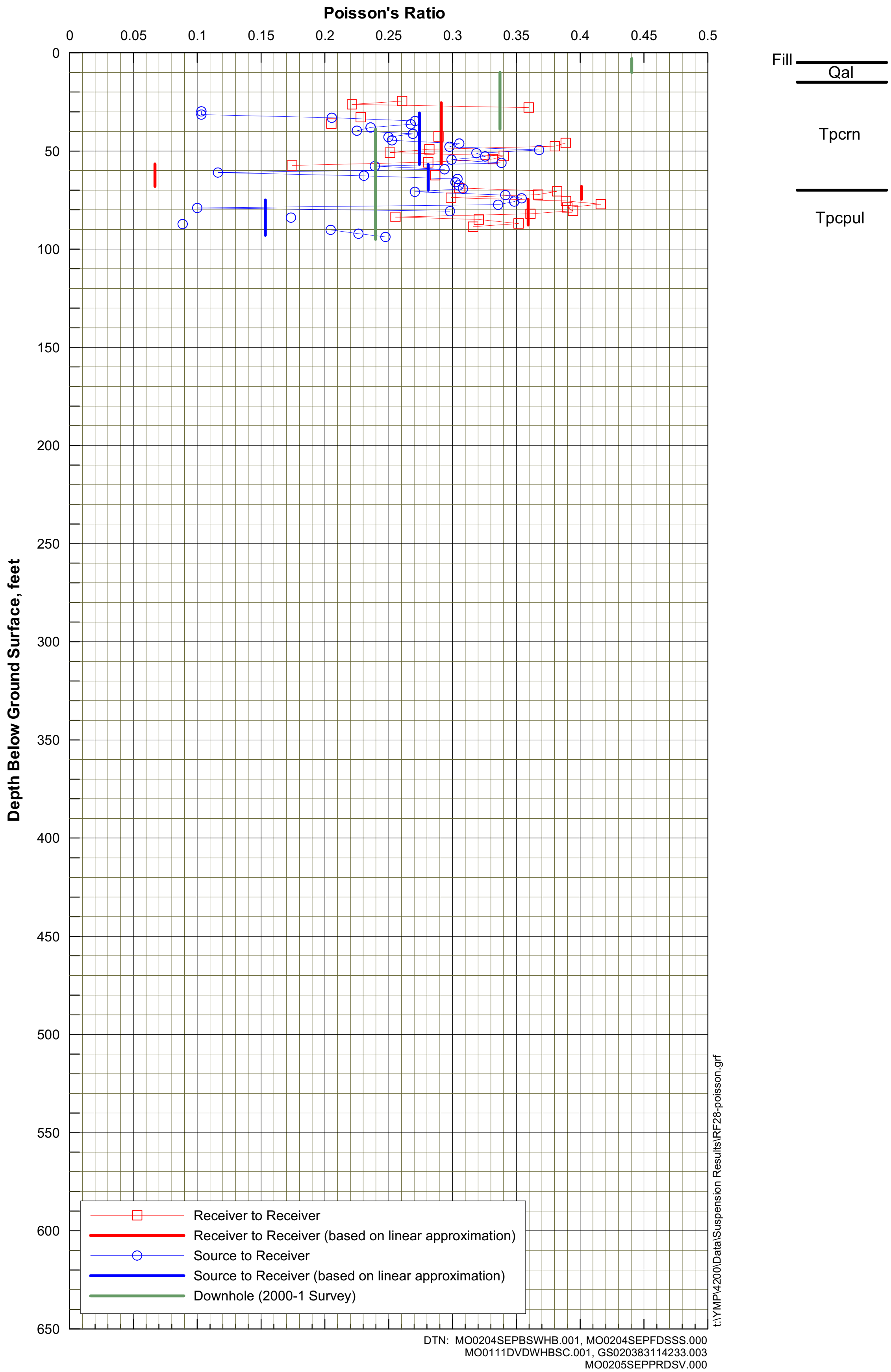
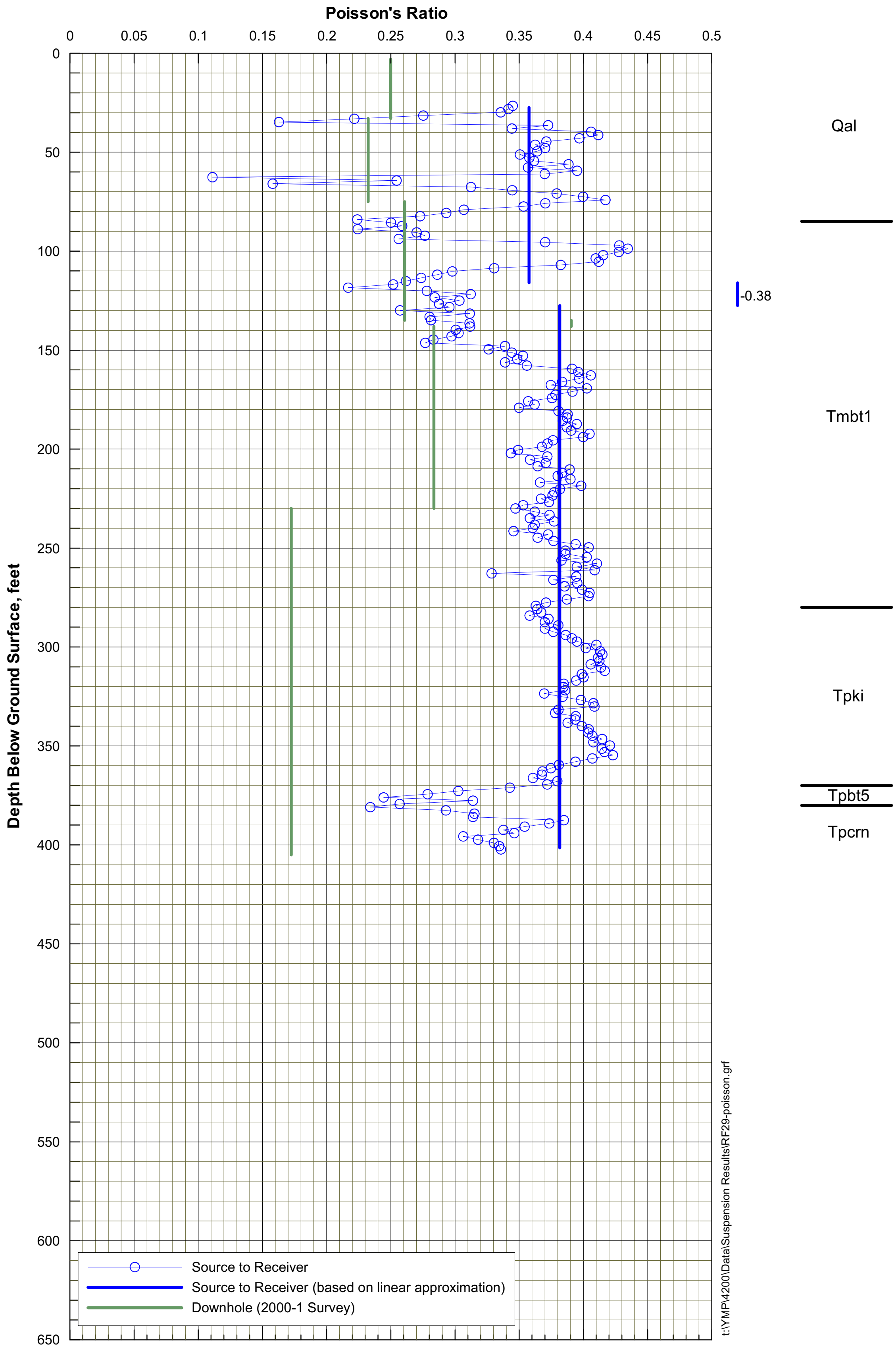


Figure VII-47. Poisson's Ratio from Suspension Seismic Source-to-Receiver and Receiver-to-Receiver Data at Borehole RF#28.



DTN: MO0204SEPBSWHB.001, MO0204SEPFDSSS.000,
MO0111DVDWHBSC.001, GS020383114233.003
MO0205SEPPRDSV.000

NOTES: Values less than 0.0 and greater than 0.5
are indicated to the right of plot and are
not plotted to scale.
No receiver to receiver data.

Figure VII-48. Poisson's Ratio from Suspension Seismic Source-to-Receiver Data at Borehole RF#29.

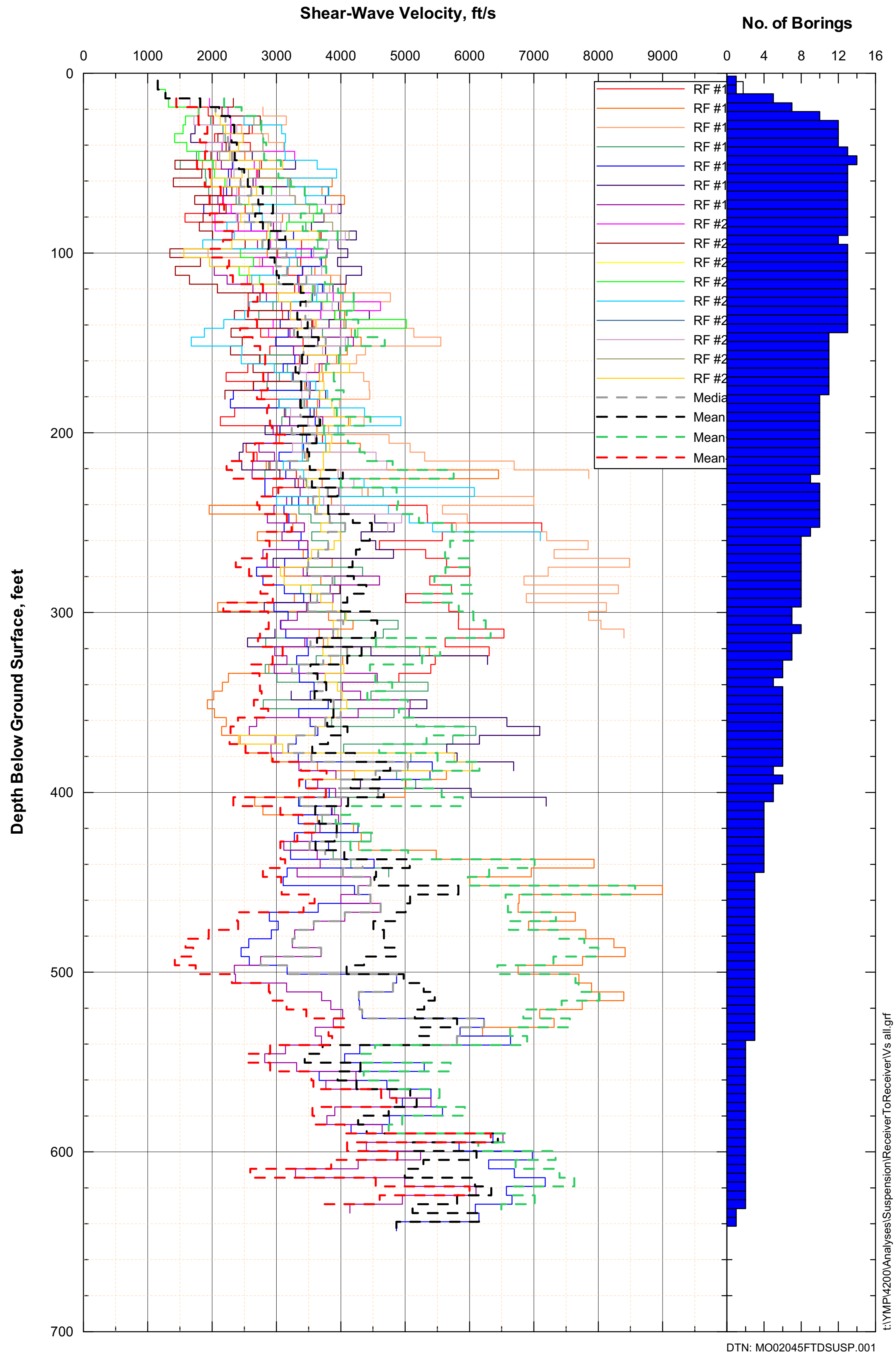


Figure VII-49. Suspension (Receiver-To-Receiver) Shear-Wave Velocity Averaged Over 4.92-foot (1.5-meter) Depth Intervals

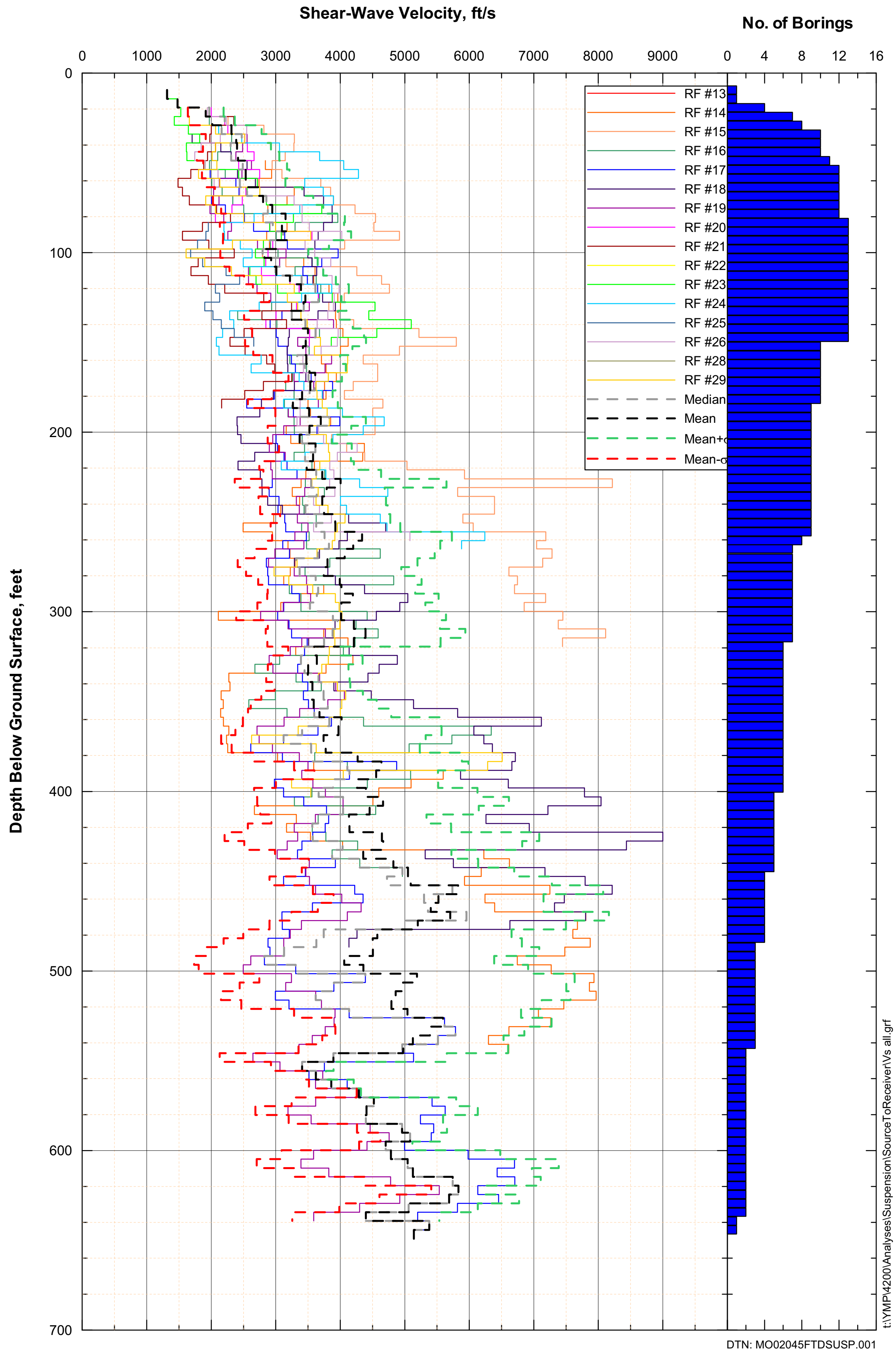


Figure VII-50. Suspension (Source-To-Receiver) Shear-Wave Velocity Averaged Over 4.92-foot (1.5-meter) Depth Intervals

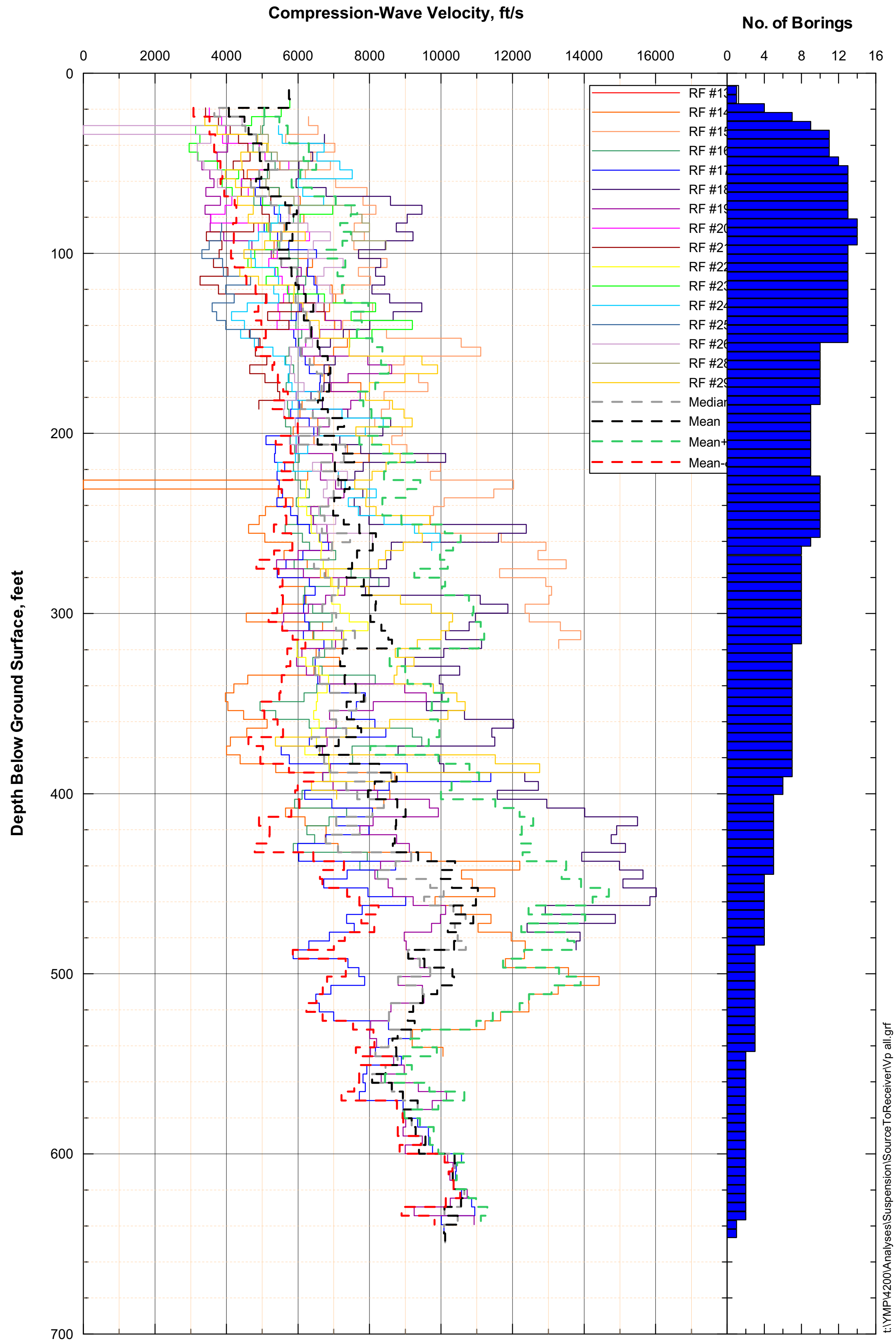


Figure VII-51. Suspension (Source-To-Receiver) Compression-Wave Velocity Averaged Over 4.92-foot (1.5-meter) Depth Intervals

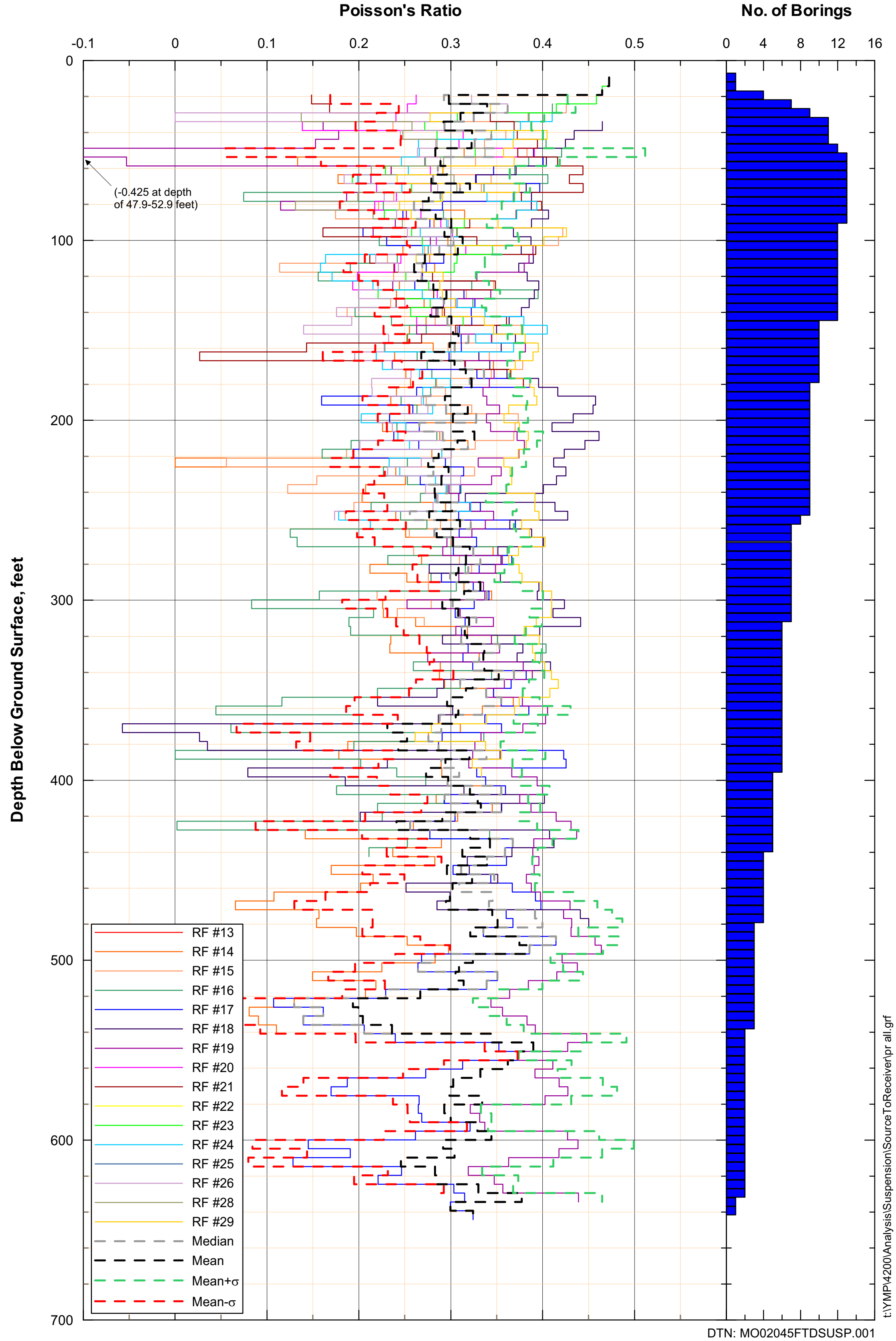


Figure VII-52. Suspension (Source-To-Receiver) Poisson's Ratio Averaged Over 4.92-foot (1.5-meter) Depth Intervals

Table VII-1. Statistics for Suspension Seismic Receiver-to-Receiver Shear-Wave Velocities by Lithostratigraphic Unit

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#13 (core)	Depth (ft)	0-12.5	12.5-98.0		98.0-164.4	164.4-169.3	169.3-219.1	219.1-231.5	231.5-286.7	286.7-300.9	300.9-350.1
	Mean V_s (ft/s)	NA	2510		3090	2200	2800	3130	5240	5540	5550
	Median V_s (ft/s)	NA	2340		3140	2210	2710	3050	5130	5560	5420
	Standard Deviation	NA	844.9		479.0	105.4	584.4	455.3	925.7	554.9	780.4
	Coeff. of var. (%)*	NA	33.7		15.5	4.8	20.9	14.5	17.7	10.0	14.1
	No. of meas.	0	43		41	3	30	5	25	9	21
RF#14 (core)	Depth (ft)		0-101.8		101.8-192.5	192.5-203.4	203.4-275.0	275.0-395.0	395.0-443.7	443.7-455.6	455.6-550.0
	Mean V_s (ft/s)		3110		3880	3450	3640	3160	4660	7360	7360
	Median V_s (ft/s)		2940		3950	3450	3500	2740	4220	6750	7470
	Standard Deviation		820.8		281.3	612.9	1394.7	1218.6	1756.4	2299.2	1004.8
	Coeff. of var. (%)		26.4		7.3	17.8	38.3	38.6	37.7	31.2	13.7
	No. of meas.		35		55	7	43	73	30	7	52
RF#15 (core)	Depth (ft)	0-6.5					6.5-78.0	78.0-196.0	196.0-242.4	242.4-256.6	256.6-330.0
	Mean V_s (ft/s)	NA					2740	4000	5700	5870	7740
	Median V_s (ft/s)	NA					2630	4070	5525	5910	7675
	Standard Deviation	NA					482.3	952.7	1492.4	195.4	837.3
	Coeff. of var. (%)	NA					17.6	23.8	26.2	3.3	10.8
	No. of meas.	0					18	48	22	9	34
RF#16 (core)	Depth (ft)	0-22.4	22.4-75.7		75.7-133.2	133.2-137.8	137.8-222.0	222.0-360.0	360.0-403.0	403.0-422.5	422.5-452.8
	Mean V_s (ft/s)	NA	2070		3430	2910	3370	3830	5020	3650	3990
	Median V_s (ft/s)	NA	2090		3510	2880	3270	3520	4890	3595	3910
	Standard Deviation	NA	362.2		476.1	226.5	638.7	964.3	1118.8	549.7	753.6
	Coeff. of var. (%)	NA	17.5		13.9	7.8	18.9	25.2	22.3	15.1	18.9
	No. of meas.	0	31		35	3	51	84	26	12	13
RF#17 (core)	Depth (ft)		0-92.4	92.4-287.2	287.2-348.4	348.4-368.9	368.9-478.0	478.0-587.3	587.3-637.6	637.6-653.2	653.2-667.8
	Mean V_s (ft/s)		2370	3210	3320	3580	3710	4470	6430	4920	NA
	Median V_s (ft/s)		2330	3220	3380	3500	3750	4490	6310	4980	NA
	Standard Deviation		509.7	433.2	298.6	273.6	983.4	1331.6	834.3	149.3	NA
	Coeff. of var. (%)		21.5	13.5	9.0	7.6	26.5	29.8	13.0	3.0	NA
	No. of meas.		27	119	37	12	67	67	29	3	0
RF#18 (cuttings)	Depth (ft)		0-60.0	60.0-65.0	65.0-204.0		204.0-292.0	292.0-425.0	425.0-470.0	470.0-493.6	
	Mean V_s (ft/s)		2380	2810	3760		3680	5230	NA	NA	
	Median V_s (ft/s)		2460	2690	3800		3800	5190	NA	NA	
	Standard Deviation		646.7	210.8	473.1		941.6	1667.7	NA	NA	
	Coeff. of var. (%)		27.2	7.5	12.6		25.6	31.9	NA	NA	
	No. of meas.		19	3	85		46	43	0	0	

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Table VII-1. Statistics for Suspension Seismic Receiver-to-Receiver Shear-Wave Velocities by Lithostratigraphic Unit (Continued)

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#19 (cuttings)	Depth (ft)		0-120.0	120.0-280.0	280.0-410.0	410.0-420.0	420.0-510.0	510.0-635.0	635.0-645.2		
	Mean Vs (ft/s)		2430	3250	3640	3910	3480	4200	NA		
	Median V_s (ft/s)		2275	3170	3690	3790	3350	4110	NA		
	Standard Deviation		508.4	535.0	754.4	392.3	865.3	1056.4	NA		
	Coeff. of var. (%)		21.0	16.5	20.7	10.0	24.9	25.2	NA		
	No. of meas.		56	97	79	7	54	74	0		
RF#20 (cuttings)	Depth (ft)	0-28.0	28.0-98.0			98.0-102.0	102.0-127.0	127.0-160.0			
	Mean Vs (ft/s)	2190	2510			3580	3070	3530			
	Median V_s (ft/s)	2225	2590			3910	3150	3000			
	Standard Deviation	260.6	455.1			869.3	604.8	1135.3			
	Coeff. of var. (%)	11.9	18.1			24.3	19.7	32.1			
	No. of meas.	8	42			3	15	12			
RF#21** (cuttings)	Depth (ft)	0-5.0	5.0-115.0				115.0-165.0	165.0-192.2			
	Mean Vs (ft/s)	NA	1960				2620	2780			
	Median V_s (ft/s)	NA	1820				2490	2555			
	Standard Deviation	NA	494.9				642.6	685.5			
	Coeff. of var. (%)	NA	25.3				24.6	24.7			
	No. of meas.	0	57				30	8			
RF#22 (cuttings /core)	Depth (ft)		0-80.0	80.0-318.0	318.0-415.0	415.0-438.0	438.0-530.0	530.0-540.0			
	Mean Vs (ft/s)		NA	3610	3460	NA	NA	NA			
	Median V_s (ft/s)		NA	3590	3485	NA	NA	NA			
	Standard Deviation		NA	132.5	323.9	NA	NA	NA			
	Coeff. of var. (%)		NA	3.7	9.4	NA	NA	NA			
	No. of meas.		0	54	44	0	0	0			
RF#23 (cuttings)	Depth (ft)	0-12.0	12.0-76.0		76.0-92.0	92.0-95.0	95.0-159.1				
	Mean Vs (ft/s)	1190	1950		3320	2680	3460				
	Median V_s (ft/s)	1155	1730		3230	2680	3310				
	Standard Deviation	221.1	612.5		531.5	NA	910.7				
	Coeff. of var. (%)	18.6	31.4		16.0	NA	26.3				
	No. of meas.	4	39		10	1	33				
RF#24 (cuttings)	Depth (ft)	0-10.0	10.0-30.0				30.0-110.0	110.0-230.0	230.0-268.0		
	Mean Vs (ft/s)	NA	2760				3050	3210	5120		
	Median V_s (ft/s)	NA	2740				3120	3170	4710		
	Standard Deviation	NA	736.9				771.4	908.3	1682.0		
	Coeff. of var. (%)	NA	26.7				25.3	28.3	32.8		
	No. of meas.	0	4				49	73	17		

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Table VII-1. Statistics for Suspension Seismic Receiver-to-Receiver Shear-Wave Velocities by Lithostratigraphic Unit (Continued)

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#25 (cuttings)	Depth (ft)	0-10.0	10.0-70.0				70.0-125.0	125.0-159.0			
	Mean Vs (ft/s)	NA	NA				2080	1860			
	Median V_s (ft/s)	NA	NA				2030	1780			
	Standard Deviation	NA	NA				399.1	295.1			
	Coeff. of var. (%)	NA	NA				19.2	15.9			
	No. of meas.	0	0				29	13			
RF#26 (cuttings)	Depth (ft)	0-14.0	14.0-85.0		85.0-204.0	204.0-211.0	211.0-264.9				
	Mean Vs (ft/s)	NA	2350		3630	3250	4260				
	Median V_s (ft/s)	NA	2210		3570	3260	4150				
	Standard Deviation	NA	674.0		362.4	190.2	796.2				
	Coeff. of var. (%)	NA	28.6		10.0	5.9	18.7				
	No. of meas.	0	43		73	4	25				
RF#28 (cuttings)	Depth (ft)	0-5.0	5.0-15.0				15.0-70.0	70.0-100.0			
	Mean Vs (ft/s)	NA	NA				2780	3680			
	Median V_s (ft/s)	NA	NA				2790	3650			
	Standard Deviation	NA	NA				365.2	377.5			
	Coeff. of var. (%)	NA	NA				13.2	10.3			
	No. of meas.	0	0				28	12			
RF#29 (cuttings)	Depth (ft)		0-85.0	85.0-280.0	280.0-370.0	370.0-380.0	380.0-430.0				
	Mean Vs (ft/s)		2430	3470	3800	3080	4850				
	Median V_s (ft/s)		2430	3640	3840	2640	5380				
	Standard Deviation		445.7	585.1	292.2	1035.6	1377.5				
	Coeff. of var. (%)		18.3	16.9	7.7	33.6	28.4				
	No. of meas.		40	158	55	6	11				
All tests	Mean Vs (ft/s)	1860	2360	3350	3600	3320	3310	3850	5370	5320	6790
	Median V_s (ft/s)	1975	2280	3395	3625	3450	3180	3670	5300	5430	7055
	Standard Deviation	547.9	663.7	508.3	510.0	701.9	1000.2	1305.9	1441.1	1634.3	1519.8
	Coeff. of var. (%)	29.5	28.1	15.2	14.2	21.2	30.2	33.9	26.8	30.7	22.4
	No. of meas.	12	435	392	514	45	538	504	149	40	120

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Notes: * Coefficient of Variation (%) = 100*standard deviation / mean

** In Assumption 4, Section 5, the contact between the Qal and Tpcrn is assumed to be at a depth of 70 feet. This table follows the geologic logs in Attachment I.

Table VII-2. Statistics for Suspension Seismic Receiver-to-Receiver Shear-Wave Velocities by Lithostratigraphic Unit

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#13 (core)	Depth (ft)	0-12.5	12.5-98.0		98.0-164.4	164.4-169.3	169.3-219.1	219.1-231.5	231.5-286.7	286.7-300.9	300.9-350.1
	Mean Vs (ft/s)	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Median V_s (ft/s)	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Standard Deviation	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Coeff. of var. (%)*	NA	NA		NA	NA	NA	NA	NA	NA	NA
	No. of meas.	0	0		0	0	0	0	0	0	0
RF#14 (core)	Depth (ft)		0-101.8		101.8-192.5	192.5-203.4	203.4-275.0	275.0-395.0	395.0-443.7	443.7-455.6	455.6-550.0
	Mean Vs (ft/s)		2940		3790	3420	3350	3130	4380	6280	7240
	Median V_s (ft/s)		2930		3830	3280	3220	3010	4310	6180	7330
	Standard Deviation		242.3		247.7	392.3	539.7	1008.6	1370.3	978.5	716.1
	Coeff. of var. (%)		8.2		6.5	11.5	16.1	32.2	31.3	15.6	9.9
	No. of meas.		31		56	6	44	73	30	7	55
RF#15 (core)	Depth (ft)	0-6.5					6.5-78.0	78.0-196.0	196.0-242.4	242.4-256.6	256.6-330.0
	Mean Vs (ft/s)	NA					3360	4380	5410	6170	7160
	Median V_s (ft/s)	NA					3230	4500	5120	6130	7180
	Standard Deviation	NA					544.6	639.0	1357.9	433.5	468.9
	Coeff. of var. (%)	NA					16.2	14.6	25.1	7.0	6.5
	No. of meas.	0					31	72	28	9	37
RF#16 (core)	Depth (ft)	0-22.4	22.4-75.7		75.7-133.2	133.2-137.8	137.8-222.0	222.0-360.0	360.0-403.0	403.0-422.5	422.5-452.8
	Mean Vs (ft/s)	NA	2180		3340	2190	3350	3620	4760	3770	4240
	Median V_s (ft/s)	NA	2200		3400	2190	3300	3570	4810	3560	4180
	Standard Deviation	NA	147.7		407.9	113.1	324.3	721.5	1075.6	570.9	541.6
	Coeff. of var. (%)	NA	6.8		12.2	5.2	9.7	20.0	22.6	15.2	12.8
	No. of meas.	0	30		35	2	52	84	26	12	15
RF#17 (core)	Depth (ft)		0-92.4	92.4-287.2	287.2-348.4	348.4-368.9	368.9-478.0	478.0-587.3	587.3-637.6	637.6-653.2	653.2-667.8
	Mean Vs (ft/s)		2420	3240	3330	3660	3540	4250	5980	5240	NA
	Median V_s (ft/s)		2460	3160	3350	3620	3450	4200	6030	5140	NA
	Standard Deviation		383.1	355.1	169.7	159.5	562.1	1053.9	616.4	156.9	NA
	Coeff. of var. (%)		15.9	11.0	5.1	4.4	15.9	24.8	10.3	3.0	NA
	No. of meas.		24	118	38	12	67	66	31	7	0
RF#18 (cuttings)	Depth (ft)		0-60.0	60.0-65.0	65.0-204.0		204.0-292.0	292.0-425.0	425.0-470.0	470.0-493.6	
	Mean Vs (ft/s)		2240	2840	3360		3440	5640	7380	5430	
	Median V_s (ft/s)		2300	2830	3540		3300	5740	7360	5160	
	Standard Deviation		316.2	140.5	441.8		716.1	1337.7	1246.7	1619.0	
	Coeff. of var. (%)		14.1	4.9	13.2		20.8	23.7	16.9	29.8	
	No. of meas.		16	3	85		53	81	28	9	

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Table VII-2. Statistics for Suspension Seismic Source-to-Receiver Shear-Wave Velocities by Lithostratigraphic Unit (Continued)

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#19 (cuttings)	Depth (ft)		0-120.0	120.0-280.0	280.0-410.0	410.0-420.0	420.0-510.0	510.0-635.0	635.0-645.2		
	Mean Vs (ft/s)		2460	3330	3390	3730	3360	3890	3590		
	Median V_s (ft/s)		2440	3340	3410	3640	3270	3770	3600		
	Standard Deviation		339.4	318.7	412.5	238.3	483.2	688.2	55.7		
	Coeff. of var. (%)		13.8	9.6	12.2	6.4	14.4	17.7	1.6		
	No. of meas.		52	98	79	6	55	76	3		
RF#20 (cuttings)	Depth (ft)	0-28.0	28.0-98.0			98.0-102.0	102.0-127.0	127.0-160.0			
	Mean Vs (ft/s)	2080	2600			2880	3170	3240			
	Median V_s (ft/s)	2080	2560			2790	3200	3310			
	Standard Deviation	90.7	386.5			314.8	418.5	377.2			
	Coeff. of var. (%)	4.4	14.9			10.9	13.2	11.6			
	No. of meas.	4	43			3	15	15			
RF#21** (cuttings)	Depth (ft)	0-5.0	5.0-115.0				115.0-165.0	6580.0-192.2			
	Mean Vs (ft/s)	NA	1910				2680	2760			
	Median V_s (ft/s)	NA	1920				2670	2750			
	Standard Deviation	NA	298.3				401.6	426.1			
	Coeff. of var. (%)	NA	15.6				15.0	15.4			
	No. of meas.	0	58				31	12			
RF#22 (cuttings /core)	Depth (ft)		0-80.0	80.0-318.0	318.0-415.0	415.0-438.0	438.0-530.0	530.0-540.0			
	Mean Vs (ft/s)		NA	3710	3560	NA	NA	NA			
	Median V_s (ft/s)		NA	3720	3610	NA	NA	NA			
	Standard Deviation		NA	118.4	214.1	NA	NA	NA			
	Coeff. of var. (%)		NA	3.2	6.0	NA	NA	NA			
	No. of meas.		0	51	47	0	0	0			
RF#23 (cuttings)	Depth (ft)	0-12.0	12.0-76.0		76.0-92.0	92.0-95.0	95.0-159.1				
	Mean Vs (ft/s)	1300	2040		3150	3110	3600				
	Median V_s (ft/s)	1300	1730		2990	3110	3550				
	Standard Deviation	NA	653.8		338.4	339.4	907.1				
	Coeff. of var. (%)	NA	32.1		10.8	10.9	25.2				
	No. of meas.	1	39		9	2	36				
RF#24 (cuttings)	Depth (ft)	0-10.0	10.0-30.0				30.0-110.0	110.0-230.0	230.0-268.0		
	Mean Vs (ft/s)	NA	2030				3060	3270	4850		
	Median V_s (ft/s)	NA	2030				2960	3370	4650		
	Standard Deviation	NA	NA				735.4	778.0	905.6		
	Coeff. of var. (%)	NA	NA				24.0	23.8	18.7		
	No. of meas.	0	1				48	74	20		

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Table VII-2. Statistics for Suspension Seismic Source-to-Receiver Shear-Wave Velocities by Lithostratigraphic Unit (Continued)

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#25 (cuttings)	Depth (ft)	0-10.0	10.0-70.0				70.0-125.0	125.0-159.0			
	Mean Vs (ft/s)	NA	NA				2010	2210			
	Median V_s (ft/s)	NA	NA				1990	2120			
	Standard Deviation	NA	NA				239.7	289.5			
	Coeff. of var. (%)	NA	NA				12.0	13.1			
	No. of meas.	0	0				26	16			
RF#26 (cuttings)	Depth (ft)	0-14.0	14.0-85.0		85.0-204.0	204.0-211.0	211.0-264.9				
	Mean Vs (ft/s)	NA	2410		3680	4040	3840				
	Median V_s (ft/s)	NA	2180		3700	4030	3800				
	Standard Deviation	NA	623.0		243.7	591.7	336.4				
	Coeff. of var. (%)	NA	25.8		6.6	14.7	8.8				
	No. of meas.	0	40		73	4	28				
RF#28 (cuttings)	Depth (ft)	0-5.0	5.0-15.0				15.0-70.0	70.0-100.0			
	Mean Vs (ft/s)	NA	NA				2970	4450			
	Median V_s (ft/s)	NA	NA				3010	4710			
	Standard Deviation	NA	NA				202.5	814.5			
	Coeff. of var. (%)	NA	NA				6.8	18.3			
	No. of meas.	0	0				25	15			
RF#29 (cuttings)	Depth (ft)		0-85.0	85.0-280.0	280.0-370.0	370.0-380.0	380.0-430.0				
	Mean Vs (ft/s)		2160	3470	3800	3650	4650				
	Median V_s (ft/s)		2070	3640	3900	3320	3920				
	Standard Deviation		351.3	576.5	295.7	1203.1	1568.0				
	Coeff. of var. (%)		16.2	16.6	7.8	33.0	33.7				
	No. of meas.		36	119	55	6	14				
All tests	Mean Vs (ft/s)	1920	2040	3390	3440	3510	3300	3970	5460	5230	6790
	Median V_s (ft/s)	2010	2190	3450	3570	3530	3230	3810	5410	5210	7040
	Standard Deviation	356.5	879.7	437.9	663.9	647.0	739.8	1227.4	1516.4	1308.5	1204.4
	Coeff. of var. (%)	18.5	43.1	12.9	19.3	18.4	22.4	31.0	27.8	25.0	17.7
	No. of meas.	5	419	389	489	41	534	575	166	44	107

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Notes: * Coefficient of Variation (%) = 100*standard deviation / mean

** In Assumption 4, Section 5, the contact between the Qal and Tpcrn is assumed to be at a depth of 70 feet. This table follows the geologic logs in Attachment I.

Table VII-3. Statistics for Suspension Seismic Source-to-Receiver Compression-Wave Velocities by Lithostratigraphic Unit

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#13 (core)	Depth (ft)	0-12.5	12.5-98.0		98.0-164.4	164.4-169.3	169.3-219.1	219.1-231.5	231.5-286.7	286.7-300.9	300.9-350.1
	Mean Vp (ft/s)	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Median Vp (ft/s)	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Standard Deviation	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Coeff. of var. (%)*	NA	NA		NA	NA	NA	NA	NA	NA	NA
	No. of meas.	0	0		0	0	0	0	0	0	0
RF#14 (core)	Depth (ft)		0-101.8		101.8-192.5	192.5-203.4	203.4-275.0	275.0-395.0	395.0-443.7	443.7-455.6	455.6-550.0
	Mean Vp (ft/s)		5450		6750	6340	5980	5560	8060	10840	11610
	Median Vp (ft/s)		5600		6810	6460	5760	5350	7260	10610	11560
	Standard Deviation		632.7		521.8	573.7	1057.8	1428.3	2042.1	1216.0	1493.3
	Coeff. of var. (%)		11.6		7.7	9.0	17.7	25.7	25.3	11.2	12.9
	No. of meas.		31		56	6	39	71	30	7	55
RF#15 (core)	Depth (ft)	0-6.5					6.5-78.0	78.0-196.0	196.0-242.4	242.4-256.6	256.6-330.0
	Mean Vp (ft/s)	NA					6950	8340	9930	9970	12860
	Median Vp (ft/s)	NA					6710	8080	9610	9880	12930
	Standard Deviation	NA					936.7	1066.7	1155.6	605.7	792.2
	Coeff. of var. (%)	NA					13.5	12.8	11.6	6.1	6.2
	No. of meas.	0					31	72	28	9	37
RF#16 (core)	Depth (ft)	0-22.4	22.4-75.7		75.7-133.2	133.2-137.8	137.8-222.0	222.0-360.0	360.0-403.0	403.0-422.5	422.5-452.8
	Mean Vp (ft/s)	NA	5060		5830	5690	5840	6440	7520	6600	7240
	Median Vp (ft/s)	NA	5050		5800	5690	5800	6340	7410	6740	7630
	Standard Deviation	NA	427.3		270.3	91.9	184.7	833.4	1343.8	700.1	1014.9
	Coeff. of var. (%)	NA	8.5		4.6	1.6	3.2	12.9	17.9	10.6	14.0
	No. of meas.	0	30		35	2	52	84	26	12	15
RF#17 (core)	Depth (ft)		0-92.4	92.4-287.2	287.2-348.4	348.4-368.9	368.9-478.0	478.0-587.3	587.3-637.6	637.6-653.2	653.2-667.8
	Mean Vp (ft/s)		5120	6020	6550	7930	7460	7800	10320	10080	NA
	Median Vp (ft/s)		5110	6070	6450	8010	7320	7840	10470	9960	NA
	Standard Deviation		342.8	483.7	480.8	492.6	1442.1	1071.3	556.9	317.4	NA
	Coeff. of var. (%)		6.7	8.0	7.3	6.2	19.3	13.7	5.4	3.1	NA
	No. of meas.		24	118	38	12	67	66	31	7	0
RF#18 (cuttings)	Depth (ft)		0-60.0	60.0-65.0	65.0-204.0		204.0-292.0	292.0-425.0	425.0-470.0	470.0-493.6	
	Mean Vp (ft/s)		6280	5960	7900		8620	11280	14960	13420	
	Median Vp (ft/s)		6210	5930	8010		8060	11200	15260	12920	
	Standard Deviation		368.8	57.7	974.5		1618.3	1897.3	1409.9	1157.8	
	Coeff. of var. (%)		5.9	1.0	12.3		18.8	16.8	9.4	8.6	
	No. of meas.		16	3	85		53	81	28	9	

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Table VII-3. Statistics for Suspension Seismic Source-to-Receiver Compression-Wave Velocities by Lithostratigraphic Unit (Continued)

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#19 (cuttings)	Depth (ft)		0-120.0	120.0-280.0	280.0-410.0	410.0-420.0	420.0-510.0	510.0-635.0	635.0-645.2		
	Mean Vp (ft/s)		4250	6710	7120	8570	9070	9240	10920		
	Median Vp (ft/s)		3800	6690	6860	8320	9080	9130	11030		
	Standard Deviation		962.5	736.1	1132.6	1064.5	701.9	928.9	342.7		
	Coeff. of var. (%)		22.7	11.0	15.9	12.4	7.7	10.1	3.1		
	No. of meas.		52	98	79	6	55	76	3		
RF#20 (cuttings)	Depth (ft)	0-28.0	28.0-98.0			98.0-102.0	102.0-127.0	127.0-160.0			
	Mean Vp (ft/s)	3710	4680			5420	5490	5790			
	Median Vp (ft/s)	3710	4740			5230	5550	5690			
	Standard Deviation	239.8	813.8			536.8	389.7	581.4			
	Coeff. of var. (%)	6.5	17.4			9.9	7.1	10.0			
	No. of meas.	4	43			3	15	15			
RF#21 (cuttings)**	Depth (ft)	0-5.0	5.0-115.0				115.0-165.0	165.0-192.2			
	Mean Vp (ft/s)	NA	4280				4960	5190			
	Median Vp (ft/s)	NA	4280				4870	5100			
	Standard Deviation	NA	609.4				958.9	529.0			
	Coeff. of var. (%)	NA	14.2				19.3	10.2			
	No. of meas.	0	58				31	12			
RF#22 (cuttings /core)	Depth (ft)		0-80.0	80.0-318.0	318.0-415.0	415.0-438.0	438.0-530.0	530.0-540.0			
	Mean Vp (ft/s)		NA	6780	6510	NA	NA	NA			
	Median Vp (ft/s)		NA	6710	6520	NA	NA	NA			
	Standard Deviation		NA	522.8	331.1	NA	NA	NA			
	Coeff. of var. (%)		NA	7.7	5.1	NA	NA	NA			
	No. of meas.		0	51	47	0	0	0			
RF#23 (cuttings)	Depth (ft)	0-12.0	12.0-76.0		76.0-92.0	92.0-95.0	95.0-159.1				
	Mean Vp (ft/s)	5470	4320		5710	5640	6540				
	Median Vp (ft/s)	5470	4230		5270	5640	6560				
	Standard Deviation	NA	1200.4		922.1	410.1	1515.8				
	Coeff. of var. (%)	NA	27.8		16.1	7.3	23.2				
	No. of meas.	1	39		9	2	36				
RF#24 (cuttings)	Depth (ft)	0-10.0	10.0-30.0				30.0-110.0	110.0-230.0	230.0-268.0		
	Mean Vp (ft/s)	NA	5390				5800	5860	8610		
	Median Vp (ft/s)	NA	5390				5620	5760	8520		
	Standard Deviation	NA	NA				935.2	1161.9	1057.4		
	Coeff. of var. (%)	NA	NA				16.1	19.8	12.3		
	No. of meas.	0	1				48	74	20		

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Table VII-3. Statistics for Suspension Seismic Source-to-Receiver Compression-Wave Velocities by Lithostratigraphic Unit (Continued)

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#25 (cuttings)	Depth (ft)	0-10.0	10.0-70.0				70.0-125.0	125.0-159.0			
	Mean Vp (ft/s)	NA	NA				3910	4170			
	Median Vp (ft/s)	NA	NA				3930	4030			
	Standard Deviation	NA	NA				453.1	553.7			
	Coeff. of var. (%)	NA	NA				11.6	13.3			
	No. of meas.	0	0				26	16			
RF#26 (cuttings)	Depth (ft)	0-14.0	14.0-85.0		85.0-204.0	204.0-211.0	211.0-264.9				
	Mean Vp (ft/s)	NA	4340		6290	6940	6890				
	Median Vp (ft/s)	NA	3840		6240	6660	6840				
	Standard Deviation	NA	1171.2		495.5	1241.1	472.3				
	Coeff. of var. (%)	NA	27.0		7.9	17.9	6.9				
	No. of meas.	0	33		73	4	28				
RF#28 (cuttings)	Depth (ft)	0-5.0	5.0-15.0				15.0-70.0	70.0-100.0			
	Mean Vp (ft/s)	NA	NA				5320	7530			
	Median Vp (ft/s)	NA	NA				5190	7650			
	Standard Deviation	NA	NA				477.3	799.1			
	Coeff. of var. (%)	NA	NA				9.0	10.6			
	No. of meas.	0	0				25	15			
RF#29 (cuttings)	Depth (ft)		0-85.0	85.0-280.0	280.0-370.0	370.0-380.0	380.0-430.0				
	Mean Vp (ft/s)		4430	7530	9150	6690	9210				
	Median Vp (ft/s)		4500	7790	9310	5830	8070				
	Standard Deviation		524.7	1593.9	1185.3	1994.0	2866.4				
	Coeff. of var. (%)		11.9	21.2	13.0	29.8	31.1				
	No. of meas.		36	119	55	6	14				
All tests	Mean Vp (ft/s)	4060	4660	6760	7100	7110	6730	7650	9990	9910	11430
	Median Vp (ft/s)	3820	4670	6550	6730	7060	6410	7470	9690	9990	12050
	Standard Deviation	812.9	948.5	1168.9	1258.6	1394.2	1828.7	2310.9	2798.1	2540.1	2167.4
	Coeff. of var. (%)	20.0	20.4	17.3	17.7	19.6	27.2	30.2	28.0	25.6	19.0
	No. of meas.	5	363	389	477	41	529	573	166	44	107

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Notes: * Coefficient of Variation (%) = 100*standard deviation / mean

** In Assumption 4, Section 5, the contact between the Qal and Tpcrn is assumed to be at a depth of 70 feet. This table follows the geologic logs in Attachment I.

Table VII-4. Statistics for Suspension Seismic Source-to-Receiver Poisson's Ratios by Lithostratigraphic Unit

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#13 (core)	Depth (ft)	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Mean	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Median	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Standard Deviation	NA	NA		NA	NA	NA	NA	NA	NA	NA
	Coeff. of var. (%)*	NA	NA		NA	NA	NA	NA	NA	NA	NA
	No. of meas.	NA	NA		NA	NA	NA	NA	NA	NA	NA
RF#14 (core)	Depth (ft)		0-101.8		101.8-192.5	192.5-203.4	203.4-275.0	275.0-395.0	395.0-443.7	443.7-455.6	455.6-550.0
	Mean		0.28		0.27	0.29	0.26	0.28	0.28	0.24	0.18
	Median		0.30		0.26	0.29	0.27	0.29	0.29	0.24	0.18
	Standard Deviation		0.09		0.03	0.05	0.05	0.07	0.08	0.07	0.08
	Coeff. of var. (%)		32.23		12.36	15.56	19.05	24.44	27.04	27.67	44.51
	No. of meas.		31		56	6	39	65	30	7	49
RF#15 (core)	Depth (ft)	0-6.5					6.5-78.0	78.0-196.0	196.0-242.4	242.4-256.6	256.6-330.0
	Mean	NA					0.34	0.29	0.27	0.19	0.27
	Median	NA					0.35	0.30	0.32	0.20	0.27
	Standard Deviation	NA					0.06	0.09	0.13	0.04	0.05
	Coeff. of var. (%)	NA					17.48	29.96	46.68	20.81	16.68
	No. of meas.	0					31	72	28	9	37
RF#16 (core)	Depth (ft)	0-22.4	22.4-75.7		75.7-133.2	133.2-137.8	137.8-222.0	222.0-360.0	360.0-403.0	403.0-422.5	422.5-452.8
	Mean	NA	0.38		0.24	0.41	0.25	0.26	0.17	0.24	0.22
	Median	NA	0.38		0.25	0.41	0.25	0.27	0.20	0.27	0.25
	Standard Deviation	NA	0.03		0.09	0.01	0.06	0.10	0.14	0.10	0.12
	Coeff. of var. (%)	NA	8.79		36.24	1.75	24.61	38.65	79.54	43.06	55.94
	No. of meas.	0	30		35	2	51	83	22	12	14
RF#17 (core)	Depth (ft)		0-92.4	92.4-287.2	287.2-348.4	348.4-368.9	368.9-478.0	478.0-587.3	587.3-637.6	637.6-653.2	653.2-667.8
	Mean		0.35	0.29	0.32	0.36	0.34	0.28	0.24	0.31	NA
	Median		0.36	0.30	0.32	0.36	0.35	0.29	0.25	0.32	NA
	Standard Deviation		0.06	0.05	0.03	0.02	0.05	0.10	0.07	0.02	NA
	Coeff. of var. (%)		17.62	18.43	8.30	5.86	14.80	34.88	30.39	7.39	NA
	No. of meas.		24	118	38	12	67	66	31	7	0
RF#18 (cuttings)	Depth (ft)		0-60.0	60.0-65.0	65.0-204.0		204.0-292.0	292.0-425.0	425.0-470.0	470.0-493.6	
	Mean		0.42	0.35	0.38		0.39	0.29	0.32	0.37	
	Median		0.42	0.35	0.38		0.41	0.34	0.33	0.40	
	Standard Deviation		0.03	0.02	0.03		0.05	0.15	0.08	0.10	
	Coeff. of var. (%)		6.73	4.44	8.15		12.64	51.38	25.42	26.77	
	No. of meas.		16	3	85		53	81	28	9	

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Table VII-4. Statistics for Suspension Seismic Source-to-Receiver Poisson's Ratios by Lithostratigraphic Unit (Continued)

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#19 (cuttings)	Depth (ft)		0-120.0	120.0-280.0	280.0-410.0	410.0-420.0	420.0-510.0	510.0-635.0	635.0-645.2		
	Mean		0.18	0.33	0.35	0.38	0.42	0.38	0.44		
	Median		0.23	0.34	0.34	0.38	0.42	0.39	0.44		
	Standard Deviation		0.21	0.04	0.04	0.02	0.03	0.05	0.01		
	Coeff. of var. (%)		114.3	13.17	11.88	4.92	6.48	11.77	1.43		
	No. of meas.		52	98	79	6	55	76	3		
RF#20 (cuttings)	Depth (ft)	0-28.0	28.0-98.0			98.0-102.0	102.0-127.0	127.0-160.0			
	Mean	0.27	0.26			0.30	0.26	0.27			
	Median	0.27	0.27			0.30	0.25	0.27			
	Standard Deviation	0.02	0.07			0.03	0.04	0.06			
	Coeff. of var. (%)	7.22	25.69			9.41	16.91	22.01			
	No. of meas.	4	42			3	14	15			
RF#21** (cuttings)	Depth (ft)	0-5.0	5.0-115.0				115.0-165.0	165.0-192.2			
	Mean	NA	0.35				0.28	0.25			
	Median	NA	0.38				0.28	0.33			
	Standard Deviation	NA	0.10				0.07	0.22			
	Coeff. of var. (%)	NA	27.73				25.76	88.44			
	No. of meas.	0	58				31	12			
RF#22 (cuttings /core)	Depth (ft)		0-80.0	80.0-318.0	318.0-415.0	415.0-438.0	438.0-530.0	530.0-540.0			
	Mean		NA	0.28	0.28	NA	NA	NA			
	Median		NA	0.27	0.29	NA	NA	NA			
	Standard Deviation		NA	0.03	0.03	NA	NA	NA			
	Coeff. of var. (%)		NA	12.42	11.27	NA	NA	NA			
	No. of meas.		0	51	47	0	0	0			
RF#23 (cuttings)	Depth (ft)	0-12.0	12.0-76.0		76.0-92.0	92.0-95.0	95.0-159.1				
	Mean	0.47	0.32		0.28	0.26	0.28				
	Median	0.47	0.31		0.28	0.26	0.29				
	Standard Deviation	NA	0.09		0.04	0.12	0.05				
	Coeff. of var. (%)	NA	27.80		13.88	46.45	17.98				
	No. of meas.	1	37		9	2	35				
RF#24 (cuttings)	Depth (ft)	0-10.0	10.0-30.0				30.0-110.0	110.0-230.0	230.0-268.0		
	Mean	NA	0.42				0.30	0.27	0.26		
	Median	NA	0.42				0.28	0.28	0.25		
	Standard Deviation	NA	NA				0.08	0.08	0.07		
	Coeff. of var. (%)	NA	NA				25.93	29.13	24.93		
	No. of meas.	0	1				48	71	20		

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Table VII-4. Statistics for Suspension Seismic Source-to-Receiver Poisson's Ratios by Lithostratigraphic Unit (Continued)

Borehole	Parameter	Fill	Qal	Tmbt1	Tpki	Tpbt5	Tpcrn	Tpcpul	Tpcpmn	Tpcpll	Tpcpln
RF#25 (cuttings)	Depth (ft)	0-10.0	10.0-70.0				70.0-125.0	125.0-159.0			
	Mean	NA	NA				0.31	0.30			
	Median	NA	NA				0.32	0.30			
	Standard Deviation	NA	NA				0.05	0.02			
	Coeff. of var. (%)	NA	NA				15.21	7.45			
	No. of meas.	0	0				26	16			
RF#26 (cuttings)	Depth (ft)	0-14.0	14.0-85.0		85.0-204.0	204.0-211.0	211.0-264.9				
	Mean	NA	0.27		0.23	0.24	0.27				
	Median	NA	0.27		0.23	0.23	0.28				
	Standard Deviation	NA	0.05		0.05	0.04	0.06				
	Coeff. of var. (%)	NA	18.08		20.72	15.66	21.15				
	No. of meas.	0	33		72	4	28				
RF#28 (cuttings)	Depth (ft)	0-5.0	5.0-15.0				15.0-70.0	70.0-100.0			
	Mean	NA	NA				0.26	0.25			
	Median	NA	NA				0.27	0.26			
	Standard Deviation	NA	NA				0.07	0.09			
	Coeff. of var. (%)	NA	NA				26.60	37.51			
	No. of meas.	0	0				25	12			
RF#29 (cuttings)	Depth (ft)		0-85.0	85.0-280.0	280.0-370.0	370.0-380.0	380.0-430.0				
	Mean		0.33	0.35	0.39	0.29	0.33				
	Median		0.36	0.37	0.39	0.29	0.33				
	Standard Deviation		0.08	0.05	0.02	0.04	0.04				
	Coeff. of var. (%)		22.77	13.75	4.52	12.73	11.22				
	No. of meas.		36	119	55	6	14				
All tests	Mean	0.31	0.27	0.32	0.29	0.30	0.30	0.29	0.22	0.22	0.17
	Median	0.27	0.30	0.32	0.31	0.33	0.31	0.30	0.26	0.24	0.21
	Standard Deviation	0.09	0.15	0.06	0.11	0.10	0.11	0.11	0.14	0.14	0.12
	Coeff. of var. (%)	29.03	56.79	17.45	37.80	33.58	36.29	36.67	63.16	61.11	67.74
	No. of meas.	5	409	389	517	44	556	568	195	53	126

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Notes: * Coefficient of Variation (%) = 100*standard deviation / mean

** In Assumption 4, Section 5, the contact between the Qal and Tpcrn is assumed to be at a depth of 70 feet. This table follows the geologic logs in Attachment I.

ATTACHMENT VIII

SUSPENSION SEISMIC ACCUMULATED VELOCITY PLOTS

ATTACHMENT VIII

SUSPENSION SEISMIC ACCUMULATED VELOCITY PLOTS

As mentioned in Section 6.2.6.4, this attachment presents plots of interpreted suspension seismic measurements as follows:

- Figures VIII-1 through VIII-16, plots of shear-wave accumulated travel time vs. depth bgs at boreholes RF#13 through RF#29, respectively.

As mentioned in Section 6.7.2, this attachment presents plots of interpreted suspension seismic measurements as follows:

- Figures VIII-17 through VIII-23, plots of (a) average shear-wave velocity versus depth bgs and (b) amplification ratio as a function of frequency at boreholes RF#14, #15, #16, #17, #18, #19 and #29, respectively.

As a reminder, the 2000-1 downhole seismic survey was performed by Redpath Geophysics and the 2000-1 downhole seismic survey was performed by GEOVision.

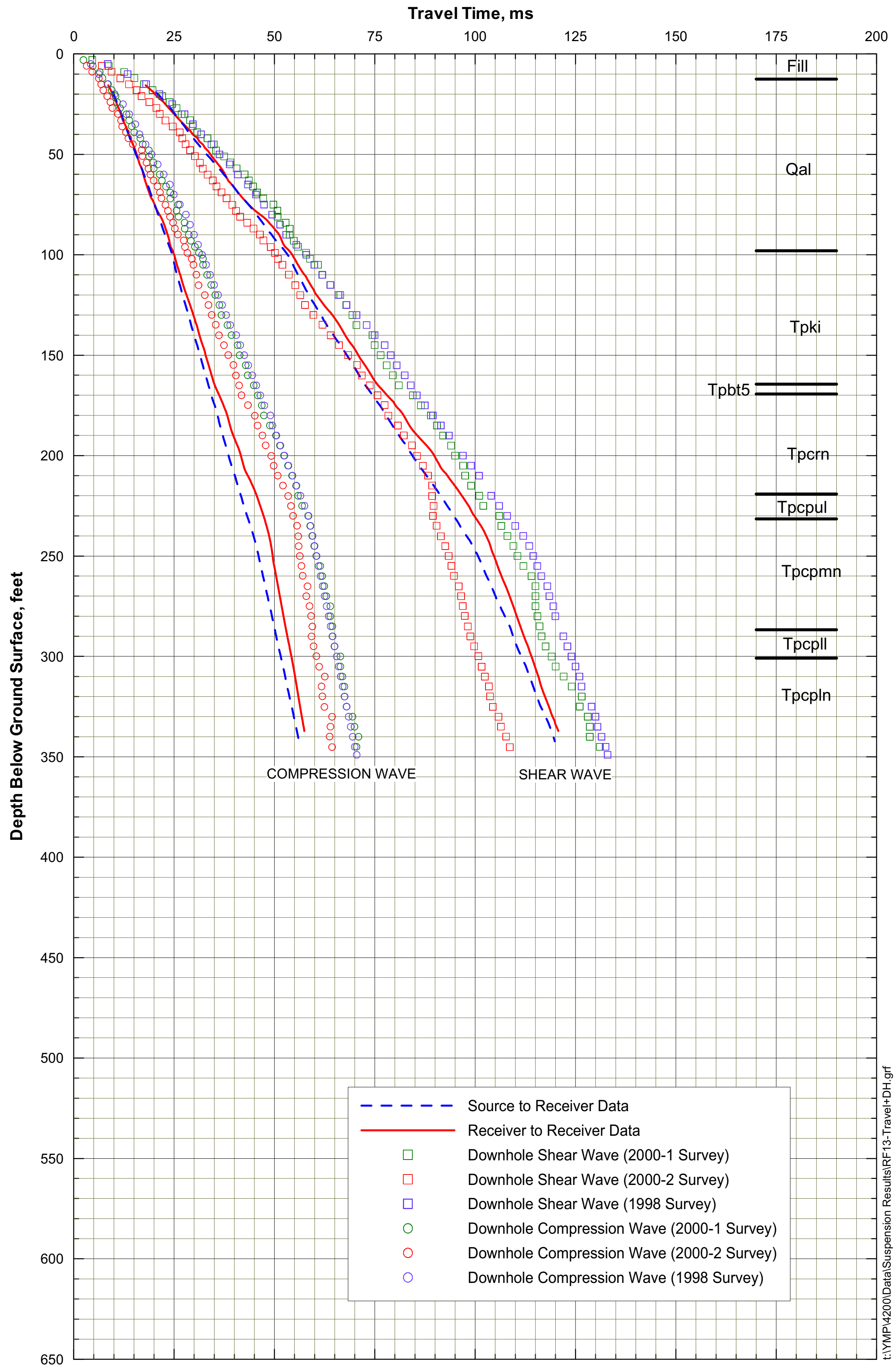

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Figure VIII-1. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#13

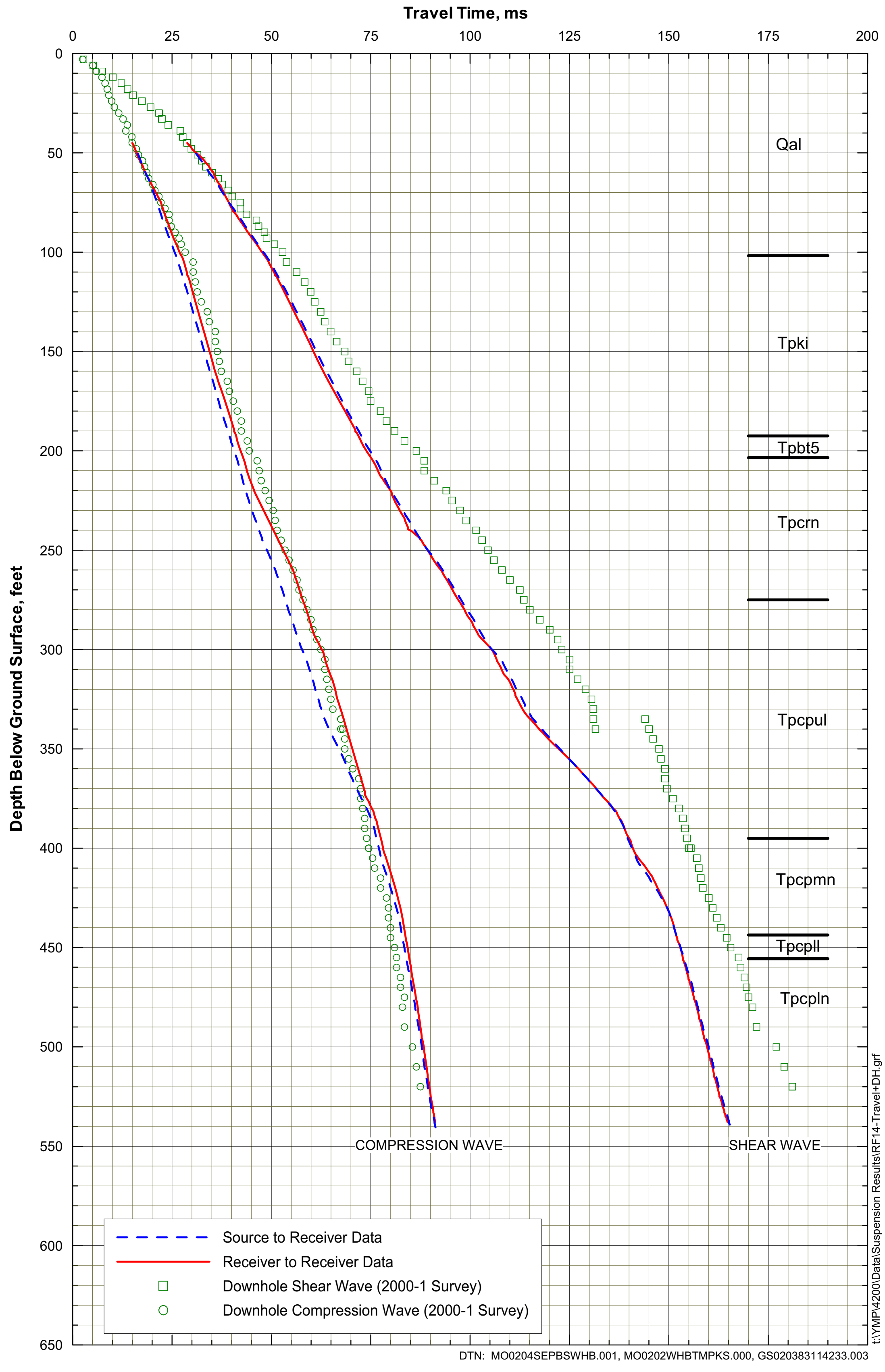


Figure VIII-2. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#14.

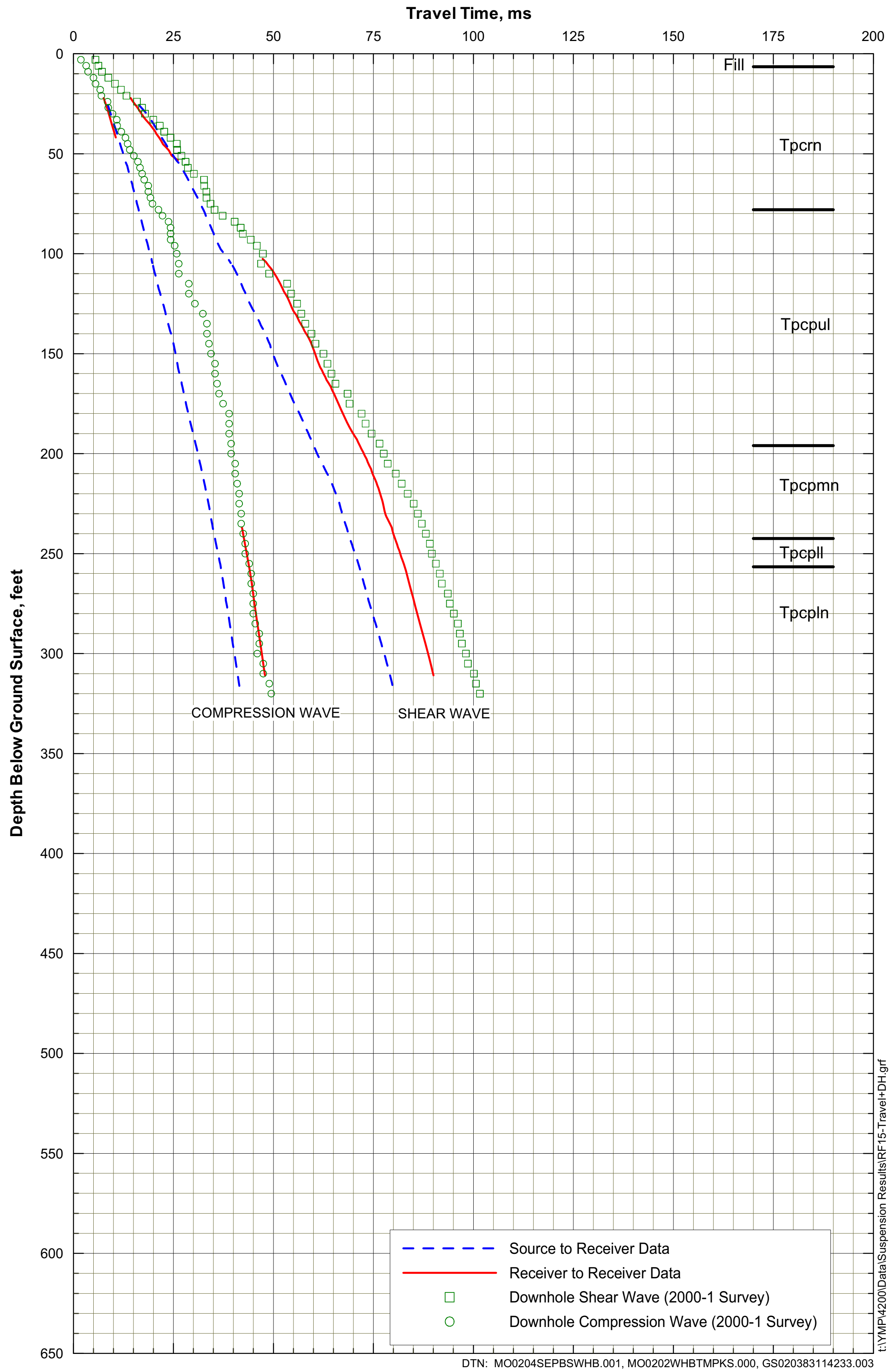


Figure VIII-3. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#15.

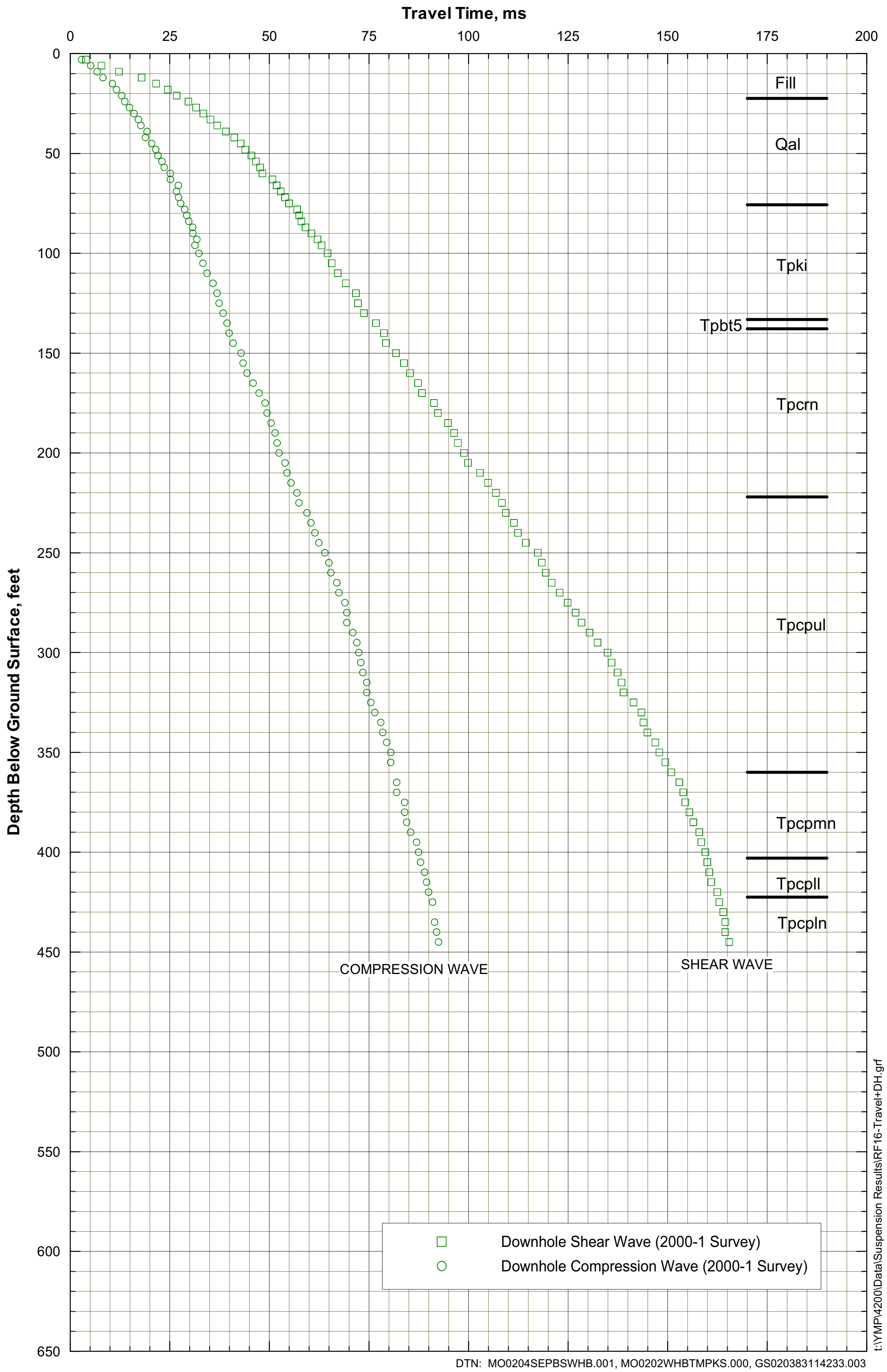


Figure VIII-4. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#16.

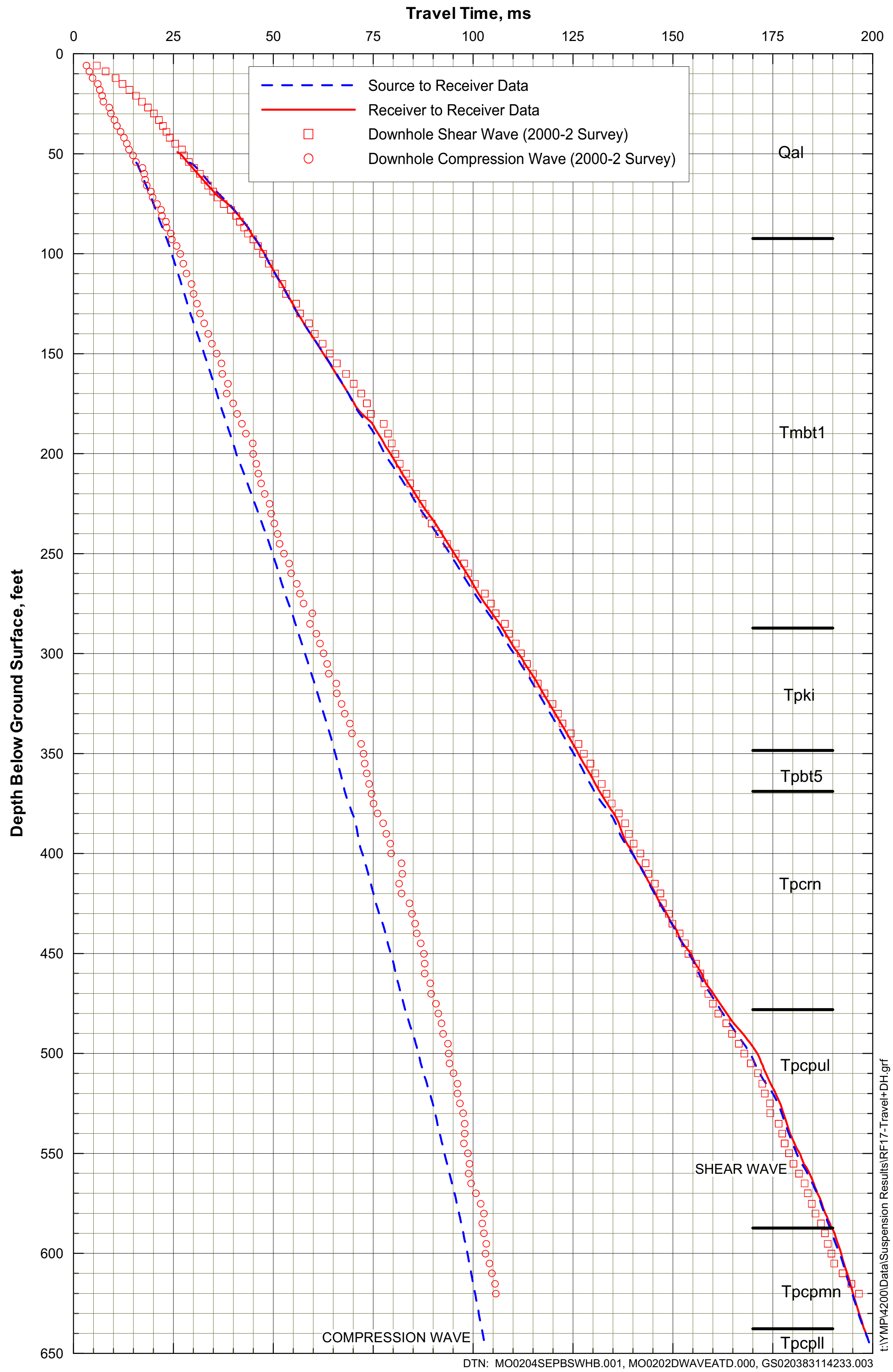


Figure VIII-5. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#17

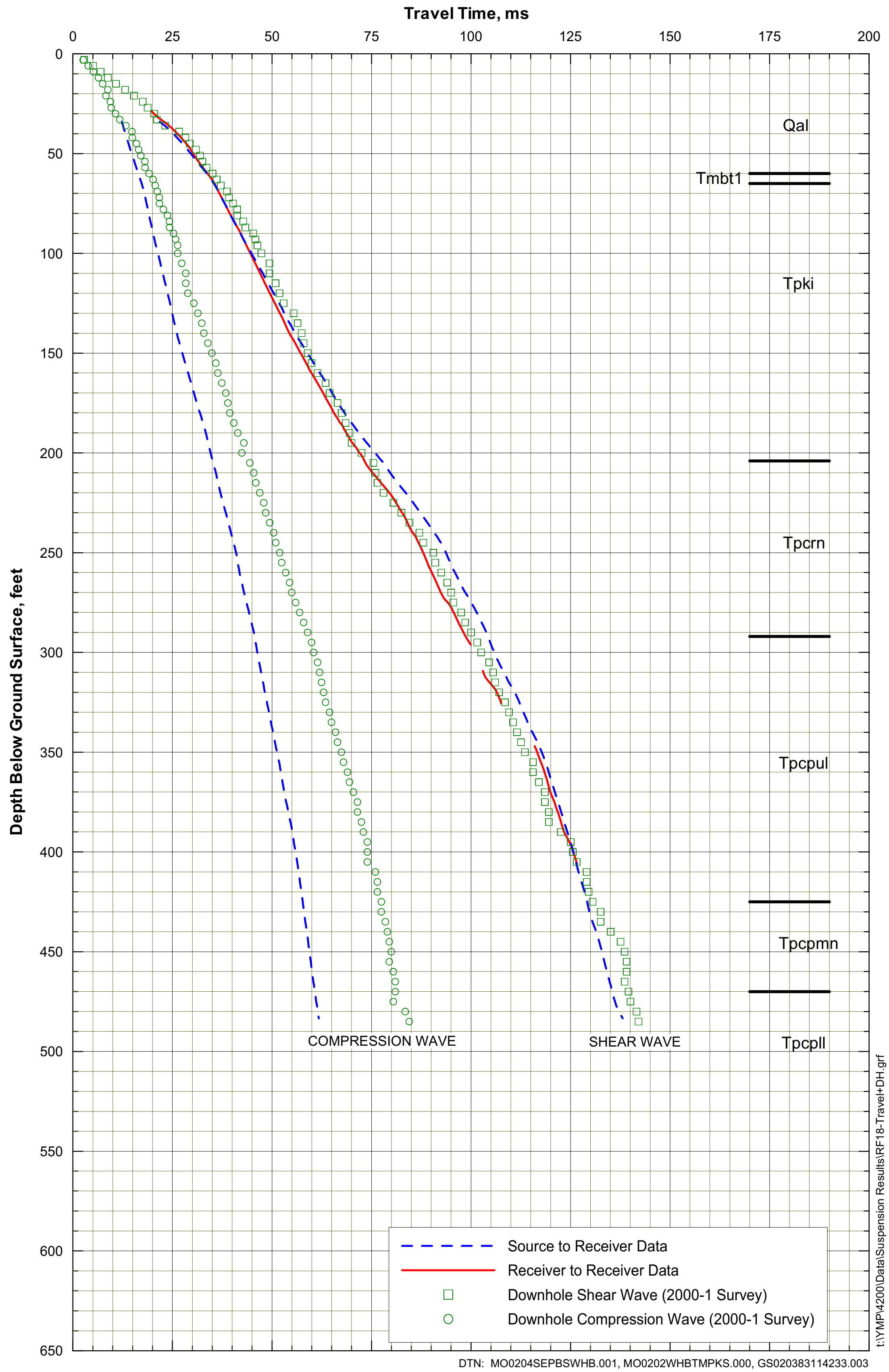


Figure VIII-6. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#18.

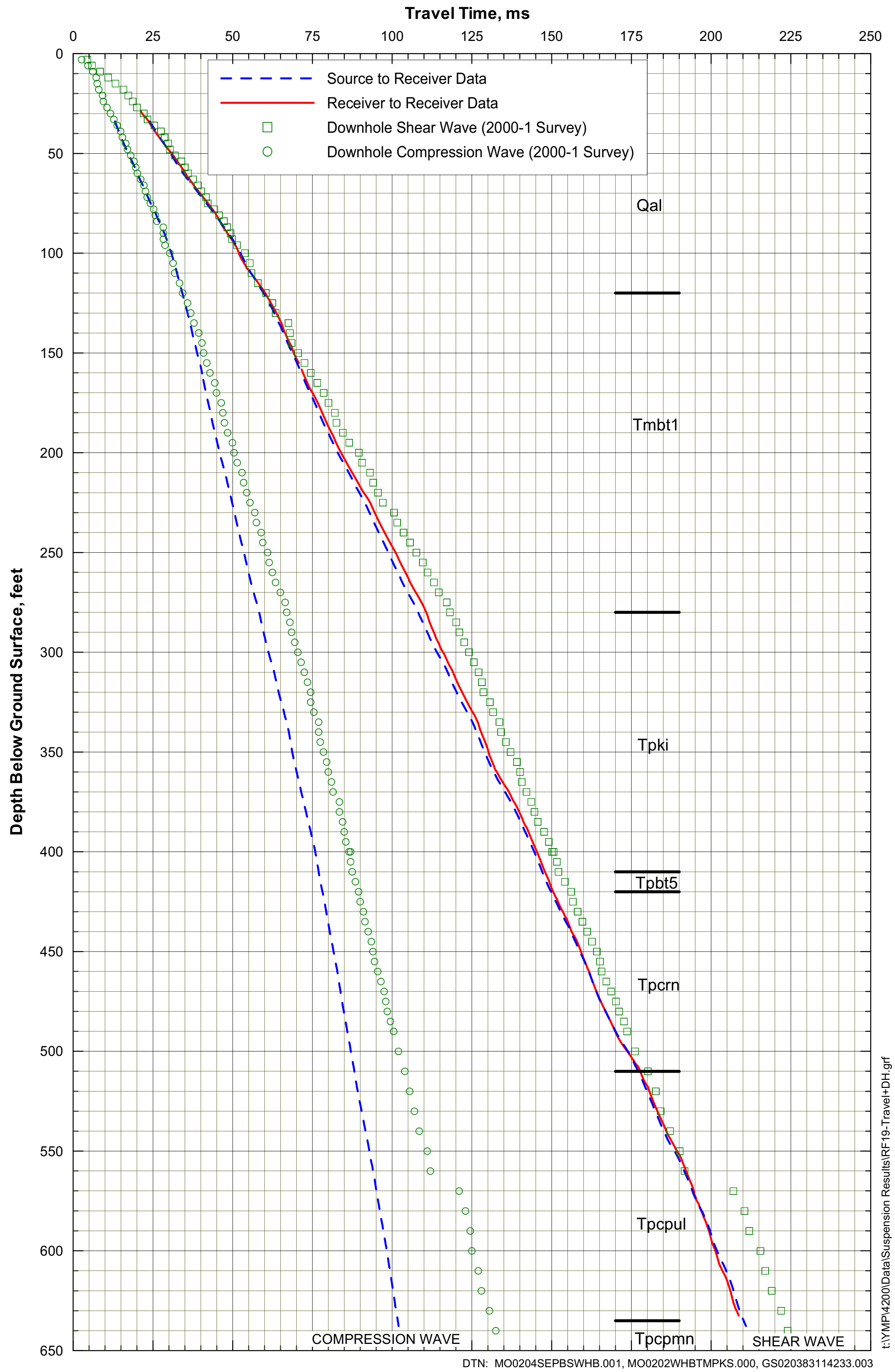
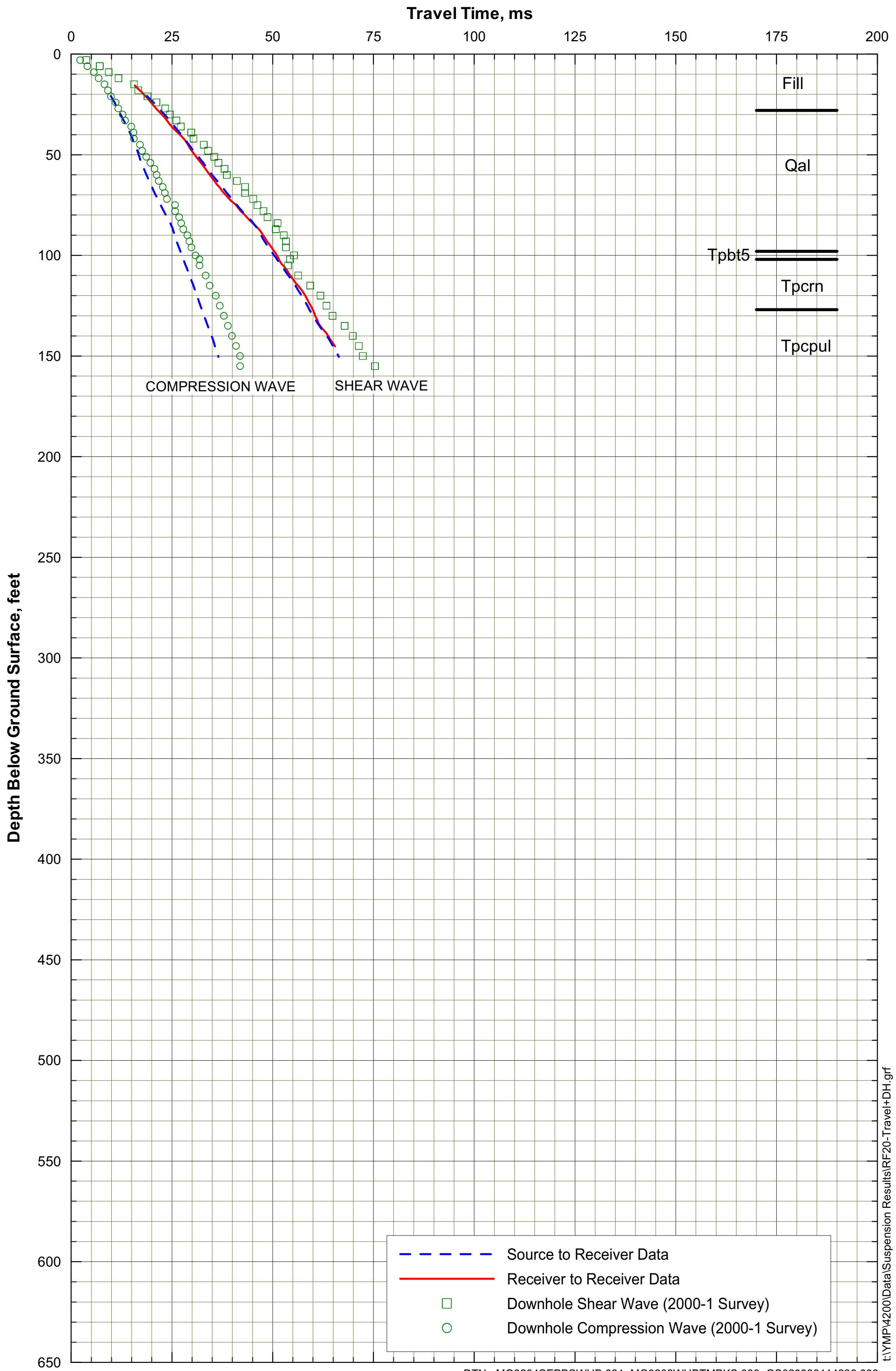
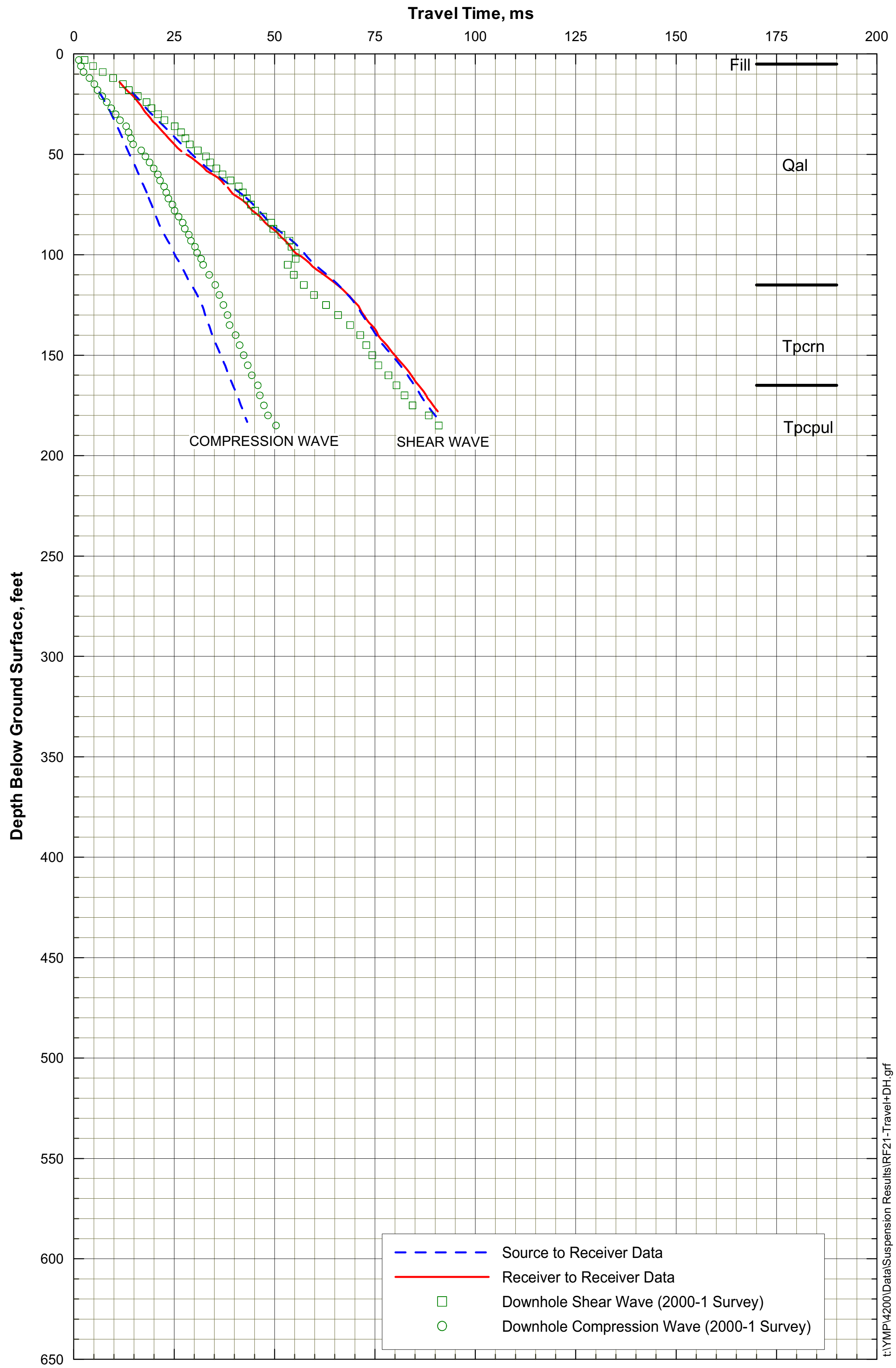


Figure VIII-7. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#19.



DTN: MO0204SEPBSWHB.001, MO0202WHBTMPKS.000, GS020383114233.003

Figure VIII-8. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#20.



DTN: MO0204SEPBSWHB.001, MO0202WHBTMPKS.000, GS020383114233.003

Figure VIII-9. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#21.

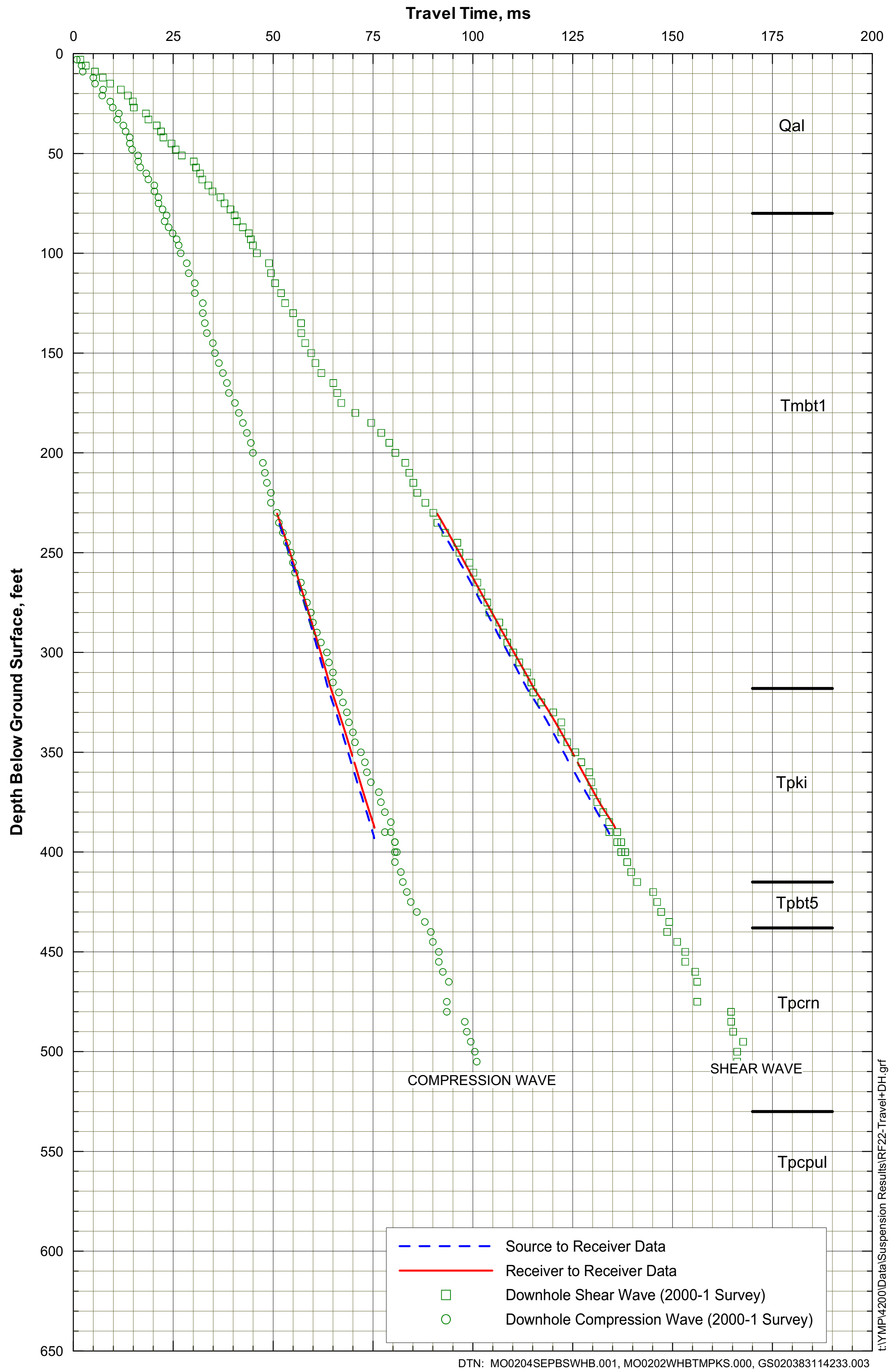


Figure VIII-10. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#22.

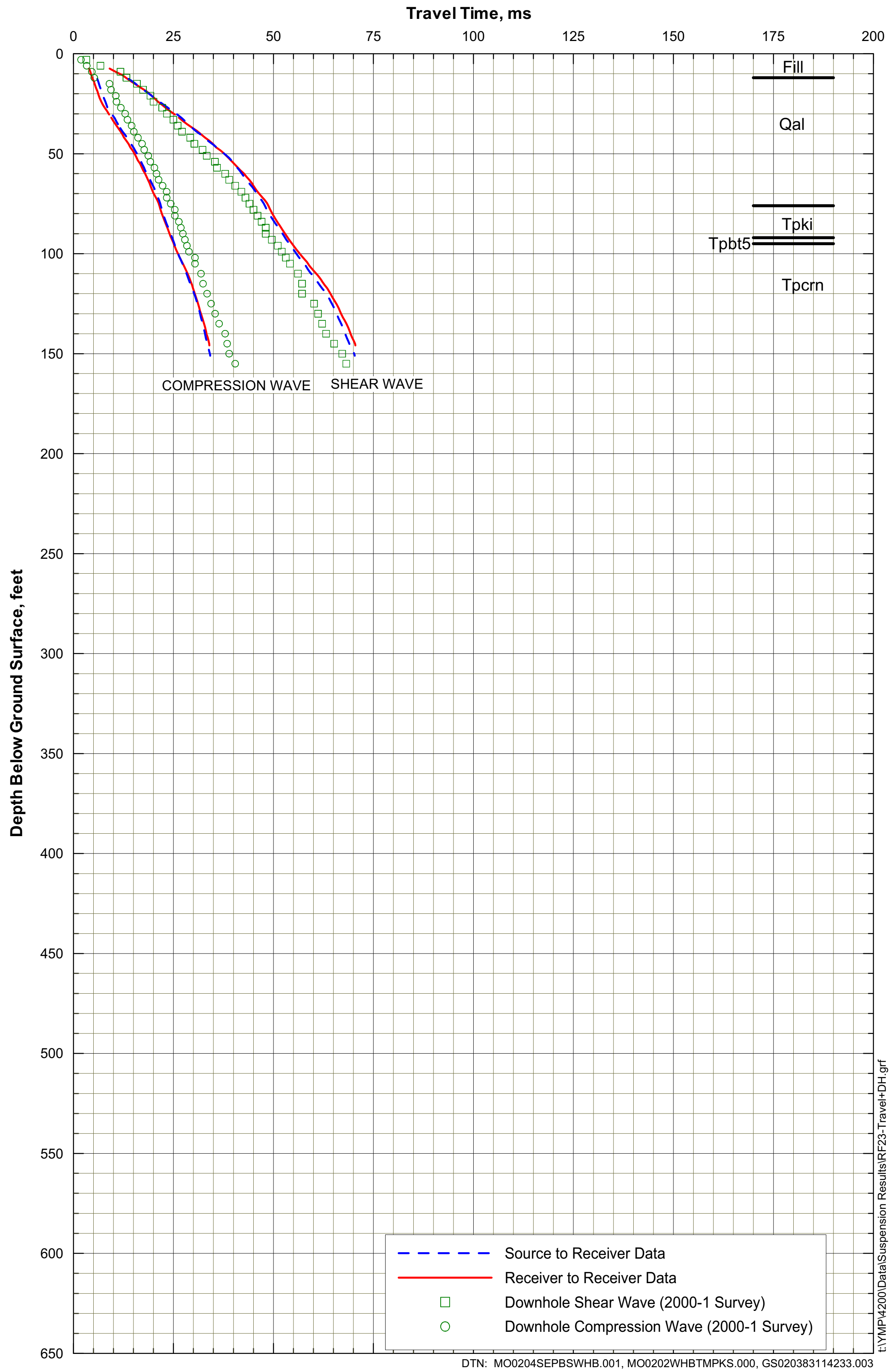


Figure VIII-11. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#23.

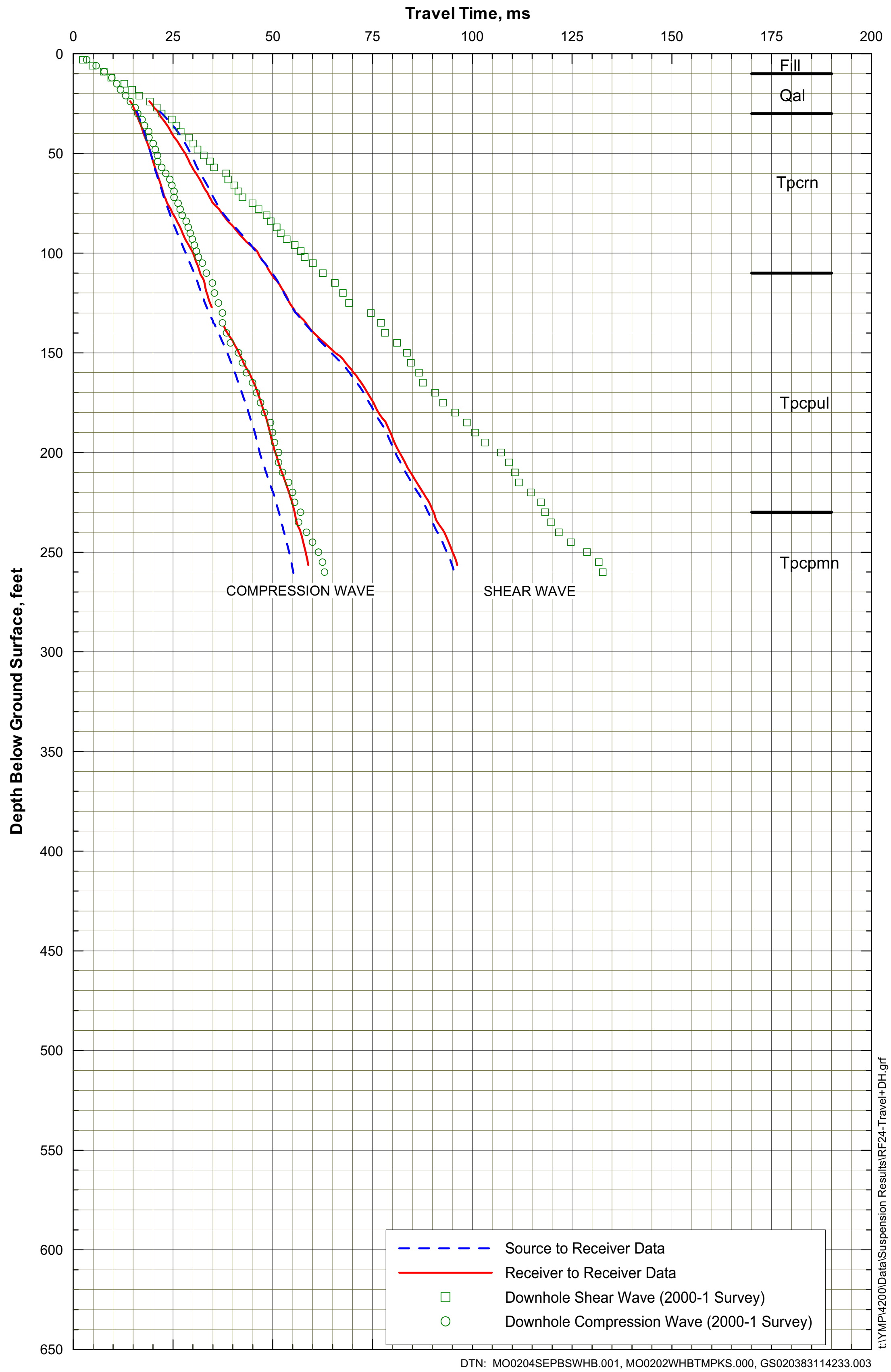


Figure VIII-12. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#24.

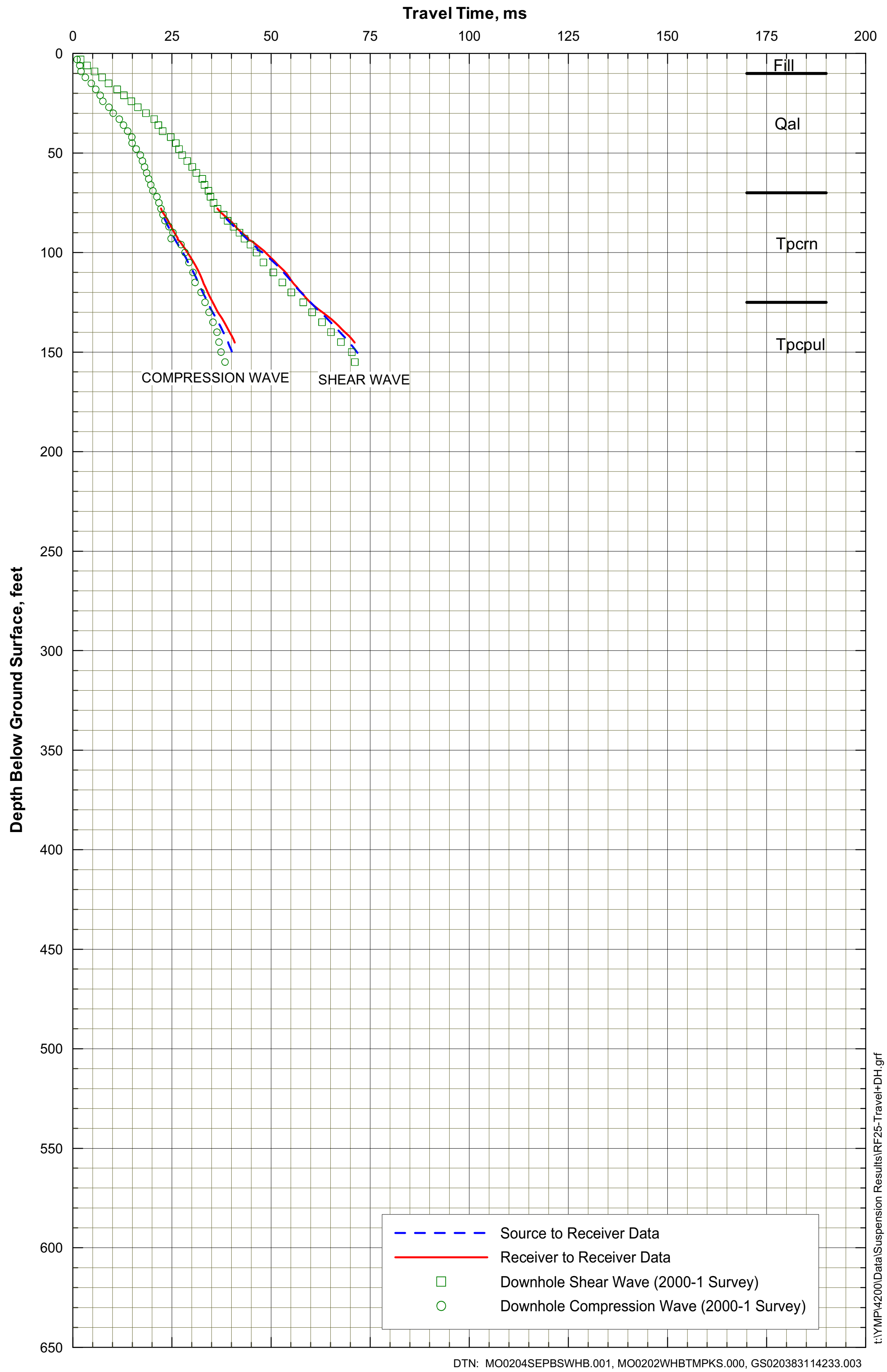
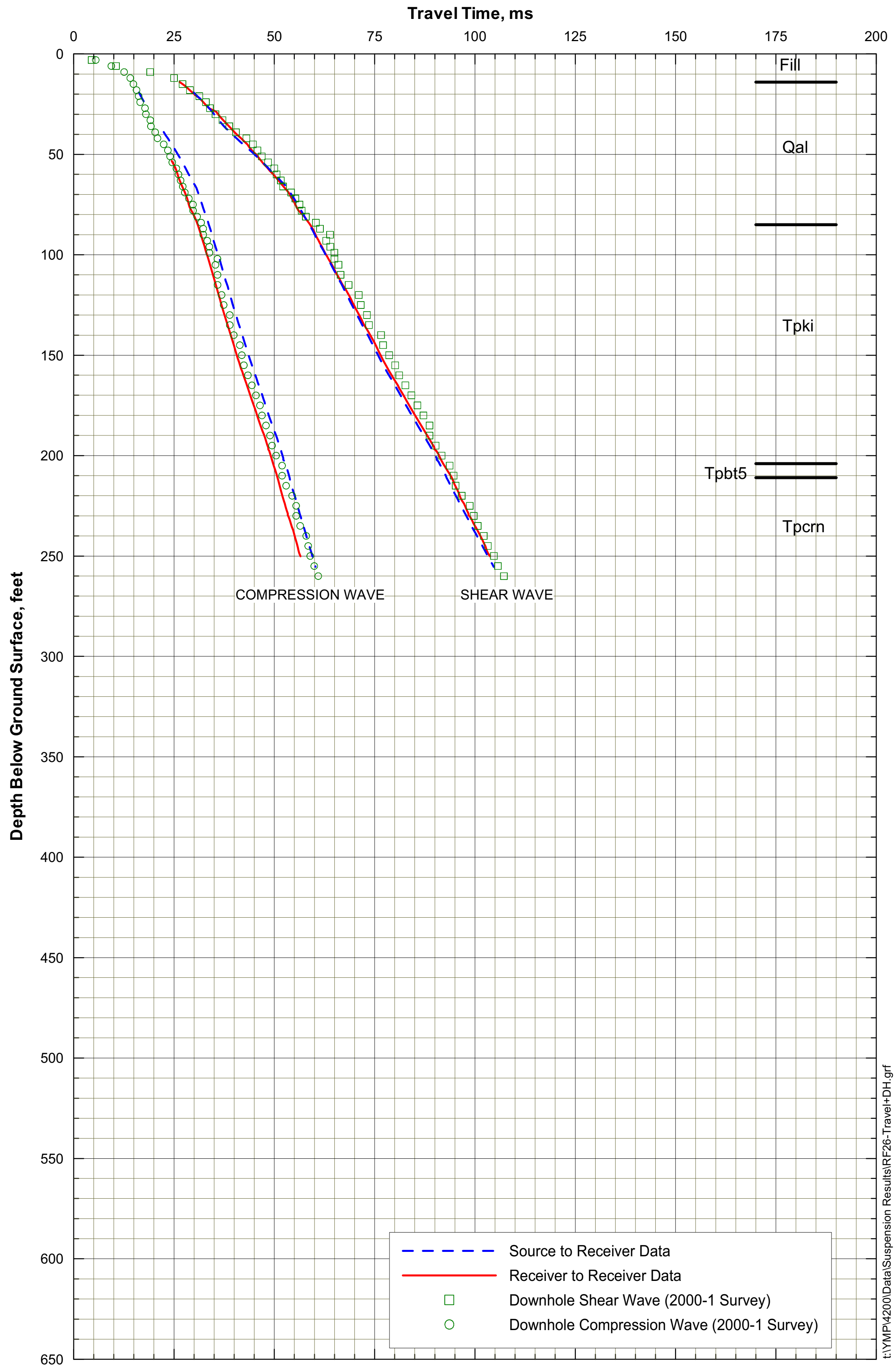


Figure VIII-13. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#25.



DTN: MO0204SEPBSWHB.001, MO0202WHBTMPKS.000, GS020383114233.003

Figure VIII-14. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#26.

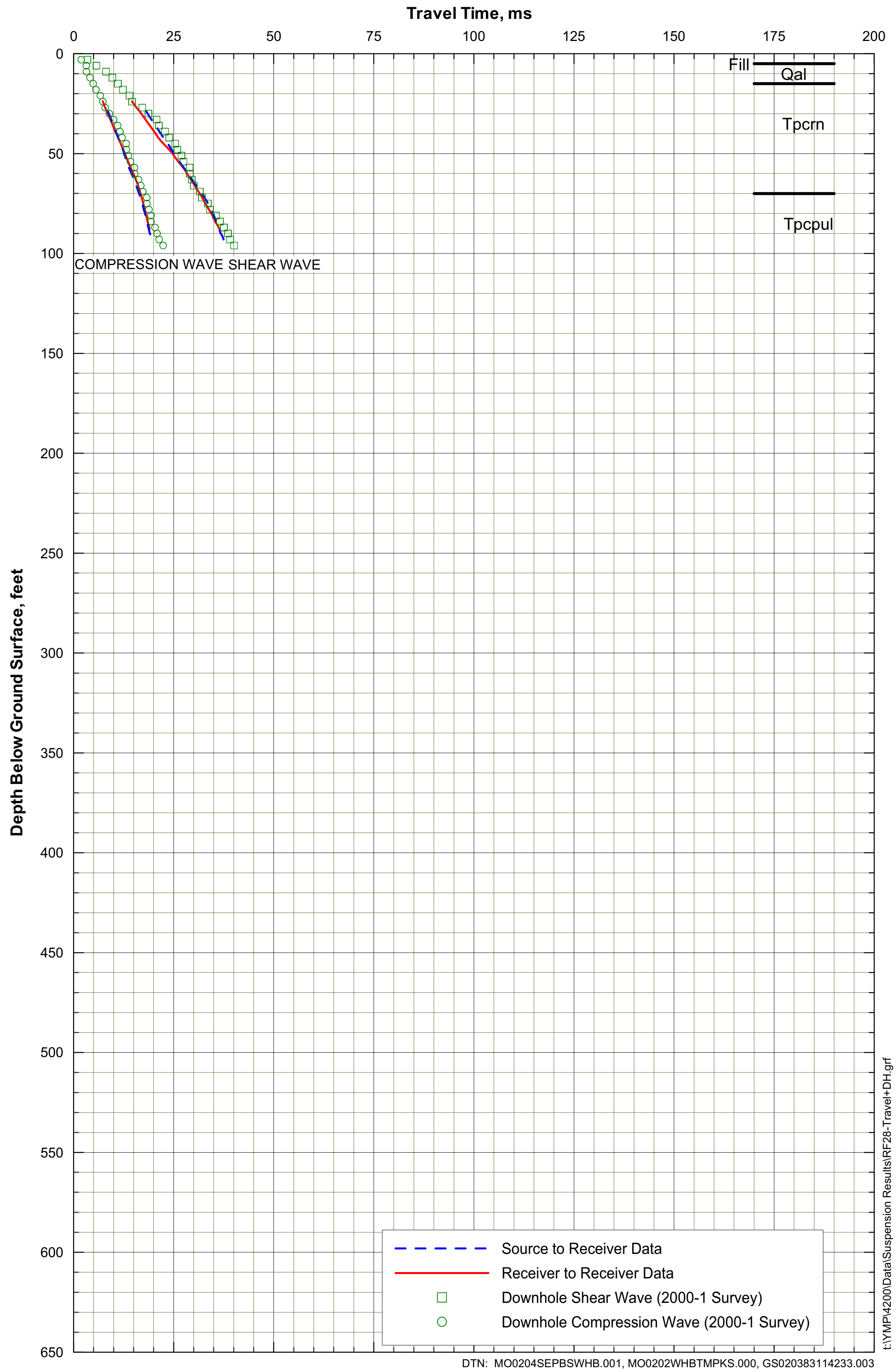


Figure VIII-15. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#28.

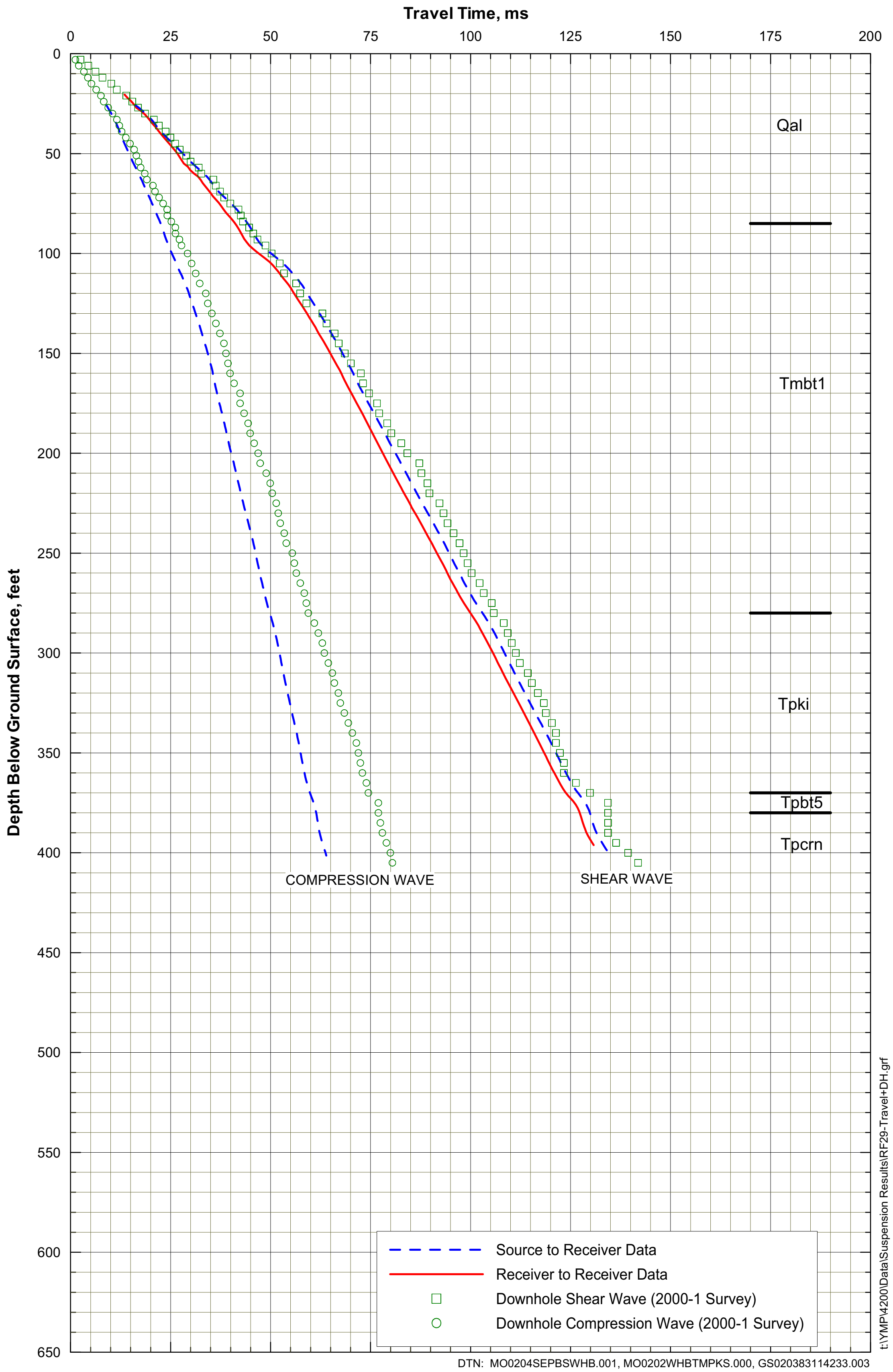
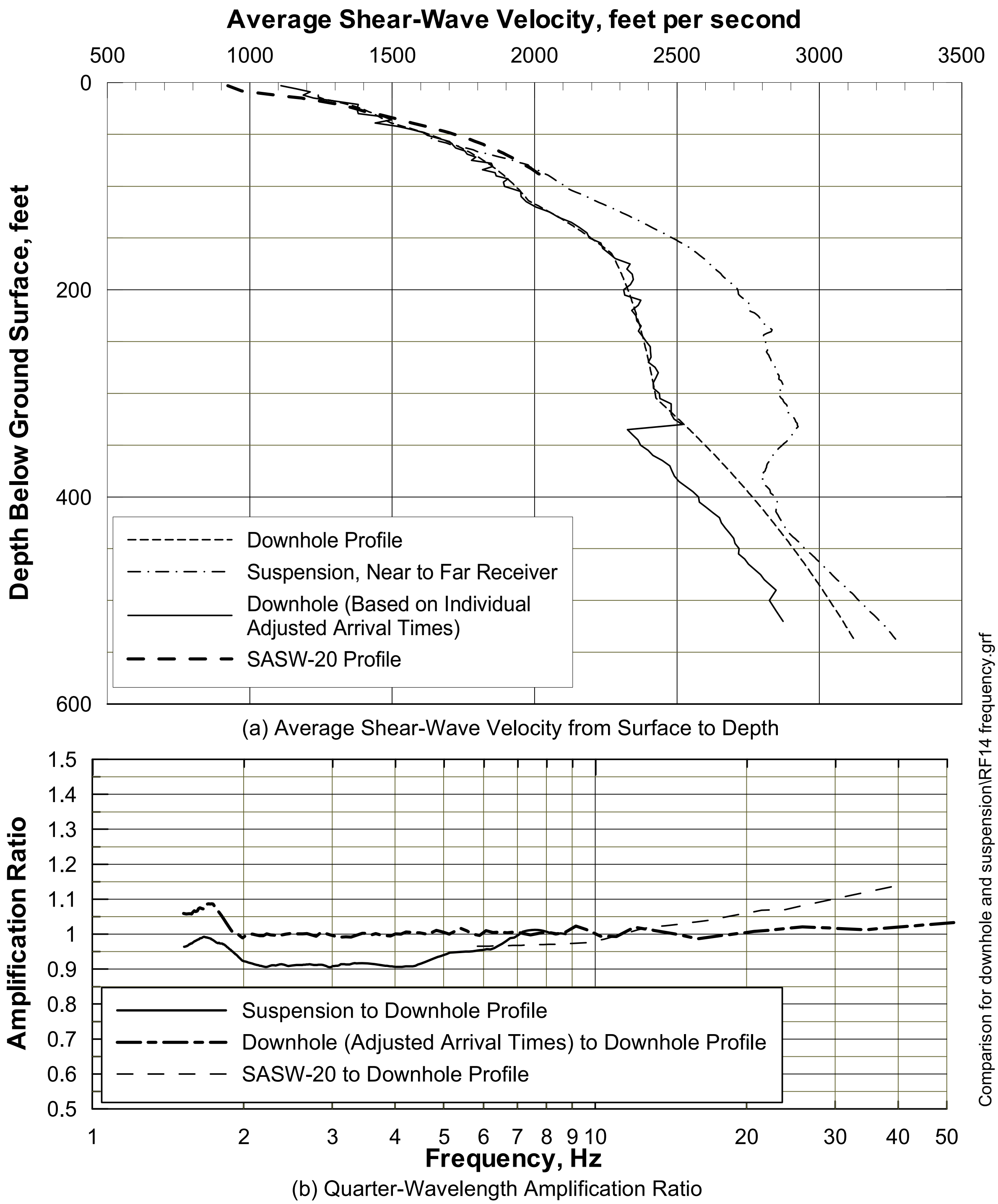
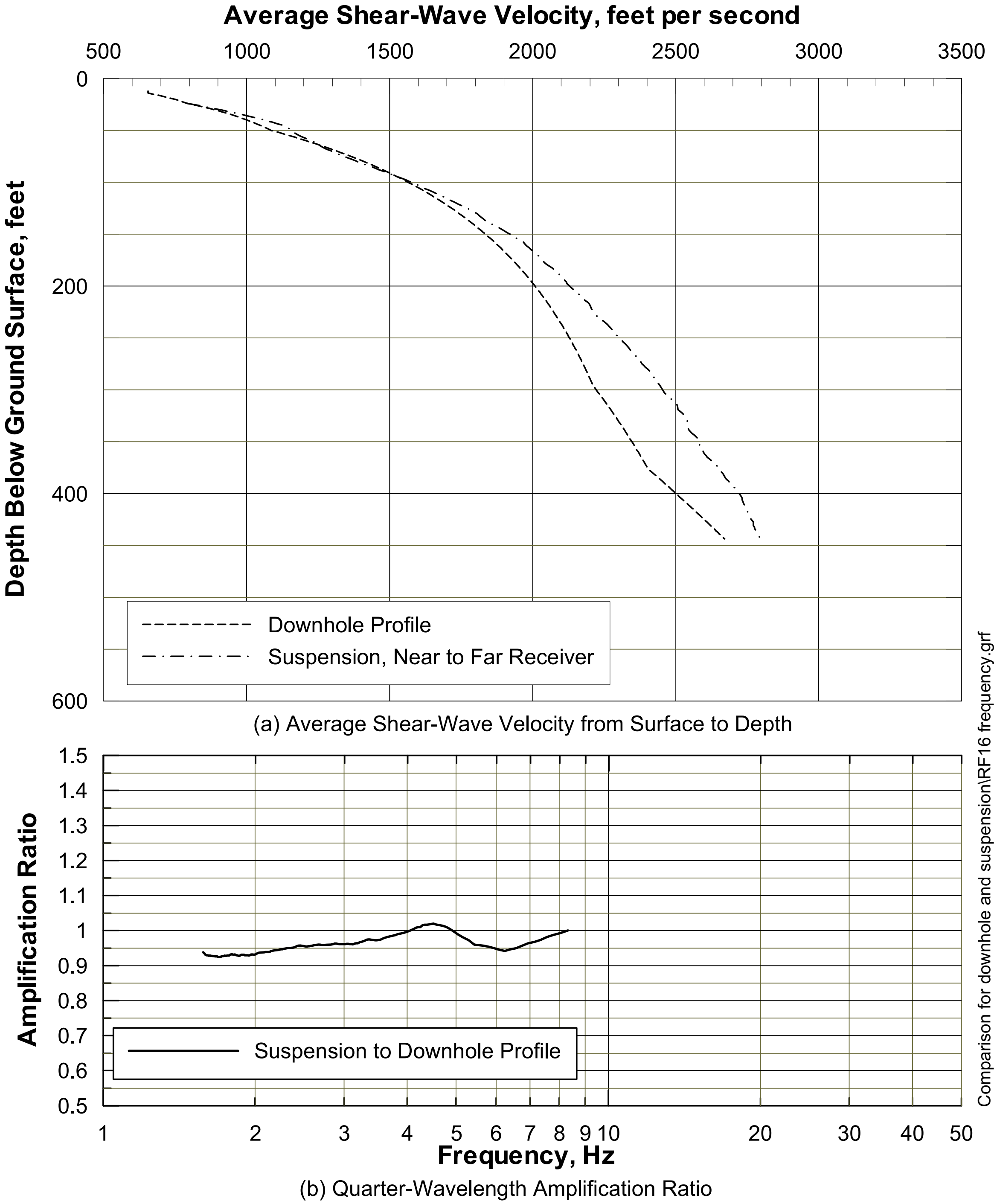


Figure VIII-16. Simulation of Travel Time from Ground Surface to Test Interval Using Suspension Seismic Data and Downhole Travel Times at Borehole RF#29.



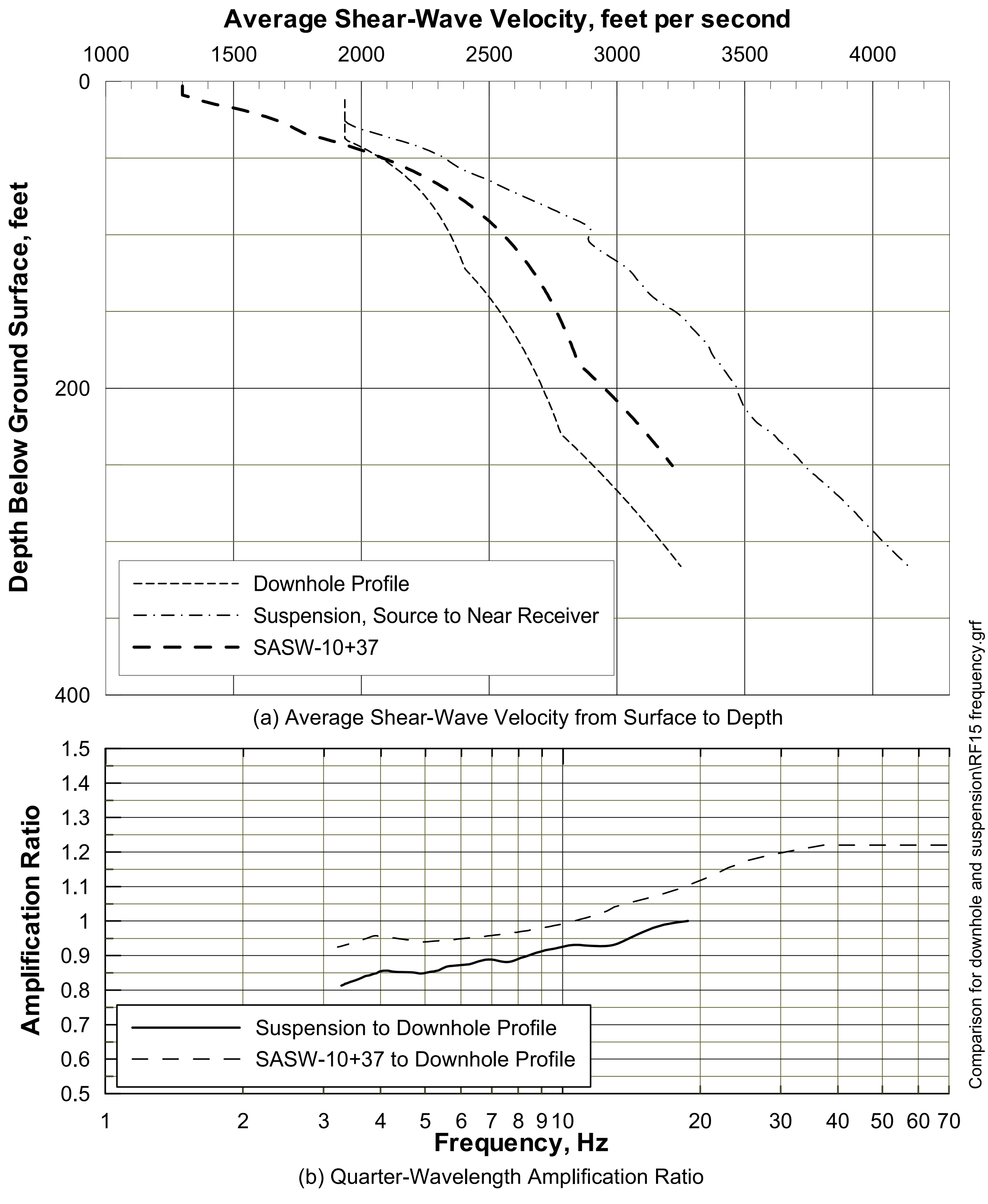
DTN: MO0205SWDQRTWF.000

Figure VIII-17. Comparison of Shear-Wave Velocity by Downhole, Suspension and SASW Logging Methods at Borehole UE-25 RF#14.



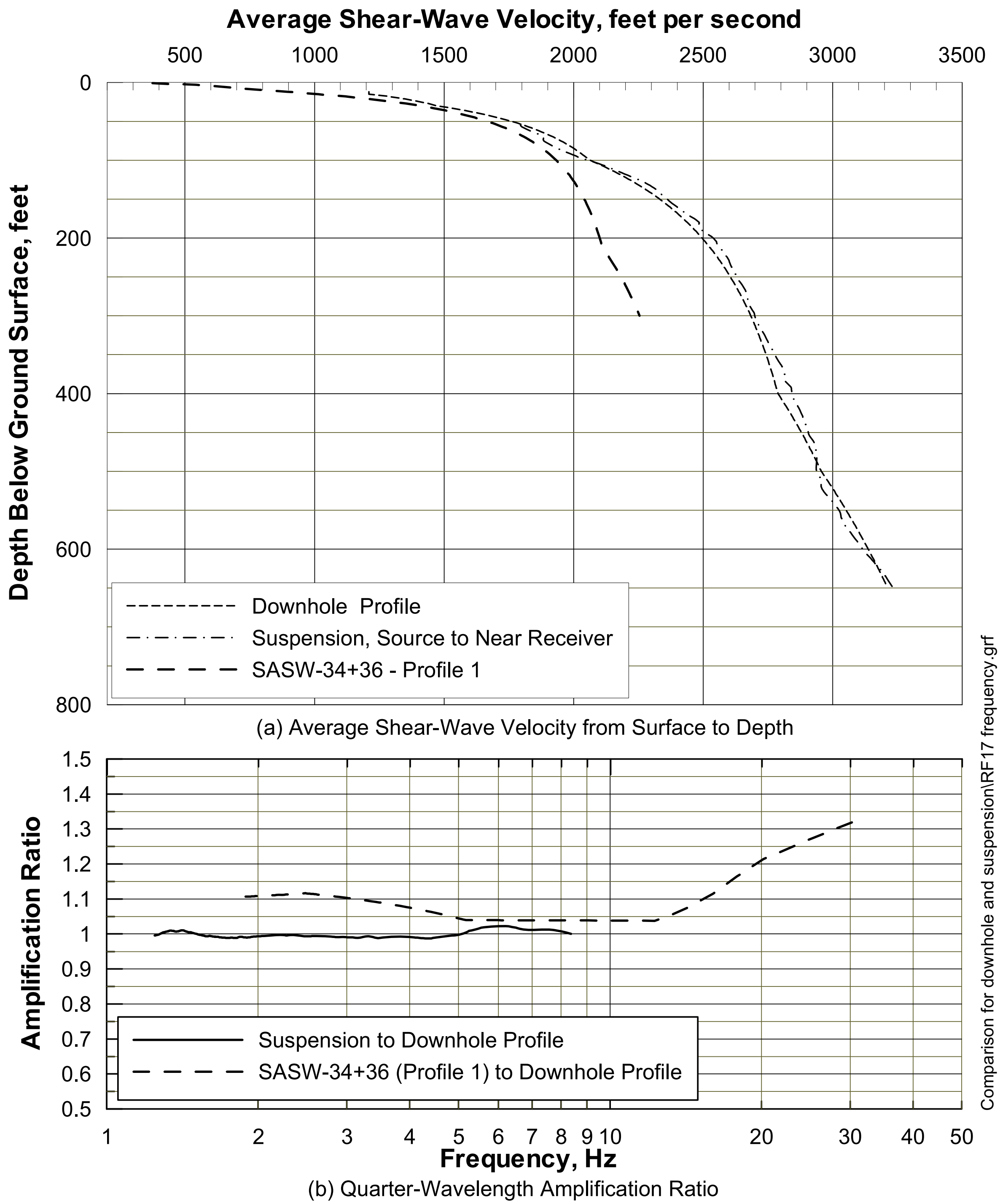
DTN: MO0205SWDQRTWF.000

Figure VIII-19. Comparison of Shear-Wave Velocity by Downhole and Suspension Logging Methods at Borehole UE-25 RF#16.



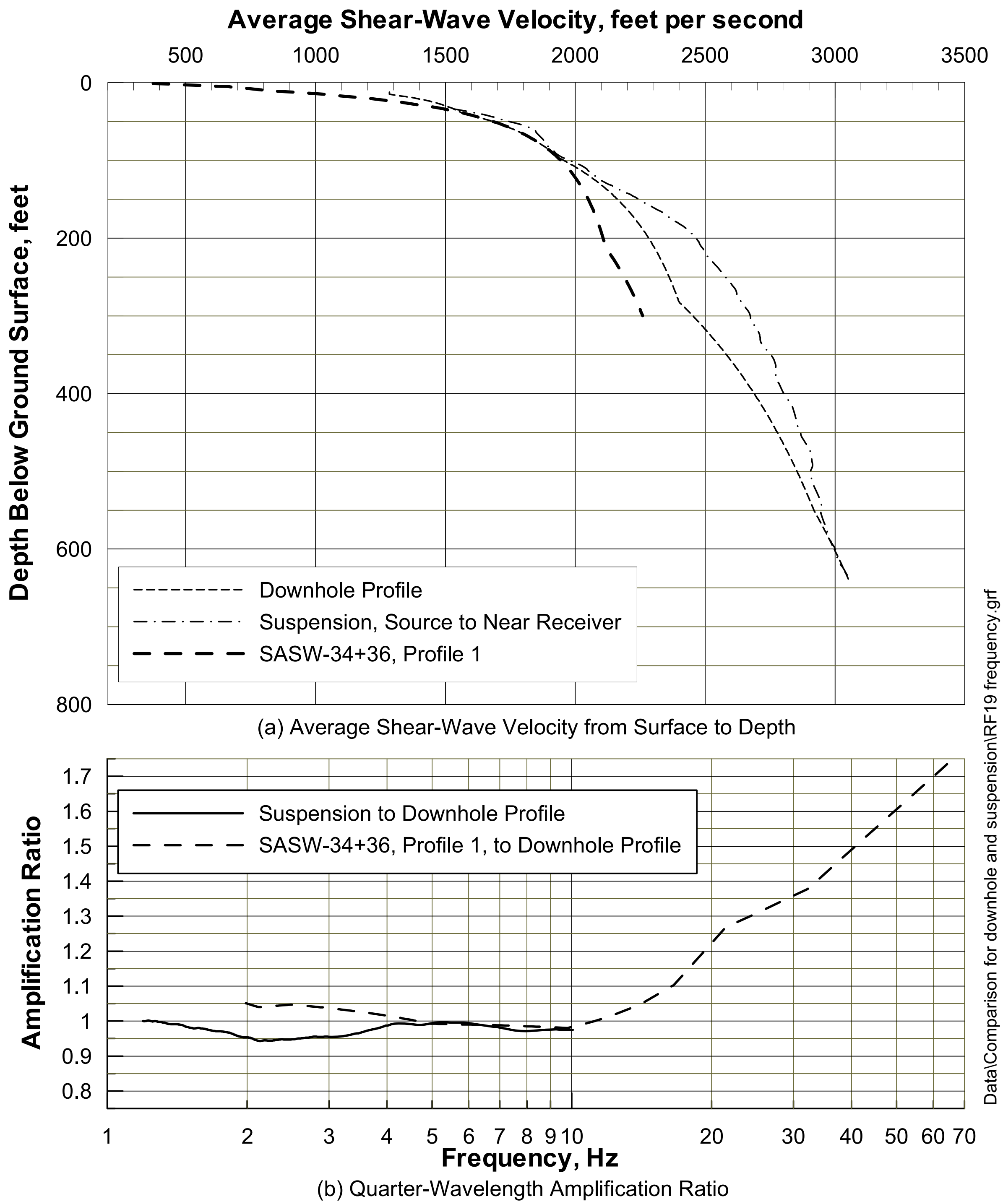
DTN: MO0205SWDQRTWF.000

Figure VIII-18. Comparison of Shear-Wave Velocity by Downhole, Suspension and SASW Logging Methods at Borehole UE-25 RF#15.



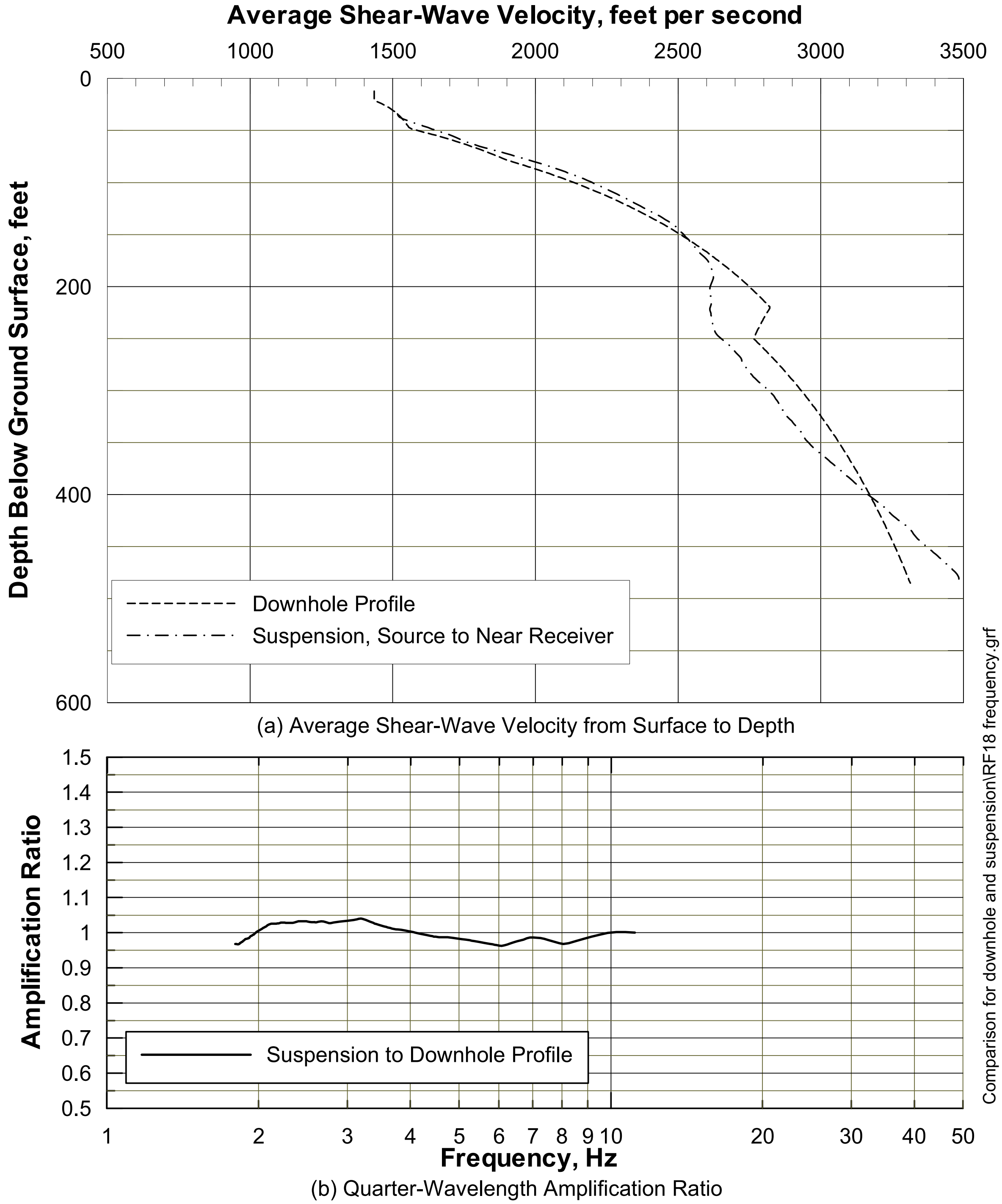
DTN: MO0205SWDQRTWF.000

Figure VIII-20. Comparison of Shear-Wave Velocity by Downhole, Suspension and SASW Logging Methods at Borehole UE-25 RF#17.



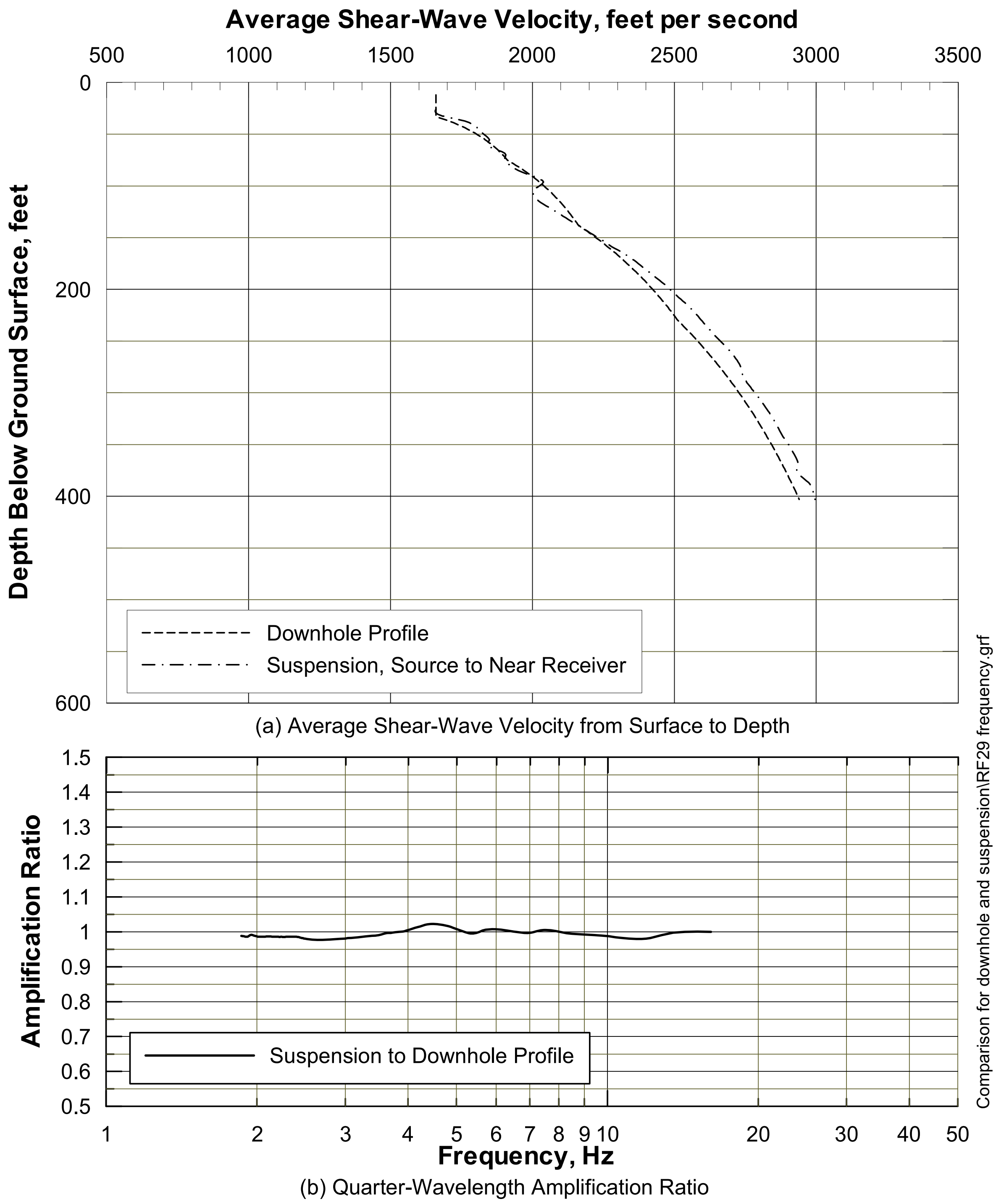
DTN: MO0205SWDQRTWF.000

Figure VIII-22. Comparison of Shear-Wave Velocity by Downhole, Suspension and SASW Logging Methods at Borehole UE-25 RF#19.



DTN: MO0205SWDQRTWF.000

Figure VIII-21. Comparison of Shear-Wave Velocity by Downhole and Suspension Logging Methods at Borehole UE-25 RF#18.



DTN: MO0205SWDQRTWF.000

Figure VIII-23. Comparison of Shear-Wave Velocity by Downhole and Suspension Logging Methods at Borehole UE-25 RF#29.

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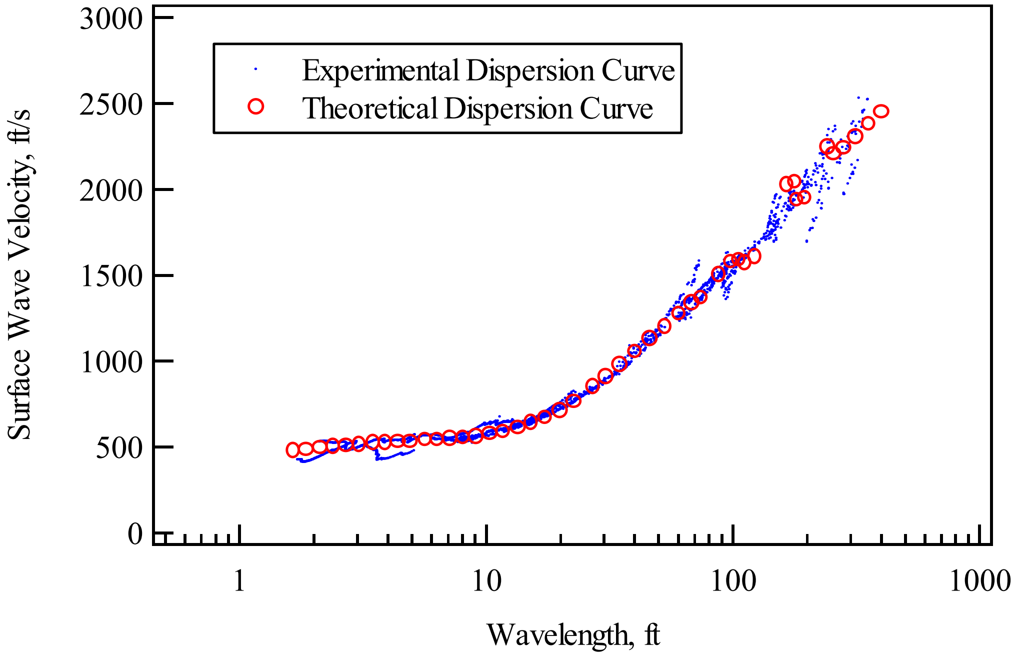
ATTACHMENT IX

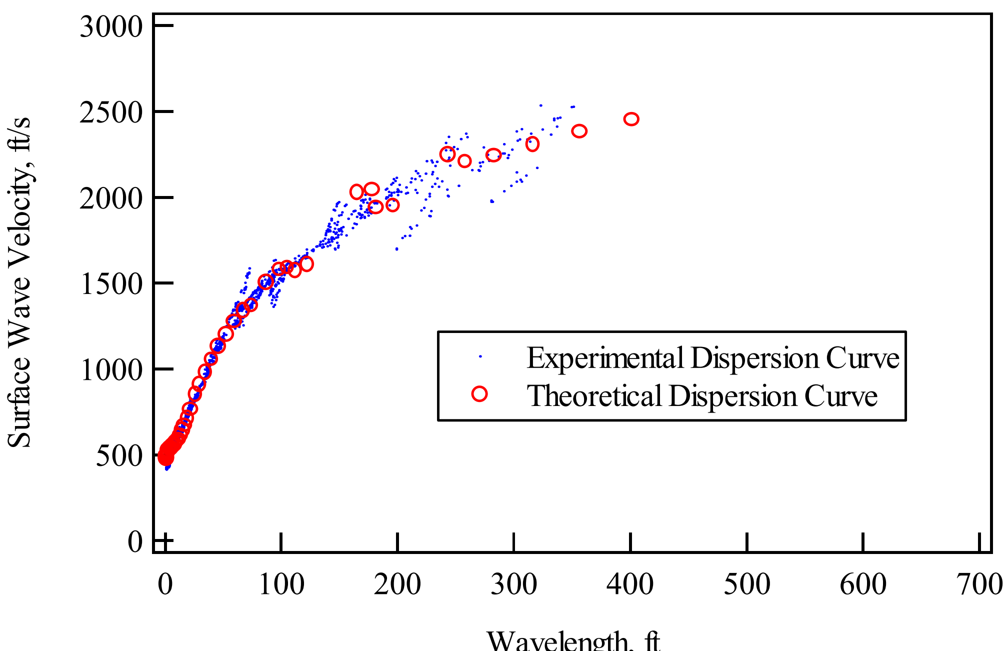
SASW VELOCITY PLOTS – WHB AREA

As described in Section 6.2.7, this attachment presents 34 figures showing detailed interpretive results for the SASW data performed in the WHB area. Each figure contains dispersion curves (both experimental and theoretical in linear and semi-log space) (Wong 2002c) and the resulting shear- and compression-wave velocity profiles. A total of 35 velocity profiles are presented. A detailed description of each analysis can be found in the associated appendix in scientific notebook SN-M&O-SCI-022-V1 (Wong 2002c).



(Wong.2002c, Appendix 1)

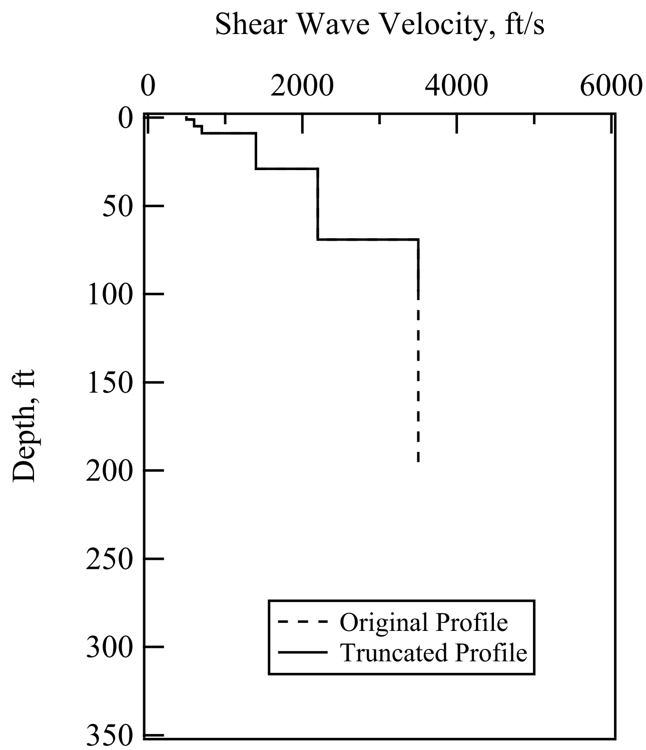
a. SASW-1 Dispersion Curves (Log Plot)



(Wong.2002c, Appendix 1)

b. SASW-1 Dispersion Curves (Linear Plot)

Figure IX-1. SASW-1 Results



DTN: MO0110SASWWHBS.000

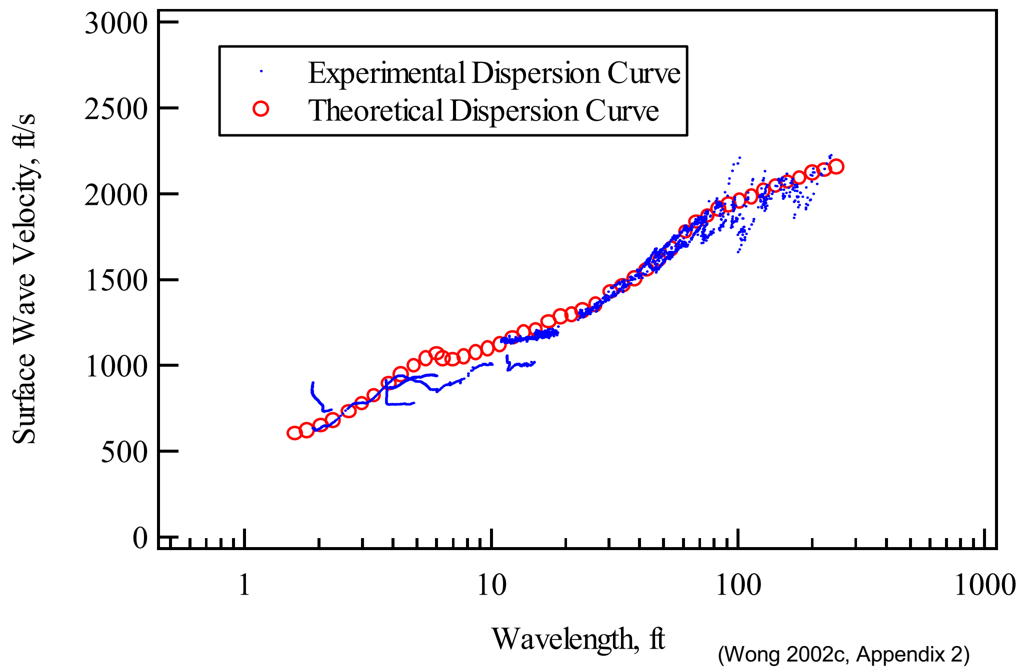
c. SASW-1 Shear Wave Velocity Profile

Location: SASW-1

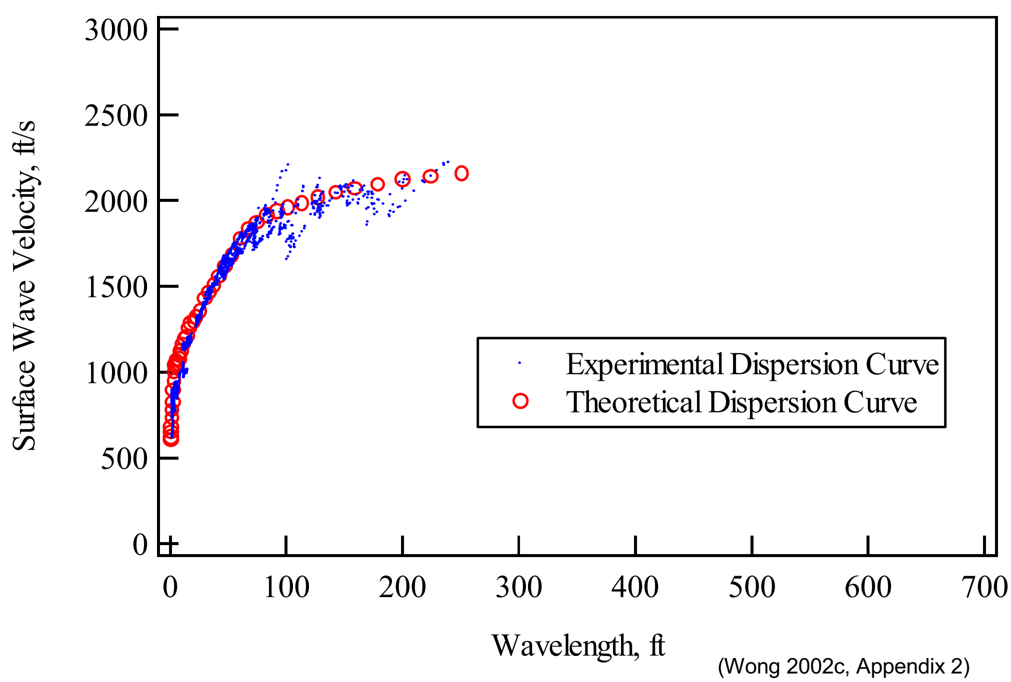
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	866	500	0.25	120
2	4	1039	600	0.25	120
3	4	1212	700	0.25	120
4	20	2425	1400	0.25	120
5	40	3810	2200	0.25	120
6	29*	6062	3500	0.25	80
7	102**	6062	3500	0.25	80

DTN: MO0110SASWWHBS.000
* Vs profile truncated at 98 ft based on geological profile showing an offset fault beginning at a depth of approximately 98 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 1)

Figure IX-1. SASW-1 Results (continued)

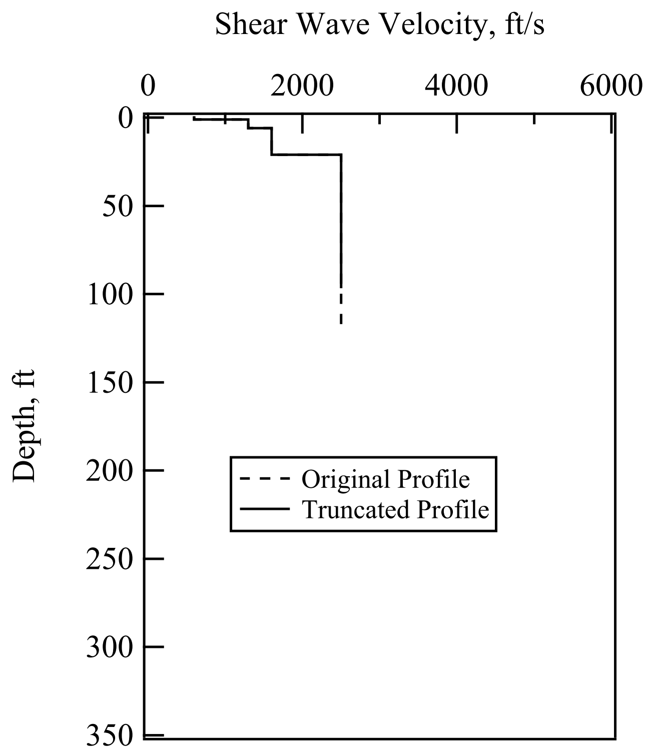


a. SASW-2 Dispersion Curves (Log Plot)



b. SASW-2 Dispersion Curves (Linear Plot)

Figure IX-2. SASW-2 Results



DTN: MO0110SASWWHBS.000

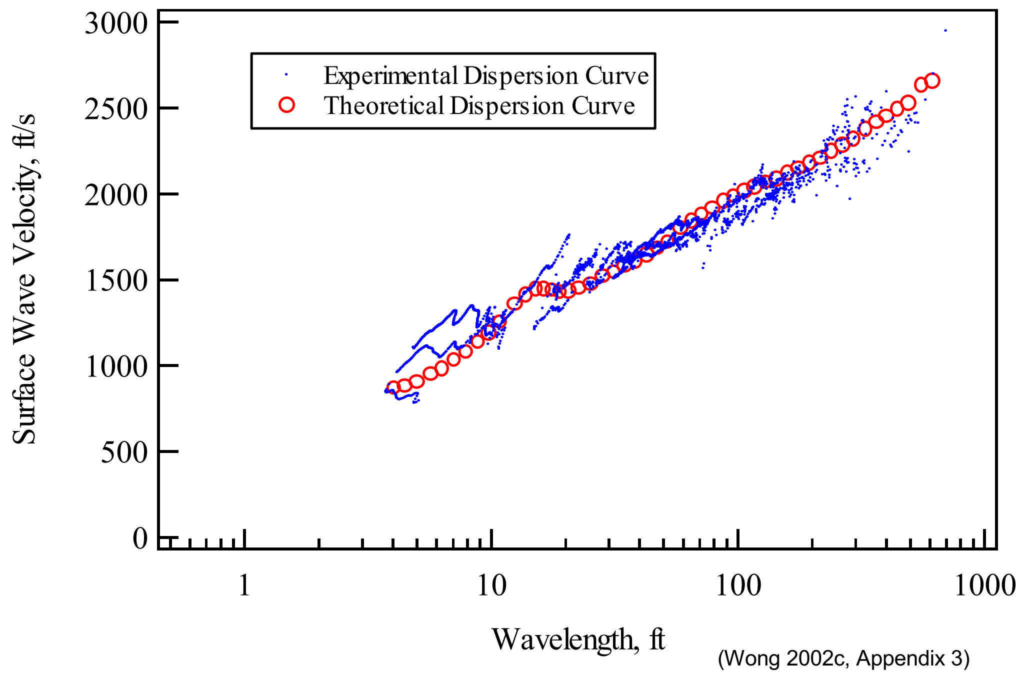
c. SASW-2 Shear Wave Velocity Profile

Location: SASW-2

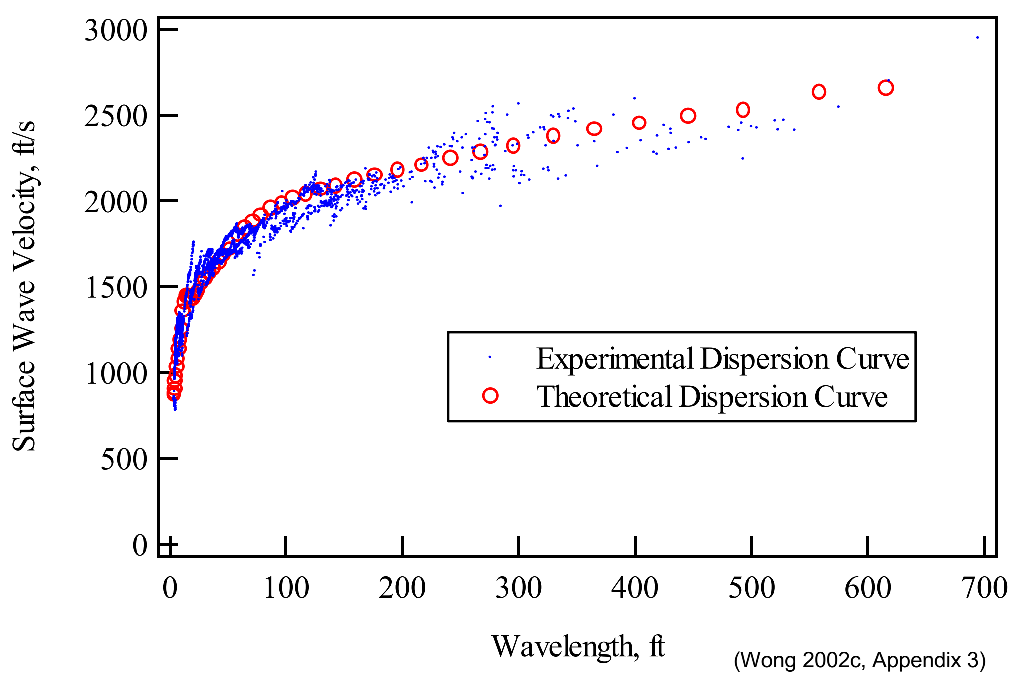
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	1039	600	0.25	120
2	5	2252	1300	0.25	120
3	15	2771	1600	0.25	120
4	75*	4850	2500	0.25	120
5	24**	4850	2500	0.25	120

DTN: MO0110SASWWHBS.000
* Vs profile truncated at 96 ft based on geological profile showing an offset fault beginning at a depth of approximately 96 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 2)

Figure IX-2. SASW-2 Results (continued)

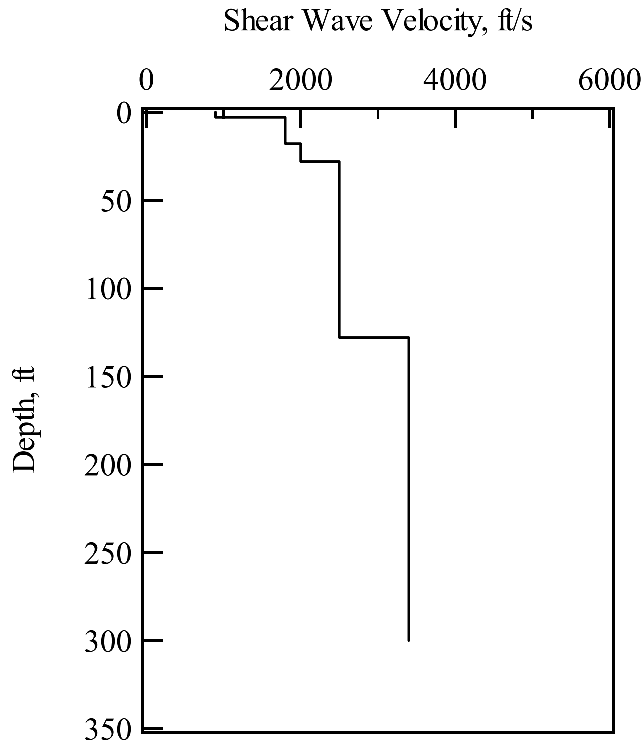


a. SASW-3 Dispersion Curves (Log Plot)



b. SASW-3 Dispersion Curves (Linear Plot)

Figure IX-3. SASW-3 Results



DTN: MO0110SASWWHBS.000

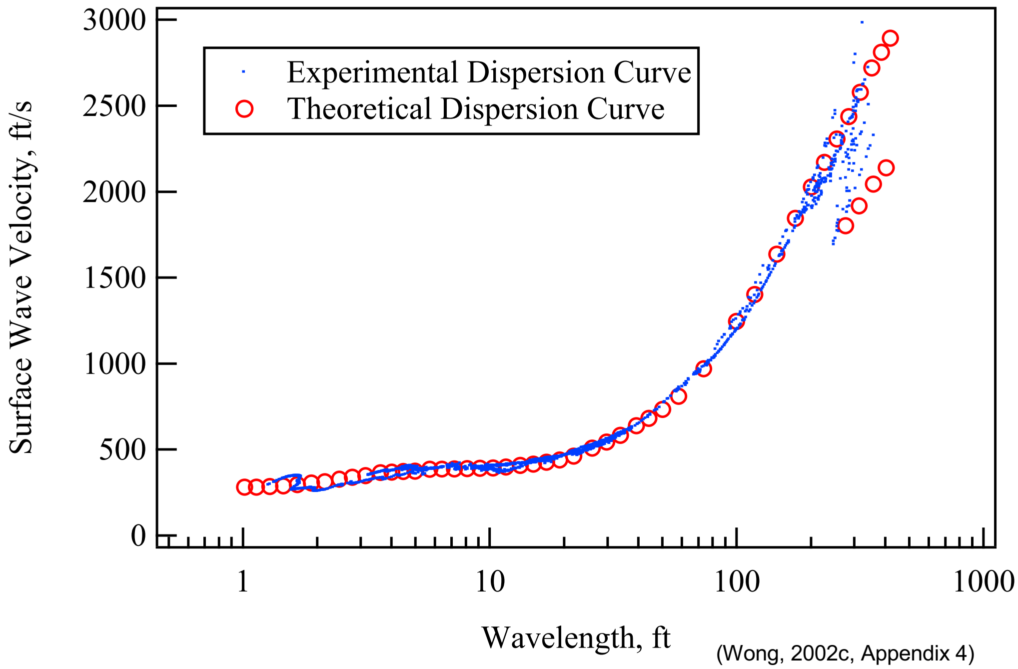
c. SASW-3 Shear Wave Velocity Profile

Location: SASW-3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	3	1559	900	0.25	120
2	15	3118	1800	0.25	120
3	10	3464	2000	0.25	120
4	100	4330	2500	0.25	120
5	173	5889	3400	0.25	80

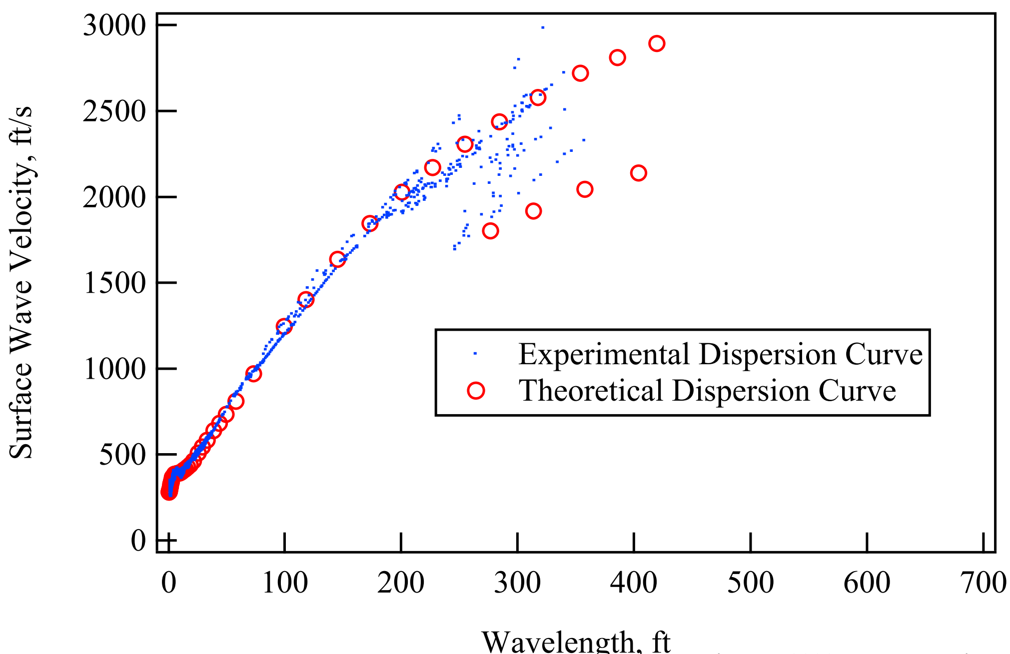
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 3)

Figure IX-3. SASW-3 Results (continued)



(Wong, 2002c, Appendix 4)

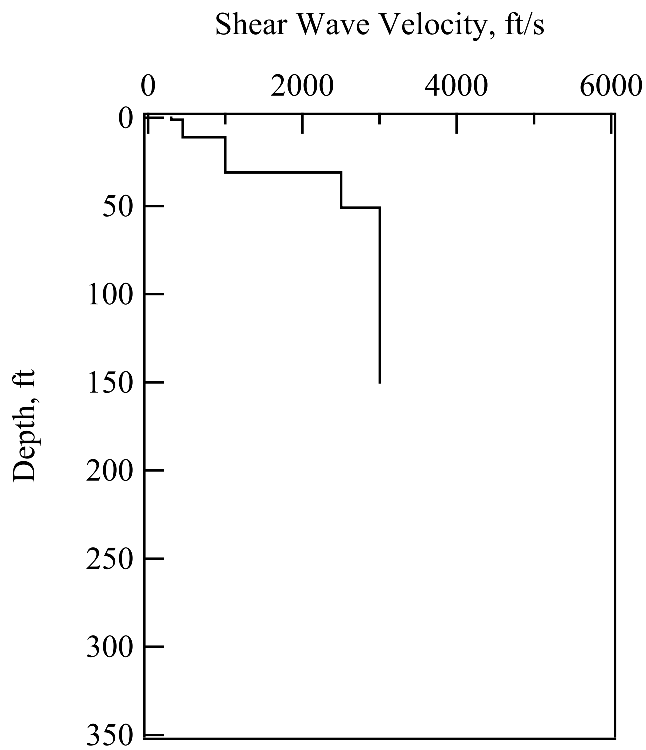
a. SASW-4 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 4)

b. SASW-4 Dispersion Curves (Linear Plot)

Figure IX-4. SASW-4 Results



DTN: MO0110SASWWHBS.000

c. SASW-4 Shear Wave Velocity Profile

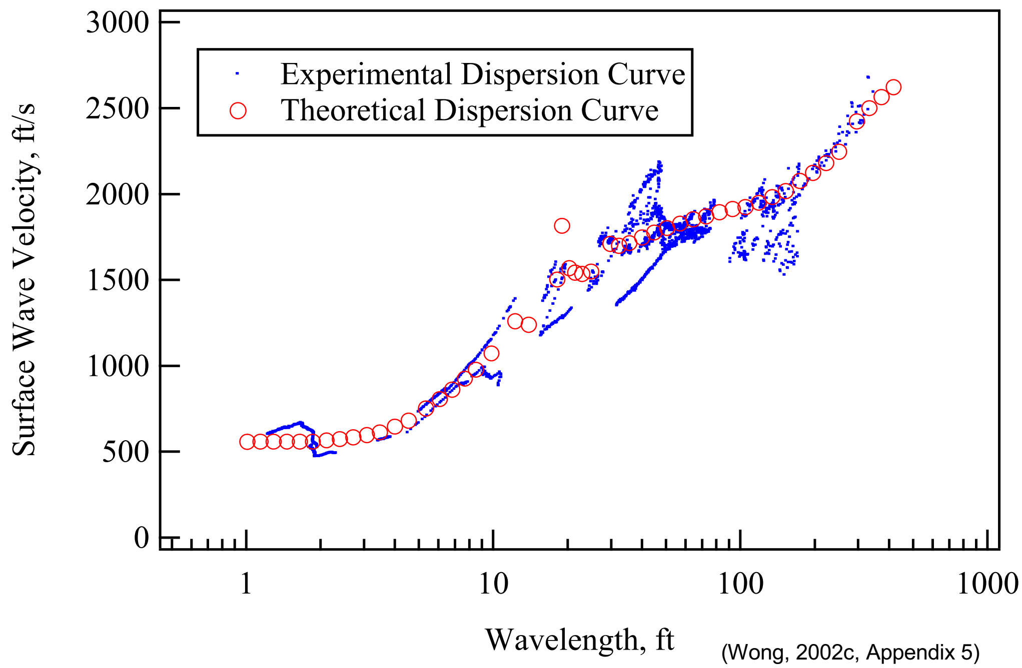
Location: SASW-4

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	520	300	0.25	120
2	10	779	450	0.25	120
3	20	1732	1000	0.25	120
4	20	4330	2500	0.25	120
5	100	5196	3000	0.25	80

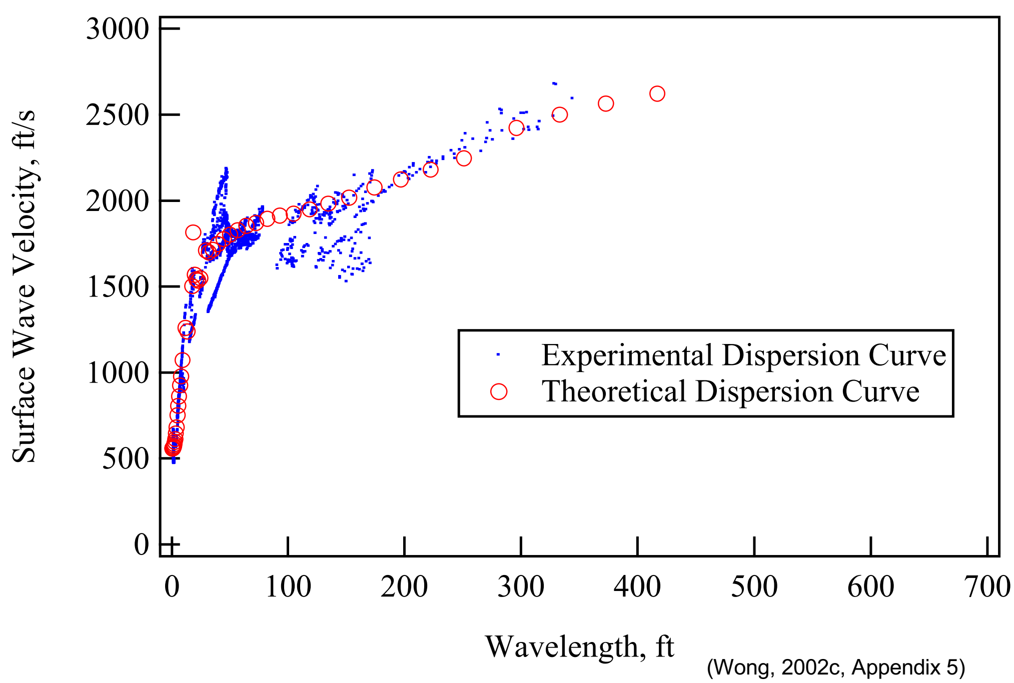
DTN: MO0110SASWWHBS.000

* Poisson's ratio and mass density from Wong (2002c, Appendix 4)

Figure IX-4. SASW-4 Results (continued)

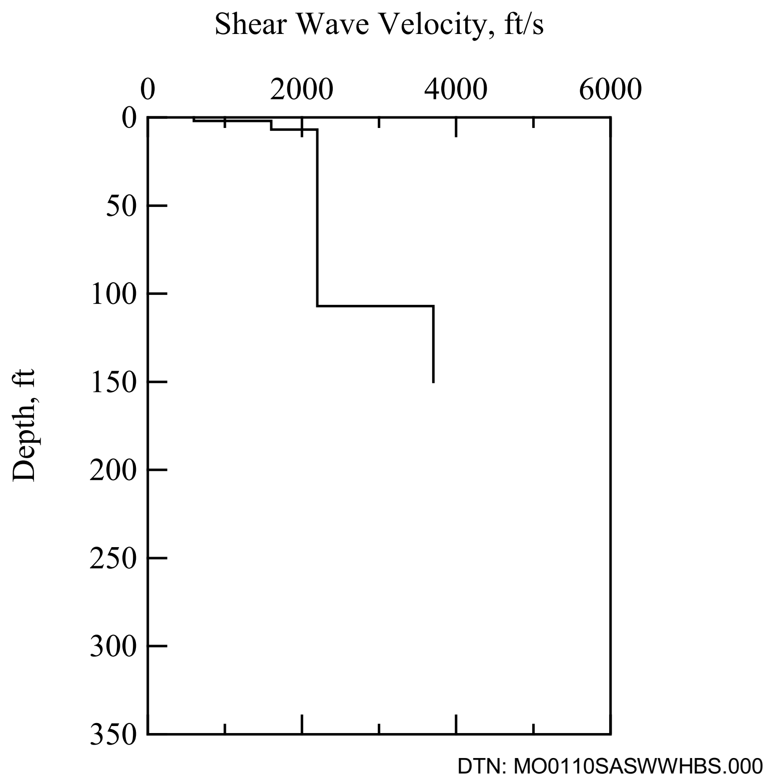


a. SASW-5 Dispersion Curves (Log Plot)



b. SASW-5 Dispersion Curves (Linear Plot)

Figure IX-5. SASW-5 Results



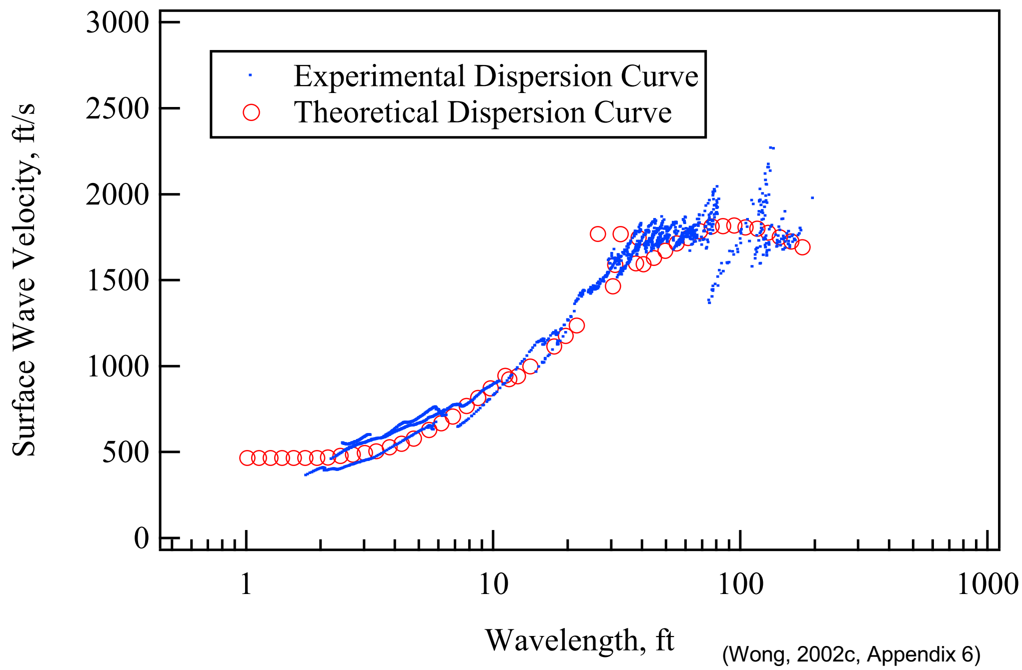
c. SASW-5 Shear Wave Velocity Profile

Location: SASW-5

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	1039	600	0.25	120
2	5	2771	1600	0.25	120
3	100	3810	2200	0.25	120
4	43	6408	3700	0.25	80

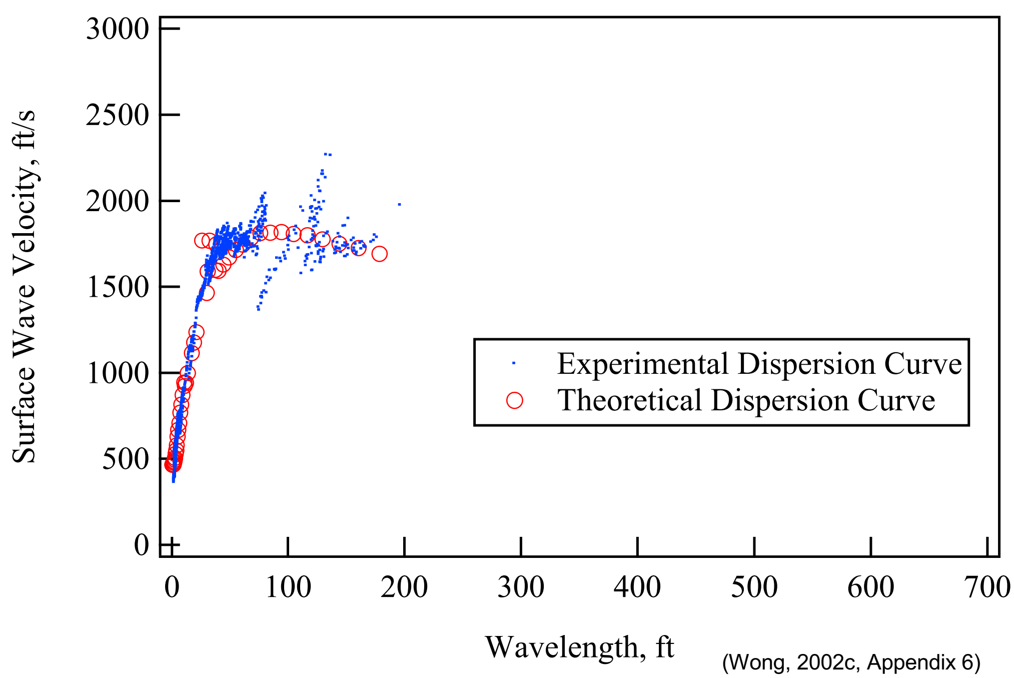
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 5)

Figure IX-5. SASW-5 Results (continued)



(Wong, 2002c, Appendix 6)

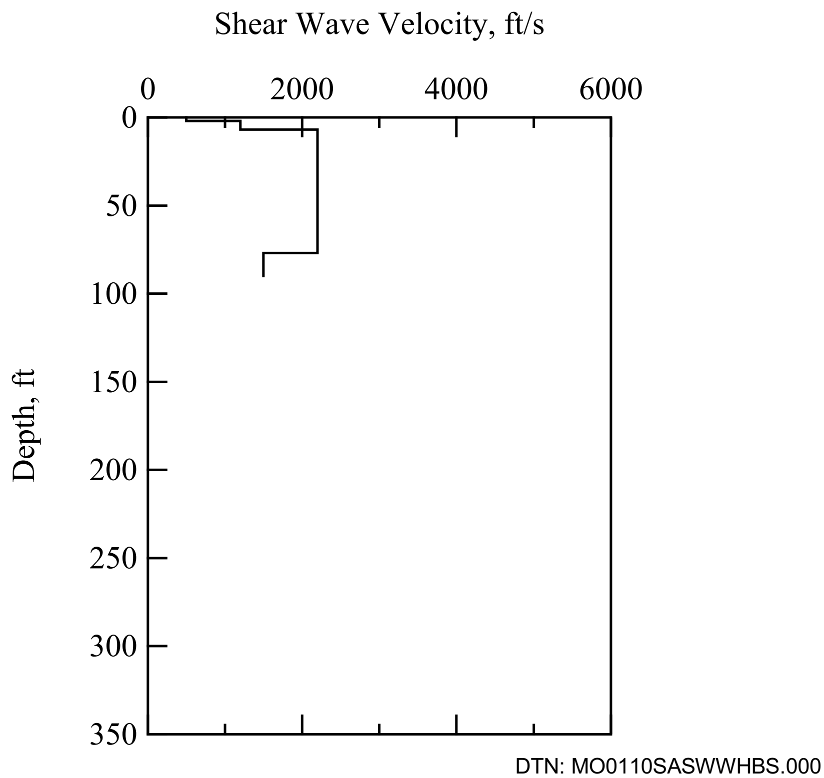
a. SASW-6 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 6)

b. SASW-6 Dispersion Curves (Linear Plot)

Figure IX-6. SASW-6 Results



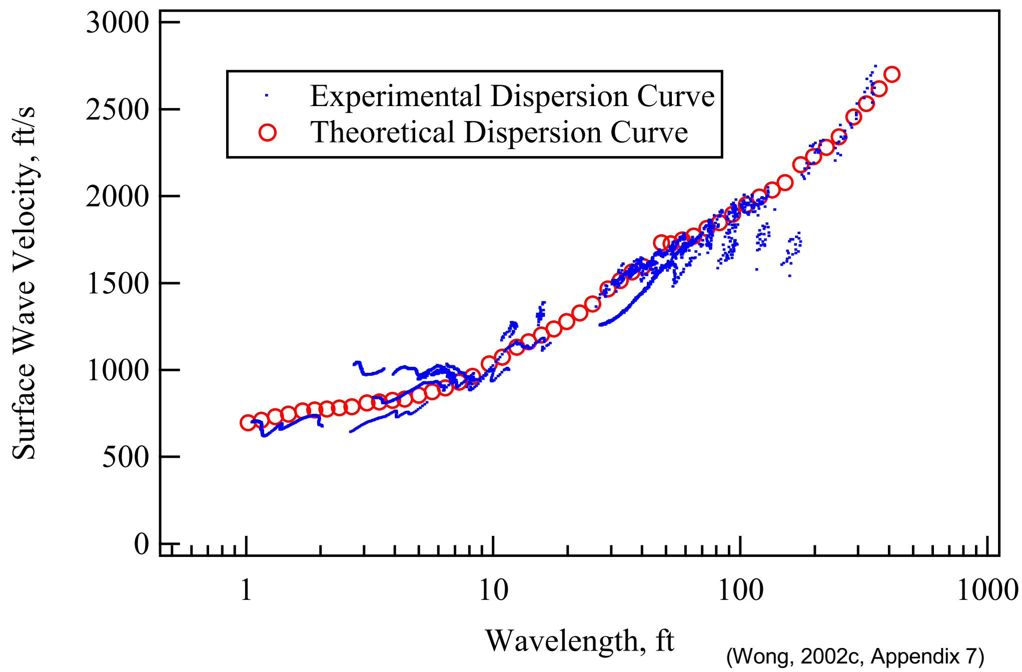
c. SASW-6 Shear Wave Velocity Profile

Location: SASW-6

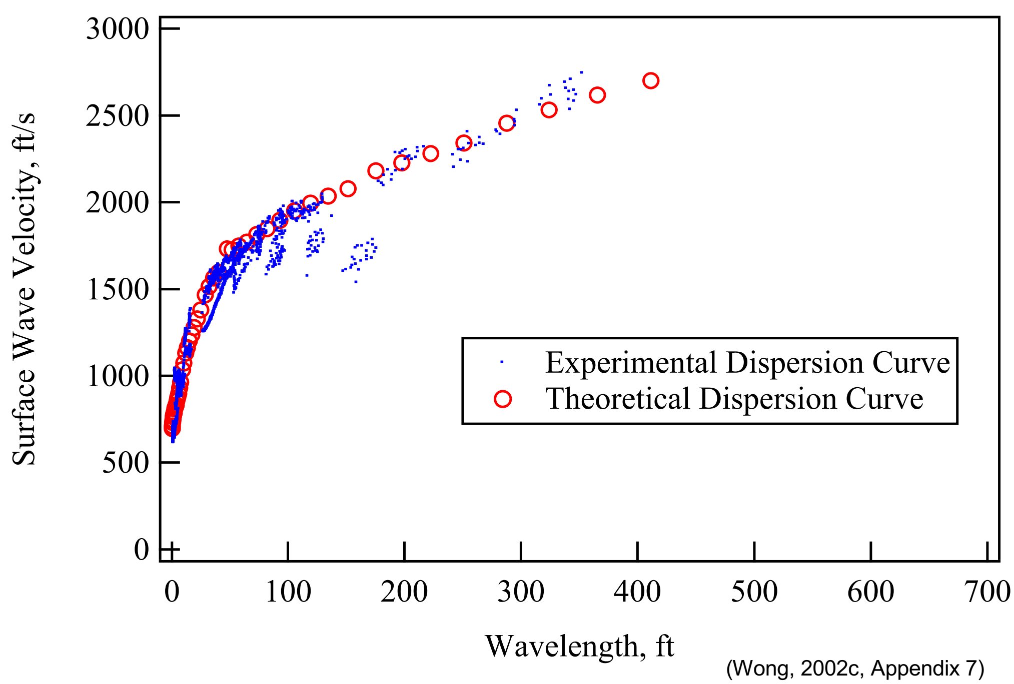
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	866	500	0.25	120
2	5	2078	1200	0.25	120
3	50	3810	2200	0.25	120
4	20	3810	2200	0.25	120
5	13	2598	1500	0.25	120

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 6)

Figure IX-6. SASW-6 Results (continued)

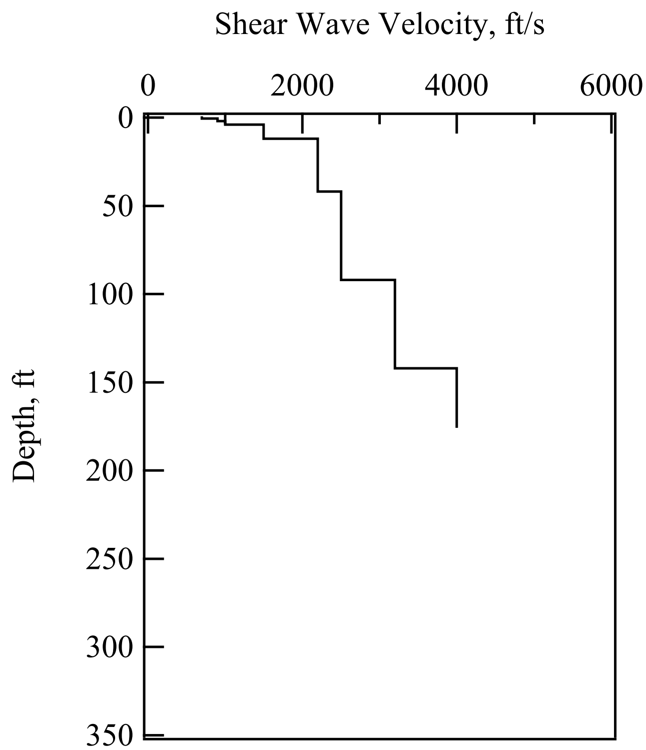


a. SASW-7 Dispersion Curves (Log Plot)



b. SASW-7 Dispersion Curves (Linear Plot)

Figure IX-7. SASW-7 Results (continued)



DTN: MO0110SASWWHBS.000

c. SASW-7 Shear Wave Velocity Profile

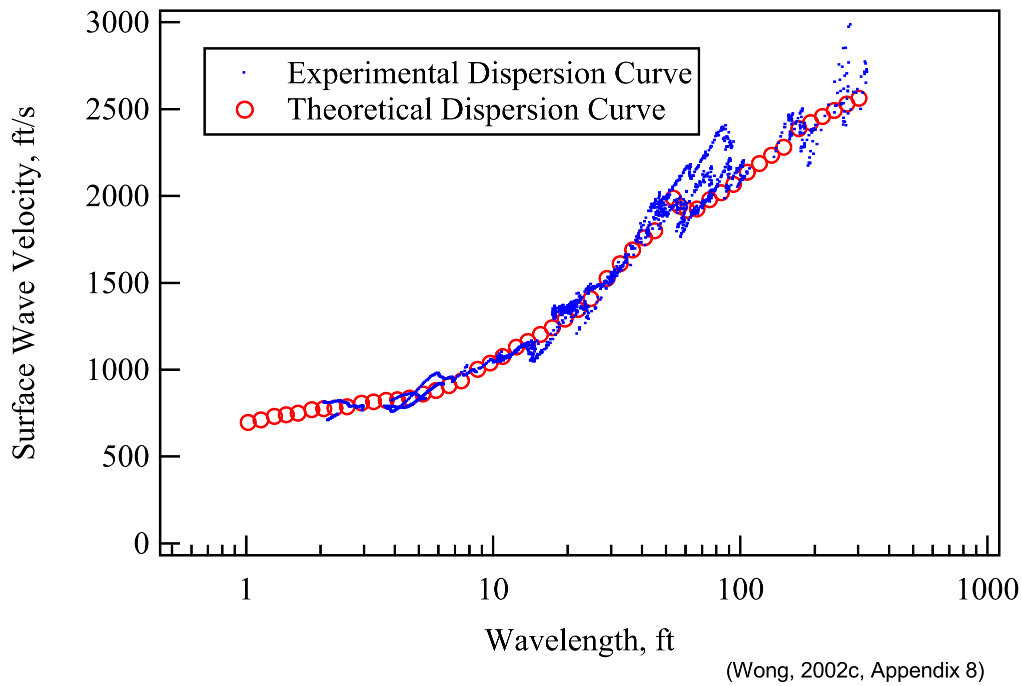
Location: SASW-7

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	1212	700	0.25	120
2	1.5	1559	900	0.25	120
3	2.0	1732	1000	0.25	120
4	8.0	2598	1500	0.25	120
5	30	3810	2200	0.25	120
6	50	4330	2500	0.25	120
7	50	5542	3200	0.25	80
8	33	6982	4000	0.25	80

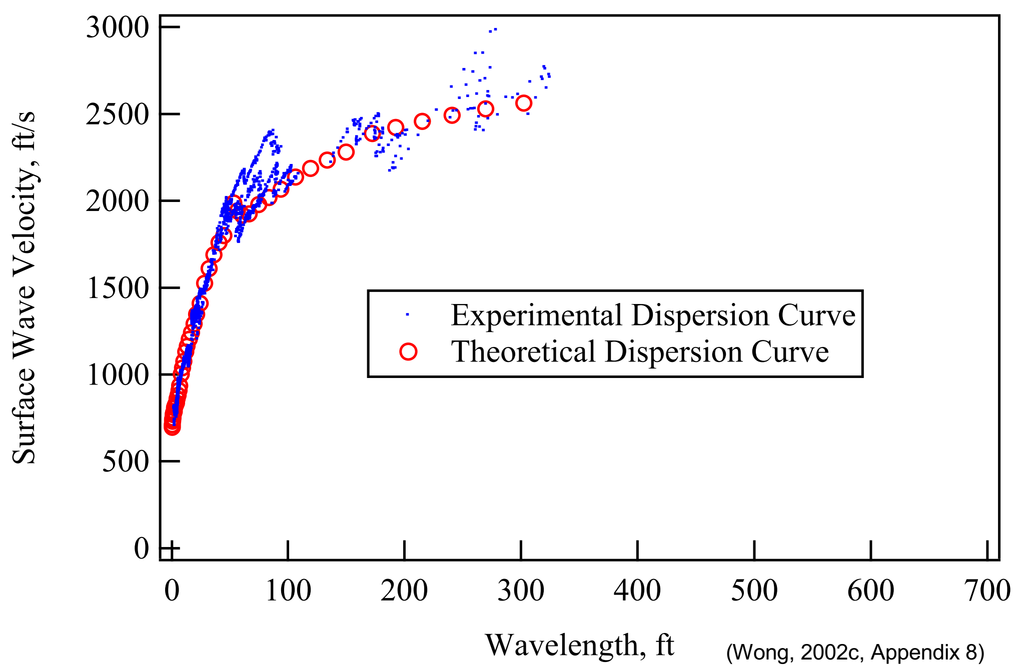
DTN: MO0110SASWWHBS.000

* Poisson's ratio and mass density from Wong (2002c, Appendix 7)

Figure IX-7. SASW-7 Results (continued)

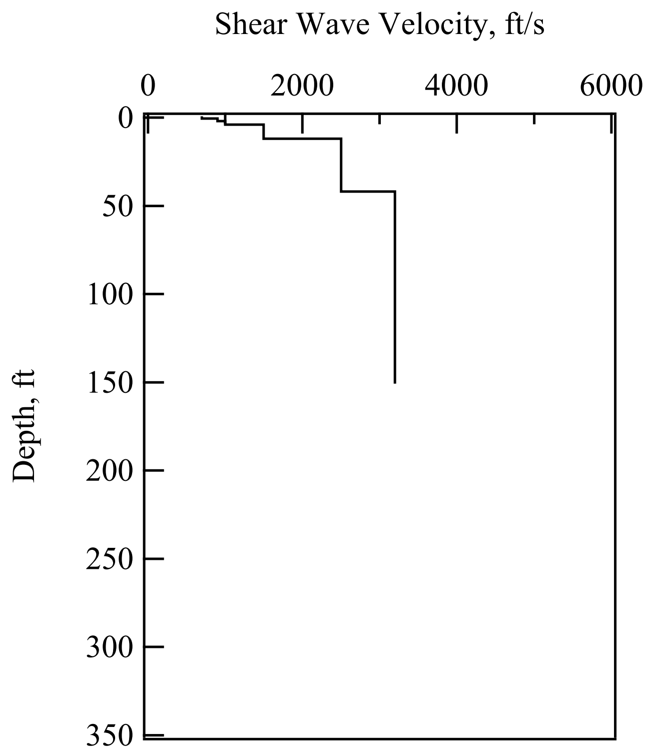


a. SASW-8 Dispersion Curves (Log Plot)



b. SASW-8 Dispersion Curves (Linear Plot)

Figure IX-8. SASW-8 Results



DTN: MO0110SASWWHBS.000

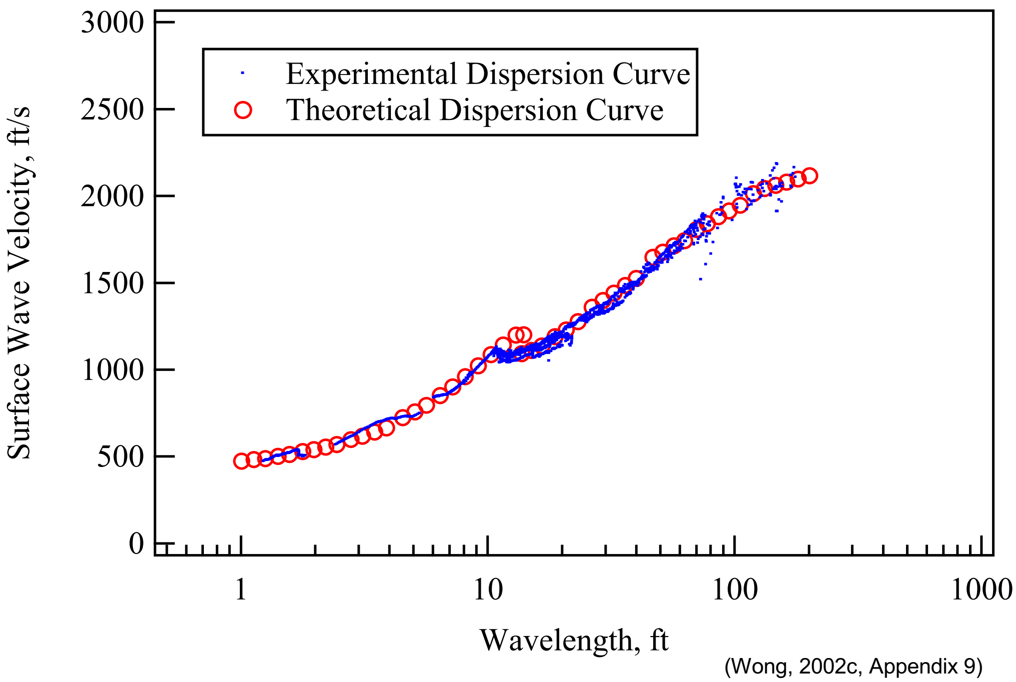
c. SASW-8 Shear Wave Velocity Profile

Location: SASW-8

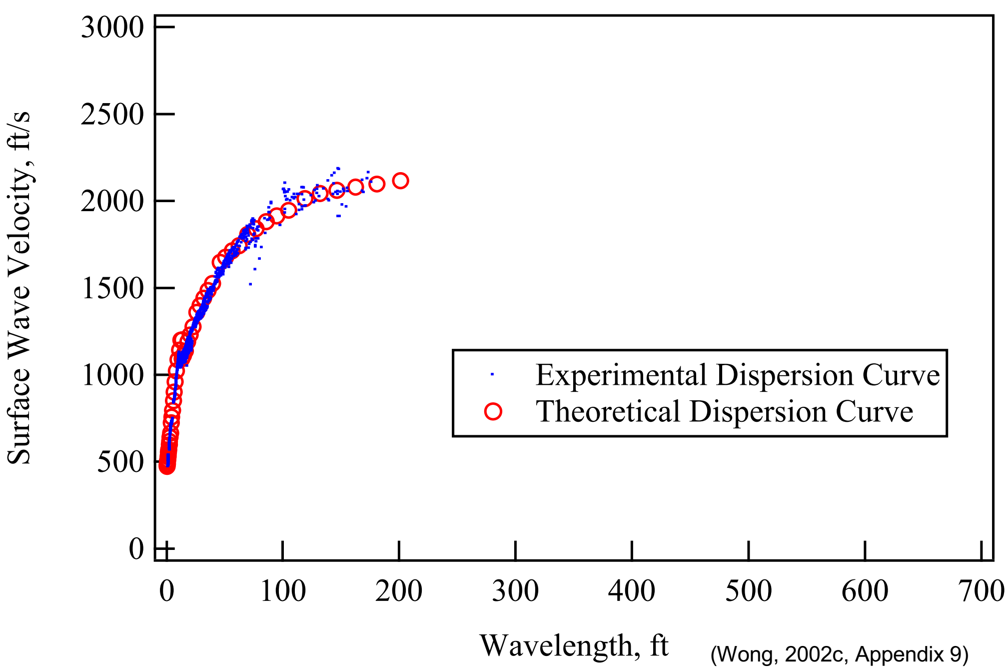
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	1212	700	0.25	120
2	1.5	1559	900	0.25	120
3	2.0	1732	1000	0.25	120
4	8	2598	1500	0.25	120
5	30	4330	2500	0.25	120
6	108	5543	3200	0.25	80

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 8)

Figure IX-8. SASW-8 Results (continued)

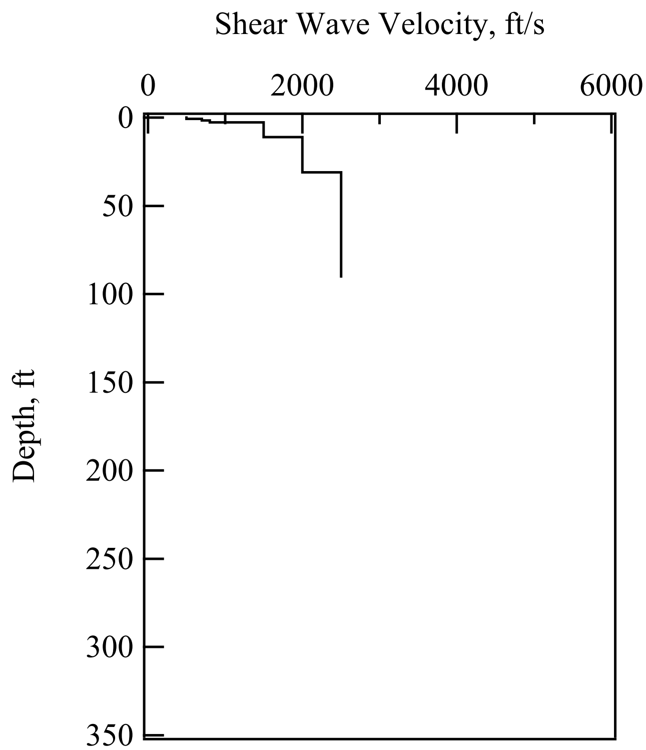


a. SASW-9 Dispersion Curves (Log Plot)



b. SASW-9 Dispersion Curves (Linear Plot)

Figure IX-9. SASW-9 Results



DTN: MO0110SASWWHBS.000

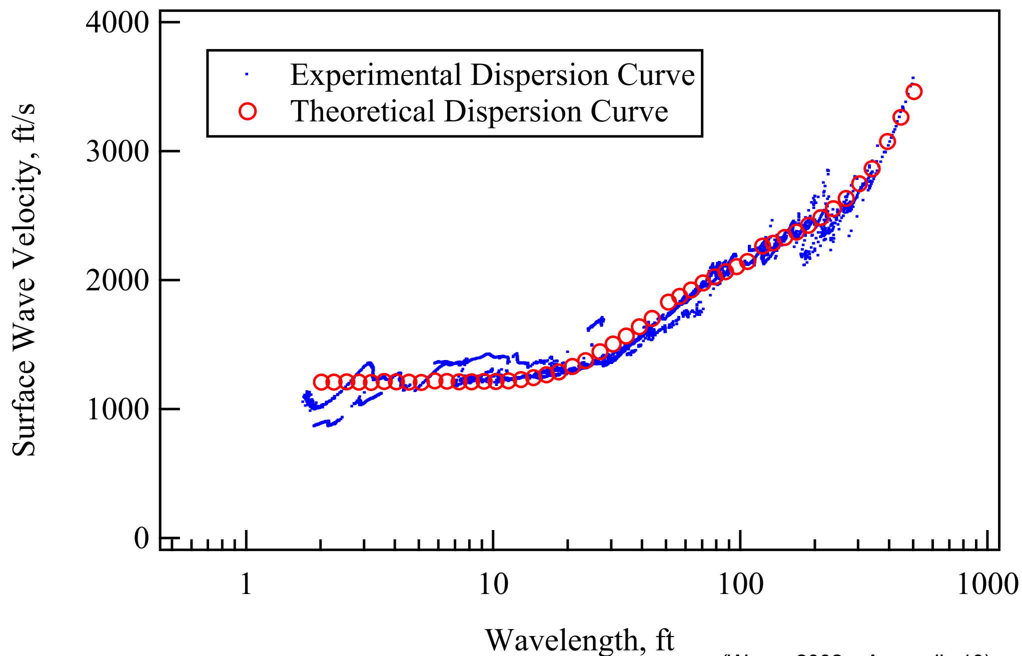
c. SASW-9 Shear Wave Velocity Profile

Location: SASW-9

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.75	866	500	0.25	120
2	1	1212	700	0.25	120
3	1	1559	800	0.25	120
4	8	2598	1500	0.25	120
5	20	3464	2000	0.25	120
6	59	4330	2500	0.25	120

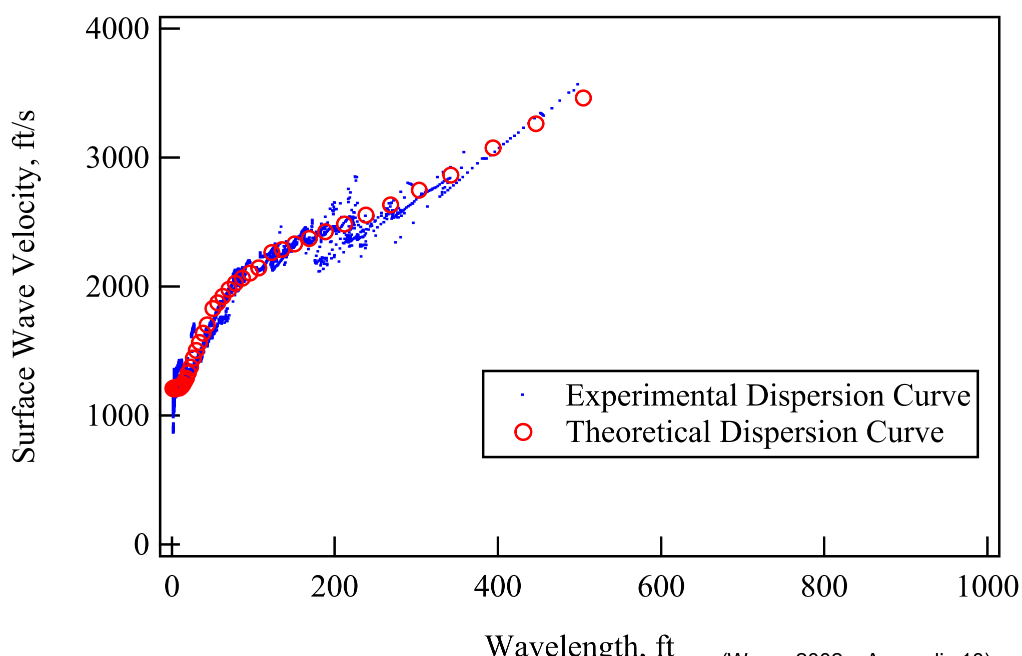
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 9)

Figure IX-9. SASW-9 Results (continued)



(Wong, 2002c, Appendix 10)

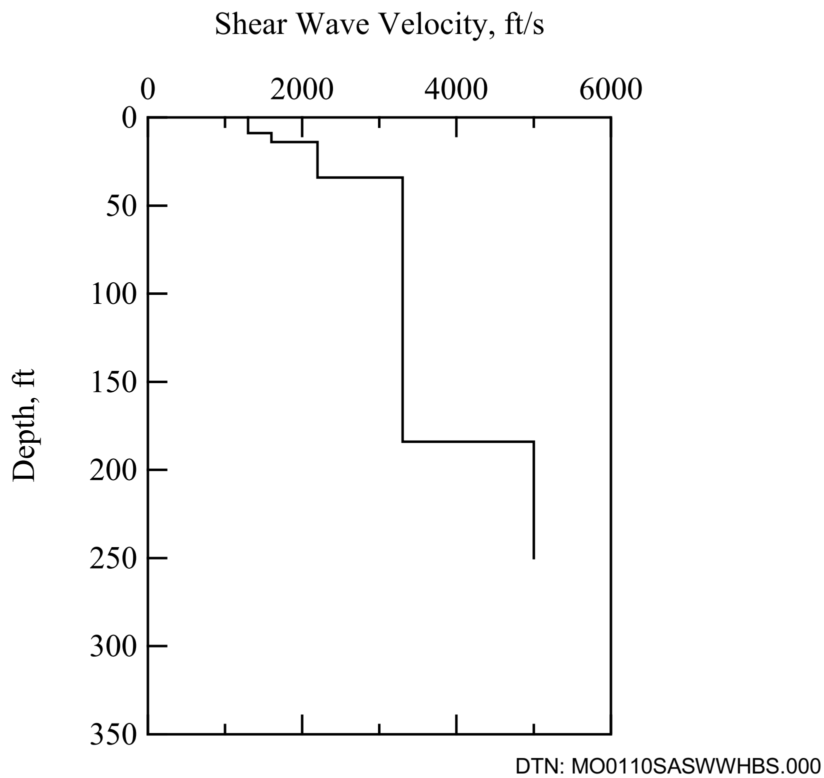
a. SASW-10+37 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 10)

b. SASW-10+37 Dispersion Curves (Linear Plot)

Figure IX-10. SASW-10+37 Results



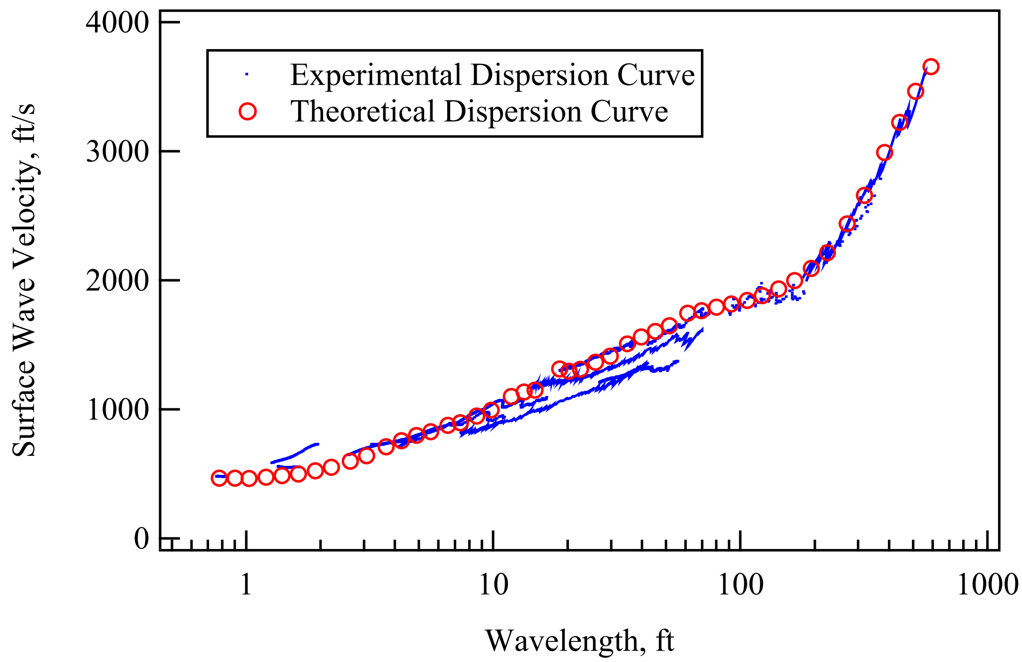
c. SASW-10+37 Shear Wave Velocity Profile

Location: SASW-10+37

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	2251	1300	0.25	120
2	8	2251	1300	0.25	120
3	5	2771	1600	0.25	120
4	20	3810	2200	0.25	120
5	150	5716	3300	0.25	80
6	66	8660	5000	0.25	145

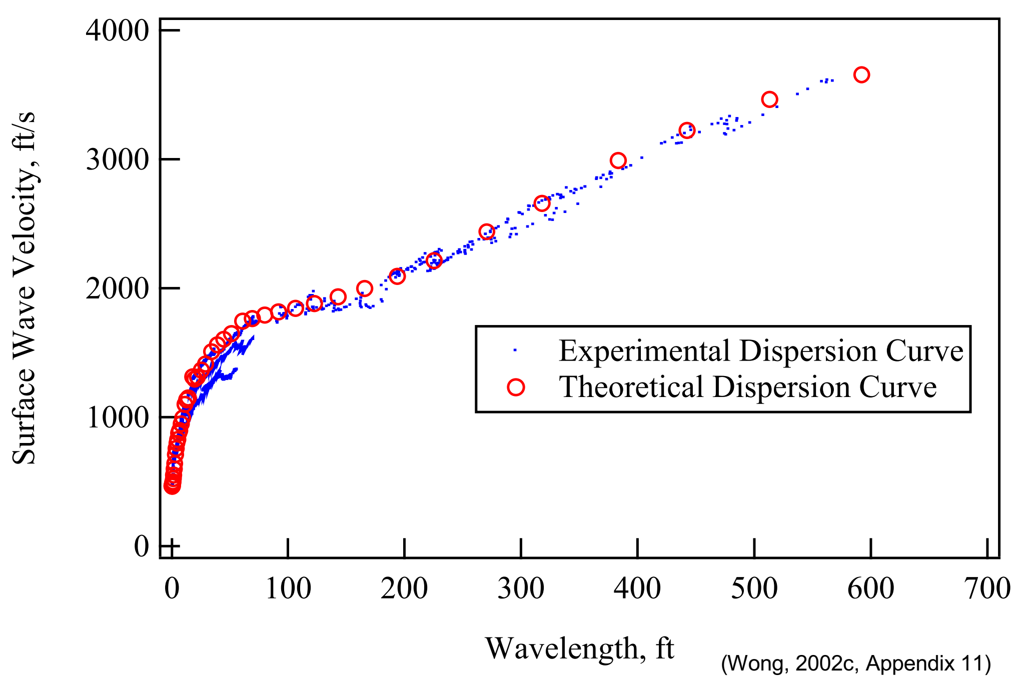
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 10)

Figure IX-10. SASW-10+37 Results (continued)



(Wong, 2002c, Appendix 11)

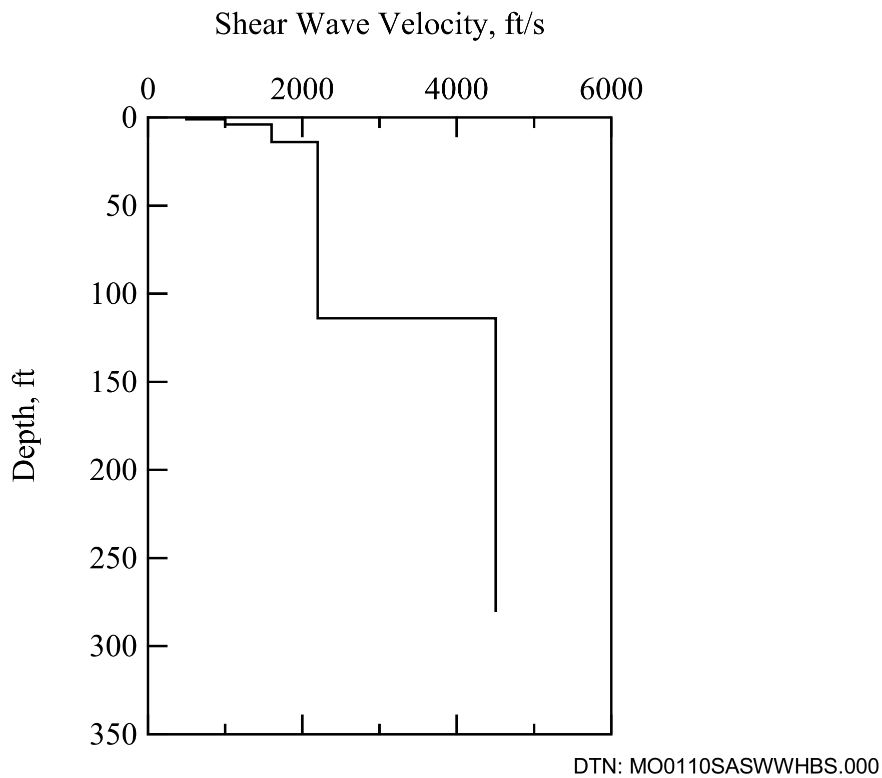
a. SASW-11 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 11)

b. SASW-11 Dispersion Curves (Linear Plot)

Figure IX-11. SASW-11 Results



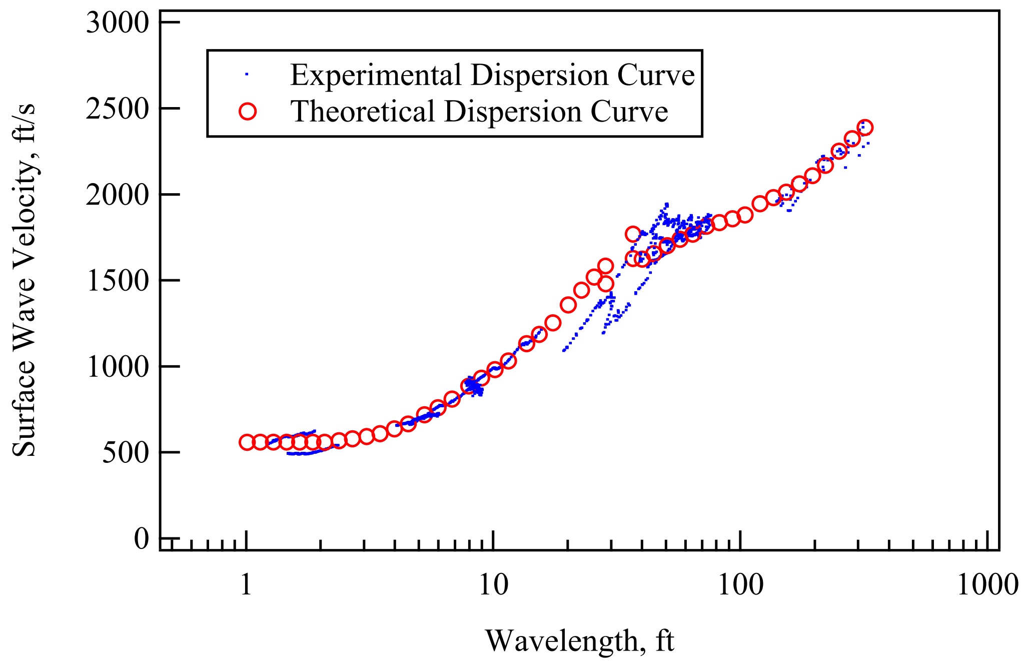
c. SASW-11 Shear Wave Velocity Profile

Location: SASW-11

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	866	500	0.25	120
2	3	1732	1000	0.25	120
3	10	2771	1600	0.25	120
4	100	3810	2200	0.25	120
5	166	7794	4500	0.25	145

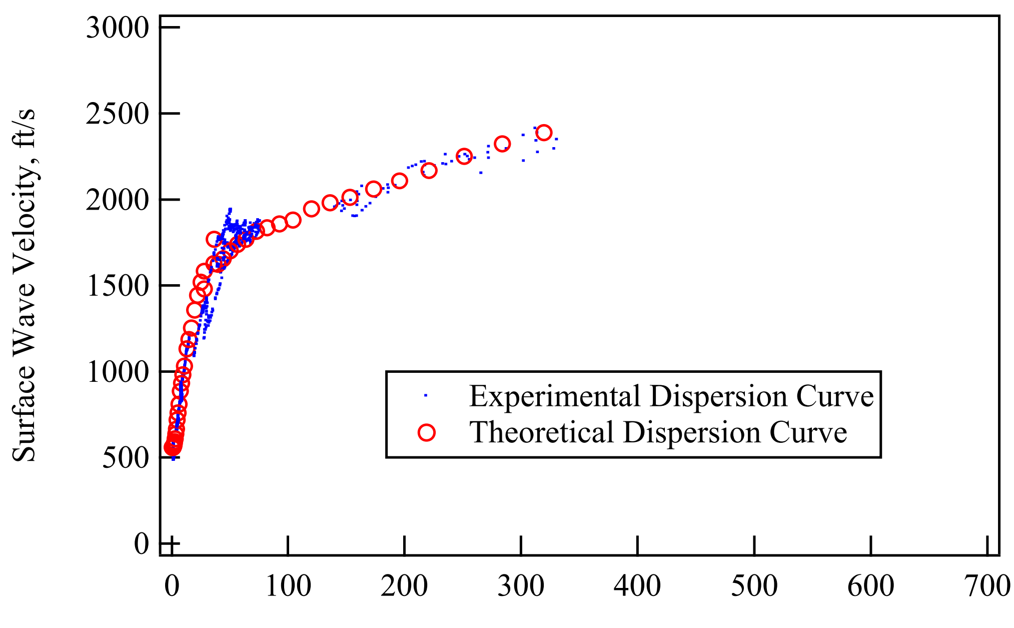
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 11)

Figure IX-11. SASW-11 Results (continued)



(Wong, 2002c, Appendix 12)

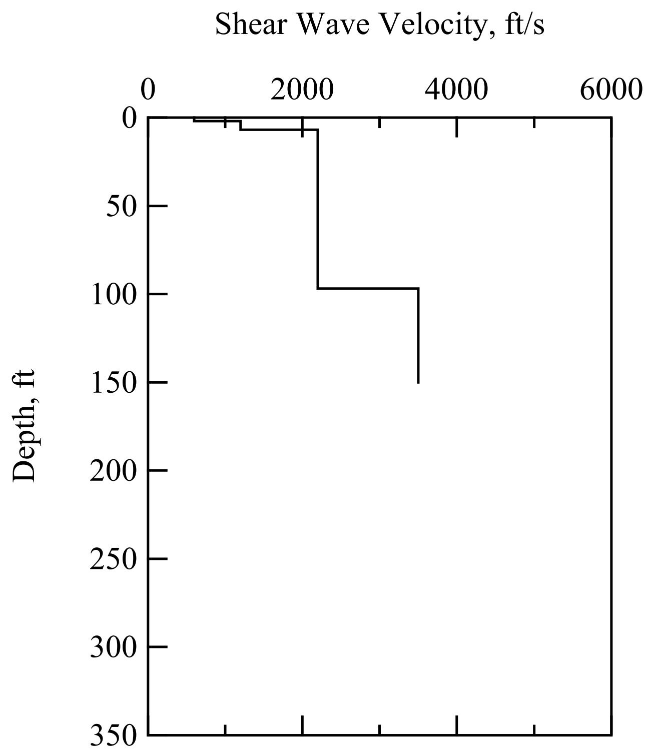
a. SASW-12 Dispersion Curves (Log [illegible]



(Wong, 2002c, Appendix 12)

b. SASW-12 Dispersion Curves (Linear Plot)

Figure IX-12. SASW-12 Results



DTN: MO0110SASWWHBS.000

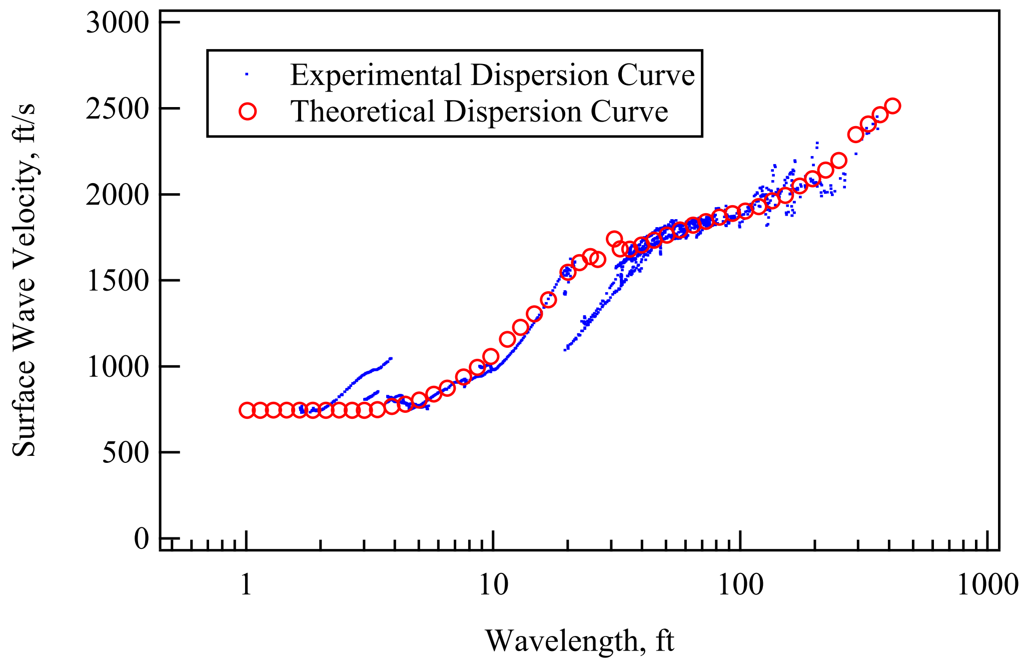
c. SASW-12 Shear Wave Velocity Profile

Location: SASW-12

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	1039	600	0.25	120
2	5	2078	1200	0.25	120
3	90	3810	2200	0.25	120
4	53	6062	3500	0.25	80

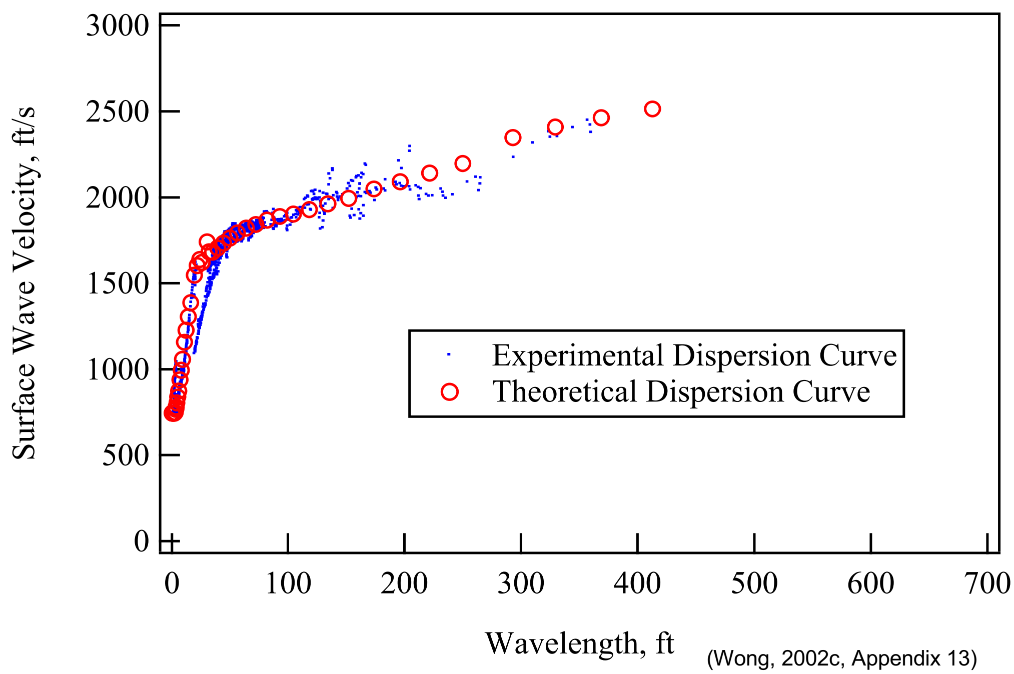
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 12)

Figure IX-12. SASW-12 Results (continued)



(Wong, 2002c, Appendix 13)

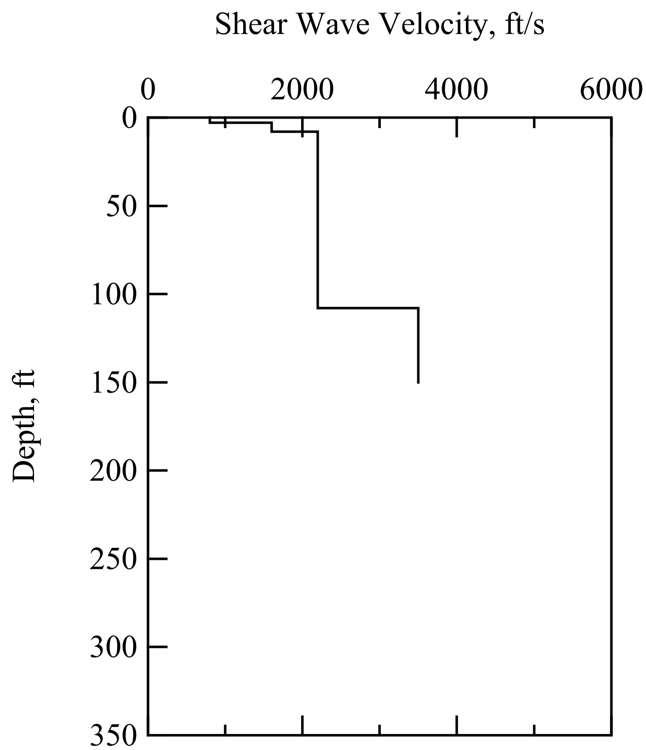
a. SASW-13 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 13)

b. SASW-13 Dispersion Curves (Linear Plot)

Figure IX-13. SASW-13 Results



DTN: MO0110SASWWHBS.000

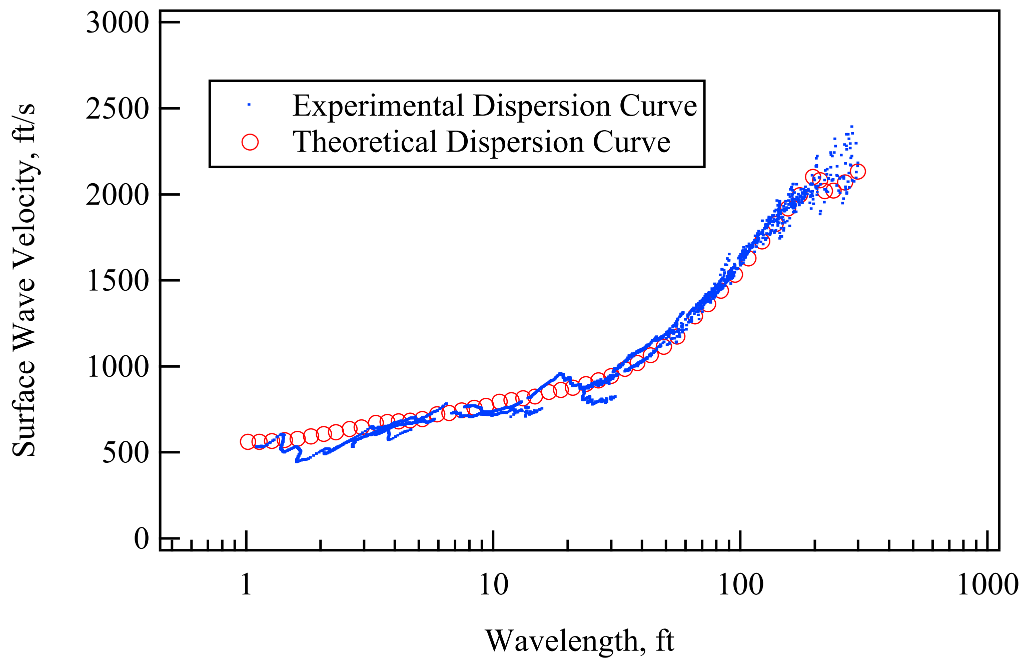
c. SASW-13 Shear Wave Velocity Profile

Location: SASW-13

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	3	1385	800	0.25	120
2	5	2771	1600	0.25	120
3	100	3810	2200	0.25	120
4	42	6062	3500	0.25	80

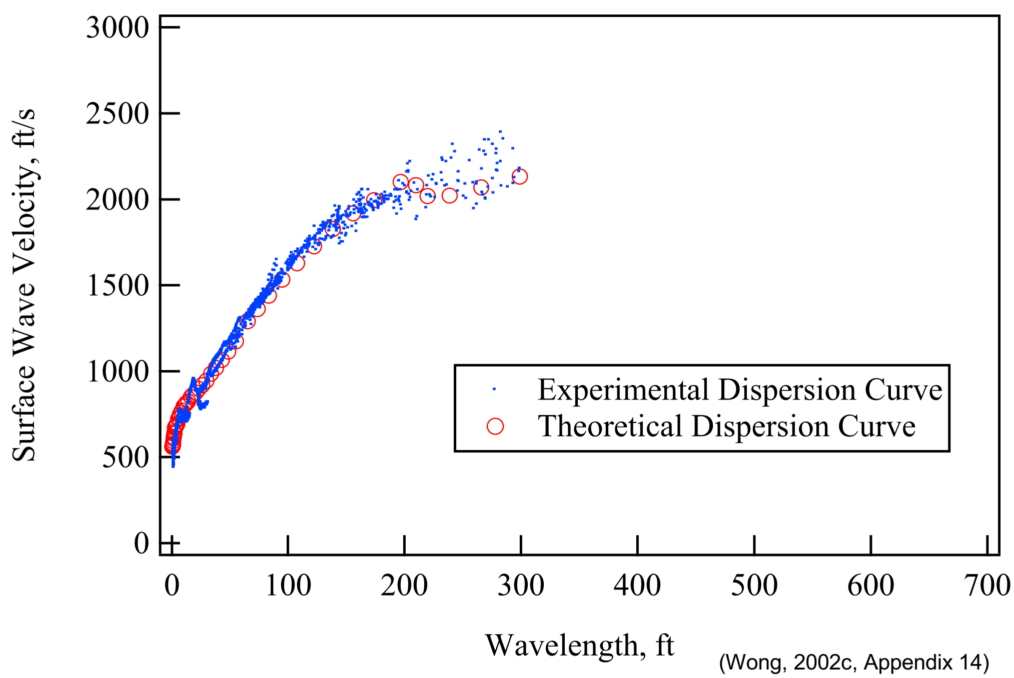
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 13)

Figure IX-13. SASW-13 Results (continued)



(Wong, 2002c, Appendix 14)

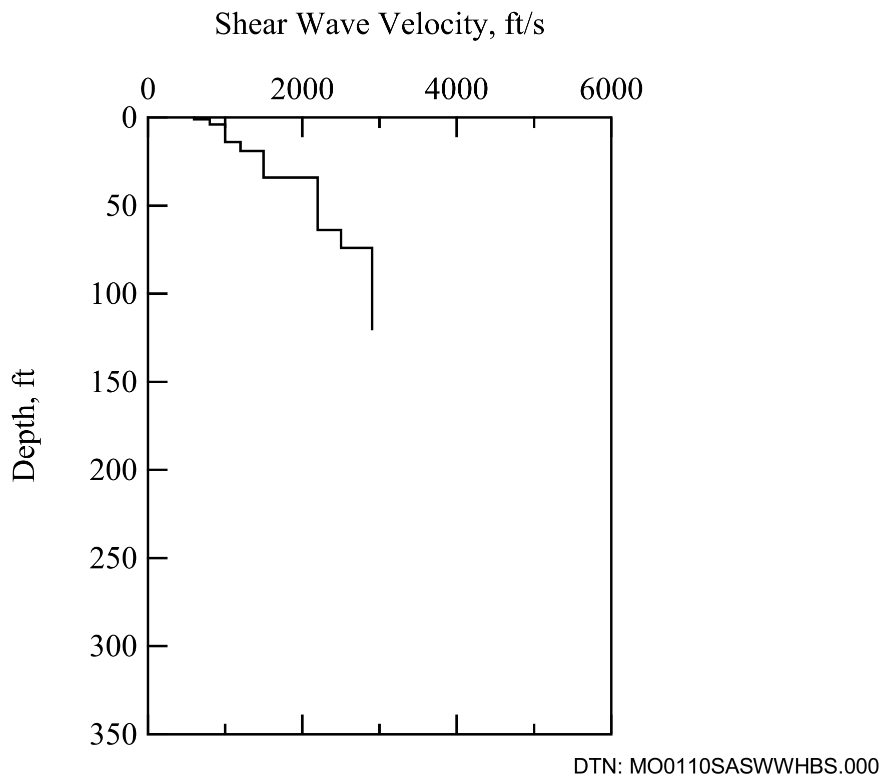
a. SASW-14 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 14)

b. SASW-14 Dispersion Curves (Linear Plot)

Figure IX-14. SASW-14 Results



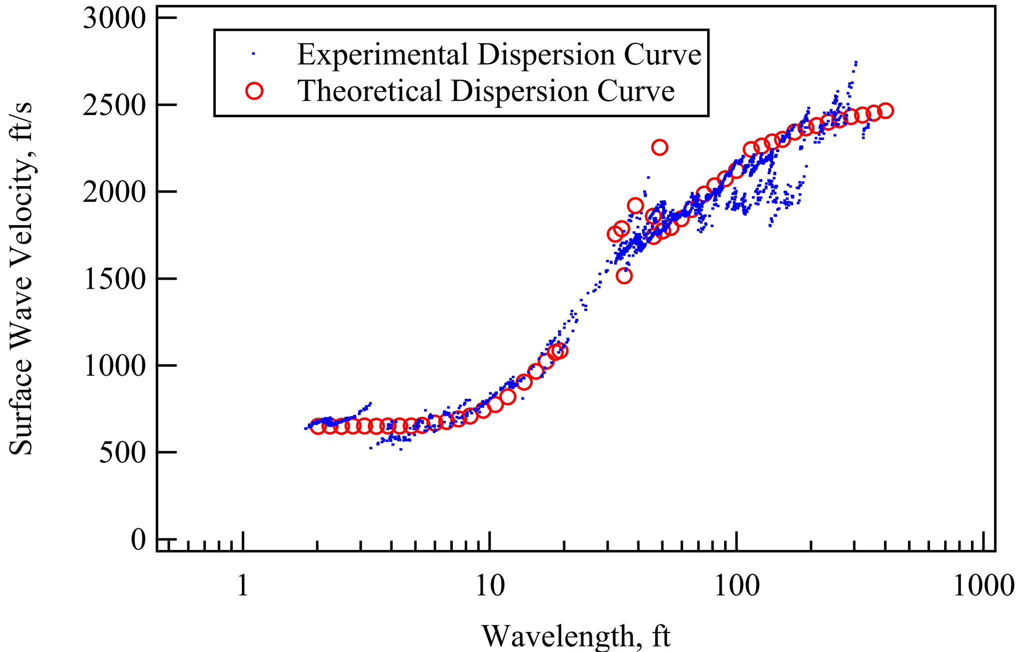
c. SASW-14 Shear Wave Velocity Profile

Location: SASW-14

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	1039	600	0.25	120
2	3	1386	800	0.25	120
3	10	1732	1000	0.25	120
4	5	2078	1200	0.25	120
5	15	2598	1500	0.25	120
6	30	3810	2200	0.25	120
7	10	4330	2500	0.25	120
8	46	5023	2900	0.25	120

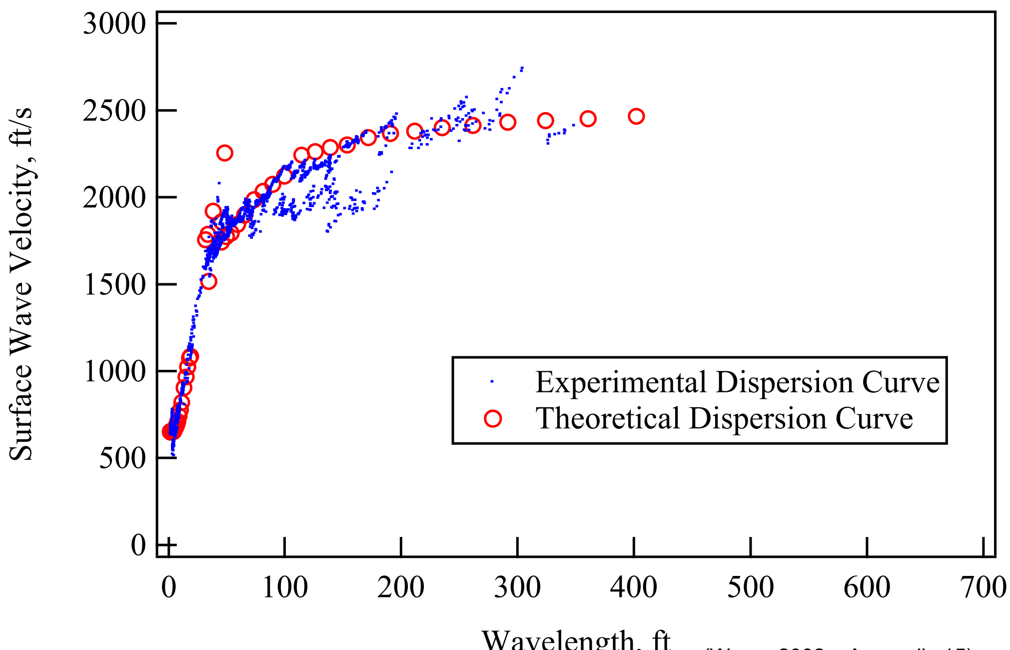
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 14)

Figure IX-14. SASW-14 Results (continued)



(Wong, 2002c, Appendix 15)

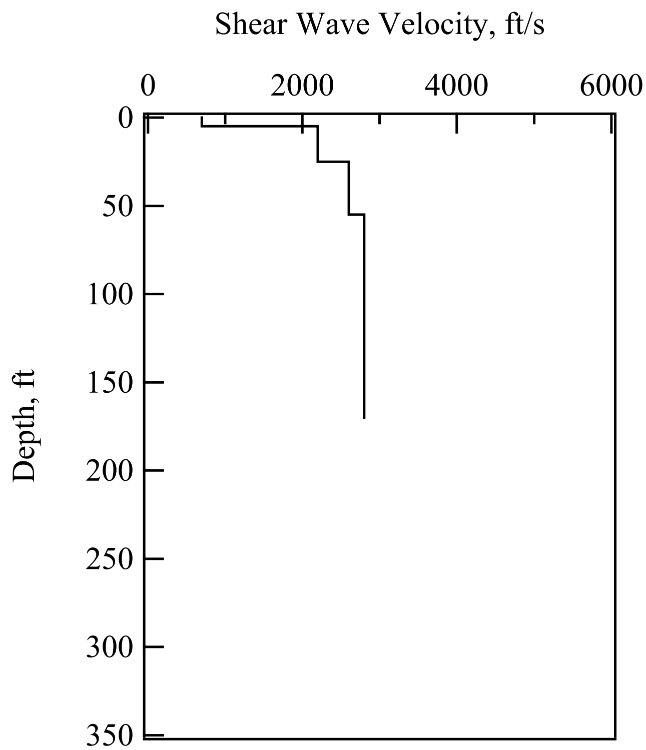
a. SASW-15 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 15)

b. SASW-15 Dispersion Curves (Linear Plot)

Figure IX-15. SASW-15 Results



DTN: MO0110SASWWHBS.000

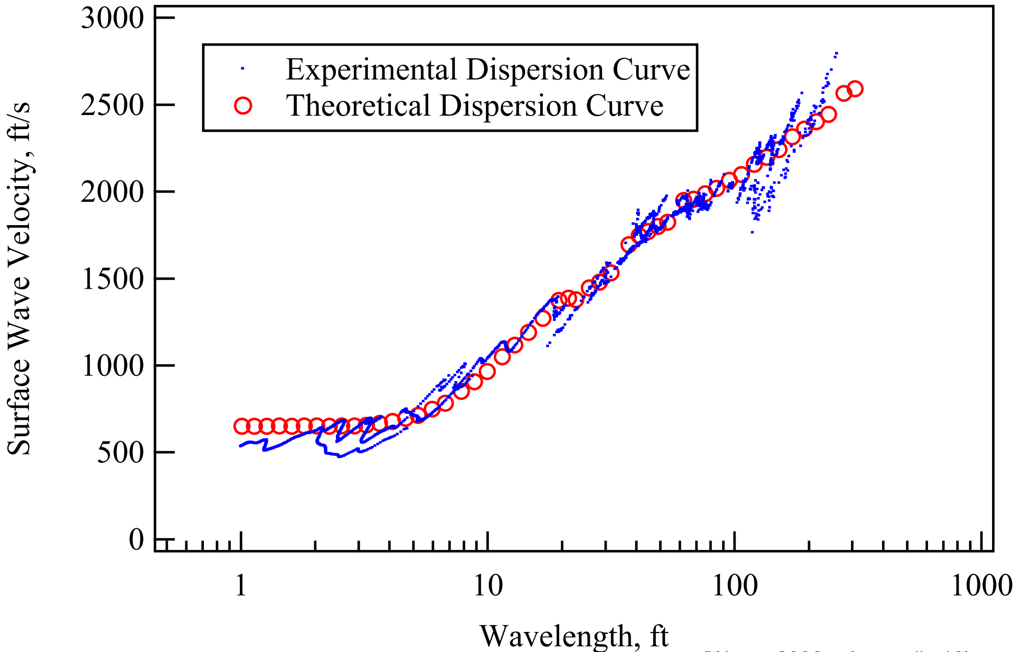
c. SASW-15 Shear Wave Velocity Profile

Location: SASW-15

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	5	1212	700	0.25	120
2	20	3810	2200	0.25	120
3	30	4503	2600	0.25	120
4	115	4850	2800	0.25	120

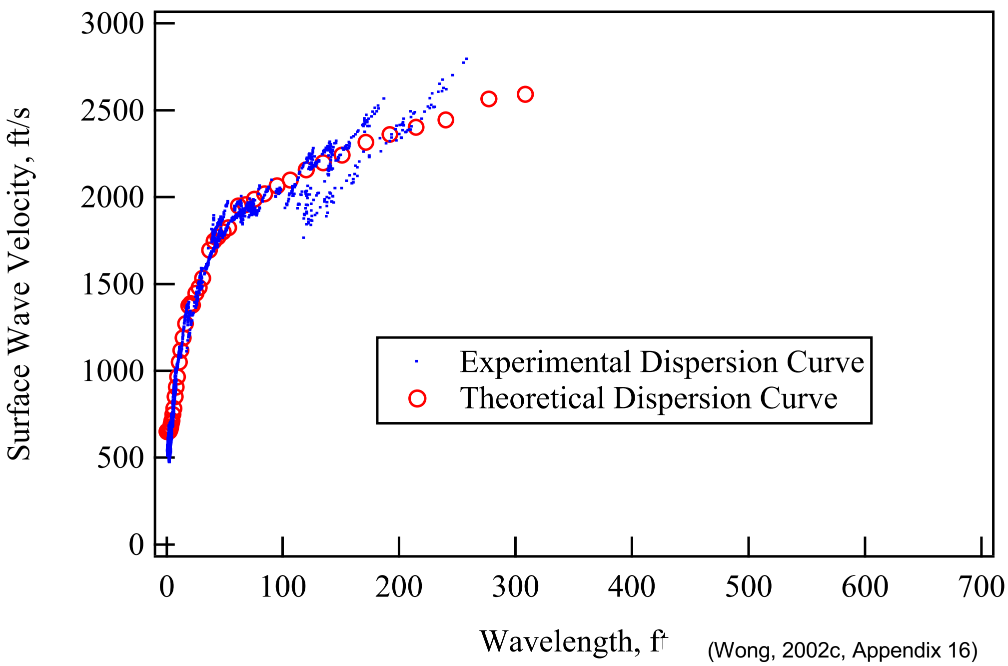
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 15)

Figure IX-15. SASW-15 Results (continued)



(Wong, 2002c, Appendix 16)

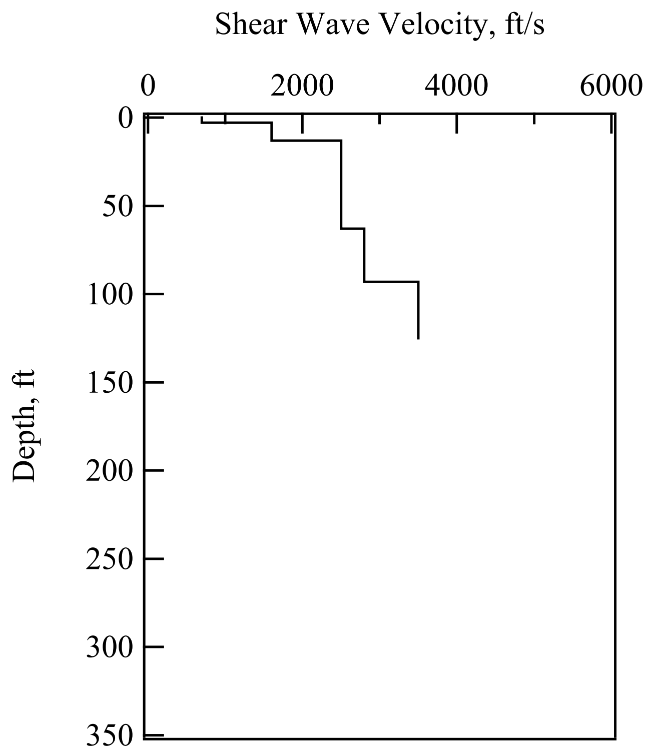
a. SASW-16 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 16)

b. SASW-16 Dispersion Curves (Linear Plot)

Figure IX-16. SASW-16 Results



DTN: MO0110SASWWHBS.000

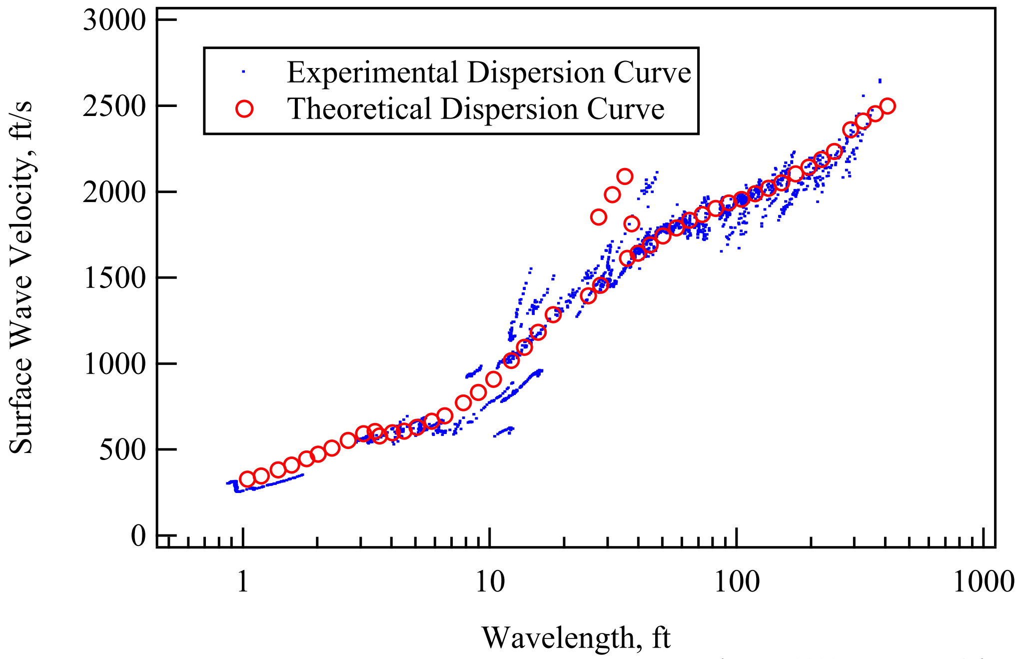
c. SASW-16 Shear Wave Velocity Profile

Location: SASW-16

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	5	1212	700	0.25	120
2	10	2741	1600	0.25	120
3	50	4330	2500	0.25	120
4	30	4850	2800	0.25	120
5	32	6062	3500	0.25	80

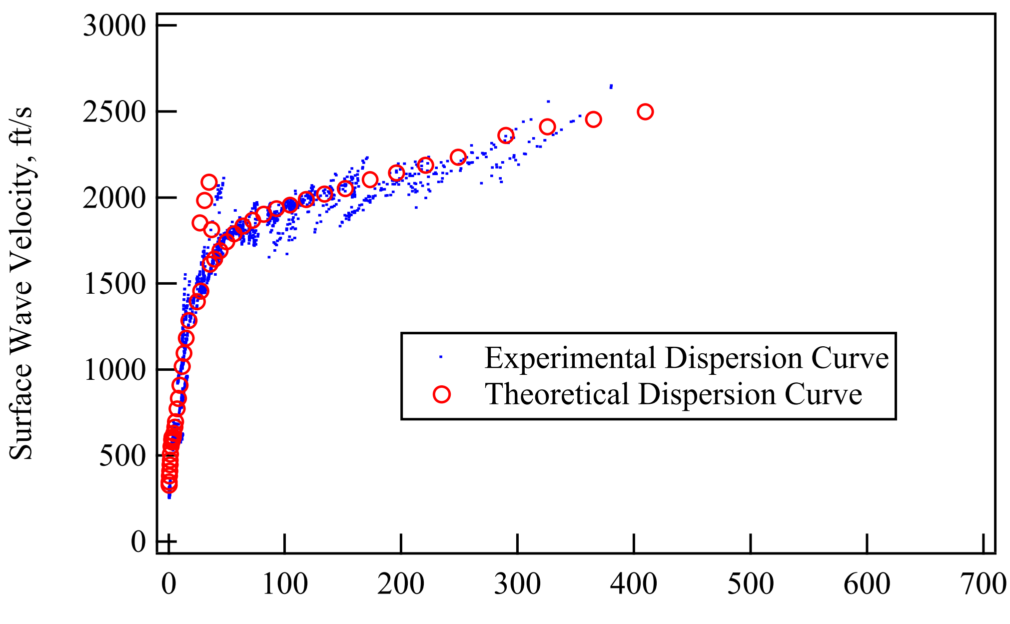
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 16)

Figure IX-16. SASW-16 Results (continued)



(Wong, 2002c, Appendix 17)

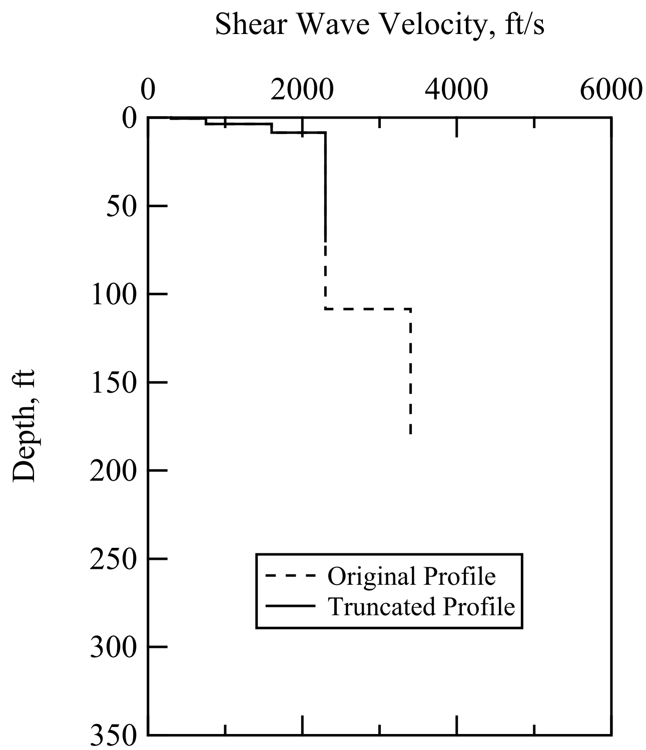
a. SASW-17 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 17)

b. SASW-17 Dispersion Curves (Linear Plot)

Figure IX-17. SASW-17 Results



DTN: MO0110SASWWHBS.000

c. SASW-17 Shear Wave Velocity Profile

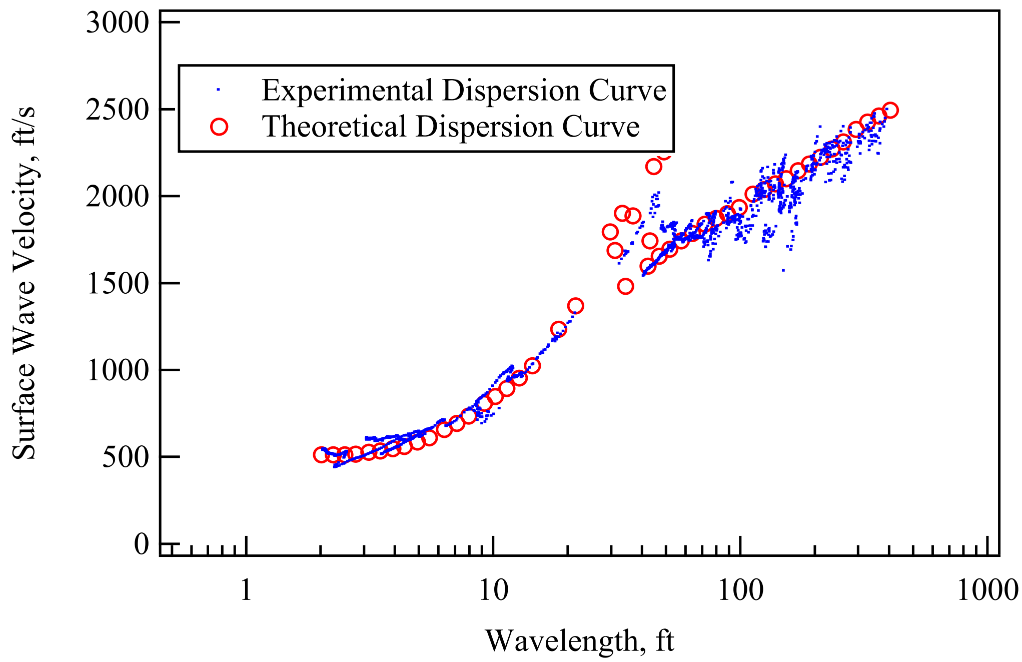
Location: SASW-17

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	0.5	520	300	0.25	120
2	3	1299	750	0.25	120
3	5	2771	1600	0.25	120
4	62.5*	3983	2300	0.25	120
5	37.5**	3983	2300	0.25	120
6	72**	5889	3400	0.25	80

DTN: MO0110SASWWHBS.000

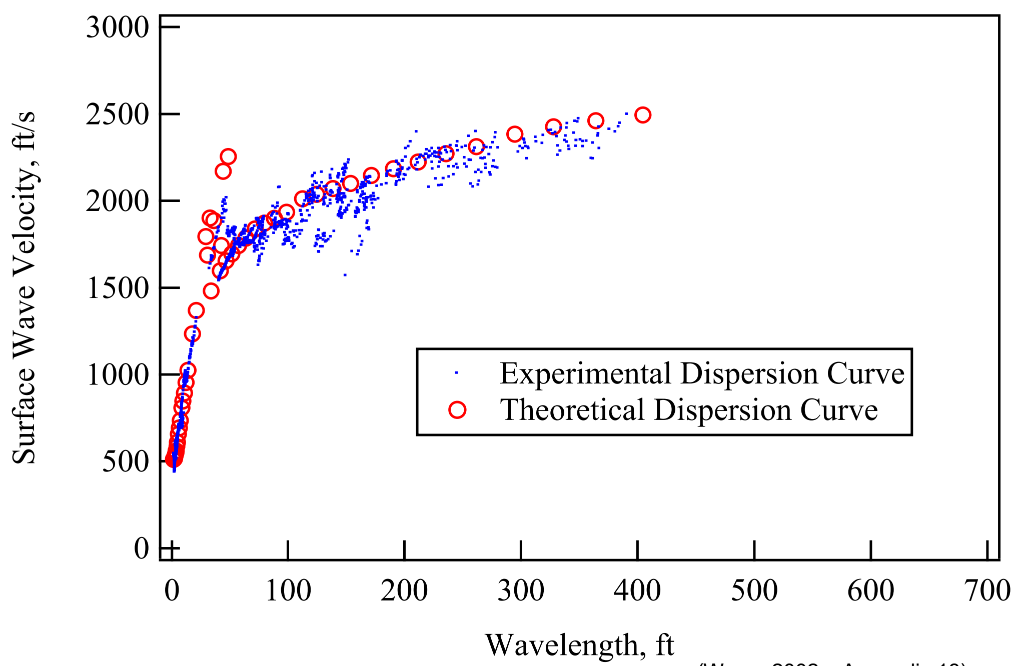
* Vs profile truncated at 70 ft based on geological profile showing an offset fault beginning at a depth of approximately 70 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 17)

Figure IX-17. SASW-17 Results (continued)



(Wong, 2002c, Appendix 18)

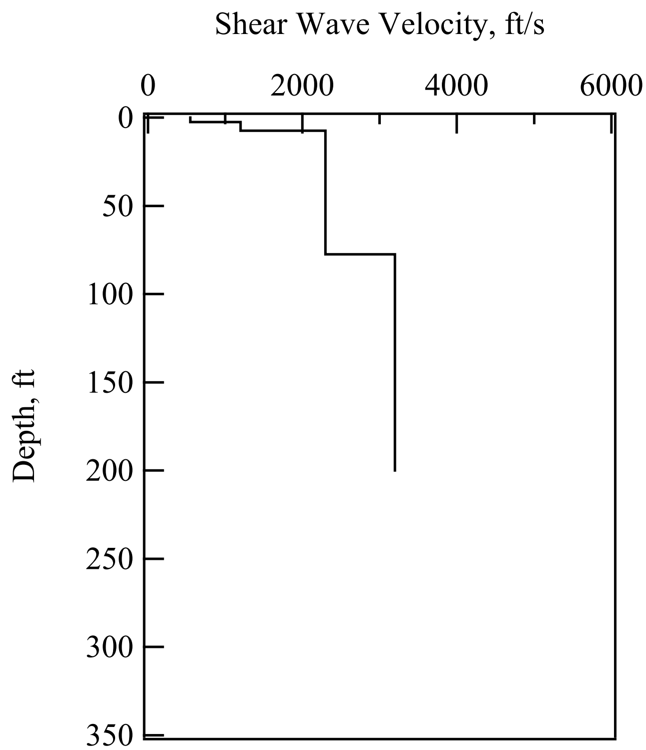
a. SASW-18 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 18)

b. SASW-18 Dispersion Curves (Linear Plot)

Figure IX-18. SASW-18 Results



DTN: MO0110SASWWHBS.000

c. SASW-18 Shear Wave Velocity Profile

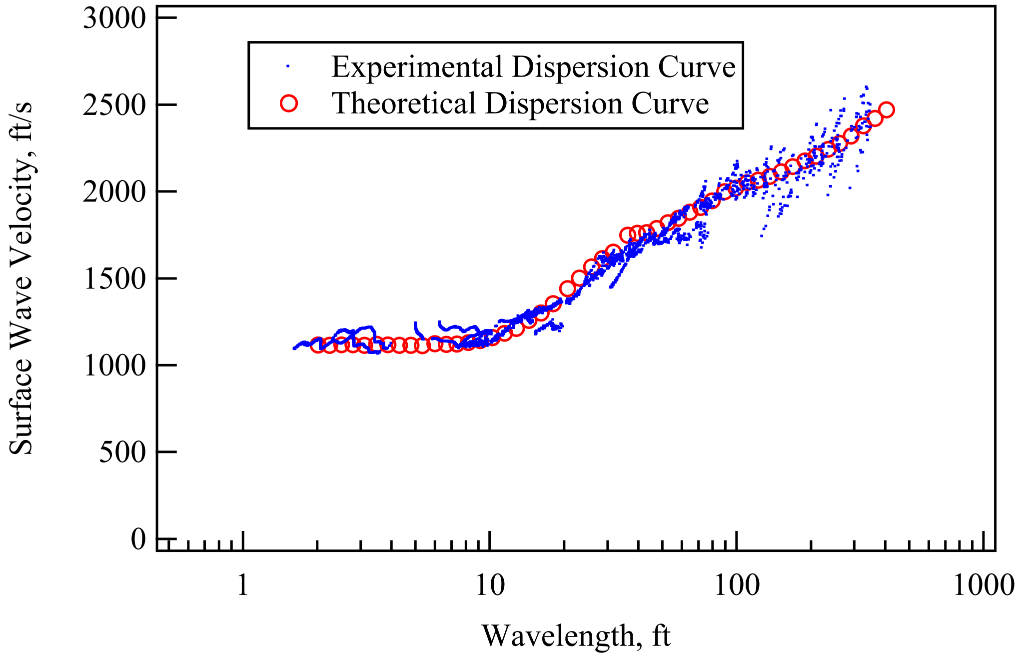
Location: SASW-18

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* cf
1	2.5	952	550	0.25	120
2	5	2078	1200	0.25	120
3	70	3983	2300	0.25	120
4	123	5542	3200	0.25	80

DTN: MO0110SASWWHBS.000

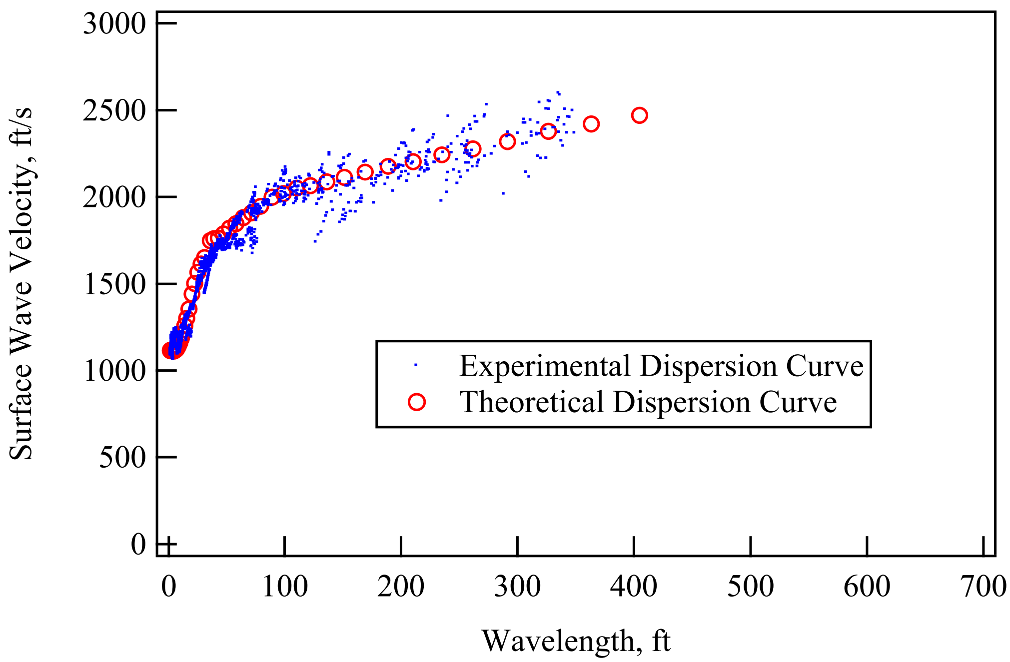
* Poisson's ratio and mass density from Wong (2002c, Appendix 18)

Figure IX-18. SASW-18 Results (continued)



(Wong, 2002c, Appendix 19)

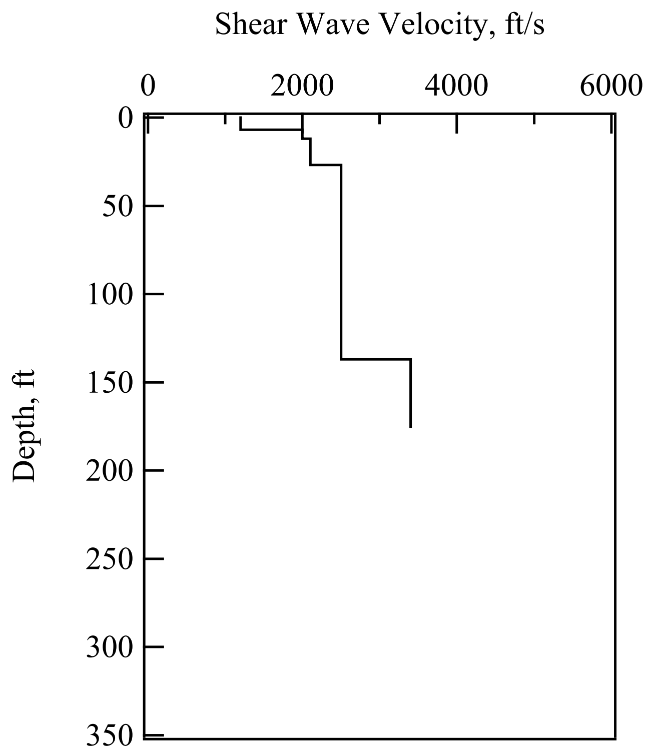
a. SASW-19 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 19)

b. SASW-19 Dispersion Curves (Linear Plot)

Figure IX-19. SASW-19 Results



DTN: MO0110SASWWHBS.000

c. SASW-19 Shear Wave Velocity Profile

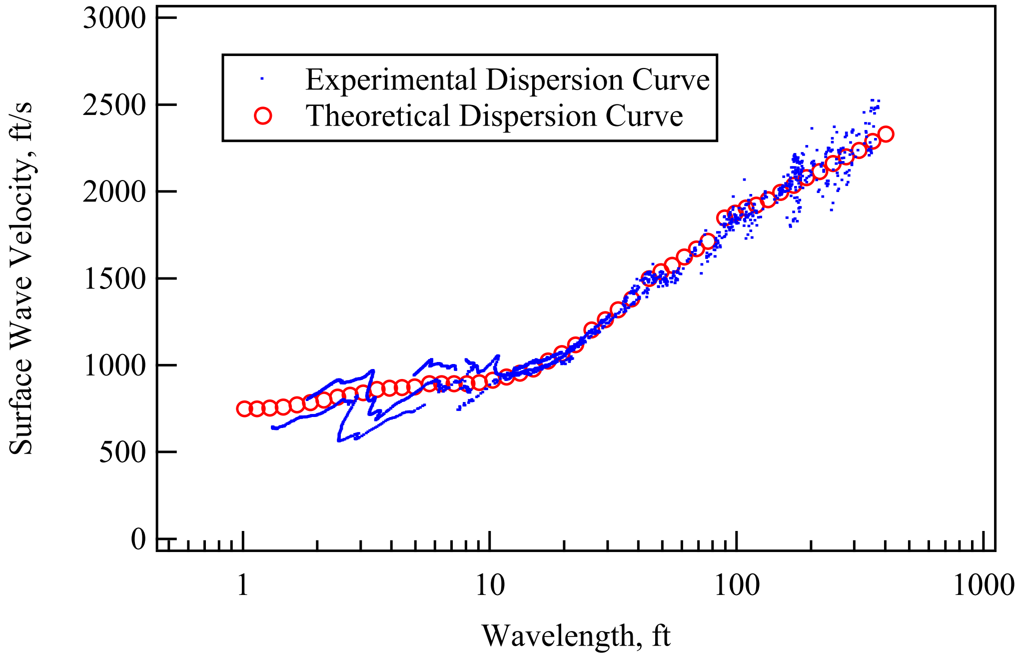
Location: SASW-19

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	7	2079	1200	0.25	120
2	5	3464	2000	0.25	120
3	15	3637	2100	0.25	120
4	110	4300	2500	0.25	120
5	38	5889	3400	0.25	80

DTN: MO0110SASWWHBS.000

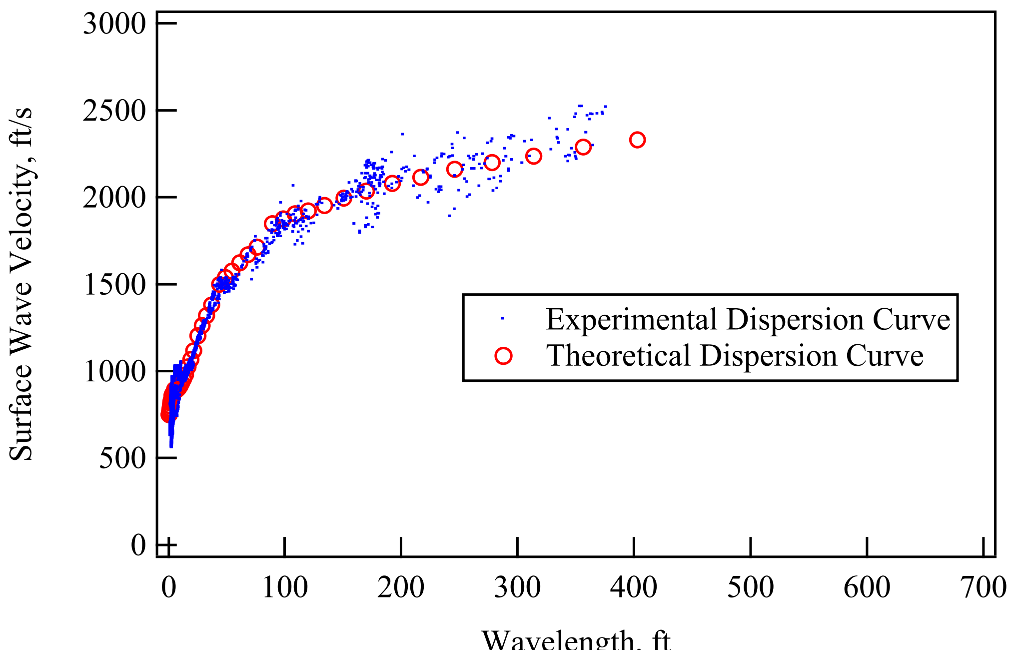
* Poisson's ratio and mass density from Wong (2002c, Appendix 19)

Figure IX-19. SASW-19 Results (continued)



(Wong, 2002c, Appendix 20)

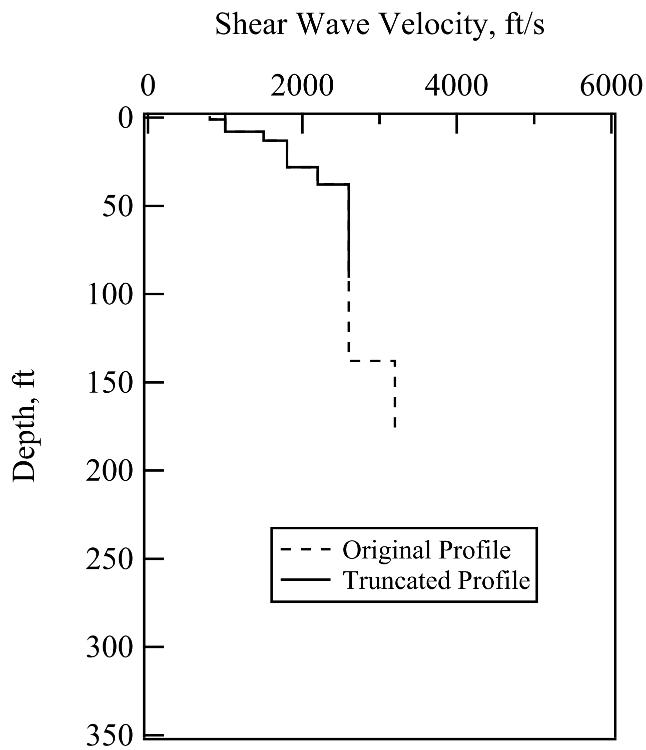
a. SASW-20 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 20)

b. SASW-20 Dispersion Curves (Linear Plot)

Figure IX-20. SASW-20 Results



DTN: MO0110SASWWHBS.000

c. SASW-20 Shear Wave Velocity Profile

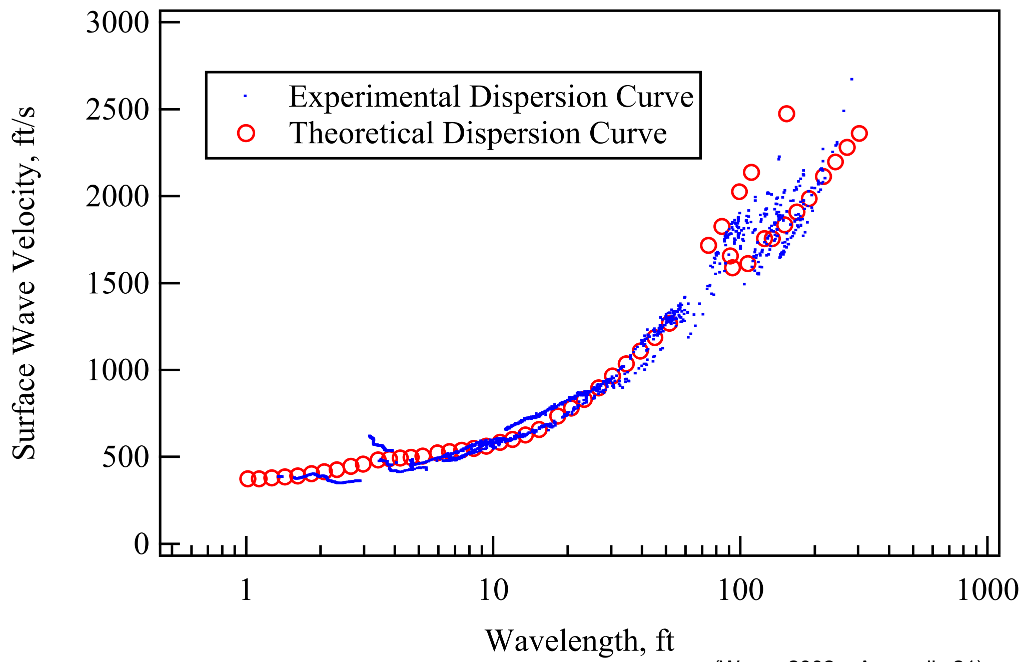
Location: SASW-20

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	1386	800	0.25	120
2	7	1732	1000	0.25	120
3	5	2598	1500	0.25	120
4	15	3117	1800	0.25	120
5	10	3810	2200	0.25	120
6	52*	4503	2600	0.25	120
7	48**	4503	2600	0.25	120
8	37**	5542	3200	0.25	80

DTN: MO0110SASWWHBS.000

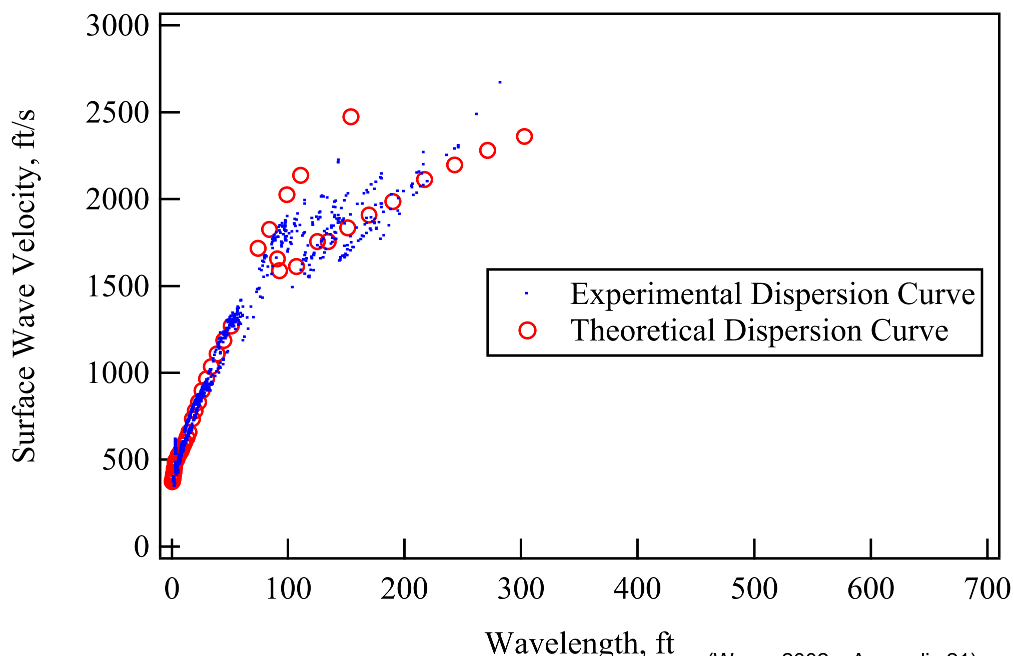
* Vs profile truncated at 90 ft based on geological profile showing an offset fault beginning at a depth of approximately 90 ft. (Attachment I)
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 20)

Figure IX-20. SASW Results (continued)



(Wong, 2002c, Appendix 21)

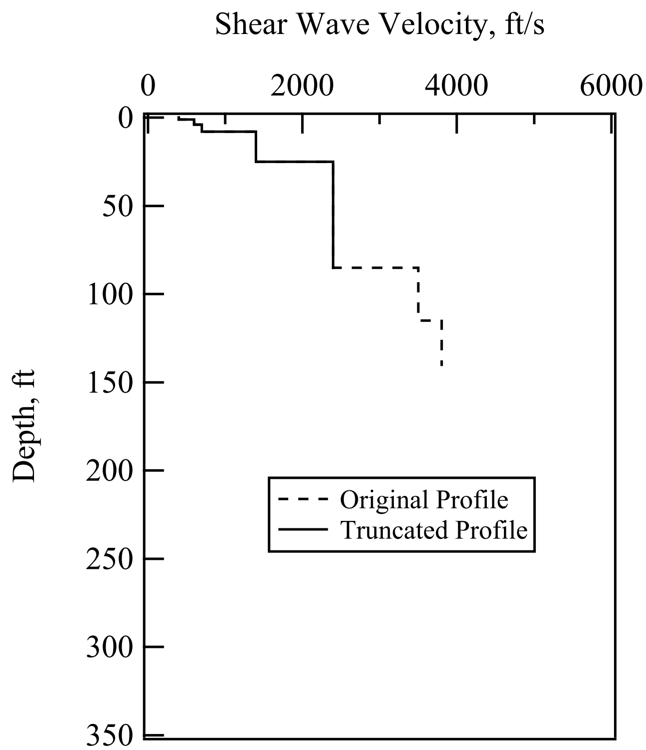
a. SASW-21 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 21)

b. SASW-21 Dispersion Curves (Linear Plot)

Figure IX-21. SASW-21 Results



DTN: MO0110SASWWHBS.000

c. SASW-21 Shear Wave Velocity Profile

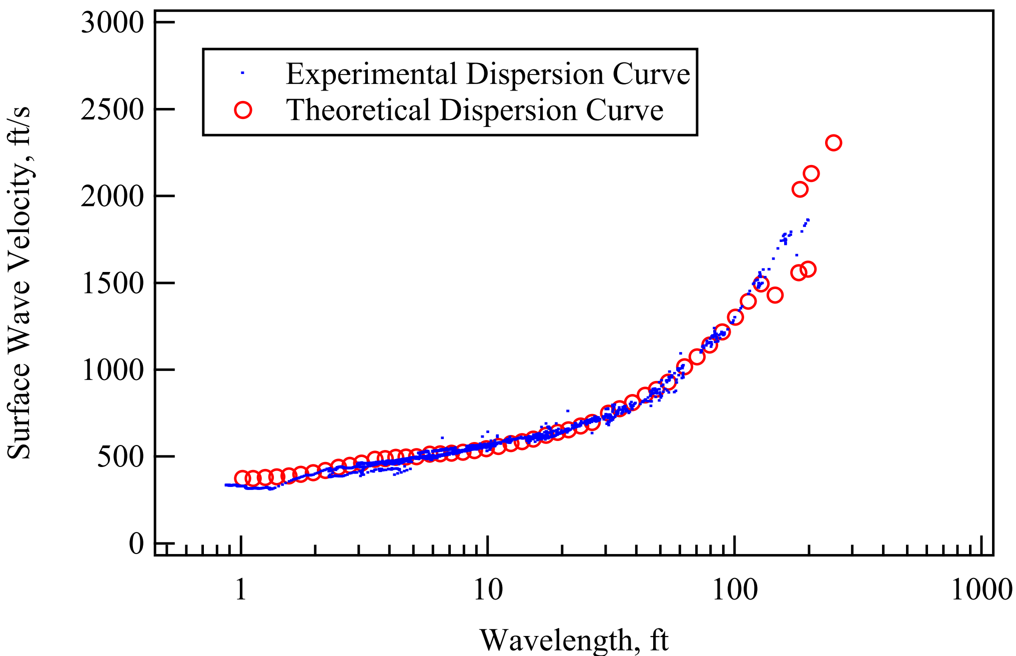
Location: SASW-21

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	692	400	0.25	120
2	3	1039	600	0.25	120
3	4	1212	700	0.25	120
4	17	2424	1400	0.25	120
5	60*	4157	2400	0.25	120
6	30**	6062	3500	0.25	80
7	25**	6581	3800	0.25	80

DTN: MO0110SASWWHBS.000

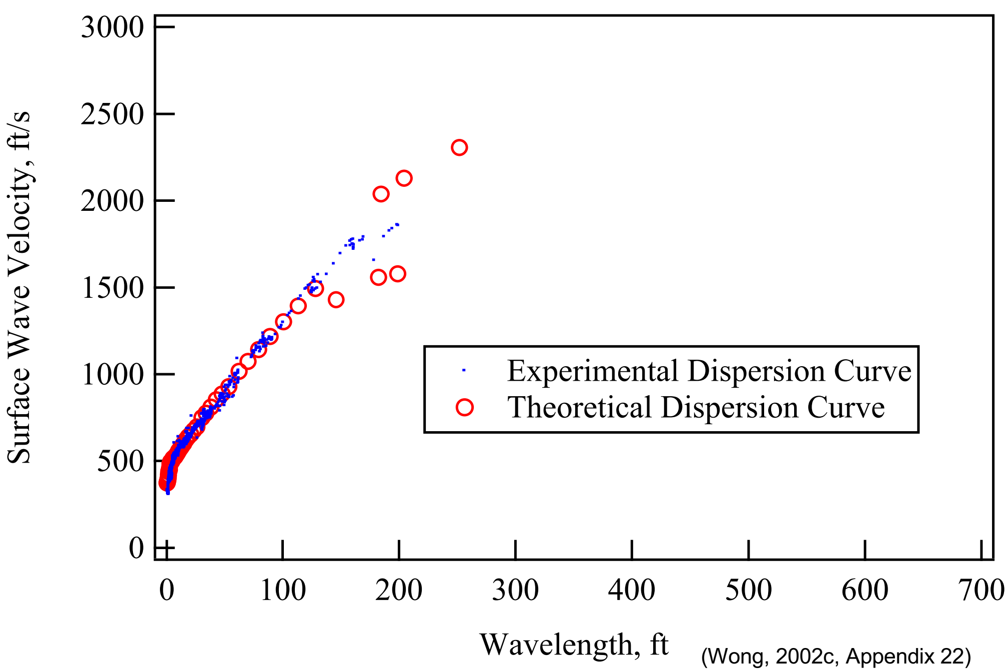
* Vs profile truncated at 85 ft based on geological profile showing an offset fault beginning at a depth of approximately 85 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 21)

Figure IX-21. SASW-21 Results (continued)



(Wong, 2002c, Appendix 22)

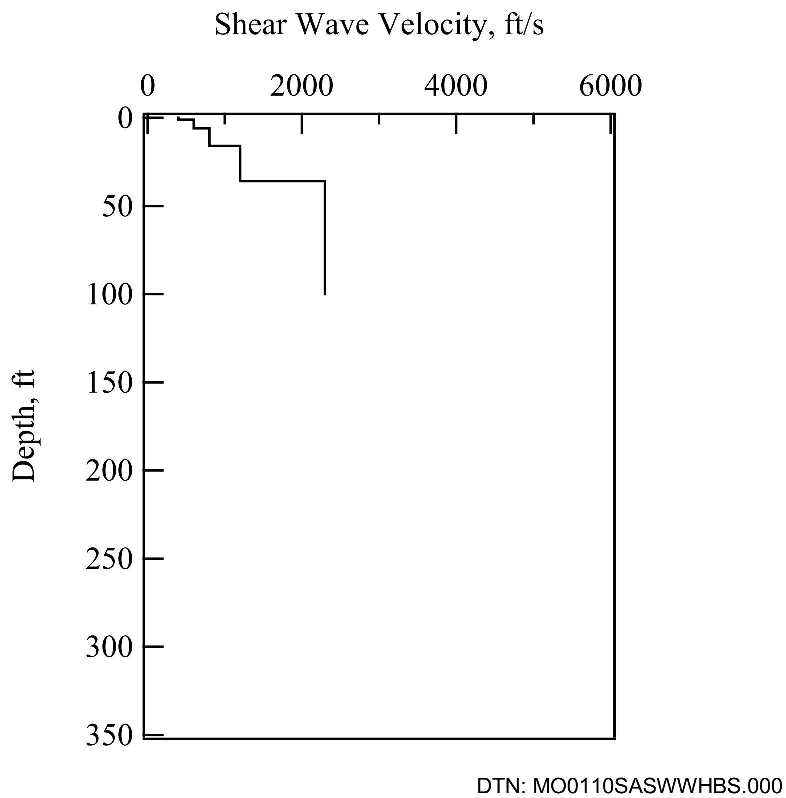
a. SASW-22 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 22)

b. SASW-22 Dispersion Curves (Linear Plot)

Figure IX-22. SASW-22 Results



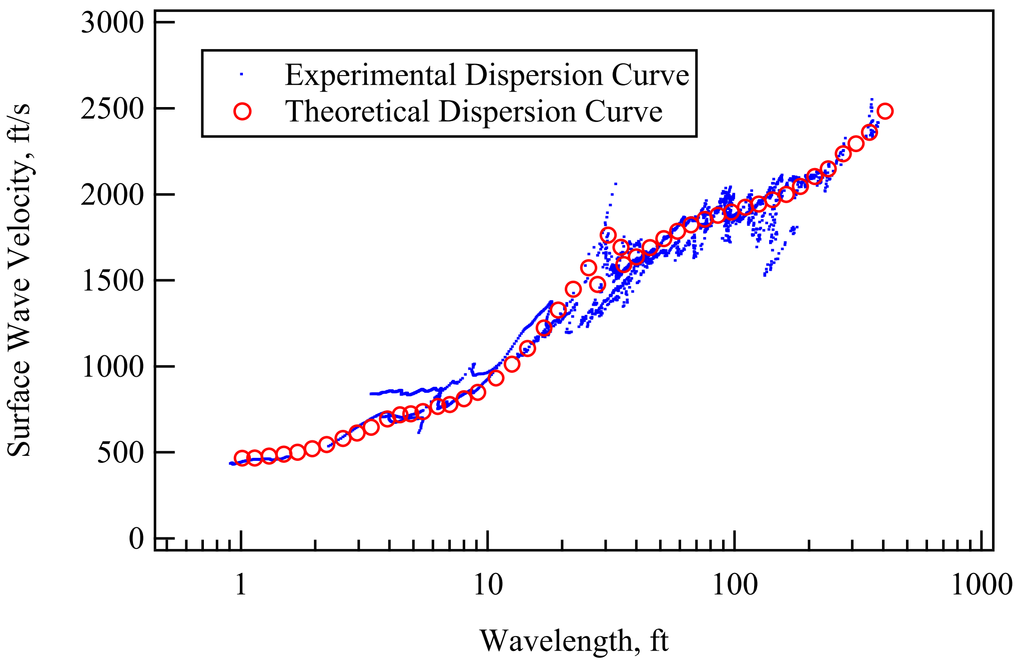
c. SASW-22 Shear Wave Velocity Profile

Location: SASW-22

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	693	400	0.25	120
2	5	1039	600	0.25	120
3	10	1386	800	0.25	120
4	20	2078	1200	0.25	120
5	64	3984	2300	0.25	120

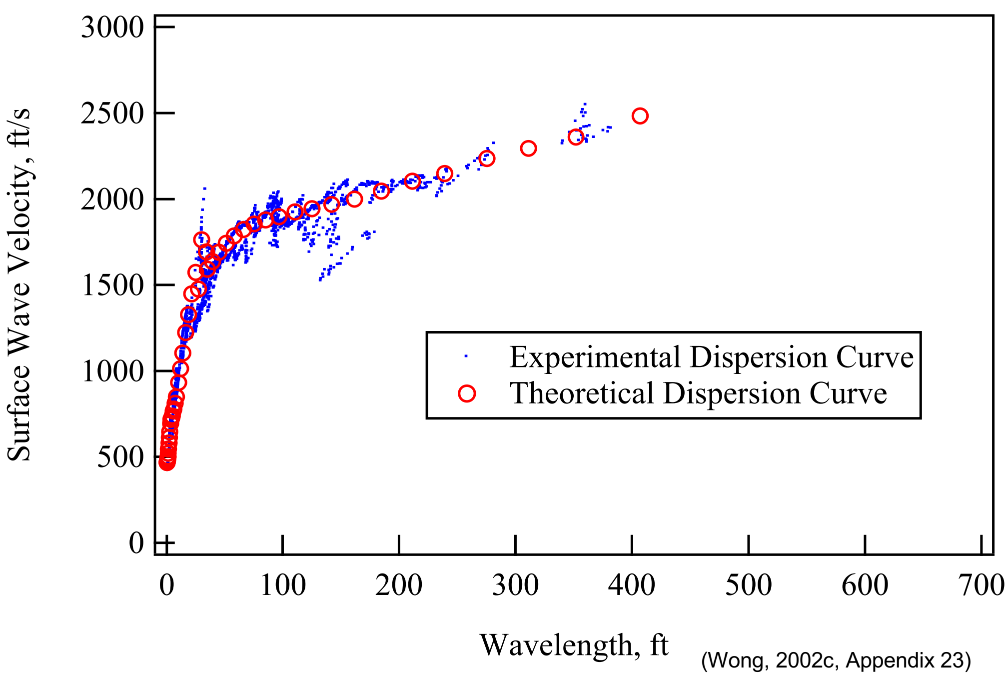
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 22)

Figure IX-22. SASW-22 Results (continued)



(Wong, 2002c, Appendix 23)

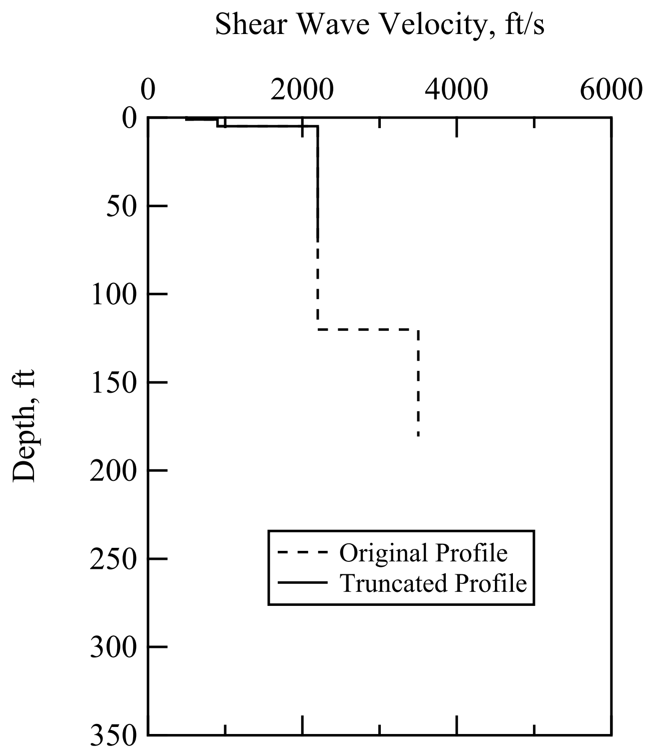
a. SASW-23 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 23)

b. SASW-23 Dispersion Curves (Linear Plot)

Figure IX-23. SASW-23 Results



DTN: MO0110SASWWHBS.000

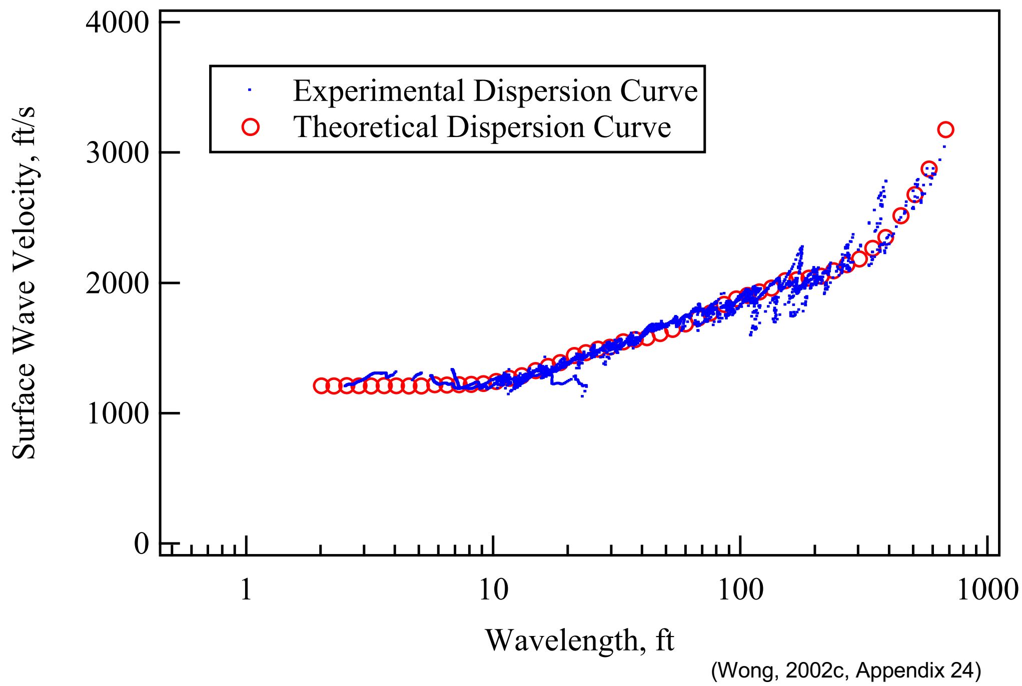
c. SASW-23 Shear Wave Velocity Profile

Location: SASW-23

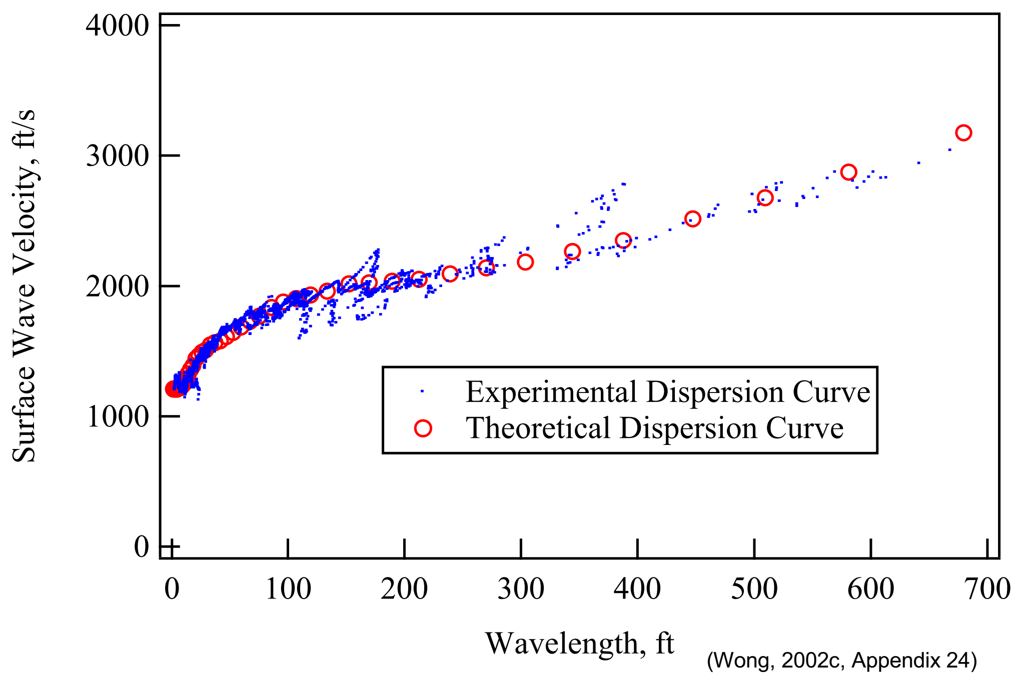
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	1	866	500	0.25	120
2	4	1559	900	0.25	120
3	65*	3810	2200	0.25	120
4	50**	3810	2200	0.25	120
5	60**	6062	3500	0.25	80

DTN: MO0110SASWWHBS.000
* Vs profile truncated at 70 ft based on geological profile showing an offset fault beginning at a depth of approximately 70 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 23)

Figure IX-23. SASW-23 Results (continued)

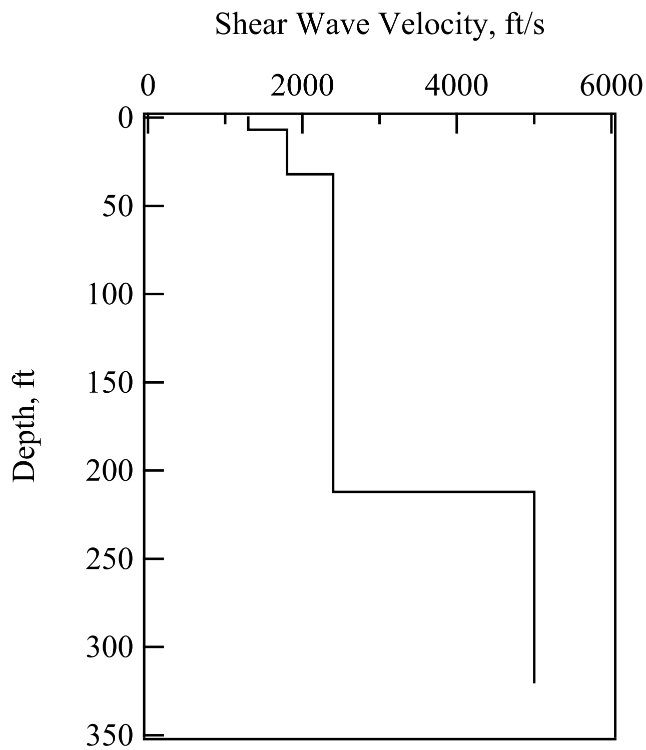


a. SASW-24 Dispersion Curves (Log Plot)



b. SASW-24 Dispersion Curves (Linear Plot)

Figure IX-24. SASW-24 Results



DTN: MO0110SASWWHBS.000

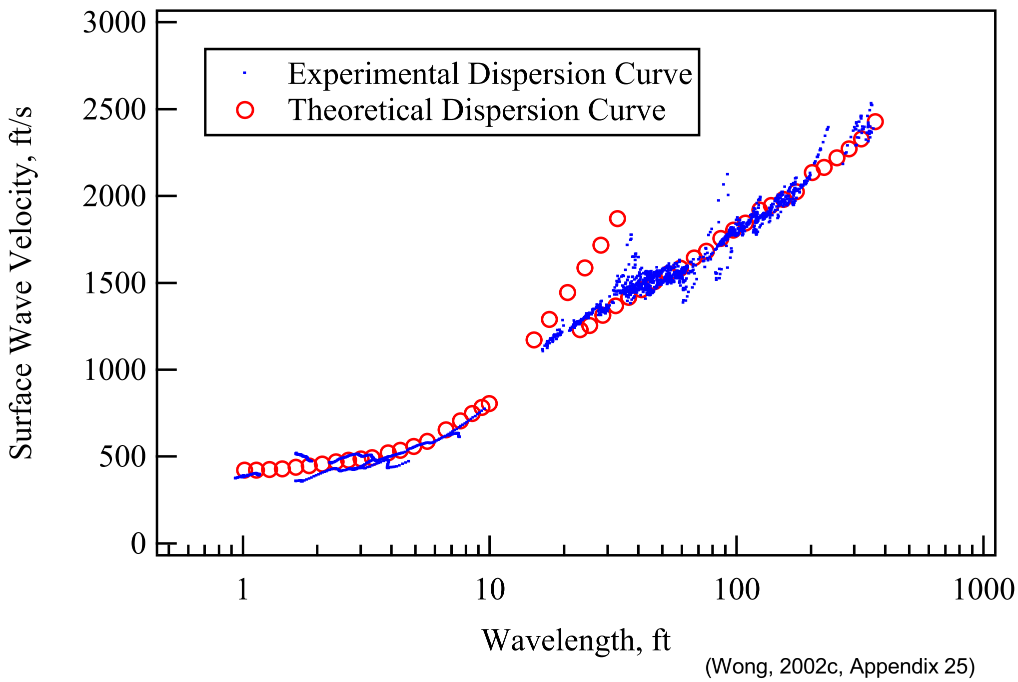
c. SASW-24 Shear Wave Velocity Profile

Location: SASW-24

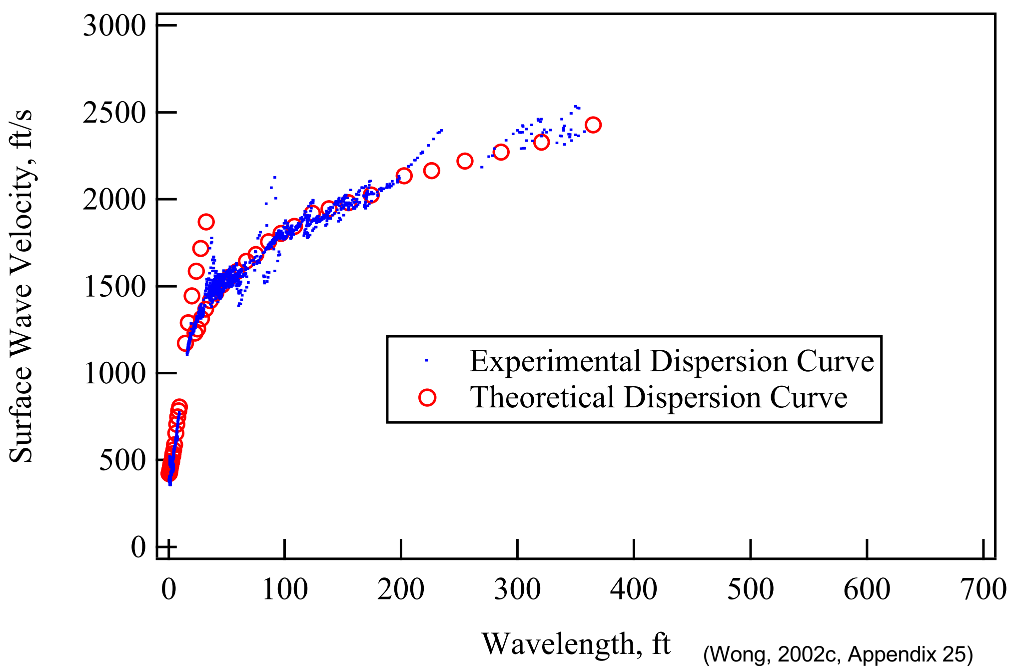
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	7	2252	1300	0.25	120
2	25	3118	1800	0.25	120
3	180	4157	2400	0.25	120
4	108	8660	5000	0.25	145

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 24)

Figure IX-24. SASW-24 Results (continued)

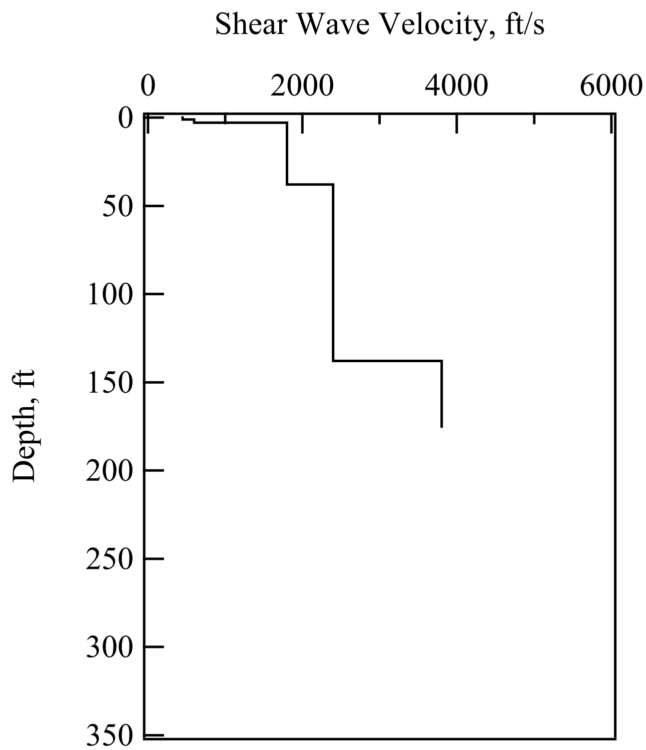


a. SASW-25 Dispersion Curves (Log Plot)



b. SASW-25 Dispersion Curves (Linear Plot)

Figure IX-25. SASW-25 Results



DTN: MO0110SASWWHBS.000

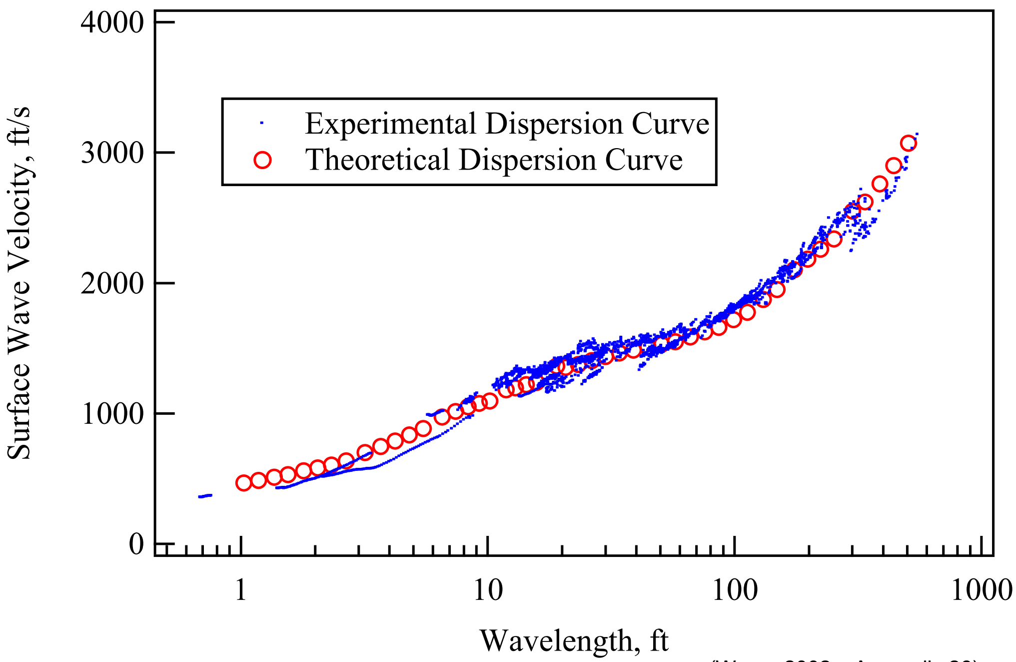
c. SASW-25 Shear Wave Velocity Profile

Location: SASW-25

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	779	450	0.25	120
2	2	1039	600	0.25	120
3	35	3118	1800	0.25	120
4	100	4157	2400	0.25	120
5	37	6582	3800	0.25	80

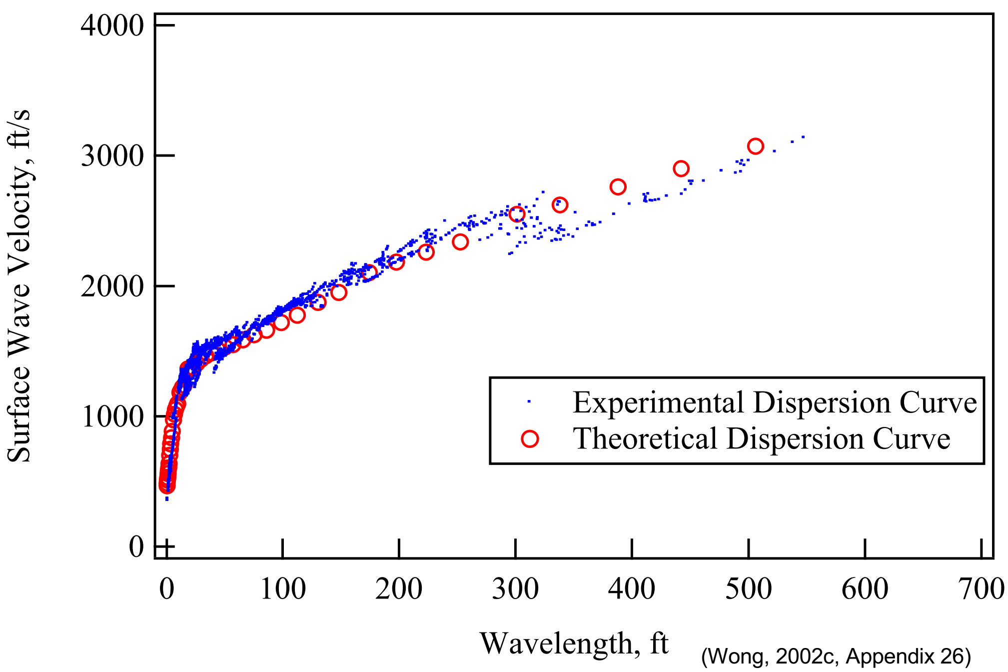
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 25)

Figure IX-25. SASW-25 Results (continued)



(Wong, 2002c, Appendix 26)

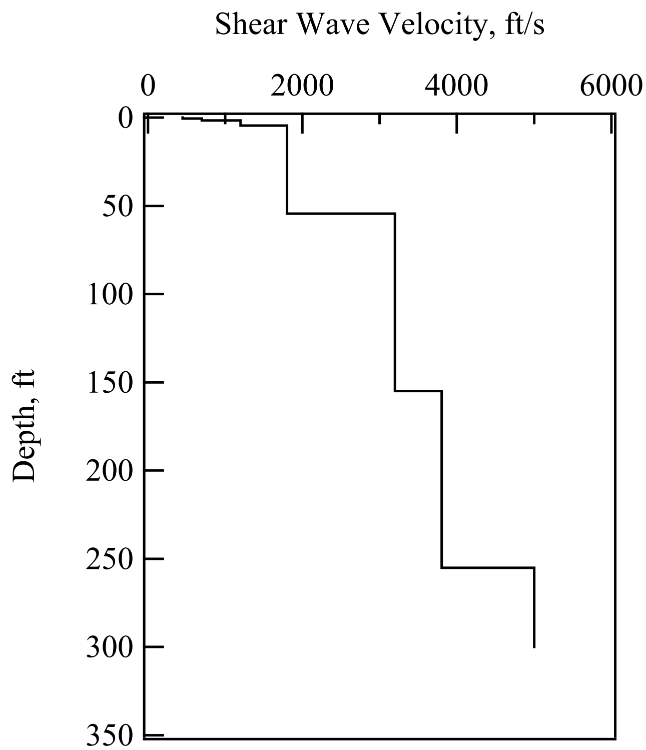
a. SASW-26 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 26)

b. SASW-26 Dispersion Curves (Linear Plot)

Figure IX-26. SASW-26 Results



DTN: MO0110SASWWHBS.000

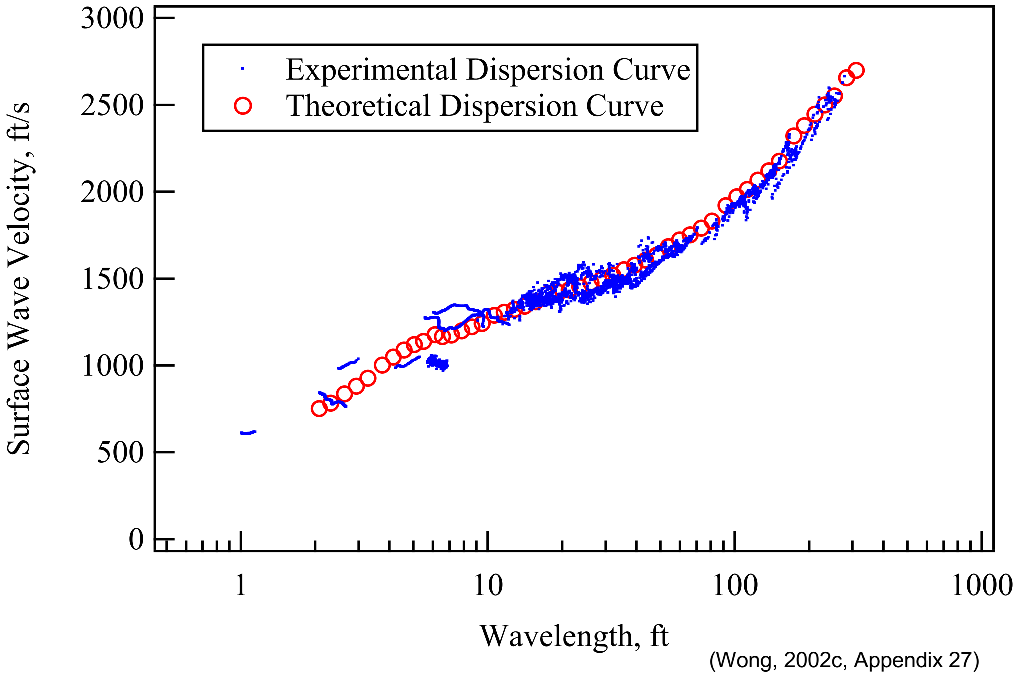
c. SASW-26 Shear Wave Velocity Profile

Location: SASW-26

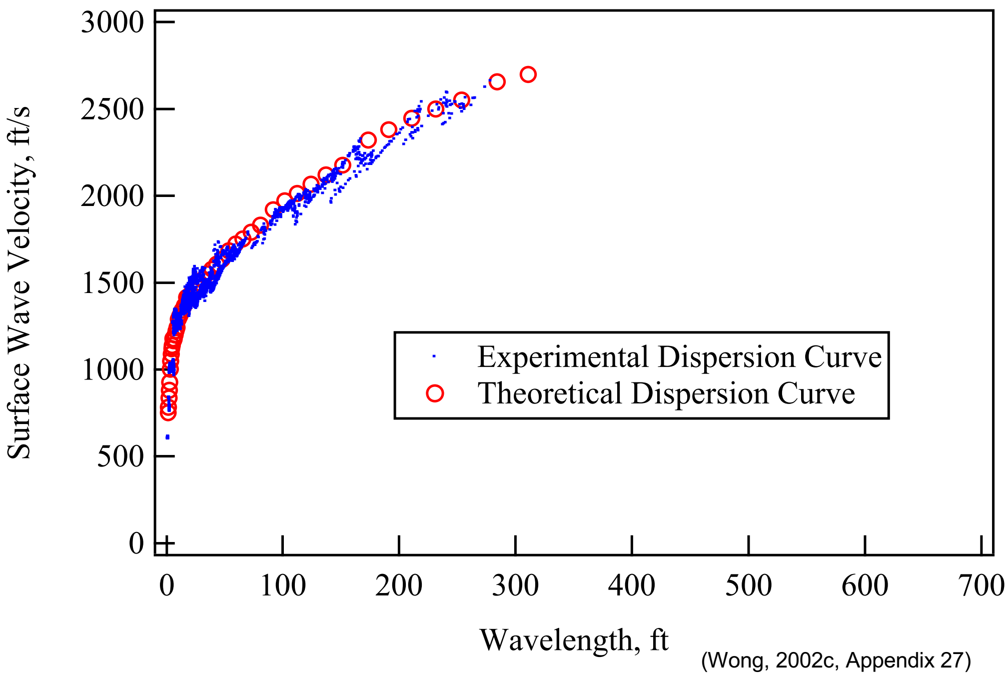
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	779	450	0.25	120
2	1	1212	700	0.25	120
3	3	2079	1200	0.25	120
4	50	3118	1800	0.25	120
5	100	5542	3200	0.25	80
6	100	6582	3800	0.25	80
7	46	8660	5000	0.25	145

DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 26)

Figure IX-26. SASW-26 Results (continued)

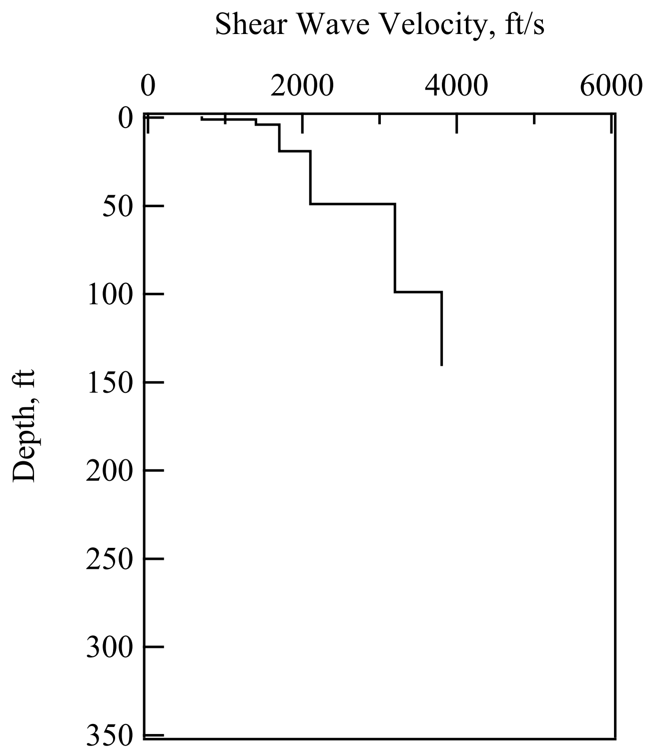


a. SASW-27 Dispersion Curves (Log Plot)



b. SASW-27 Dispersion Curves (Linear Plot)

Figure IX-27. SASW-27 Results



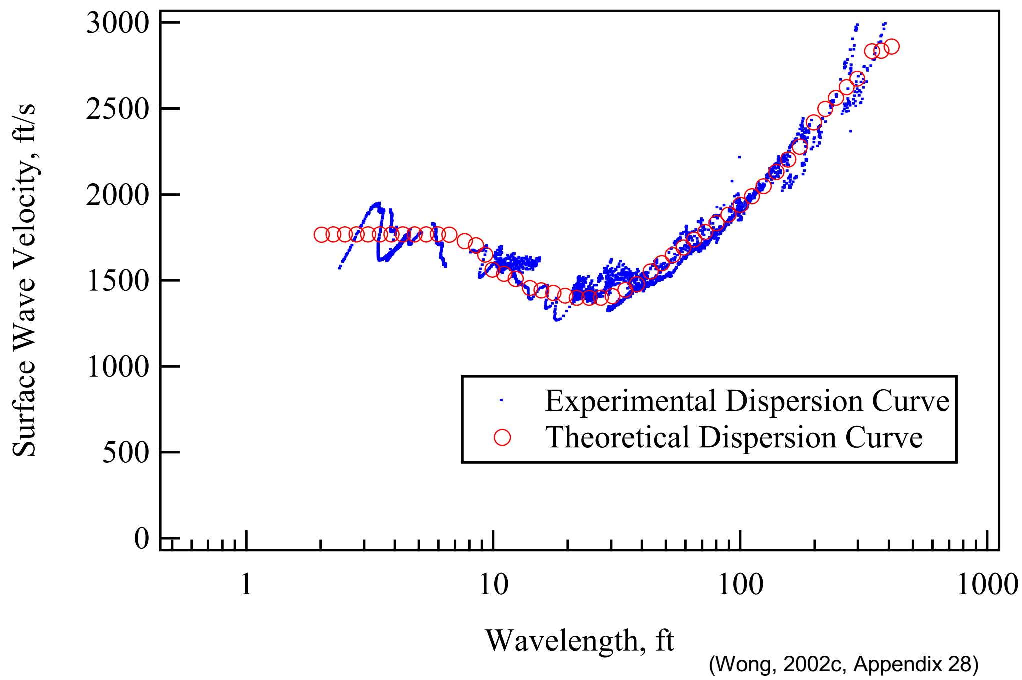
c. SASW-27 Shear Wave Velocity Profile

Location: SASW-27

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	1212	700	0.25	120
2	3	2425	1400	0.25	120
3	15	2945	1700	0.25	120
4	30	3637	2100	0.25	120
5	50	5543	3200	0.25	80
6	50	6582	3800	0.25	80

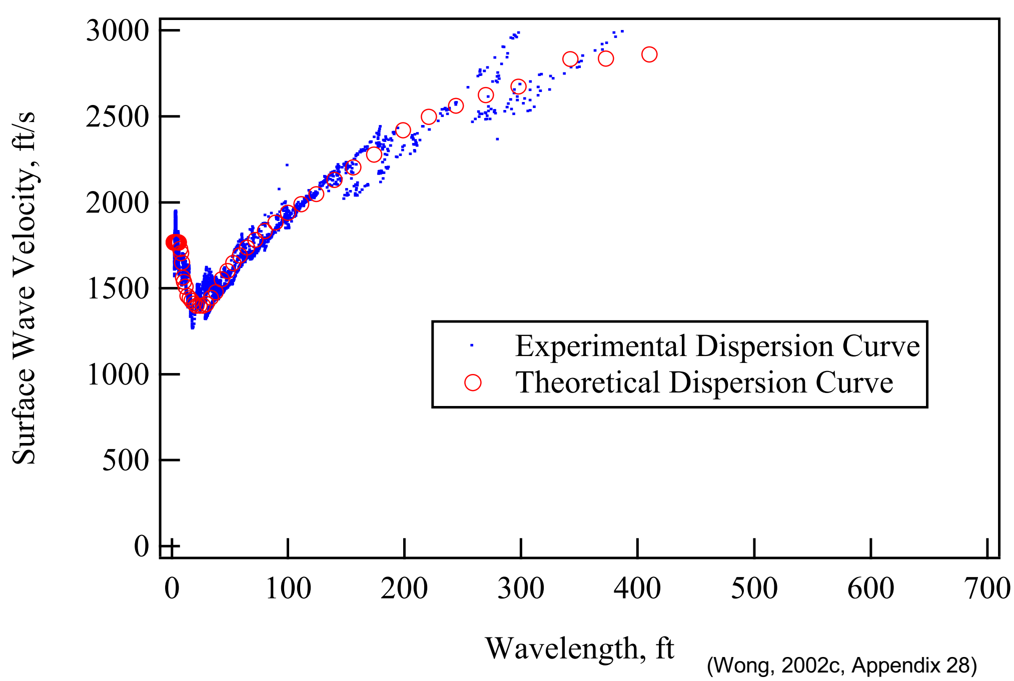
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 27)

Figure IX-27. SASW-27 Results (continued)



(Wong, 2002c, Appendix 28)

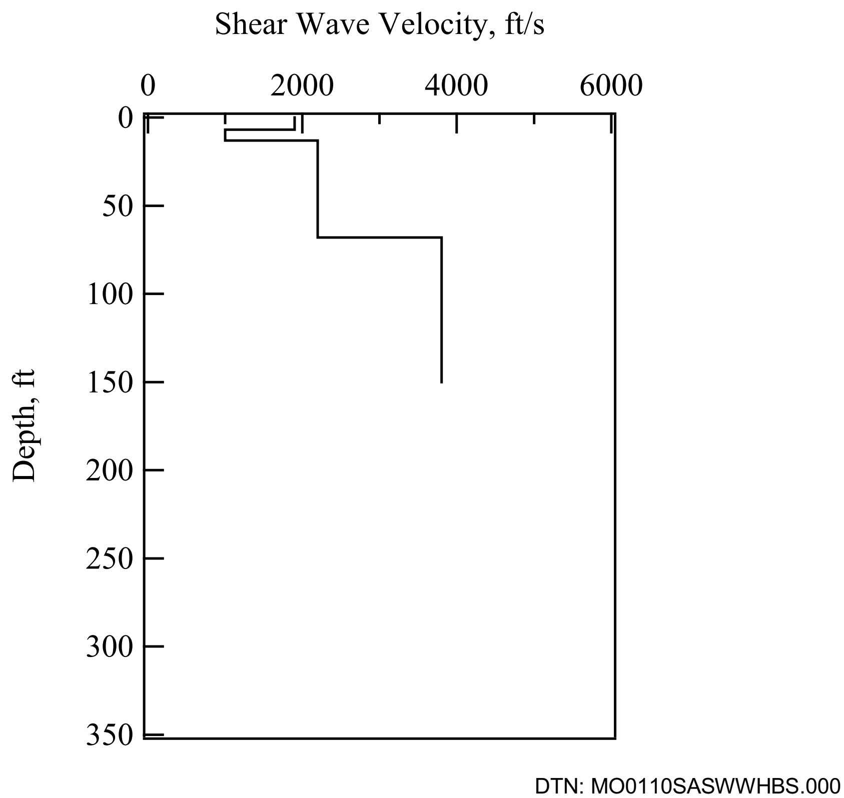
a. SASW-28 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 28)

b. SASW-28 Dispersion Curves (Linear Plot)

Figure IX-28. SASW-28 Results



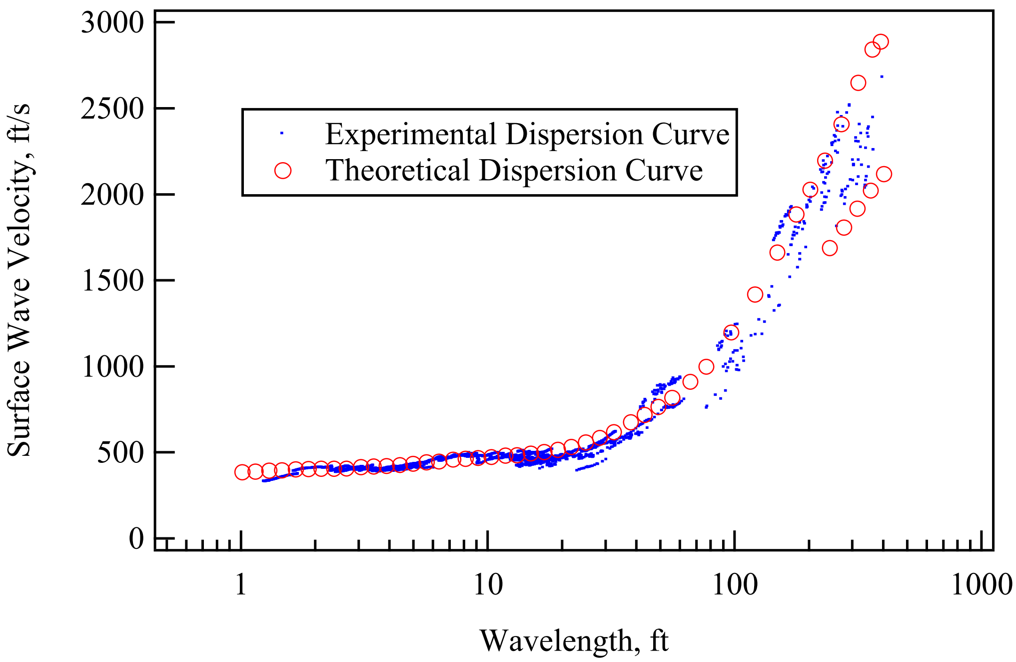
c. SASW-28 Shear Wave Velocity Profile

Location: SASW-28

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	7	3291	1900	0.25	120
2	6	1732	1000	0.25	120
3	55	3810	2200	0.25	120
4	82	6062	3800	0.25	80

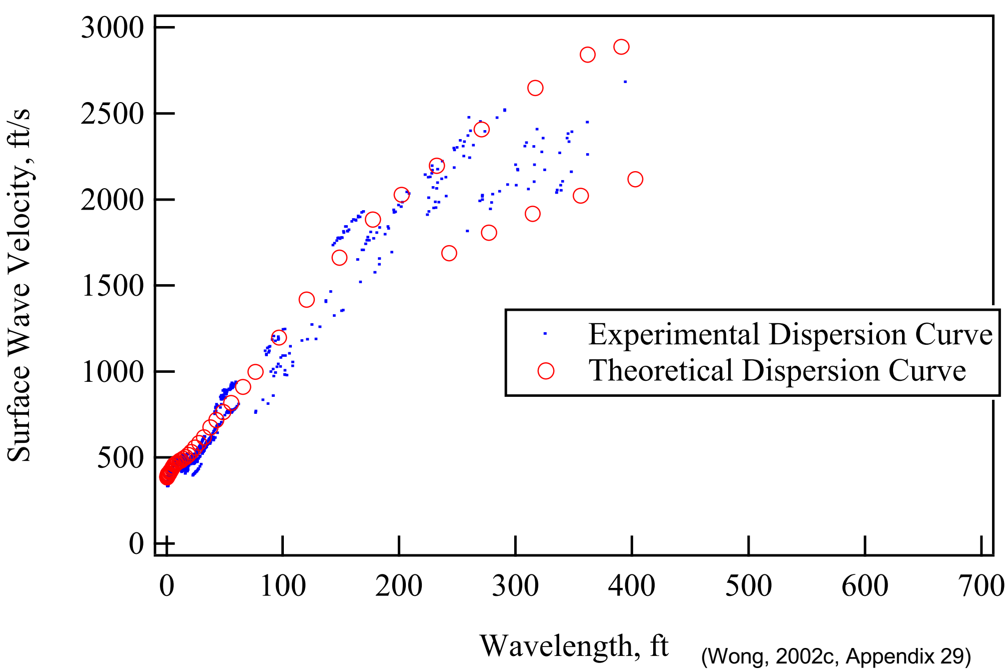
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 28)

Figure IX-28. SASW-28 Results (continued)



(Wong, 2002c, Appendix 29)

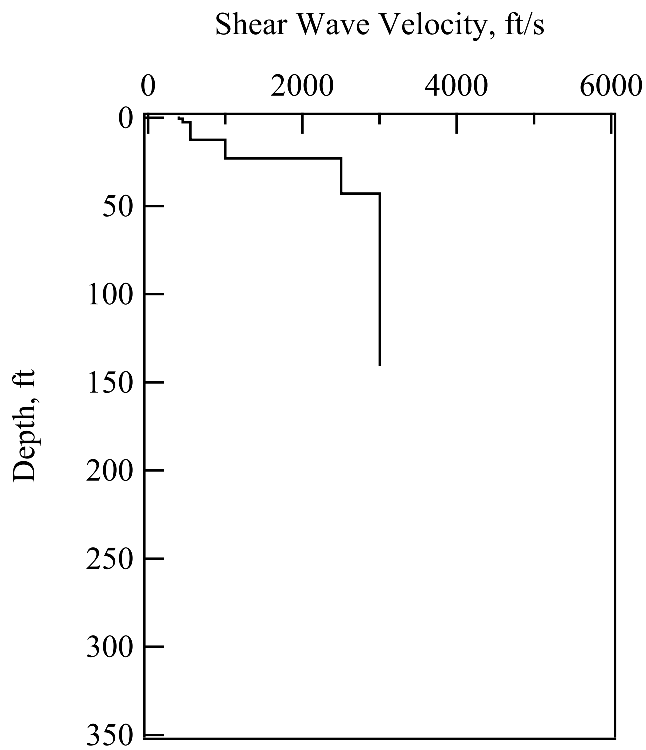
a. SASW-29 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 29)

b. SASW-29 Dispersion Curves (Linear Plot)

Figure IX-29. SASW-29 Results



DTN: MO0110SASWWHBS.000

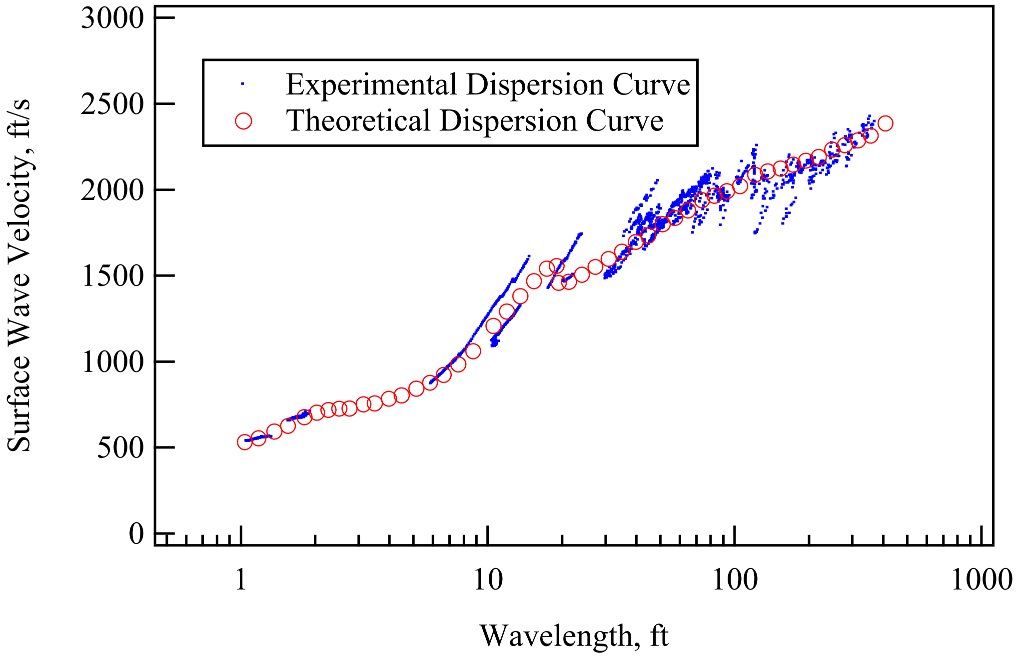
c. SASW-29 Shear Wave Velocity Profile

Location: SASW-29

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	692	400	0.25	120
2	2	779	450	0.25	120
3	10	952	550	0.25	120
4	20	1732	1000	0.25	120
5	20	4330	2500	0.25	120
6	88	5196	3000	0.25	80

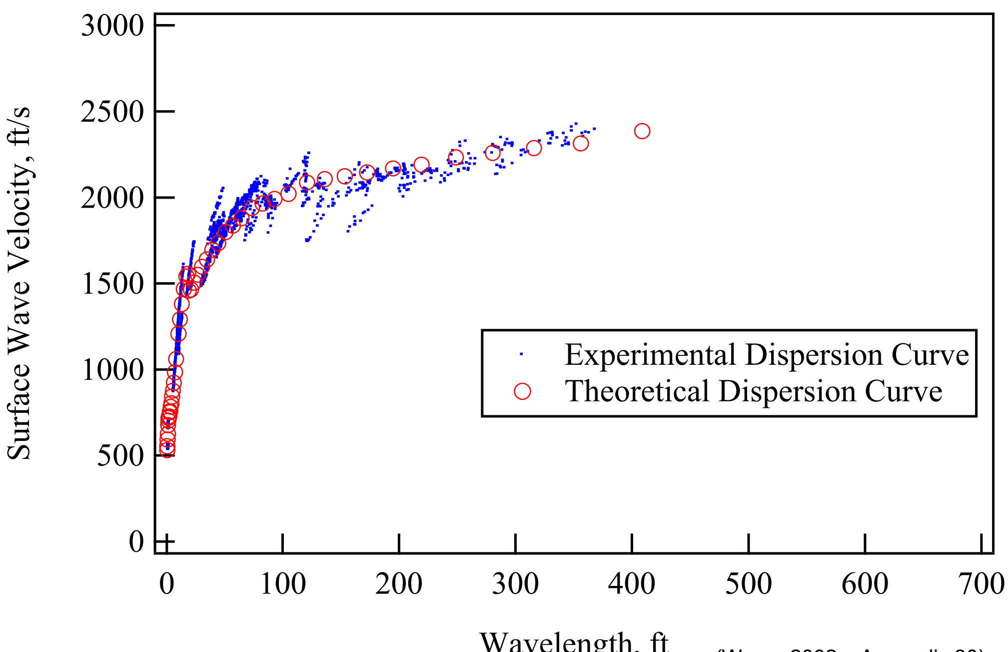
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 29)

Figure IX-29. SASW-29 Results (continued)



(Wong, 2002c, Appendix 30)

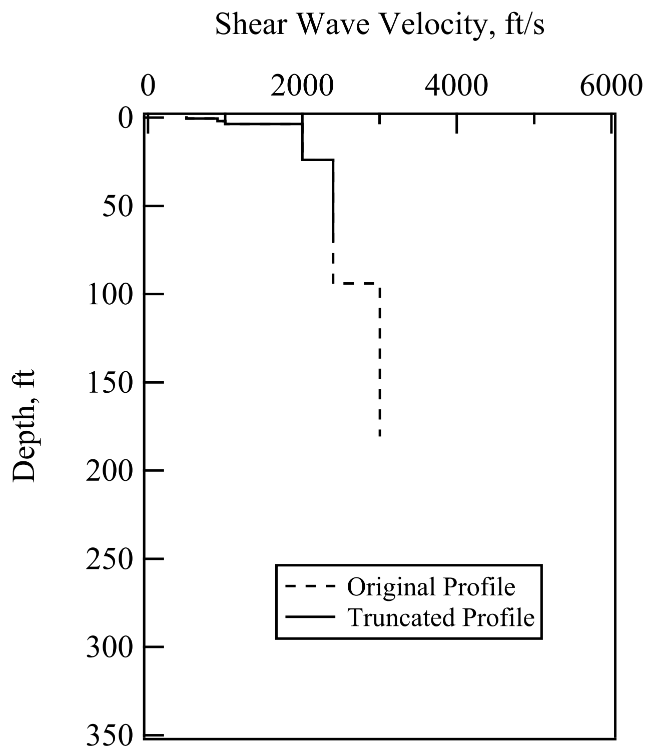
a. SASW-30 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 30)

b. SASW-30 Dispersion Curves (Linear Plot)

Figure IX-30. SASW-30 Results



DTN: MO0110SASWWHBS.000

c. SASW-30 Shear Wave Velocity Profile

Location: SASW-30

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	0.5	866	500	0.25	120
2	1.5	1559	900	0.25	120
3	1.5	1732	1000	0.25	120
4	20	3464	2000	0.25	120
5	46.5*	4157	2400	0.25	120
6	23.5**	4157	2400	0.25	120
7	82**	5196	3000	0.25	80

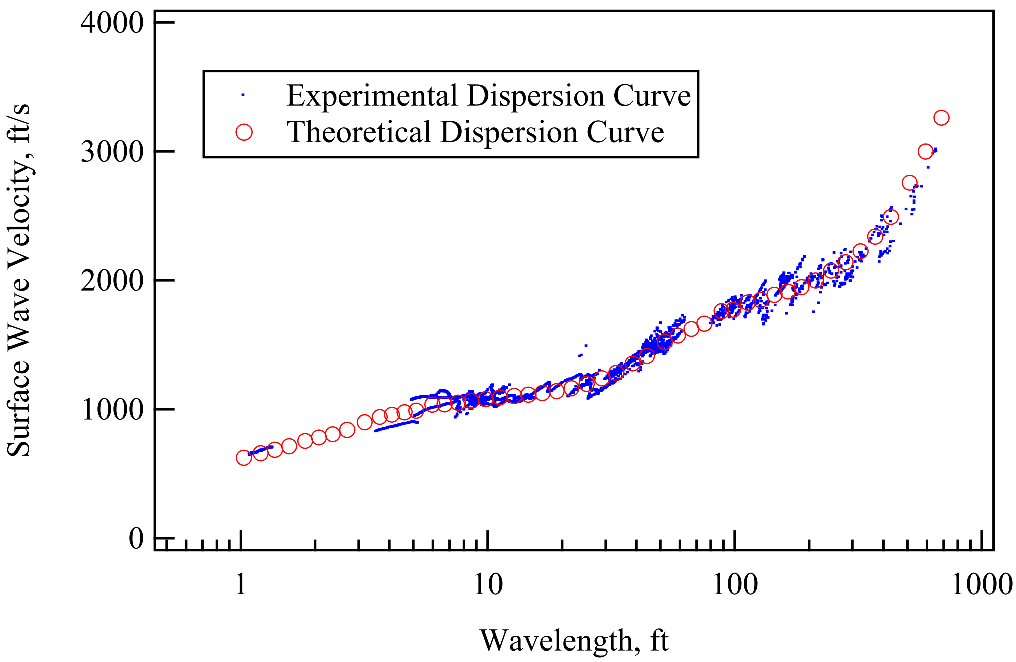
DTN: MO0110SASWWHBS.000

* Vs profile truncated at 70 ft based on geological profile showing an offset fault beginning at a depth of approximately 70 ft.

** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve

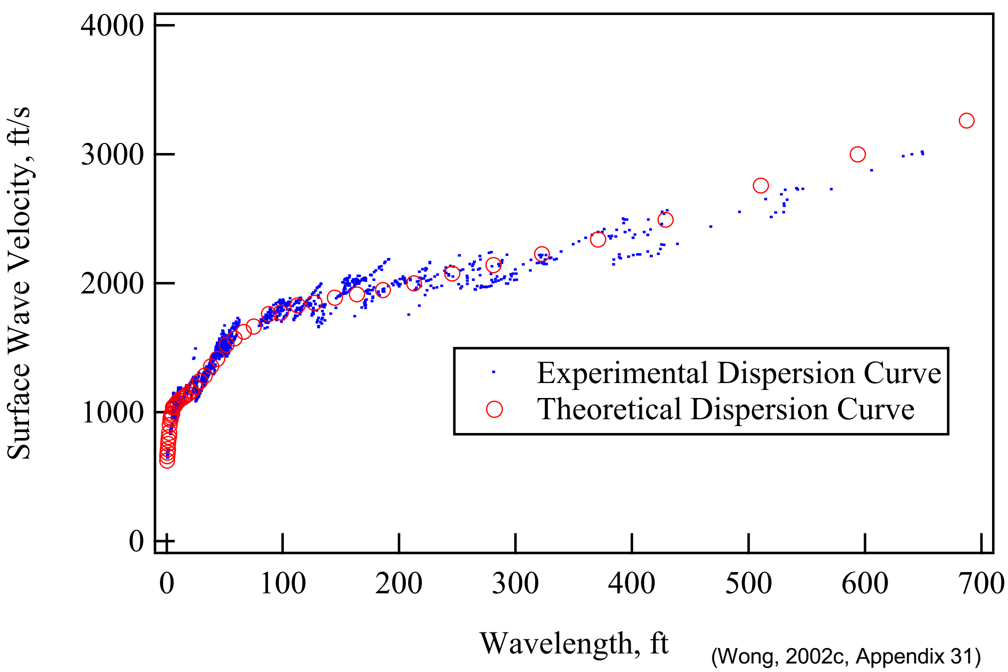
*** Poisson's ratio and mass density from Wong (2002c, Appendix 30)

Figure IX-30. SASW-30 Results (continued)



(Wong, 2002c, Appendix 31)

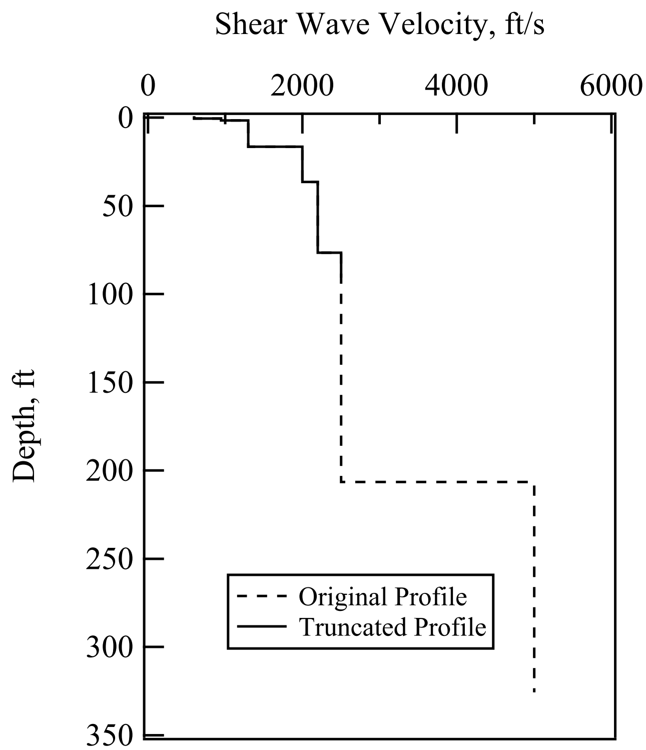
a. SASW-31 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 31)

b. SASW-31 Dispersion Curves (Linear Plot)

Figure IX-31. SASW-31 Results



DTN: MO0110SASWWHBS.000

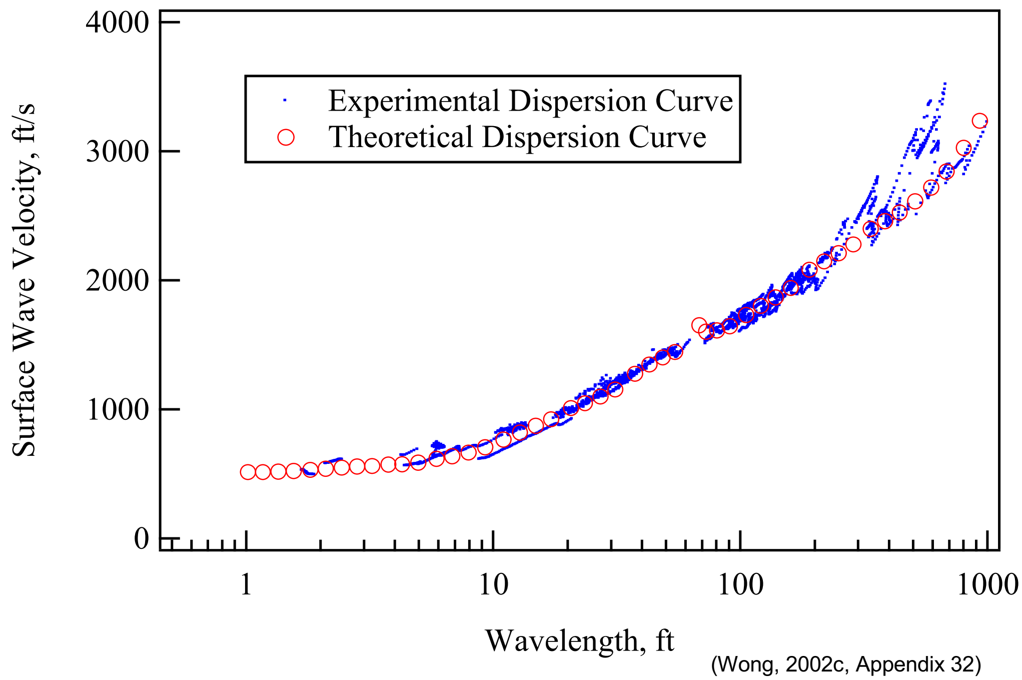
c. SASW-31 Shear Wave Velocity Profile

Location: SASW-31

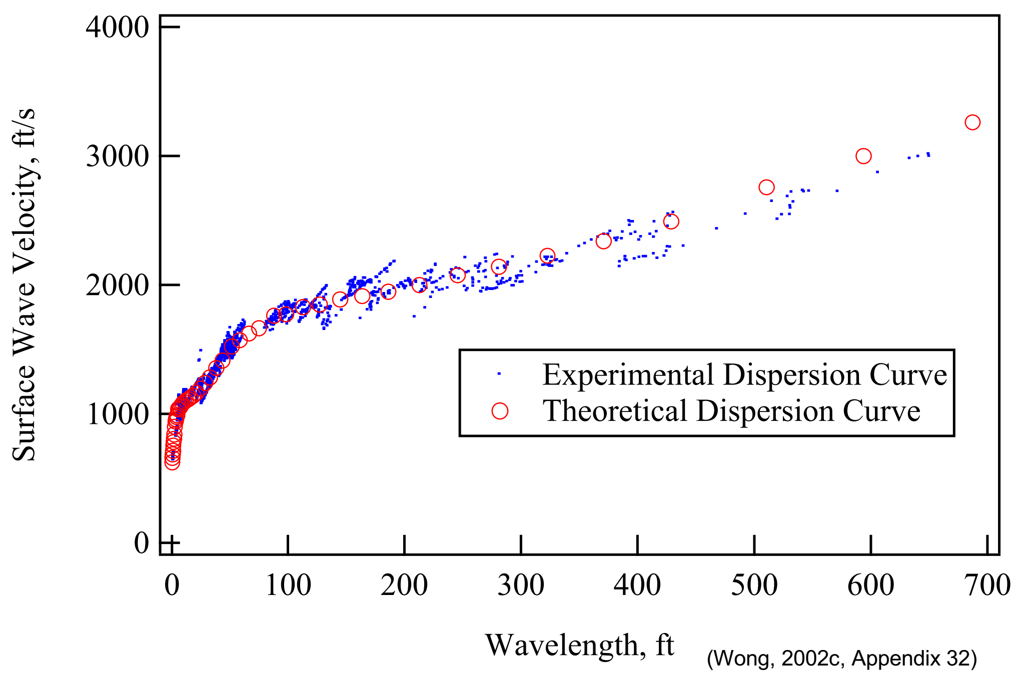
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio***	Mass Density*** pcf
1	0.5	1039	600	0.25	120
2	1	1645	950	0.25	120
3	15	2251	1300	0.25	120
4	20	3464	2000	0.25	120
5	40	3811	2200	0.25	120
6	13.5*	4330	2500	0.25	120
7	116.5**	4330	2500	0.25	120
8	118	8660	5000	0.25	145

DTN: MO0110SASWWHBS.000
* Vs profile truncated at 90 ft based on geological profile showing an offset fault beginning at a depth of approximately 90 ft.
** Additional layering used in matching the theoretical dispersion curve to the complete experimental dispersion curve
*** Poisson's ratio and mass density from Wong (2002c, Appendix 31)

Figure IX-31. SASW-31 Results (continued)

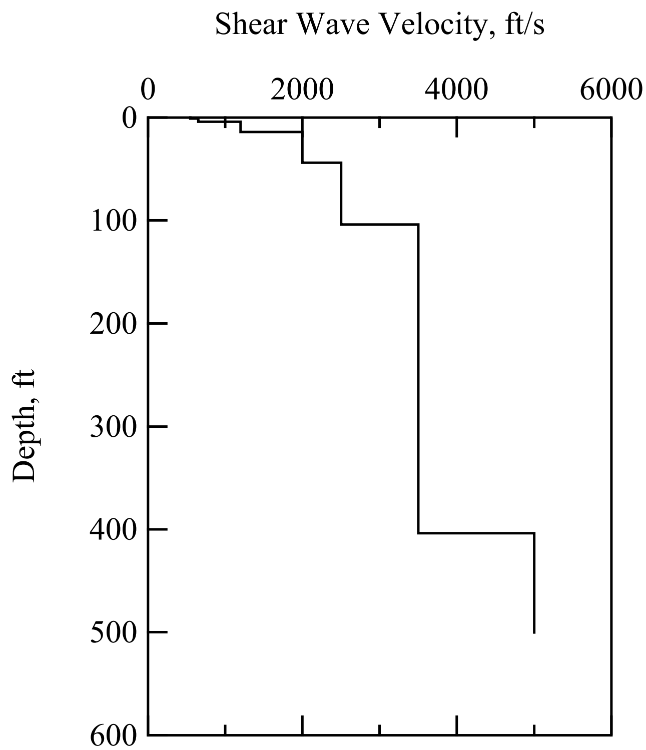


a. SASW-32+35 Dispersion Curves (Log Plot)



b. SASW-32+35 Dispersion Curves (Linear Plot)

Figure IX-32. SASW-32+35 Results



DTN: MO0110SASWWHBS.000

c. SASW-32+35 Shear Wave Velocity Profile

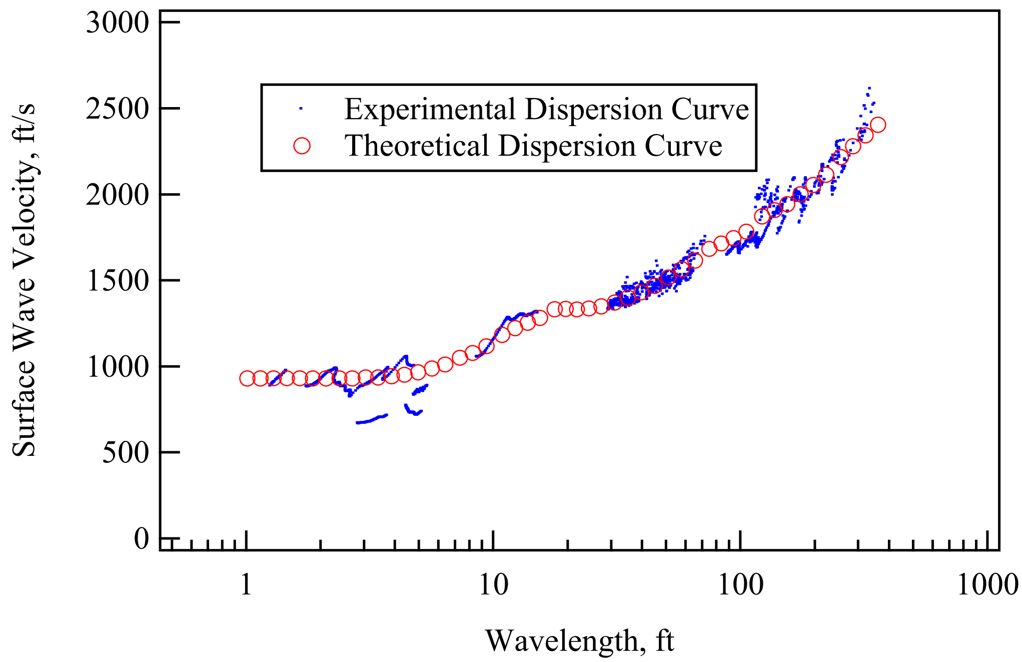
Location: SASW-32+35

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	953	550	0.25	120
2	3	1126	650	0.25	120
3	10	2079	1200	0.25	120
4	30	3464	2000	0.25	120
5	60	4330	2500	0.25	120
6	300	5543	3500	0.25	80
7	96	8660	5000	0.25	145

DTN: MO0110SASWWHBS.000

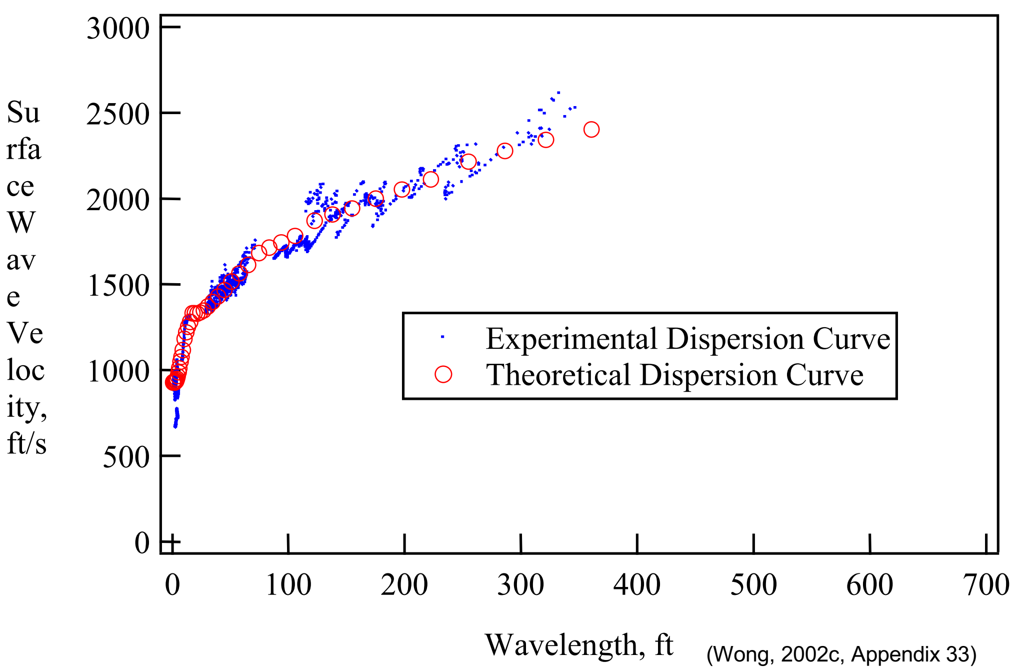
* Poisson's ratio and mass density from Wong (2002c, Appendix 32)

Figure IX-32. SASW-32+35 Results (continued)



(Wong, 2002c, Appendix 33)

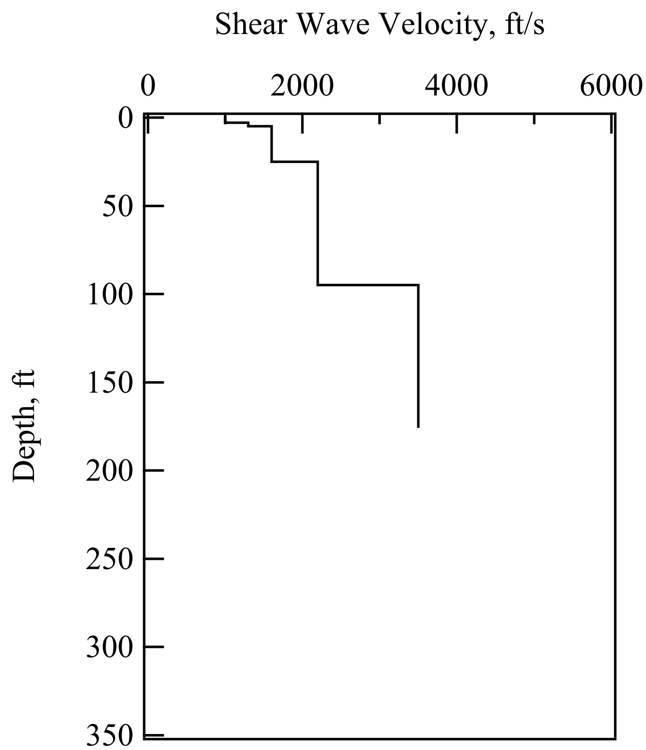
a. SASW-33 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 33)

b. SASW-33 Dispersion Curves (Linear Plot)

Figure IX-33. SASW-33 Results



DTN: MO0110SASWWHBS.000

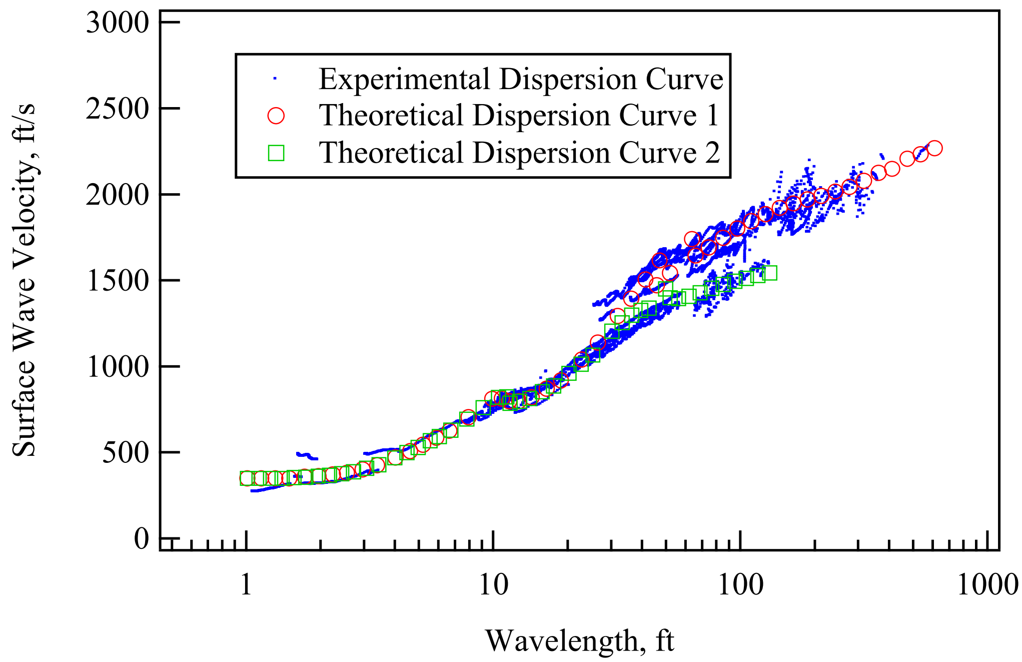
c. SASW-33 Shear Wave Velocity Profile

Location: SASW-33

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	3	1732	1000	0.25	120
2	2	2252	1300	0.25	120
3	20	2771	1600	0.25	120
4	70	3810	2200	0.25	120
5	80	6062	3500	0.25	80

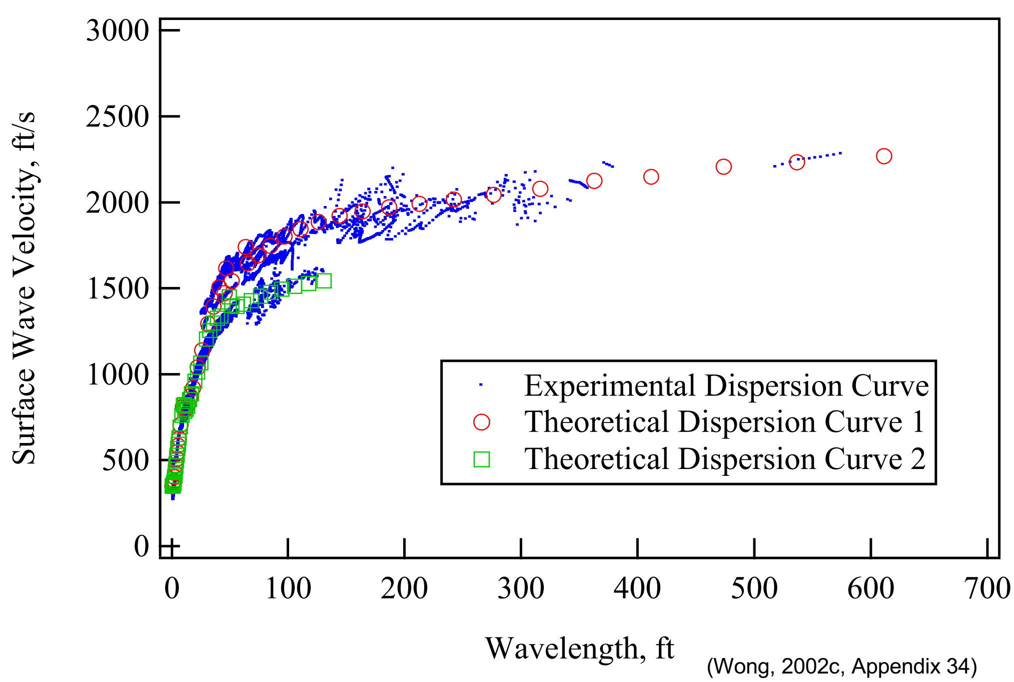
DTN: MO0110SASWWHBS.000
* Poisson's ratio and mass density from Wong (2002c, Appendix 33)

Figure IX-33. SASW-33 Results (continued)



(Wong, 2002c, Appendix 34)

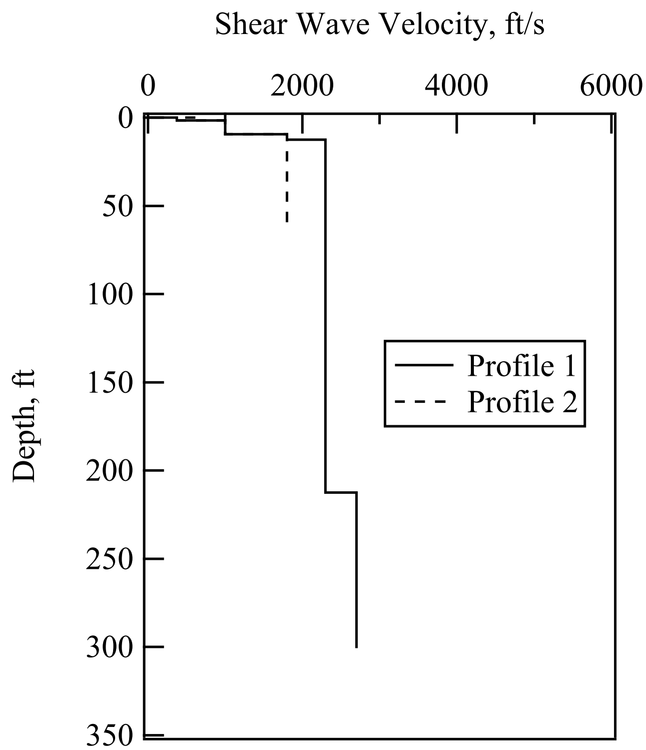
a. SASW-34+36 Dispersion Curves (Log Plot)



(Wong, 2002c, Appendix 34)

b. SASW-34+36 Dispersion Curves (Linear Plot)

Figure IX-34. SASW-34+36 Results



DTN: MO0110SASWWHBS.000

c. SASW-34+36 Shear Wave Velocity Profile

Location: SASW-34+36 Profile 1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1.5	650	375	0.25	120
2	8	1732	1000	0.25	120
3	3	3117	1800	0.25	120
4	200	3983	2300	0.25	120
5	88	4676	2700	0.25	120

Location: SASW-34+36 Profile 2

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	650	375	0.25	120
2	8	1732	1000	0.25	120
3	51	3117	1800	0.25	120

DTN: MO0110SASWWHBS.000

* Poisson's ratio and mass density from Wong (2002c, Appendix 34)

Figure IX-34. SASW-34+36 Results (continued)

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ATTACHMENT X

BOREHOLE GEOPHYSICAL SURVEYS

ATTACHMENT X

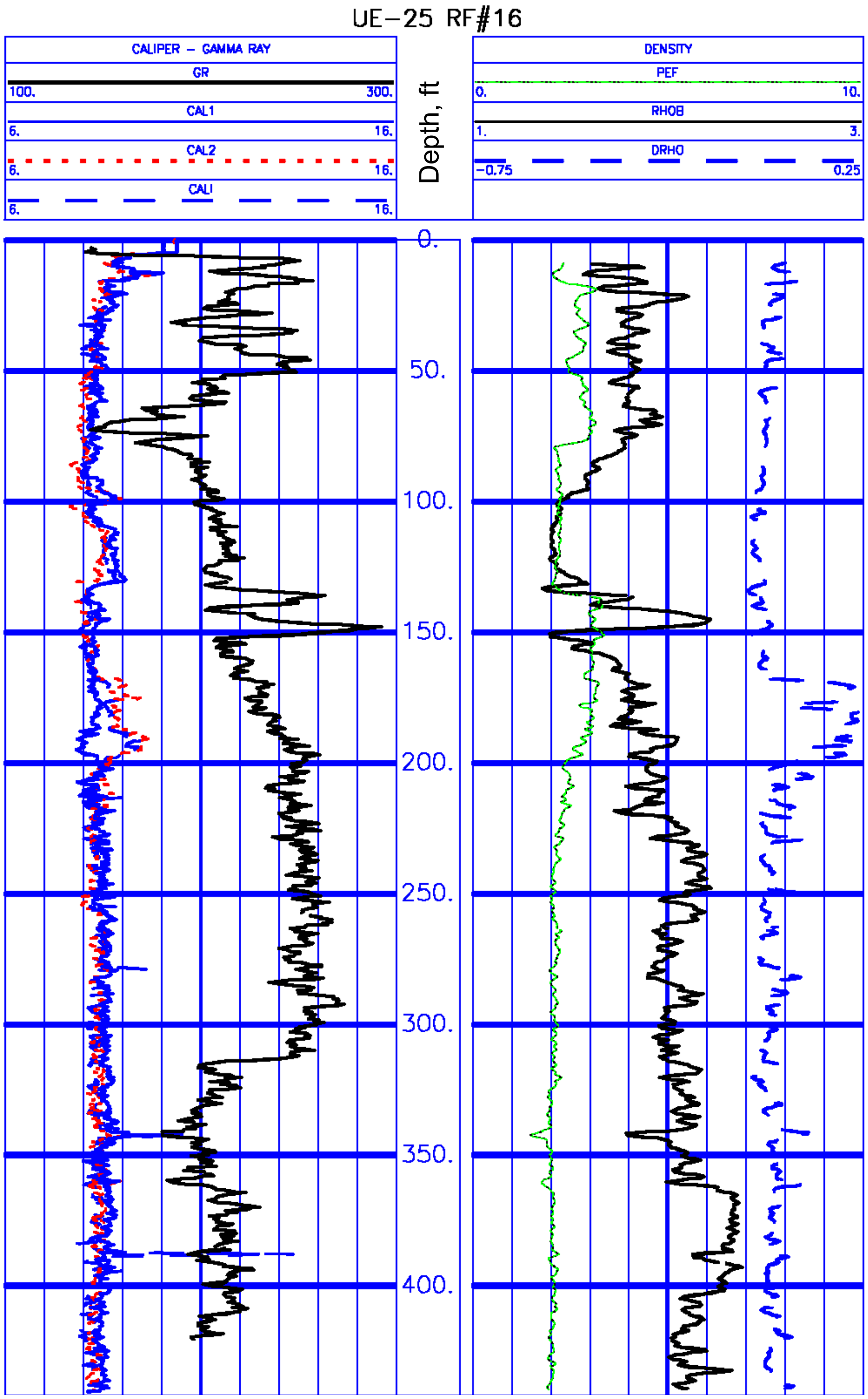
BOREHOLE GEOPHYSICAL SURVEYS

As mentioned in Section 6.2.8, this attachment presents plots of the data from borehole geophysical measurements. The results are presented in the following order: borehole RF#16, RF#18, RF#20, RF#21, RF#22, RF#24 and RF#28.

The parameters shown on the plots are defined as follows:

Name	Description	Definition	Units
CAL1	Caliper 1 from 4-arm caliper tool	Borehole radius along a vertical plane 90° away from CAL2	inches
CAL2	Caliper 1 from 4-arm caliper tool	Borehole radius along a vertical plane 90° away from CAL1	inches
CAL	Caliper from density tool	Borehole radius along a vertical plane coincident with the density source-detectors	inches
Depth	Measured depth	Depth into the borehole	feet
DRHO	Bulk density correction	The amount of density correction computed from the long-spaced and short-spaced detectors. This value is included in the RHOB data	gm/cm^3
RHOB	Bulk density	The mass per unit volume of a formation	gm/cm^3
GR	Gamma ray intensity	Passive measurement of gamma rays emitted by K40 and the radioactive elements of uranium and potassium. The response, measured at the tool is given by: $GR = \frac{\Sigma \rho_i V_i A_i}{\rho_b}$ where: ρ_i = the densities of the radioactive minerals; V_i = the bulk volume factors of the minerals; A_i = proportionality factors corresponding to the radioactivity of the mineral.; ρ_b = bulk density	G_{API} (see note)
PEF	Photoelectric capture cross section	Photoelectric cross section (PEF); related to Z by the following relationship: $PEF = \frac{Z^{3.6}}{10}$ where: Z is the atomic number	--

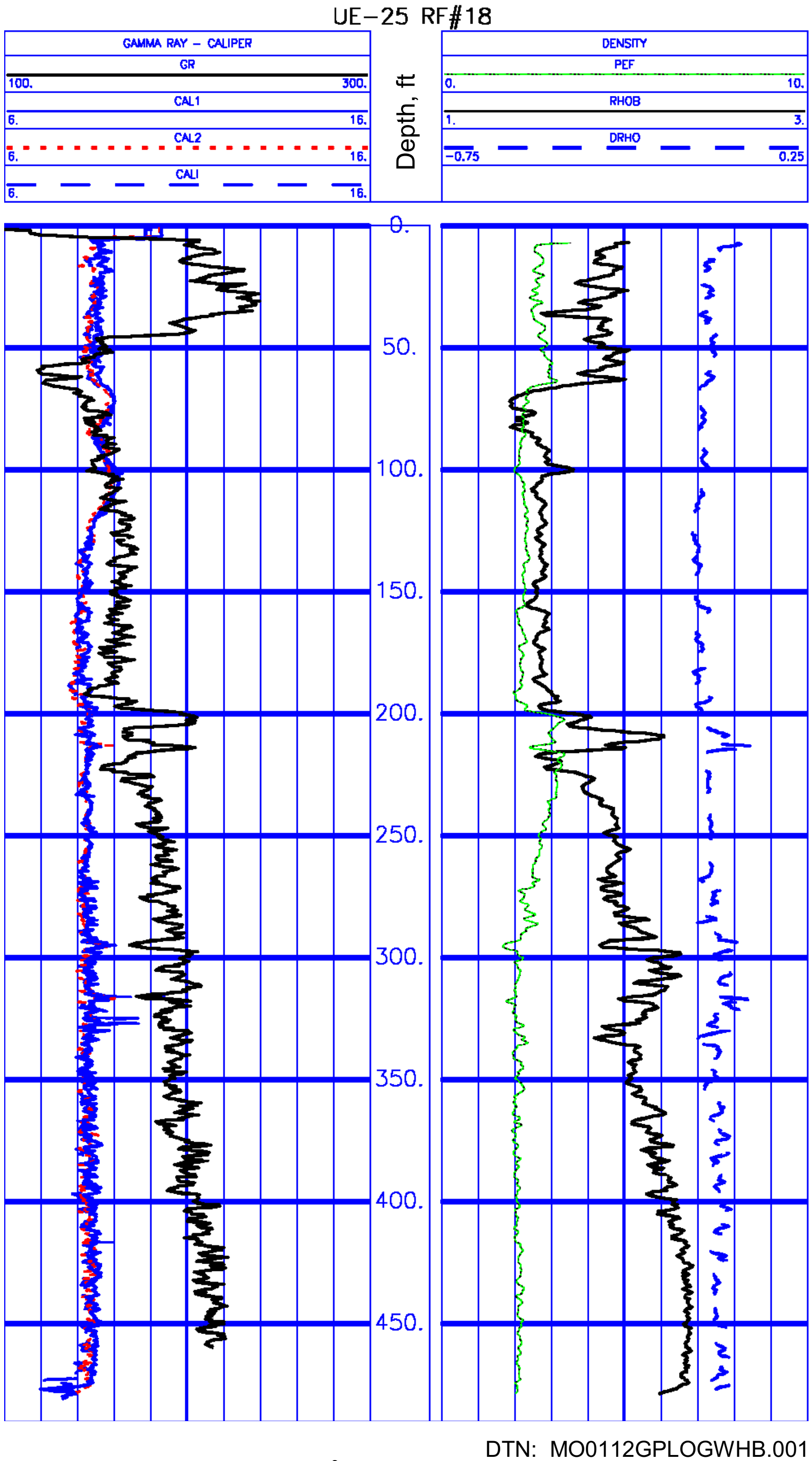
Note: The G_{API} units are based on an American Petroleum Institute calibration standard. Gamma ray (GR) count rates frequently vary significantly between detectors, even those of the same design. For this reason, GR detectors are calibrated in normalized count rate units. GR logs run in low radioactivity environments are often calibrated in API units. GR API calibration units are based on GR logging tool response to the API Calibration Pits maintained by the University of Houston (Schlumberger Educational Services 1987, page 24). Prior to the API calibration procedure, GR logs were scaled in microgram of radium-equivalent per ton of formation (μg Ra-eq/ton).



DTN: MO0112GPLOGWHB.001

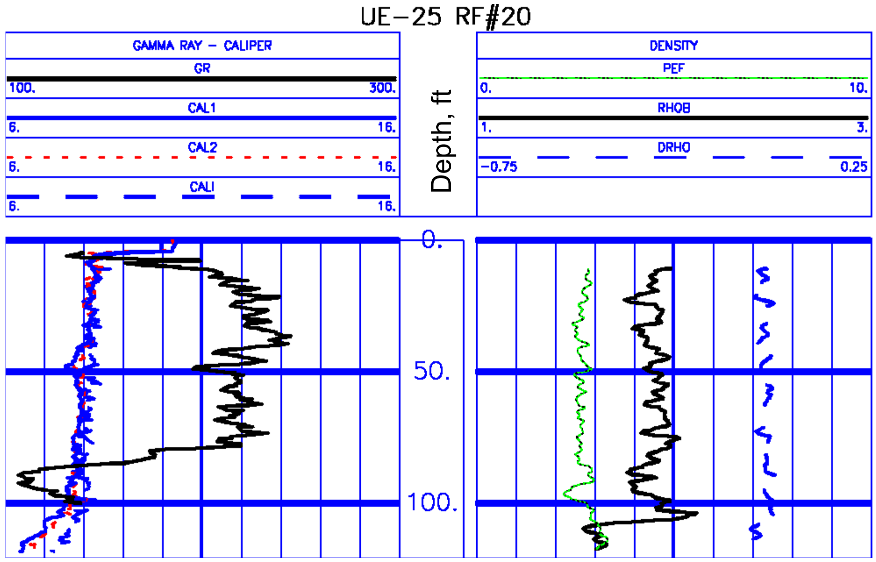
Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-1. Geophysical Log of Borehole RF#16



Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

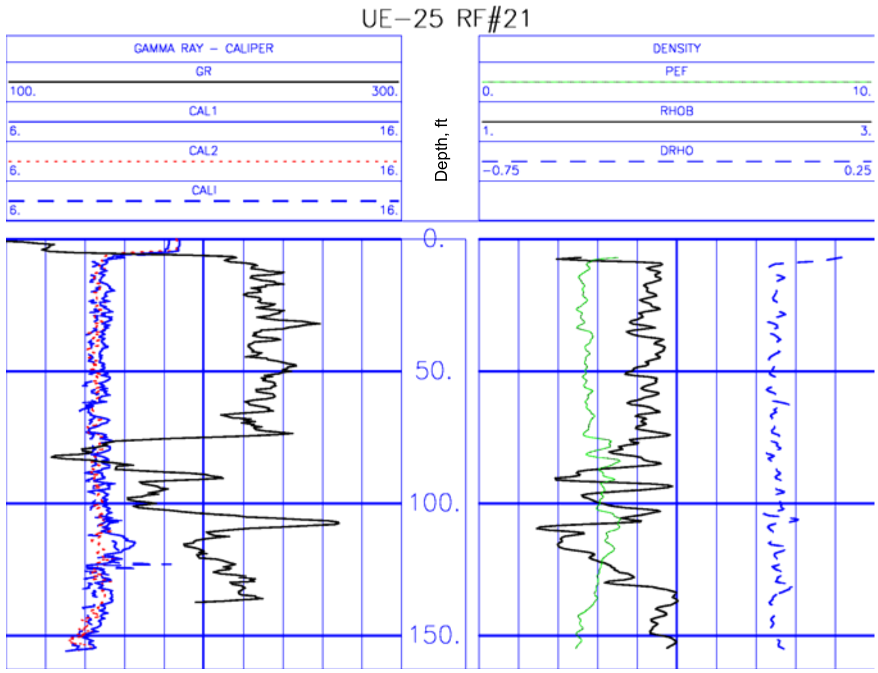
Figure X-2. Geophysical Log of Borehole RF#18



DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

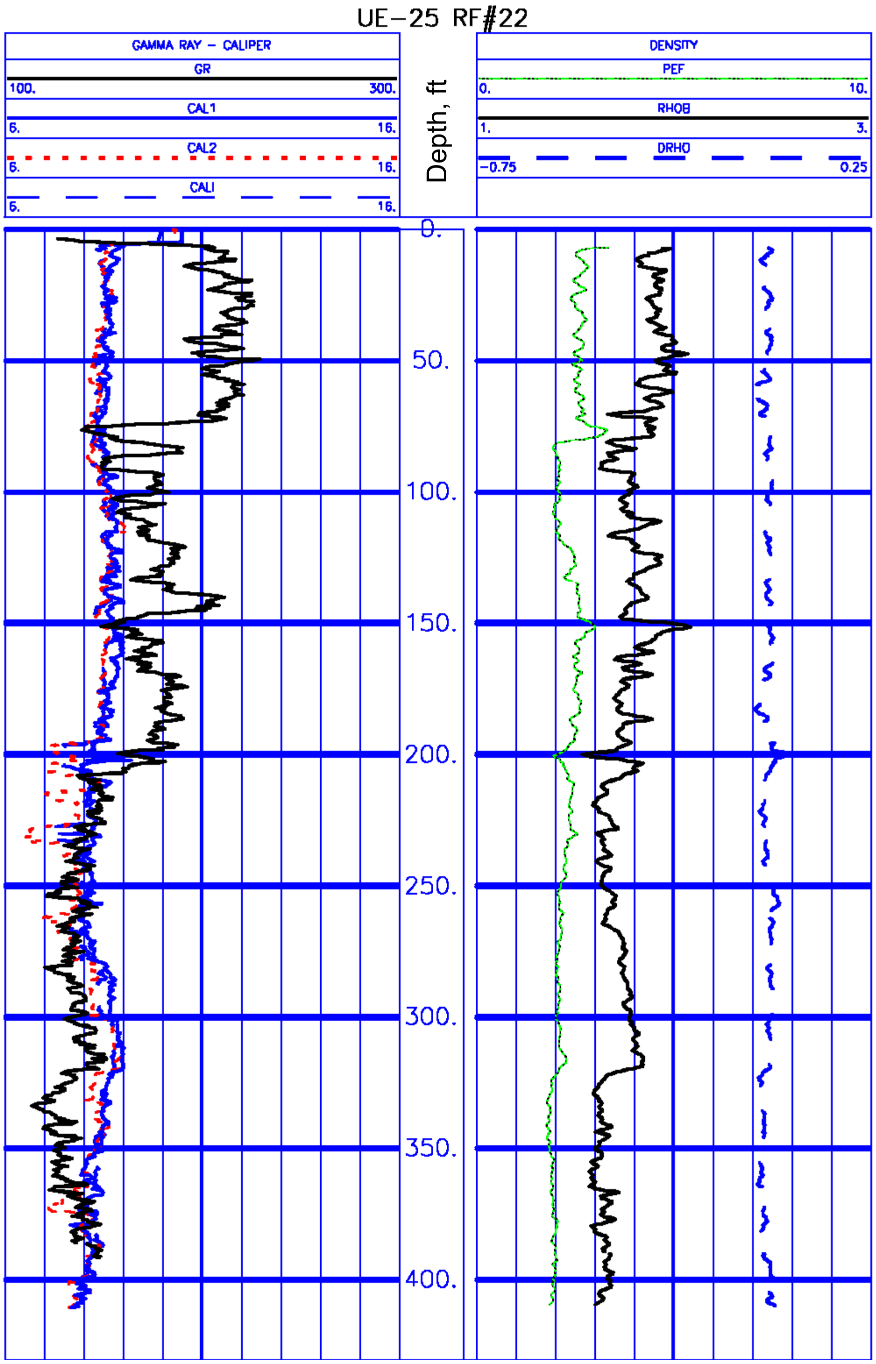
Figure X-3. Geophysical Log of Borehole RF#20



DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

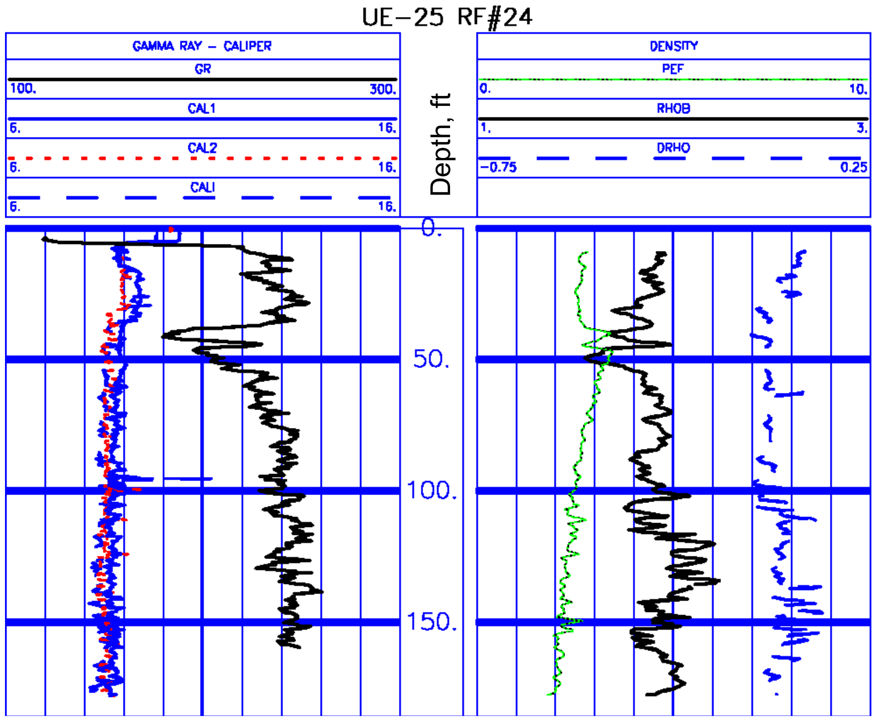
Figure X-4. Geophysical Log of Borehole RF#21



DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

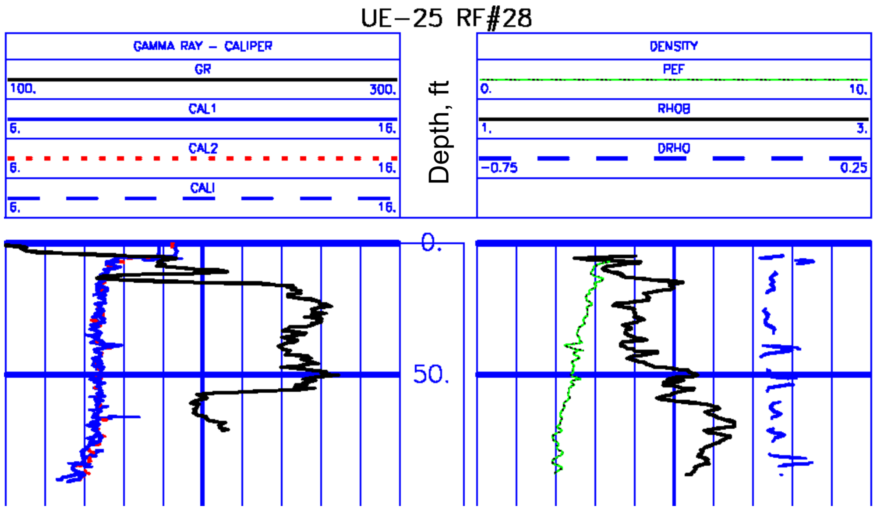
Figure X-5. Geophysical Log of Borehole RF#22



DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-6. Geophysical Log of Borehole RF#24



DTN: MO0112GPLOGWHB.001

Note: DRHO, RHOB are in g/cm^3
CAL1, CAL2 and CAL are in inches
GR is in G_{API}.

Figure X-7. Geophysical Log of Borehole RF#2

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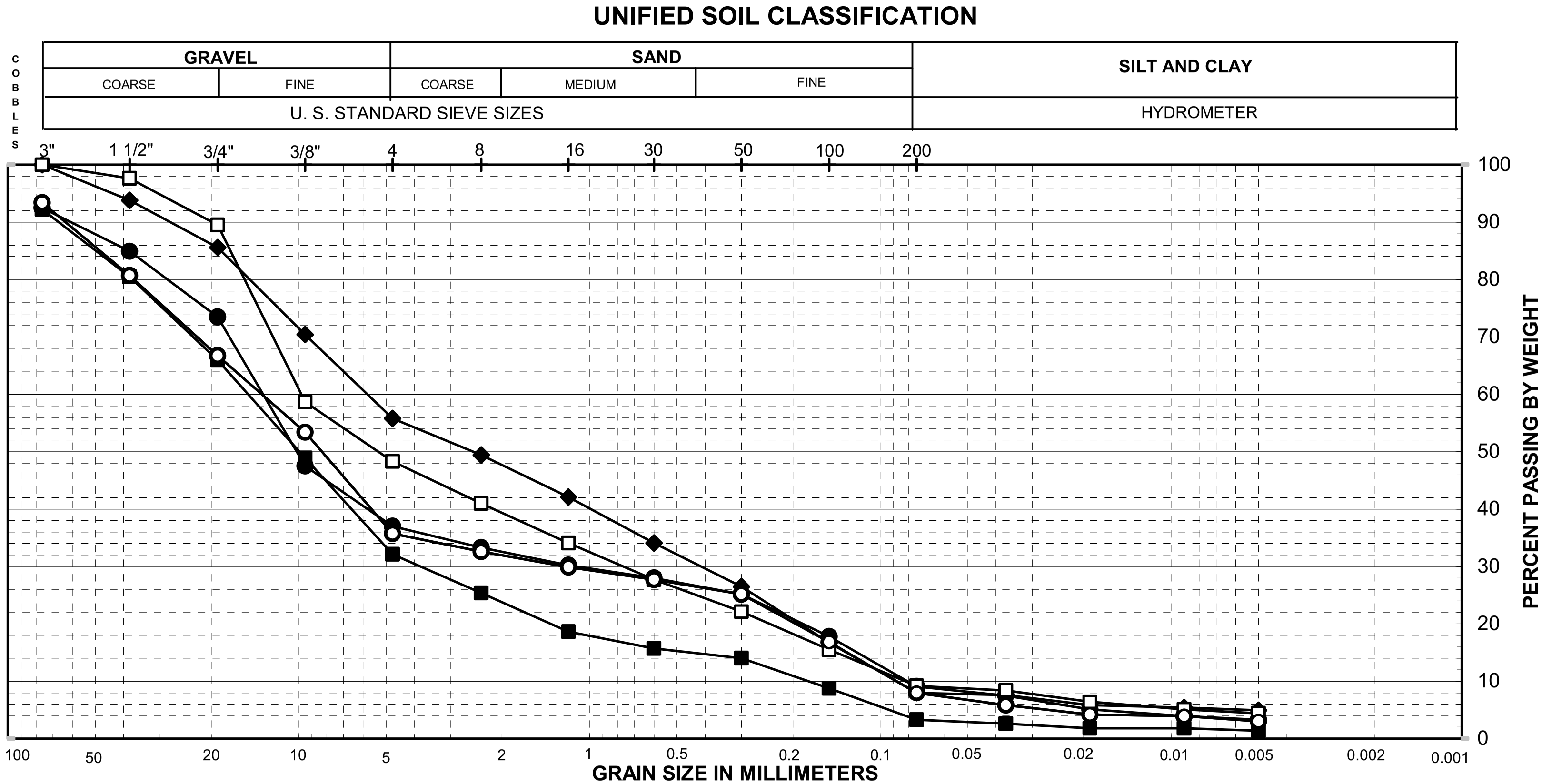
ATTACHMENT XI

GEOTECHNICAL LABORATORY STATIC TESTING – WHB AREA

ATTACHMENT XI

GEOTECHNICAL LABORATORY STATIC TESTING – WHB AREA

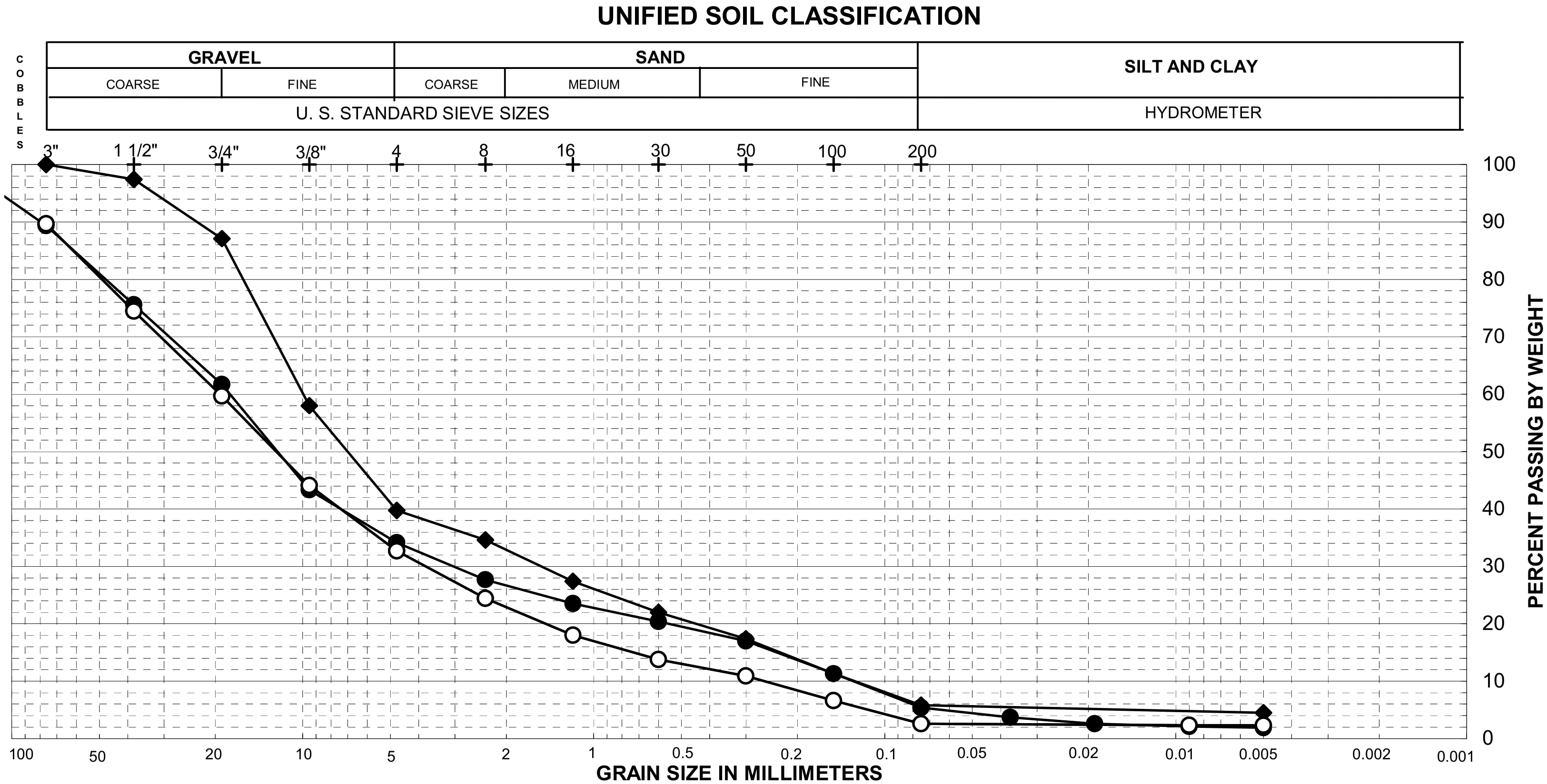
The geotechnical laboratory in Denver, Colorado, performed tests on the alluvium removed from in-place density test excavations performed in test pits TP-WHB-1 through -4. Most of the results are presented in Section 6.2.9 of the main text. This attachment presents plots of the particle-size distribution tests.



Exploration No.	Depth (ft)	SYMBOL	$W_{\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-1	4.0	○	7.9	NP	NP	3.0	Well-graded Gravel with silt and sand (GW-GM)	13	1.21	0.09	144.7	1.2
TP-WHB-1	12.0	●	7.5	NP	NP	3.3	Well-graded Gravel with silt and sand (GW-GM)	13.3	1.12	0.08	166.3	1.2
TP-WHB-1	12.0	□	4.4	NP	NP	4.4	Poorly graded Gravel with silt and sand (GP-GM)	9.88	0.77	0.09	109.8	0.7
TP-WHB-1	12.3	◆	5.6	NP	NP	4.9	Poorly graded Sand with silt and gravel (SP-SM)	6.04	0.41	0.09	67.1	0.3
TP-WHB-1	20.0	■	4.8	NP	NP	1.4	Poorly graded Gravel with sand (GP)	14.8	4.09	0.17	87.1	6.6

DTN: GS020483114233.004

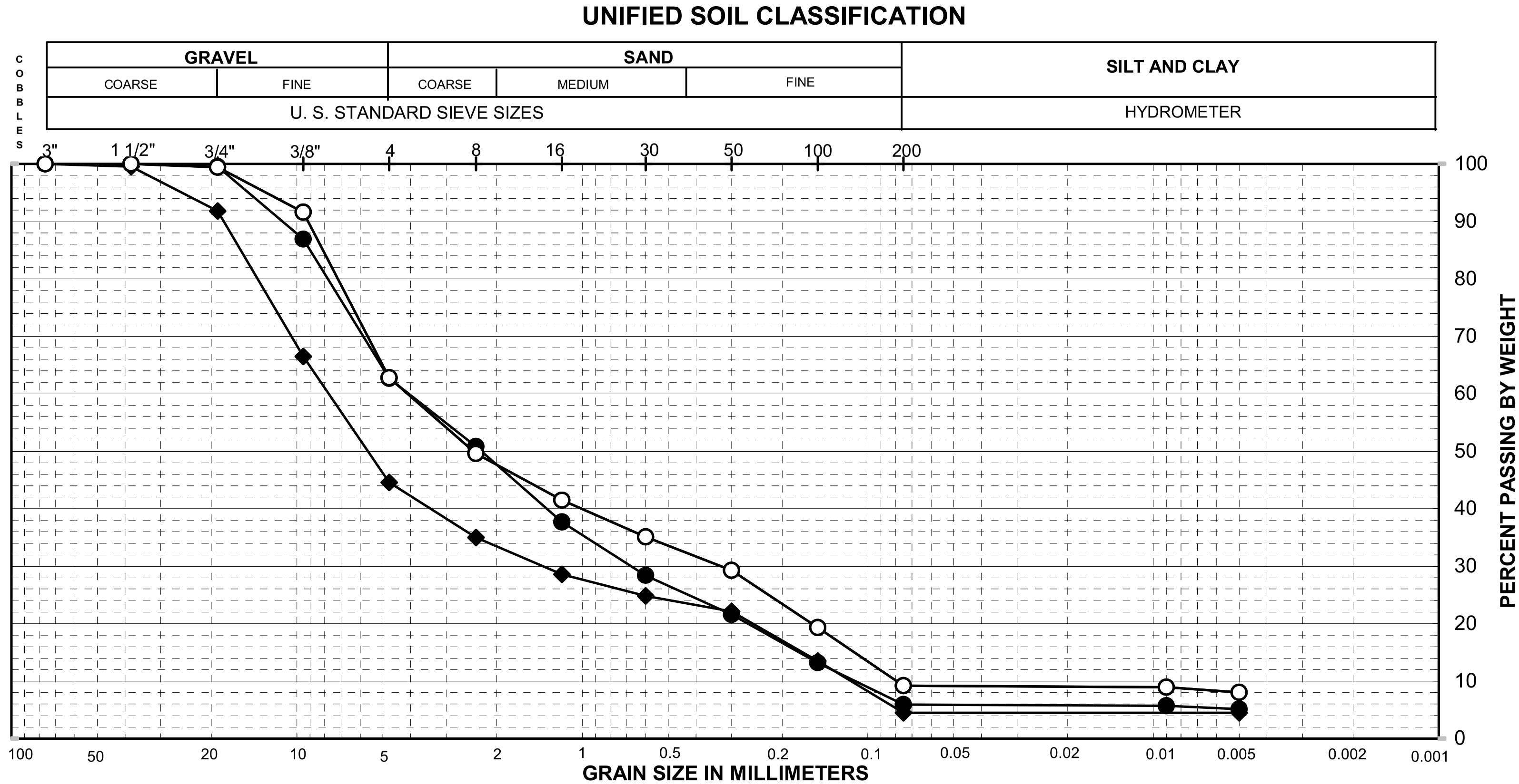
Figure XI-1. Particle-Size Distribution for Samples from Test Pit TP-WHB-1



Exploration No.	Depth (ft)	SYMBOL	$W_{-\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-2	8.0	○	10.6	NP	NP	2.3	Poorly graded Gravel with sand (GP)					
TP-WHB-2	12.0	●	5.8	NP	NP	1.9	Poorly graded Gravel with silt and sand (GP-GM)	17.8	3.09	0.13	137	4.1
TP-WHB-2	16.0	◆	8.7	NP	NP	4.5	Well-graded Gravel with silt and sand (GW-GM)	10	1.49	0.13	76.9	1.7

DTN: GS020483114233.004

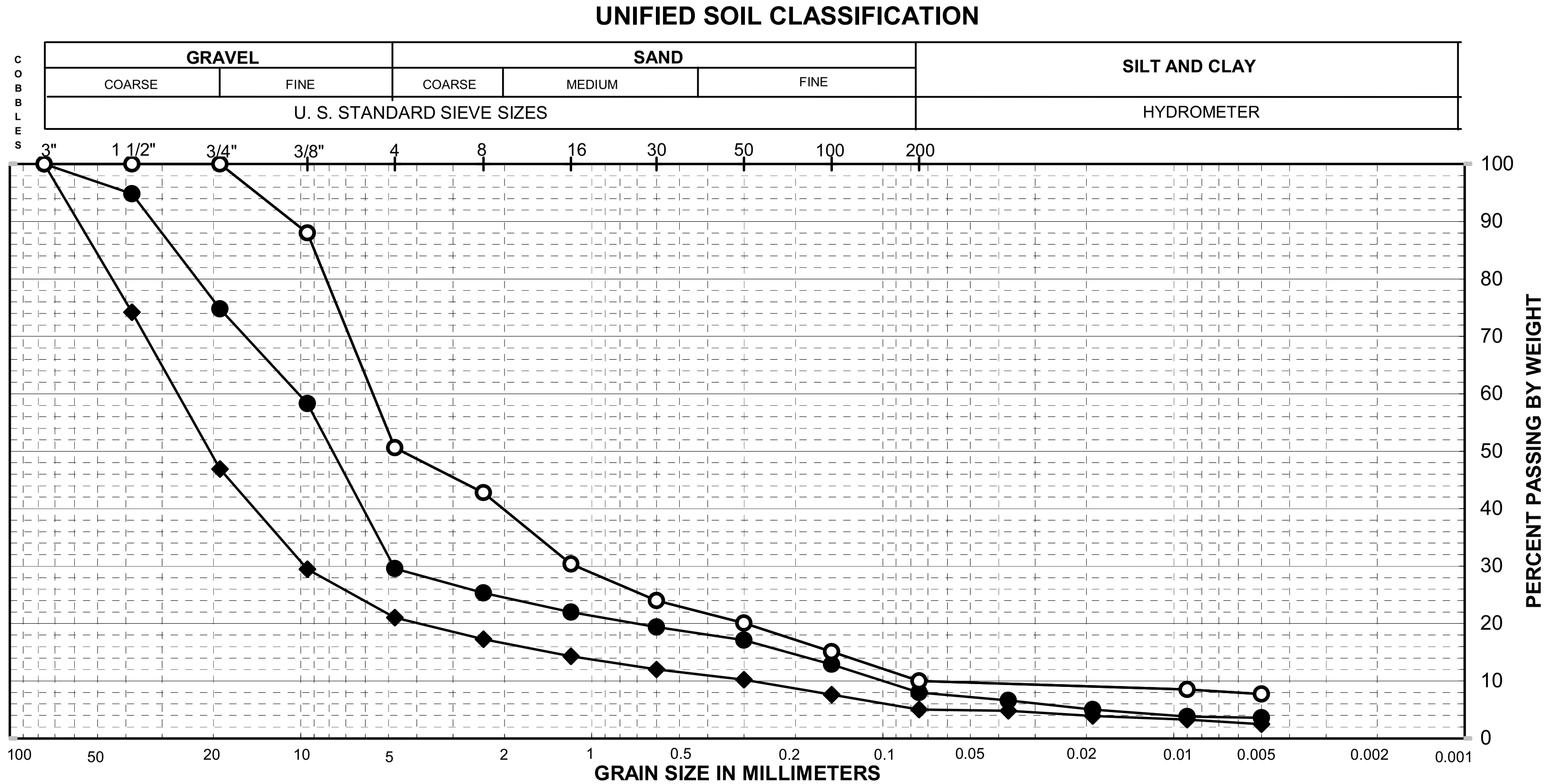
Figure XI-2. Particle-Size Distribution for Samples from Test Pit TP-WHB-2



Exploration No.	Depth (ft)	SYMBOL	$W_{-\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-2	16.0	○	7.4	NP	NP	8.0	Well-graded Sand with silt and gravel (SW-SM)	4.35	0.32	0.02	218	1.2
TP-WHB-2	16.0	●	5.3	NP	NP	5.1	Poorly graded Sand with silt and gravel (SP-SM)	4.25	0.69	0.12	35.4	0.9
TP-WHB-2	19.0	◆	9.6	NP	NP	4.5	Well-graded Gravel with sand (GW)	8.02	1.4	0.12	66.8	2.0

DTN: GS020483114233.004

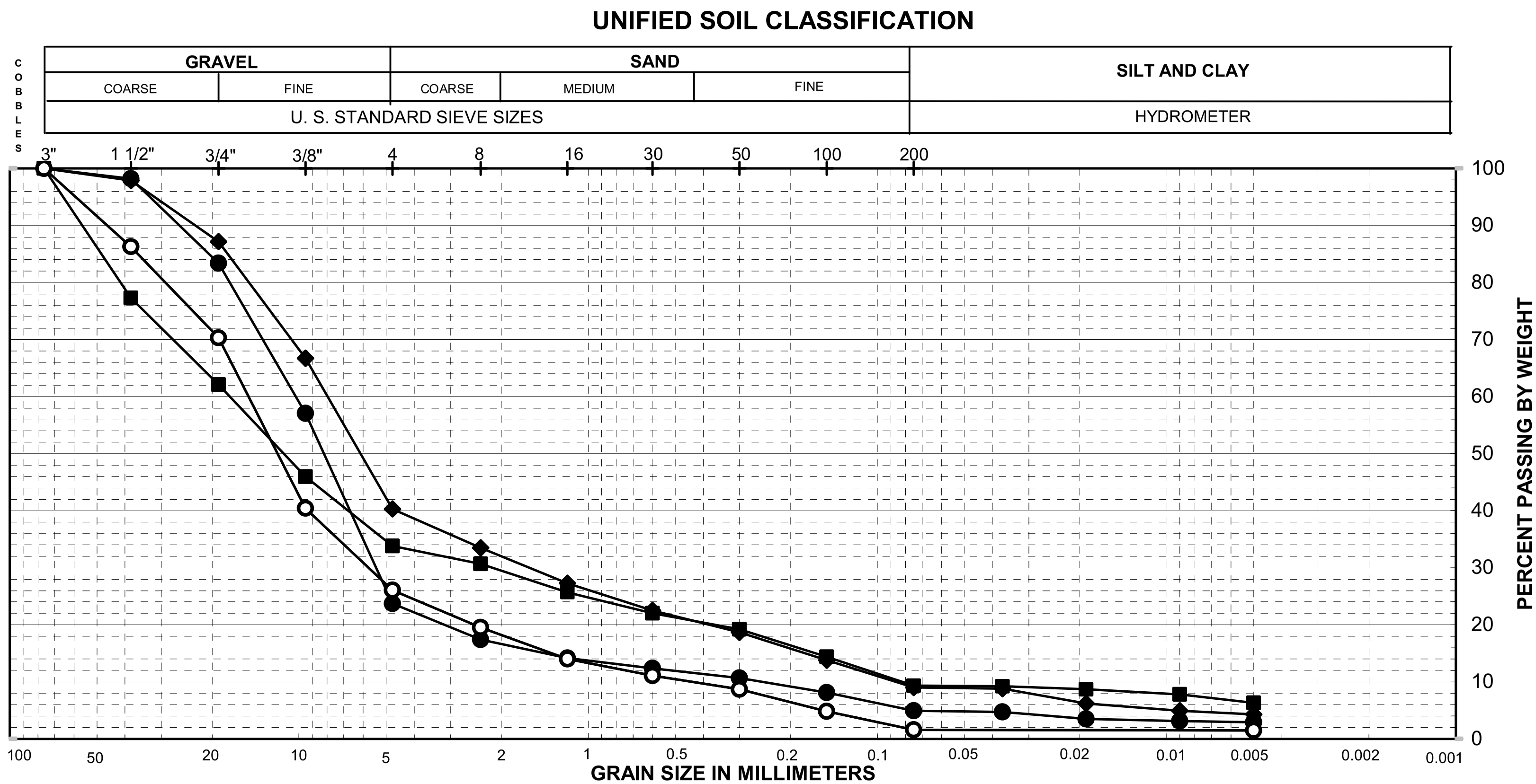
Figure XI-3. Particle-Size Distribution for Samples from Test Pit TP-WHB-2



Exploration No.	Depth (ft)	SYMBOL	$W_{-\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-3	8.0	○	3.5	NP	NP	7.7	Poorly graded Gravel with silt and sand (GP-GM)	5.81	1.15	0.02	290.5	11.4
TP-WHB-3	8.0	●	4.4	NP	NP	3.6	Poorly graded Gravel with silt and sand (GP-GM)	10	4.82	0.10	100.1	23.2
TP-WHB-3	8.0	◆	5.1	NP	NP	2.5	Poorly graded Gravel with silt and sand (GP-GM)	26.9	9.8	0.28	96.1	12.8

DTN: GS020483114233.004

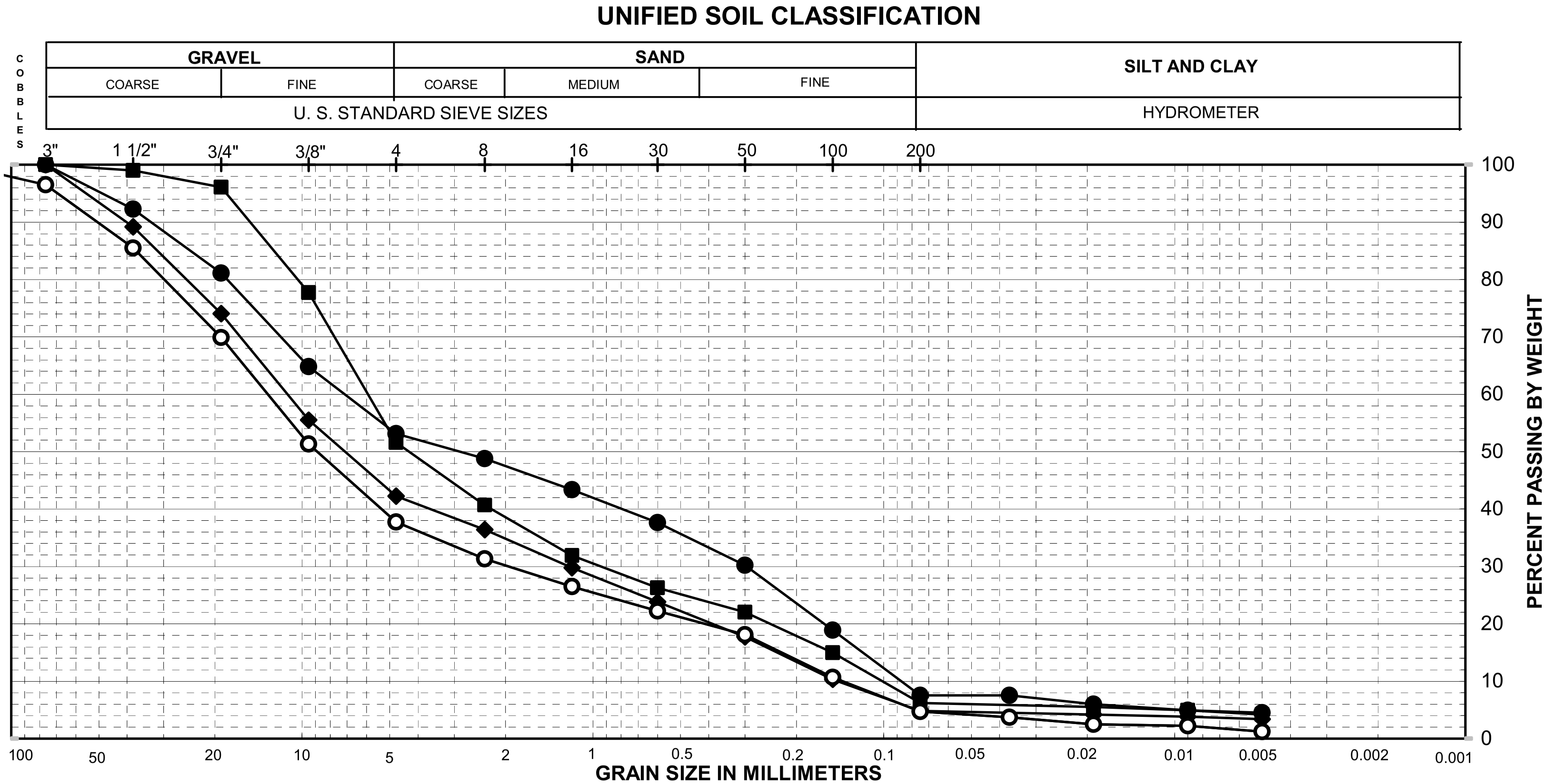
Figure XI-4. Particle-Size Distribution for Samples from Test Pit TP-WHB-3



Exploration No.	Depth (ft)	SYMBOL	$W_{-\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-3	12.0	○	8.9	NP	NP	1.5	Poorly graded Gravel with sand (GP)	14.9	6.32	0.42	35.5	6.4
TP-WHB-3	12.0	●	6.9	NP	NP	2.9	Poorly graded Gravel with sand (GP)	10.1	5.63	0.24	42.1	13.1
TP-WHB-3	12.0	◆	4.1	NP	NP	4.3	Poorly graded Gravel with silt and sand (GP-GM)	8.09	1.55	0.09	89.9	3.3
TP-WHB-3	19.0	■	16.0	NP	NP	6.3	Well-graded Gravel with silt and sand (GW-GM)	17.3	2.07	0.09	192.4	2.7

DTN: GS020483114233.004

Figure XI-5. Particle-Size Distribution for Samples from Test Pit TP-WHB-3



Exploration No.	Depth (ft)	SYMBOL	$W_{-\#4}$ (%)	LL	PI	%<5 μm	Description and Classification	D_{60}	D_{30}	D_{10}	Cu	Cc
TP-WHB-4	4.0	○	6.7	NP	NP	1.2	Well-graded Gravel with sand (GW)	13.9	2.09	0.14	99.1	2.2
TP-WHB-4	8.0	●	6.9	NP	NP	4.5	Poorly graded Gravel with silt and sand (GP-GM)	7.56	0.3	0.09	84.0	0.1
TP-WHB-4	12.0	◆	8.0	NP	NP	3.4	Poorly graded Gravel with sand (GP)	11.3	1.2	0.15	75.5	0.8
TP-WHB-4	16.0	■	8.0	NP	NP	4.2	Well-graded Gravel with silt and sand (GW-GM)	6.11	0.98	0.11	55.5	1.4

DTN: GS020483114233.004

Figure XI-6. Particle-Size Distribution for Samples from Test Pit TP-WHB-4

ATTACHMENT XII

GEOTECHNICAL LABORATORY DYNAMIC TESTING – WHB AREA

As discussed in Section 6.2.10, this attachment presents the results of resonant column and torsional shear (RCTS) tests on core samples of alluvium and bedrock taken from boreholes advanced in the WHB Area. Results are presented in plots and tables as follows:

- Figures XII-1 through XII-19, plots of RCTS test results for Specimens UTA-20-A through UTA-20-D, UTA-23-A through UTA-23-J, UTA-23-Q through UTA-23-T, and UTA-23-X, respectively.

- Figures XII-20 through XII-22, plots of variation in normalized small-strain shear modulus with excitation frequency of intact tuff specimens.

- Figures XII-23 through XII-25, plots of variation in normalized small-strain material damping ratio with excitation frequency of intact tuff specimens.

- Figure XII-26, plot of variation in small-strain shear modulus with excitation frequency of reconstituted Quaternary alluvium specimen recovered from borehole UE-25 RF#17.

- Figure XII-27, plot of variation in small-strain material damping ratio with excitation frequency of reconstituted Quaternary alluvium specimen recovered from borehole UE-25 RF#17.

- Figure XII-28, plot of comparison of small-strain shear wave velocity measured with fixed-free and free-free resonant columns.

- Tables XII-1 through XII-19 present results of RCTS tests for Specimens UTA-20-A through UTA-20-D, UTA-23-A through UTA-23-J, UTA-23-Q through UTA-23-T and UTA-23-X. Each table spans two pages. These data are contained in DTN: MO0203DHRSSWHB.001. The first table for each specimen contains effective isotropic confining pressure in psi, psf and kPa units. The data in the above DTN is in psf units only. The data in psi and kPa and low- amplitude shear modulus in MPa are from Scientific Notebook SN-M&O-SCI-033-VI (Wong 2002e, Appendices 6 through 9, 15 through 24, 31 through 34, and 38).

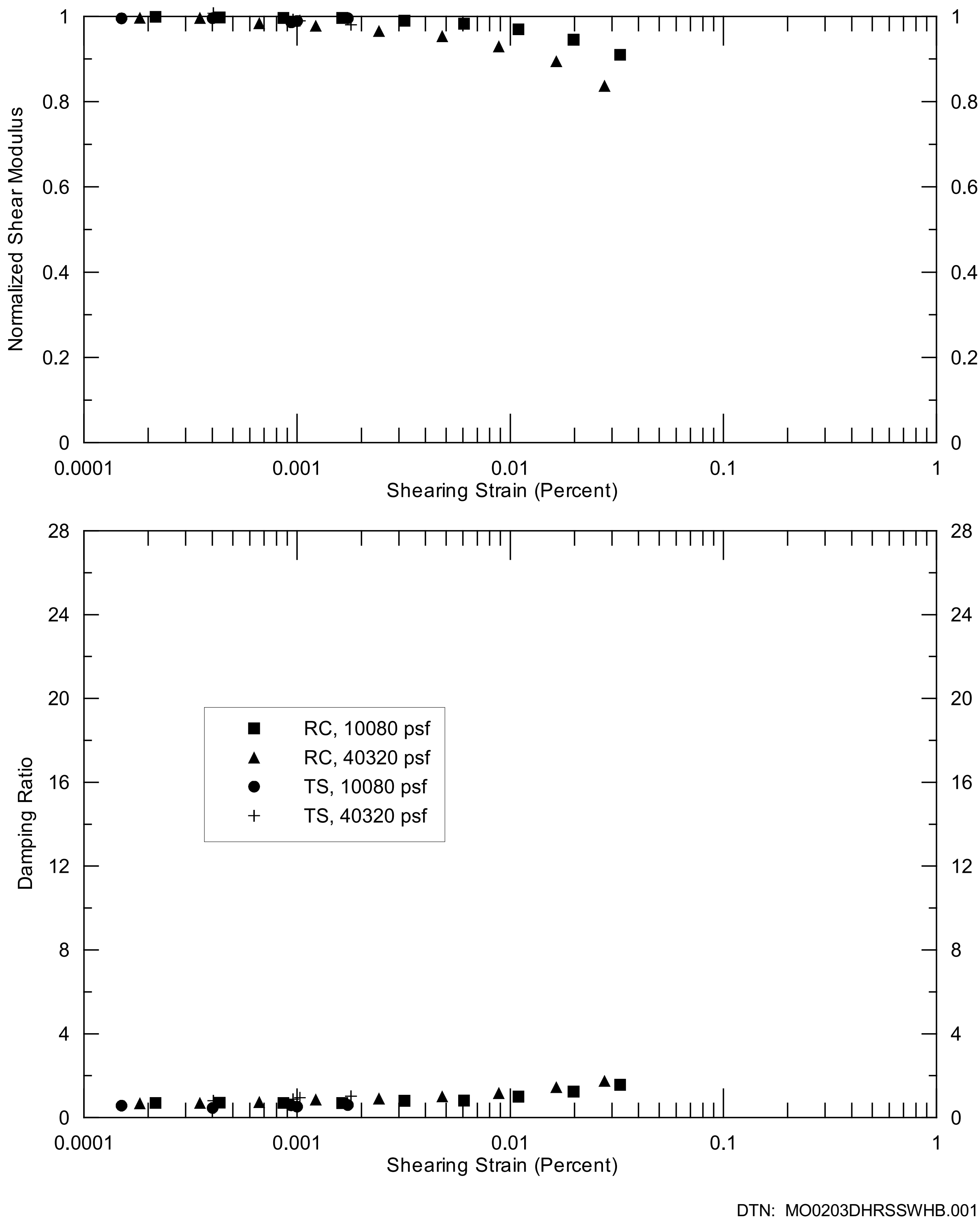
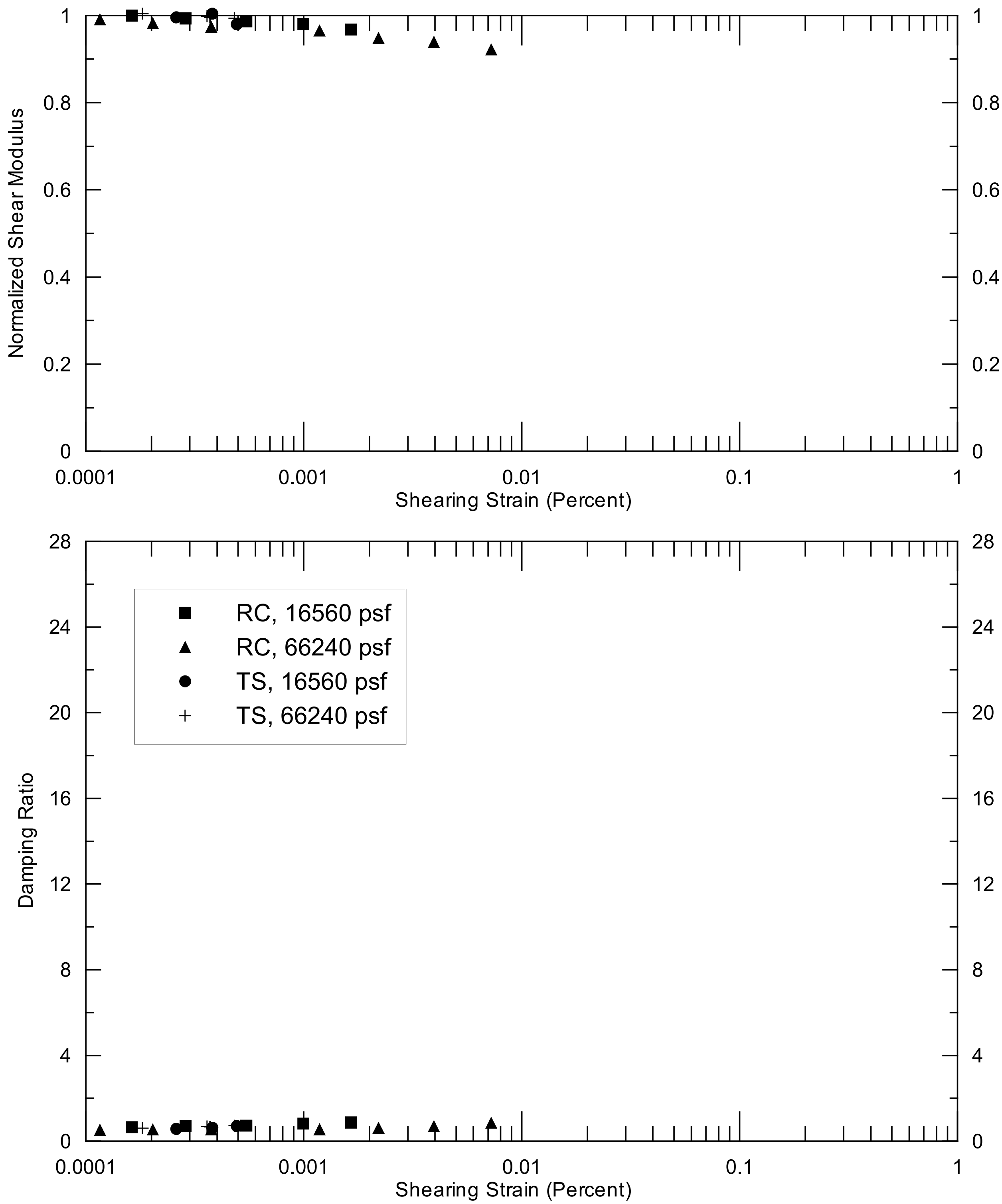
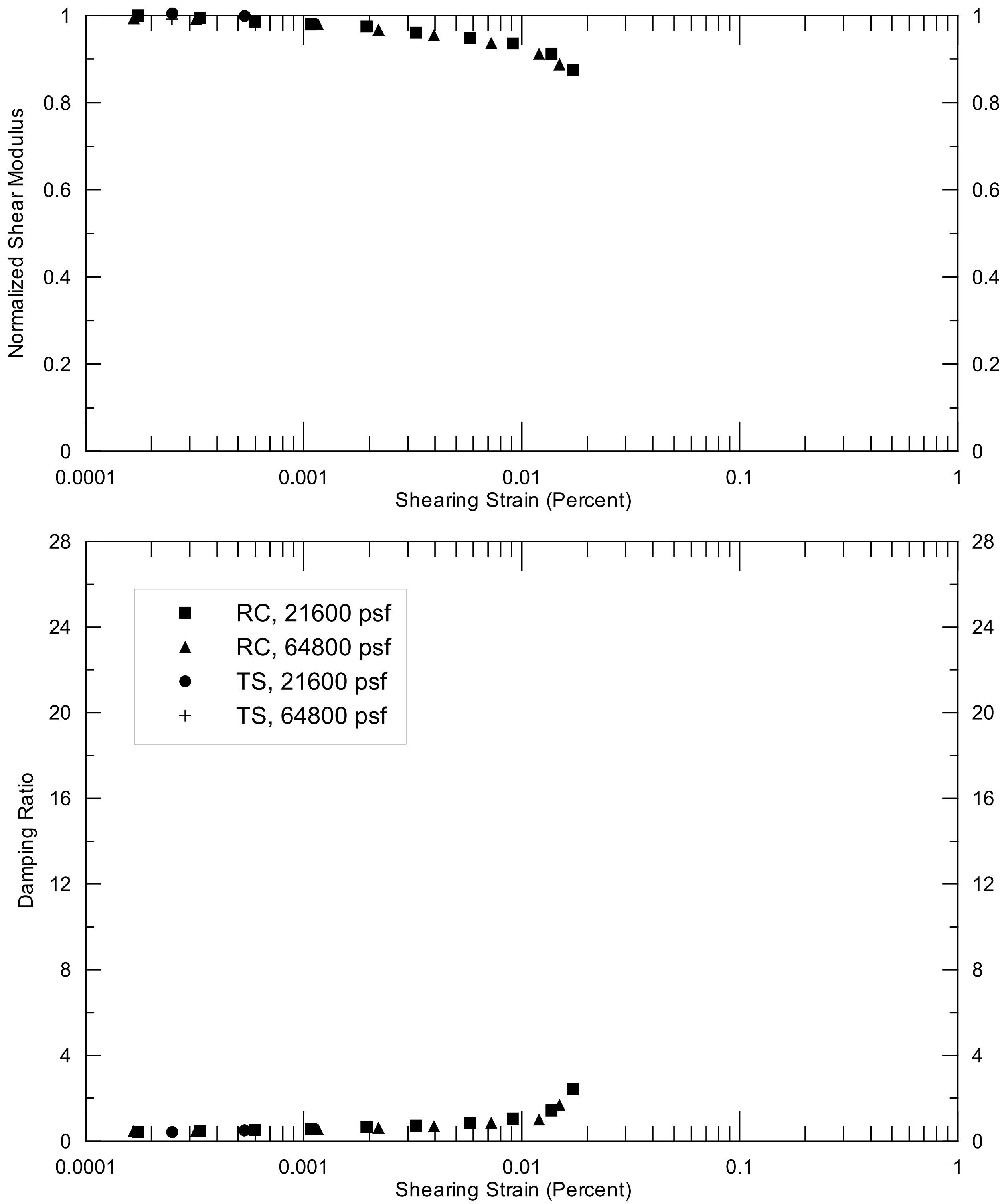


Figure XII-1. Resonant Column and Torsional Shear Results for Specimen UTA-20-A



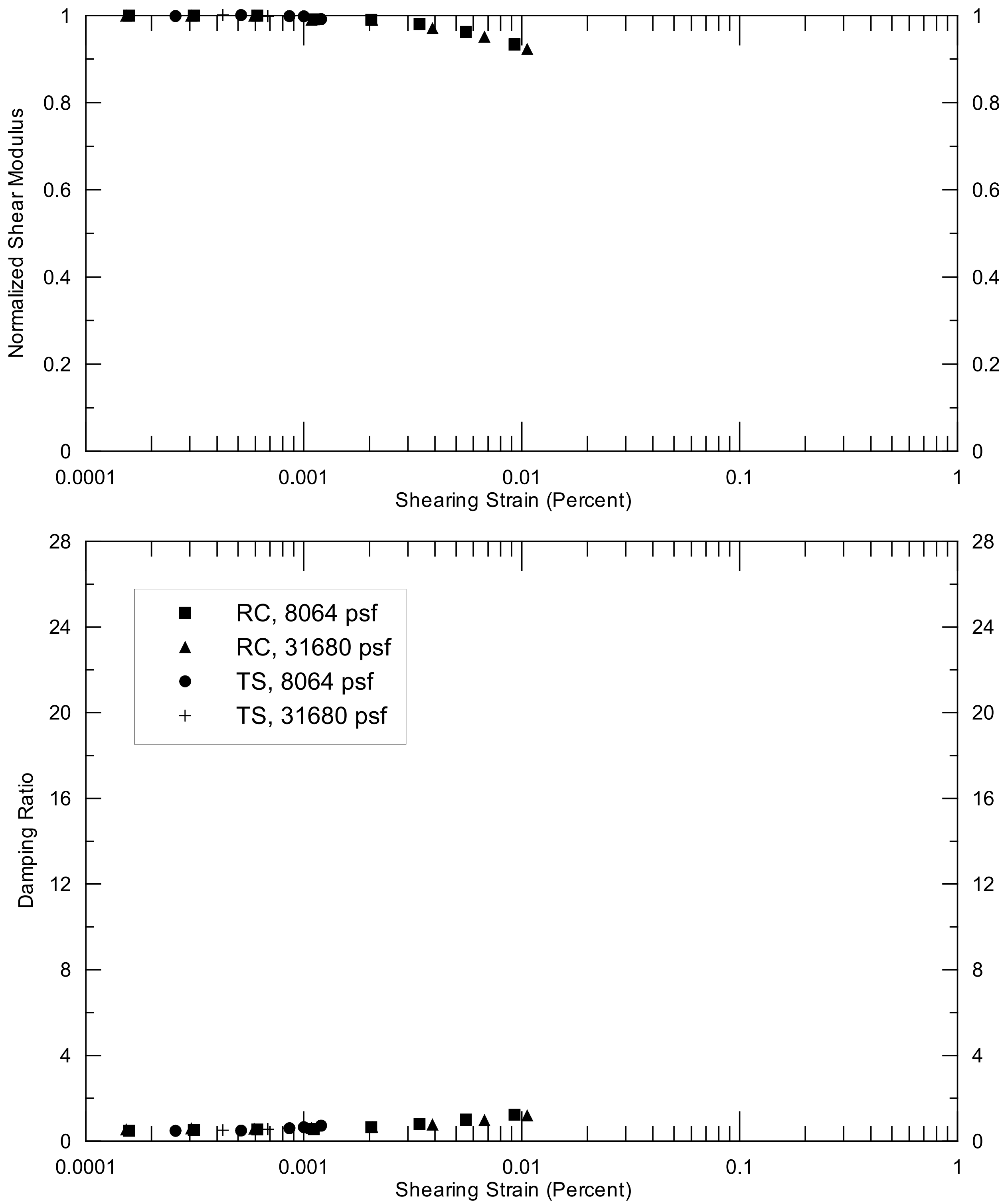
DTN: MO0203DHRSSWHB.001

Figure XII-2. Resonant Column and Torsional Shear Results for Specimen UTA-20-B



DTN: MO0203DHRSSWHB.001

Figure XII-3. Resonant Column and Torsional Shear Results for Specimen UTA-20-C



DTN: MO0203DHRSSWHB.001

Figure XII-4. Resonant Column and Torsional Shear Results for Specimen UTA-20-D

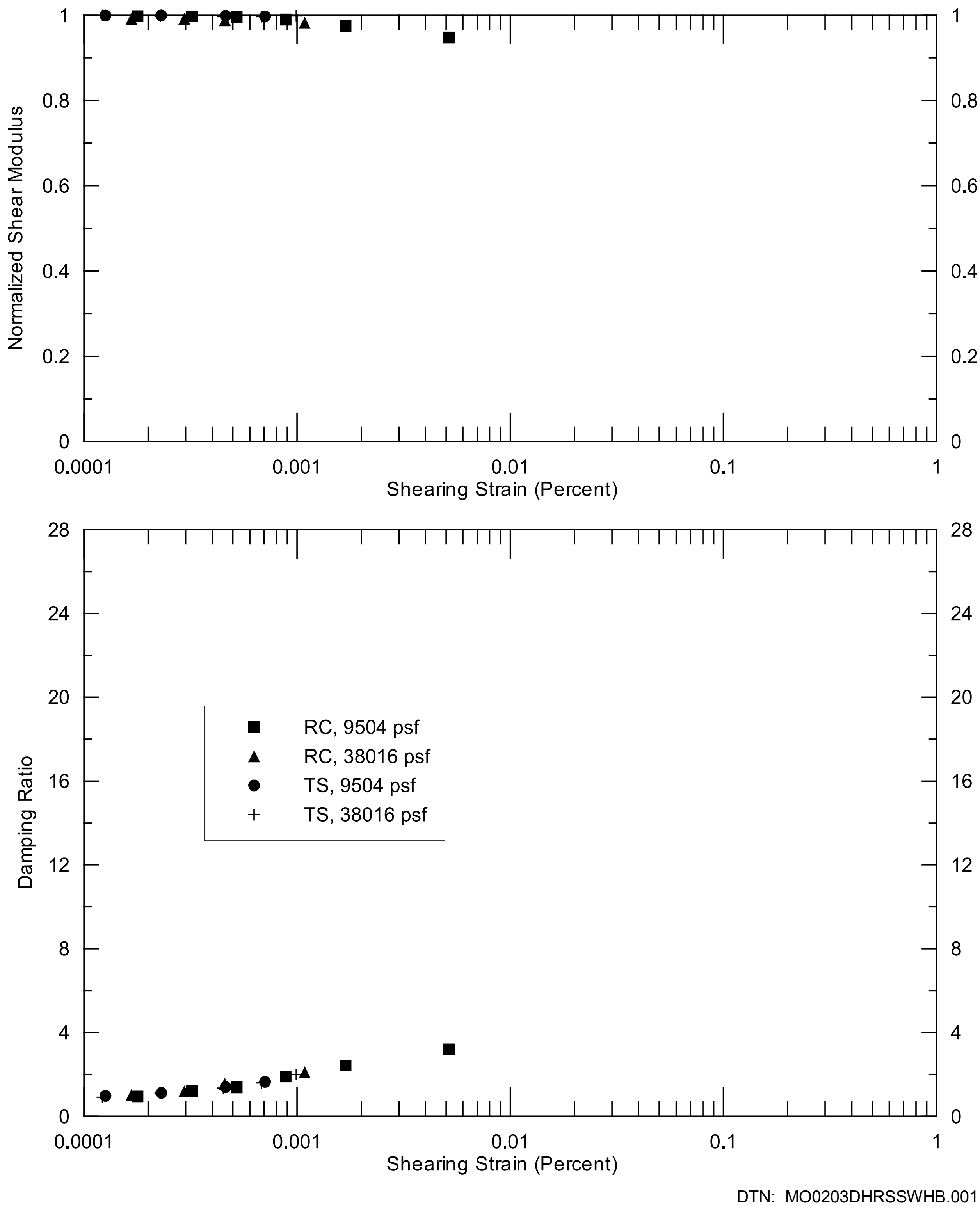
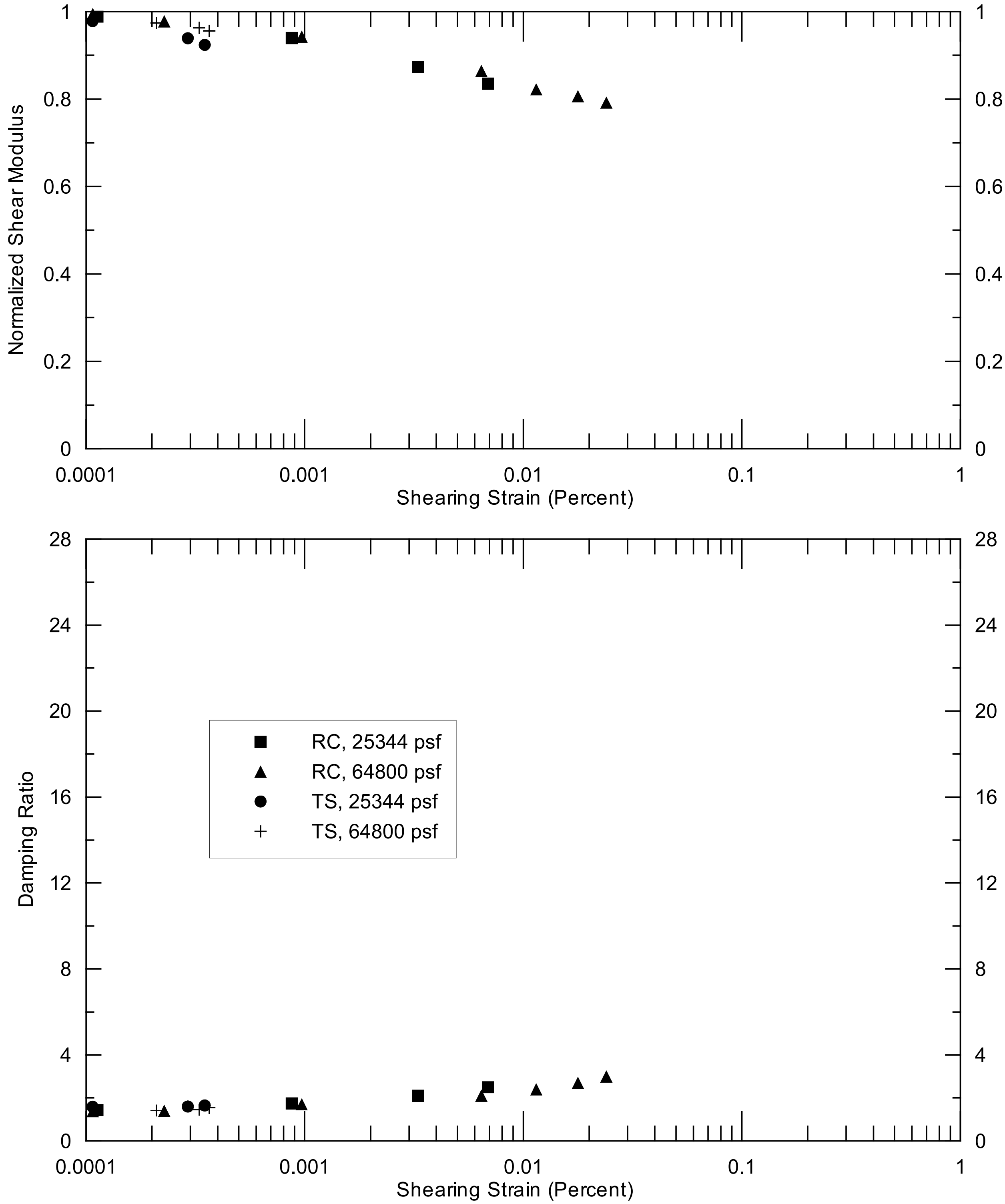
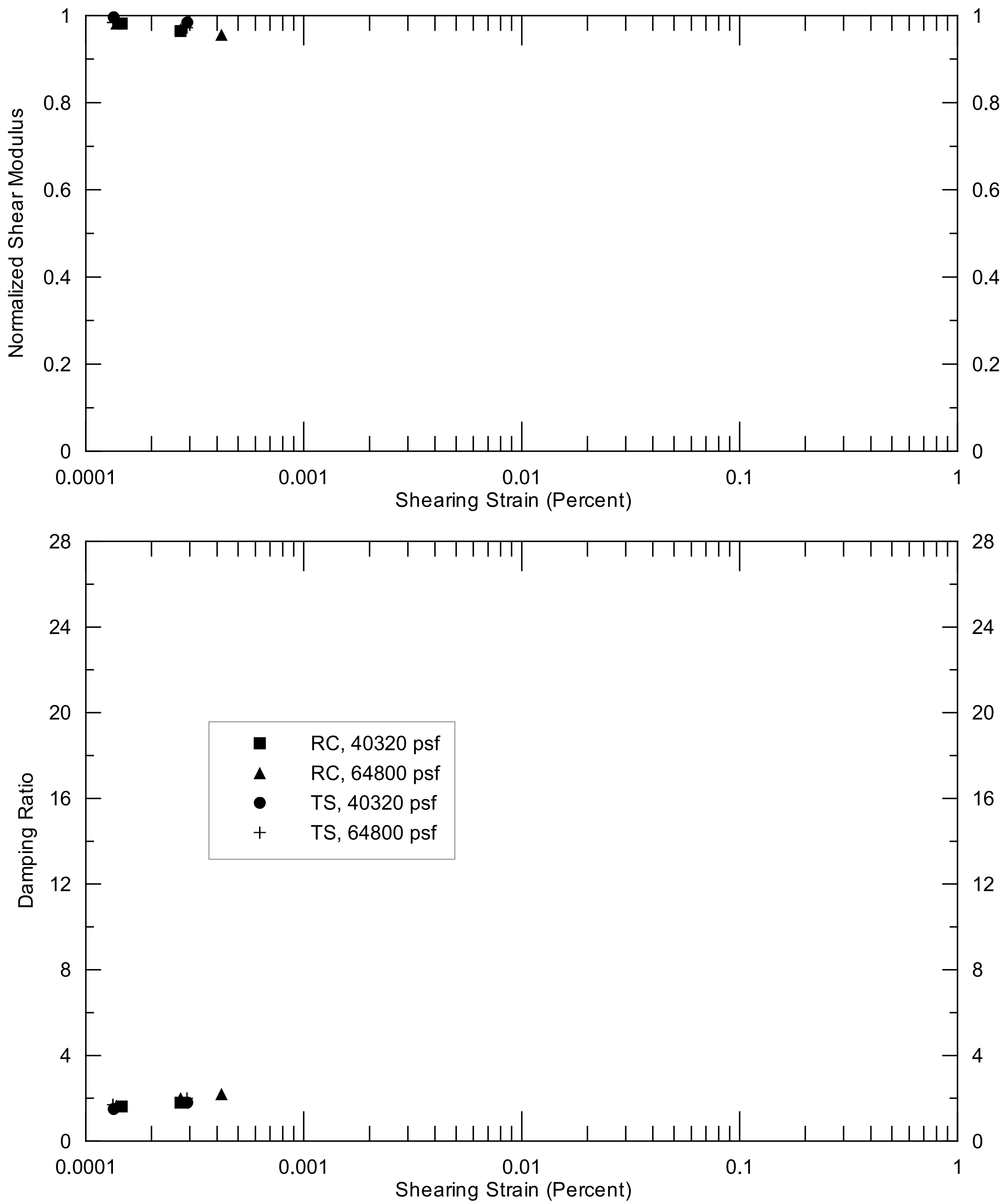


Figure XII-5. Resonant Column and Torsional Shear Results for Specimen UTA-23-A



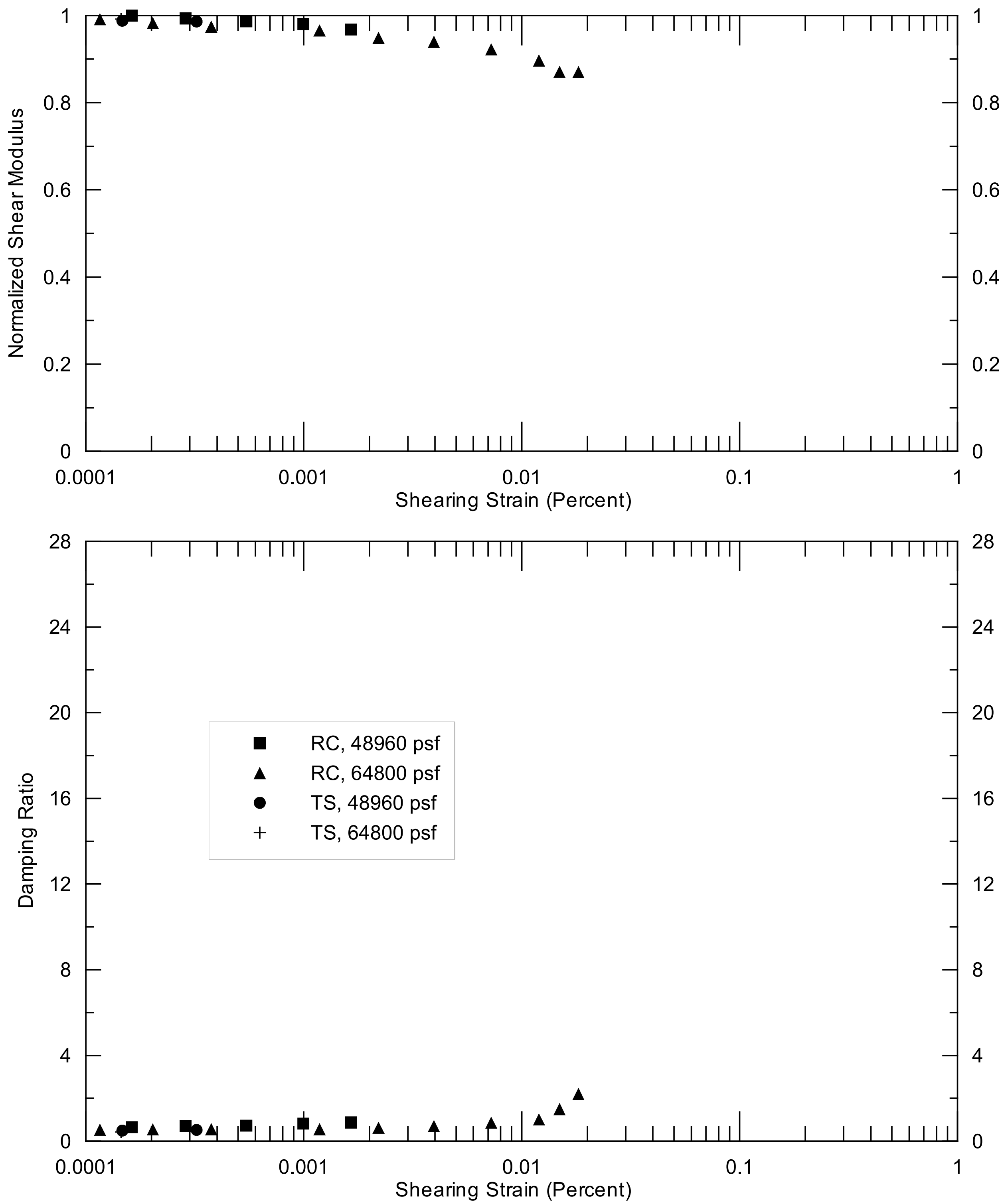
DTN: MO0203DHRSSWHB.001

Figure XII-6. Resonant Column and Torsional Shear Results for Specimen UTA-23-B



DTN: MO0203DHRSSWHB.001

Figure XII-7. Resonant Column and Torsional Shear Results for Specimen UTA-23-C



DTN: MO0203DHRSSWHB.001

Figure XII-8. Resonant Column and Torsional Shear Results for Specimen UTA-23-D

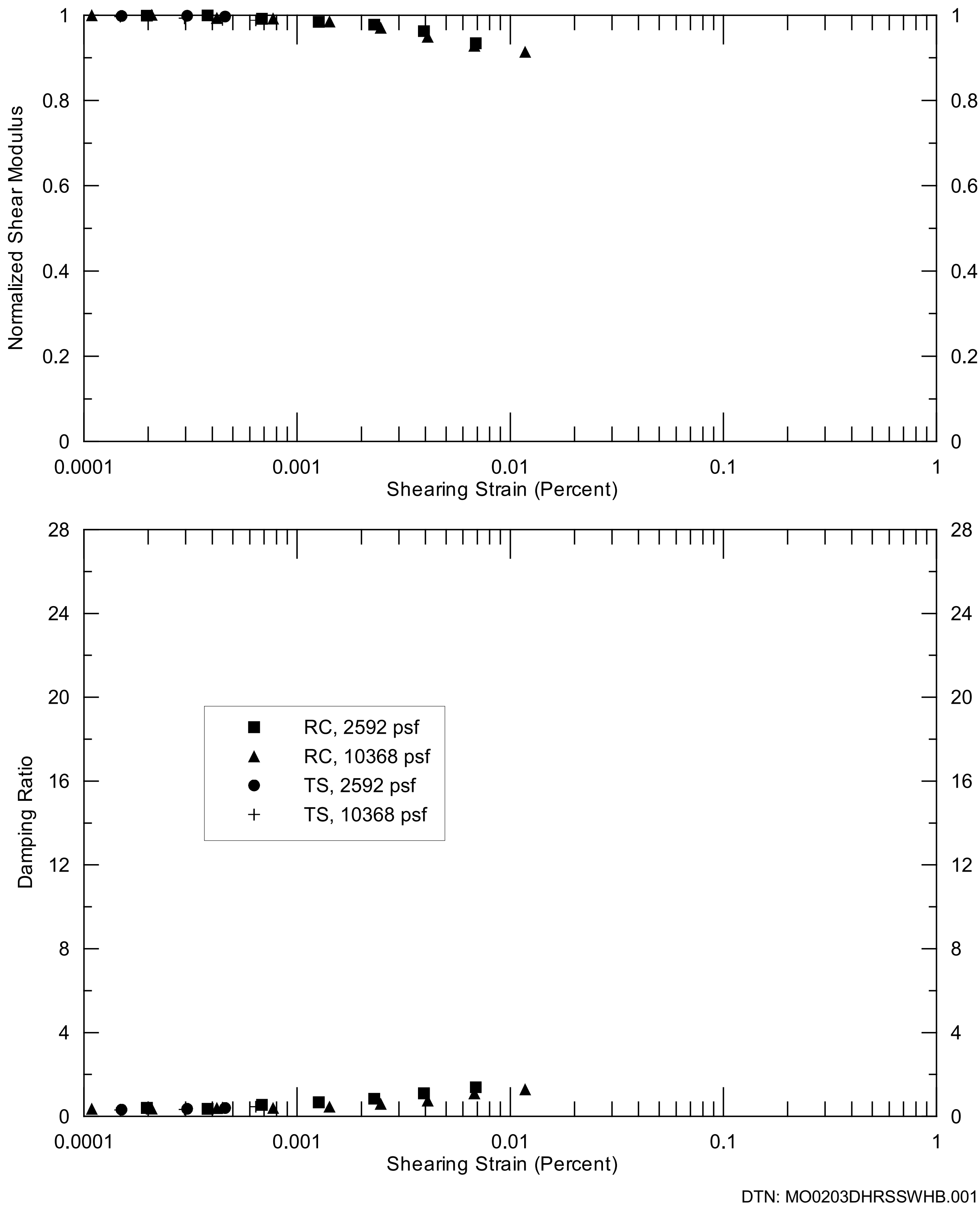


Figure XII-9. Resonant Column and Torsional Shear Results for Specimen UTA-23-E

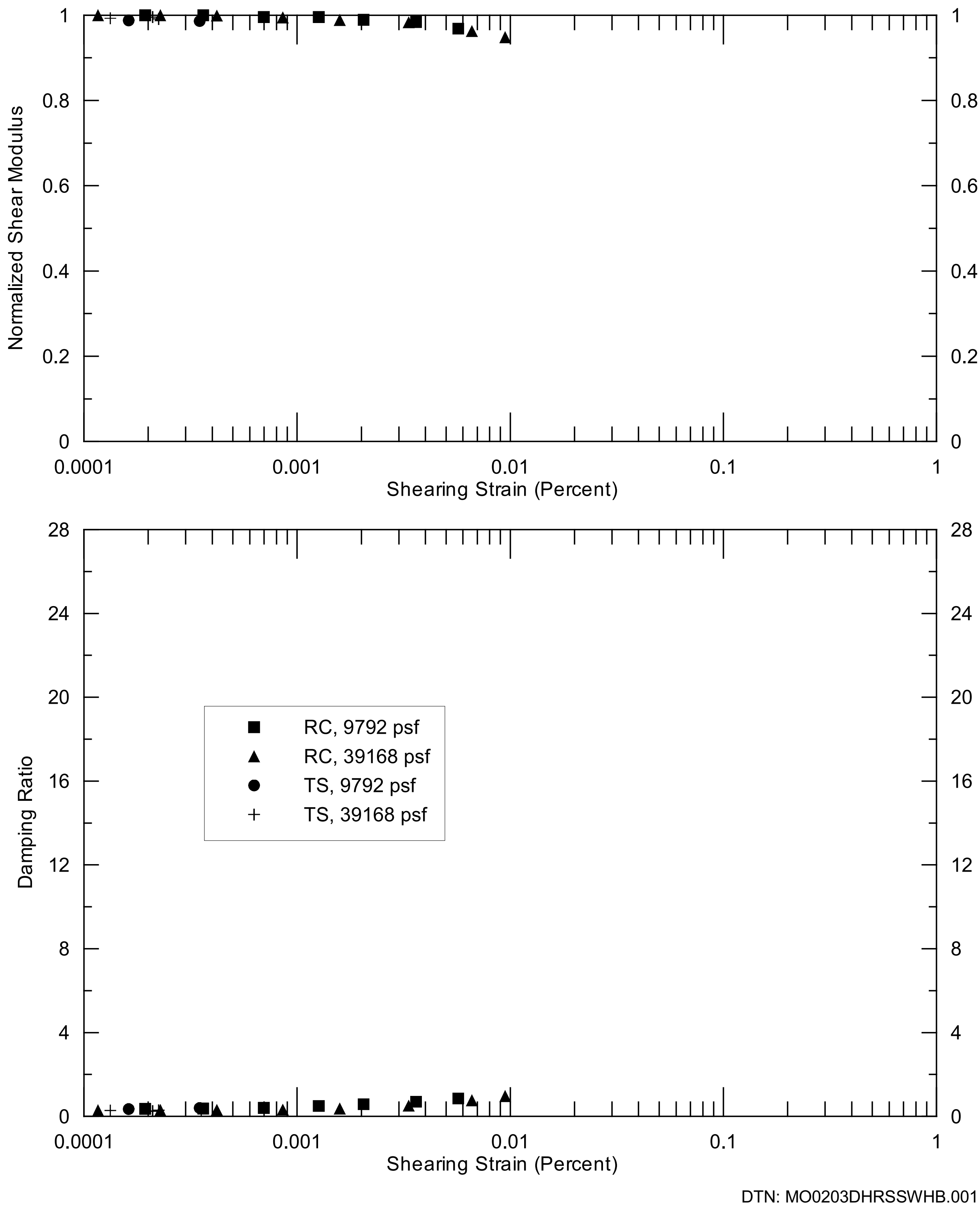
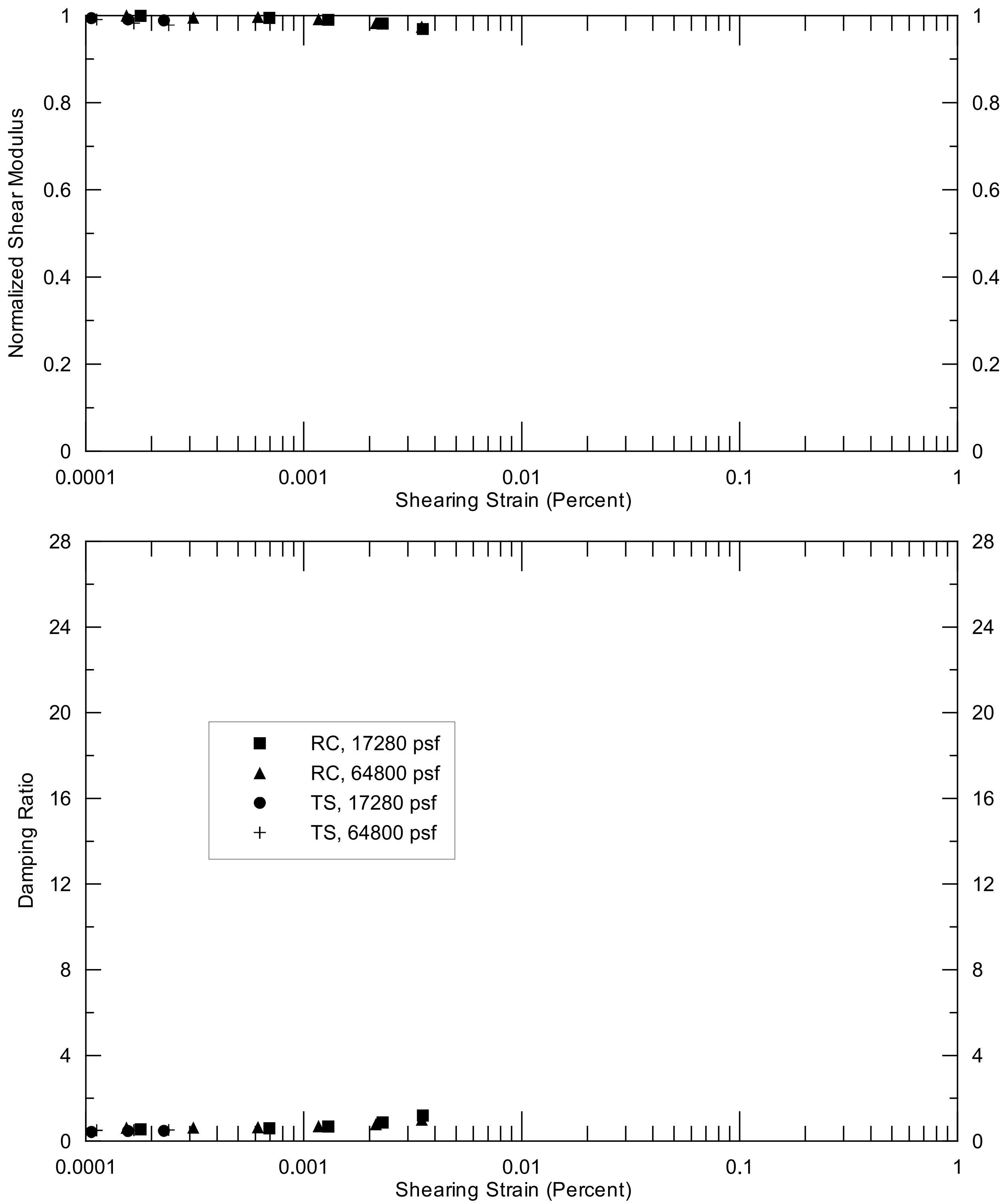
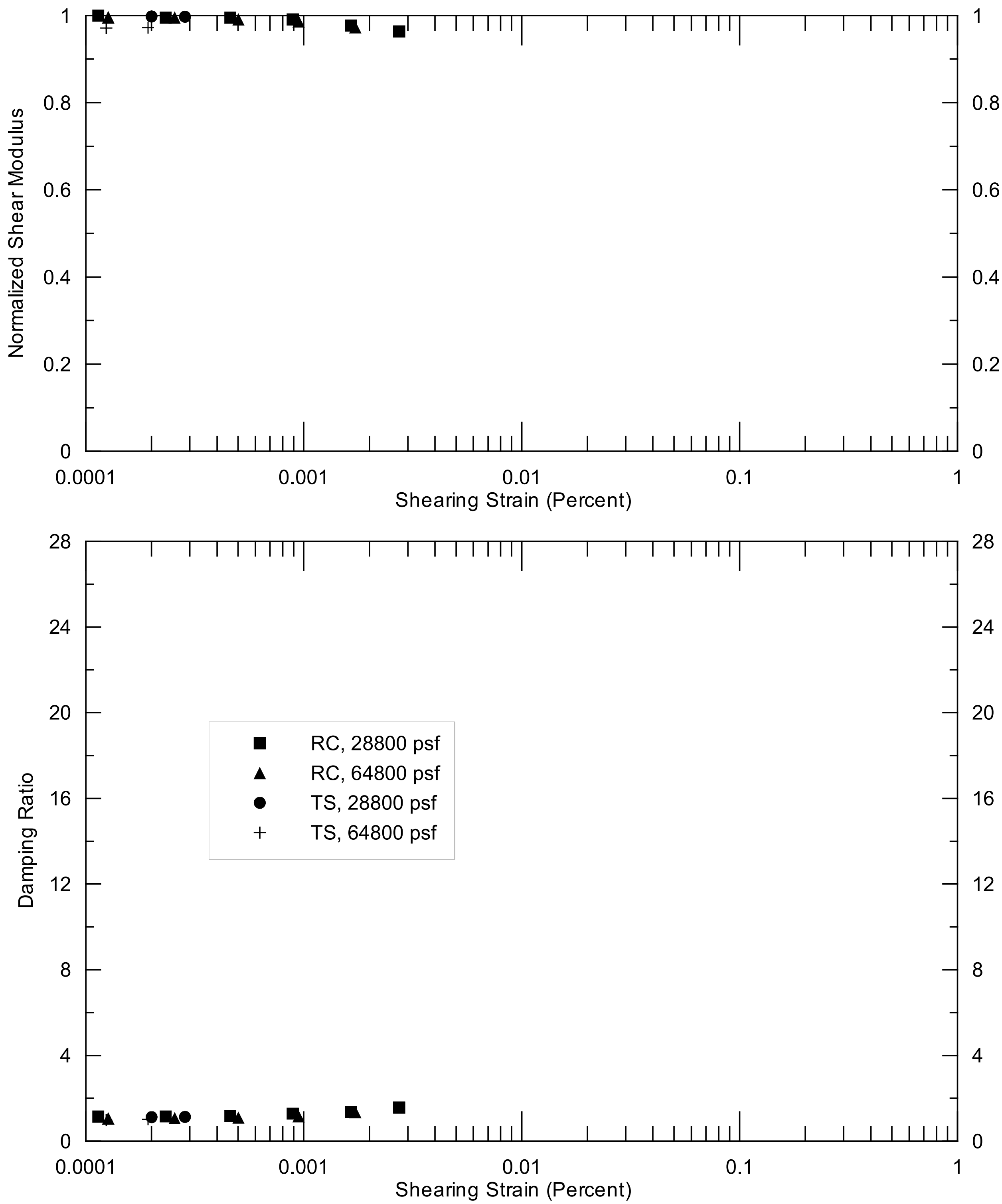


Figure XII-10. Resonant Column and Torsional Shear Results for Specimen UTA-23-F



DTN: MO0203DHRSSWHB.001

Figure XII-11. Resonant Column and Torsional Shear Results for Specimen UTA-23-G



DTN: MO0203DHRSSWHB.001

Figure XII-12. Resonant Column and Torsional Shear Results for Specimen UTA-23-H

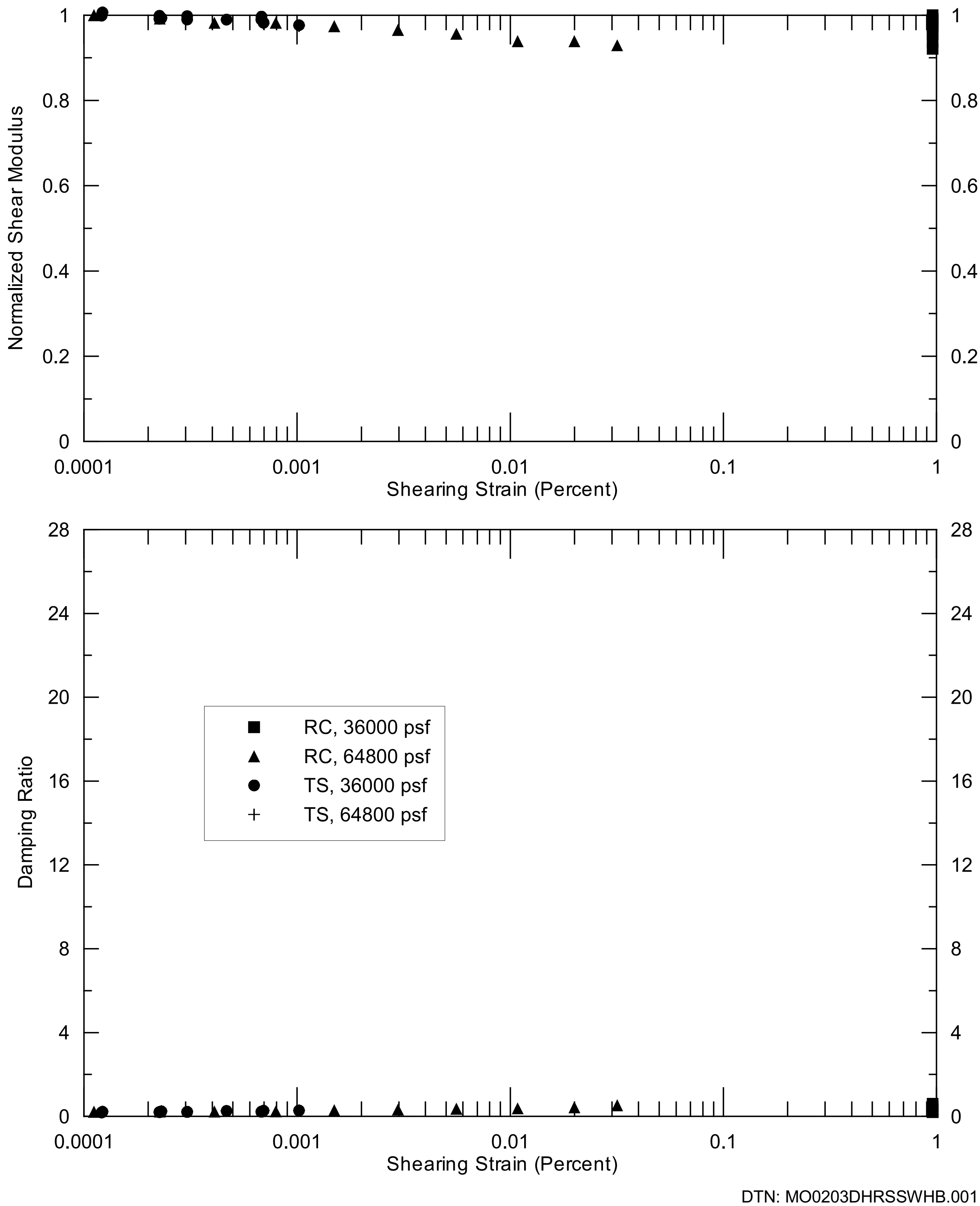
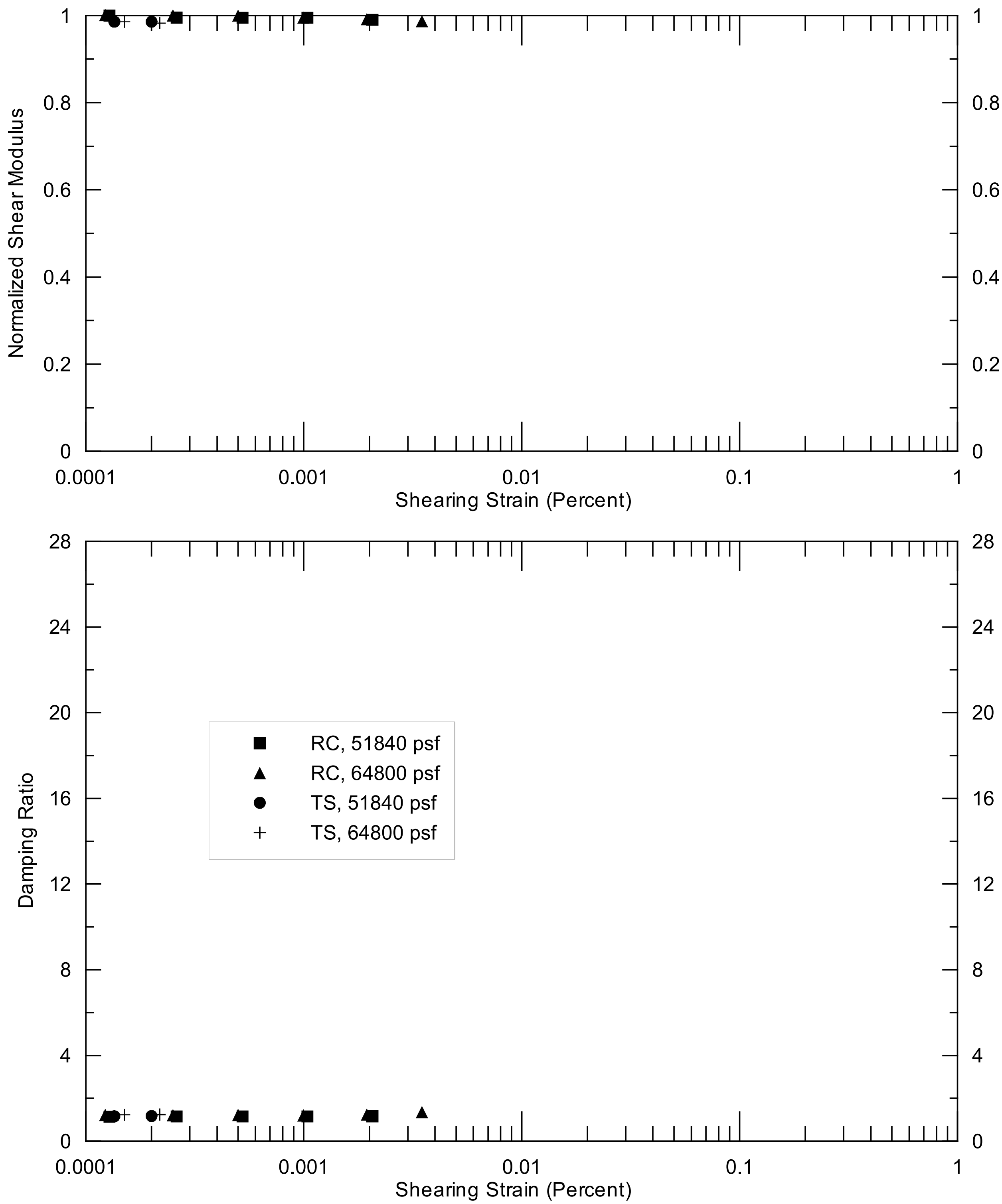
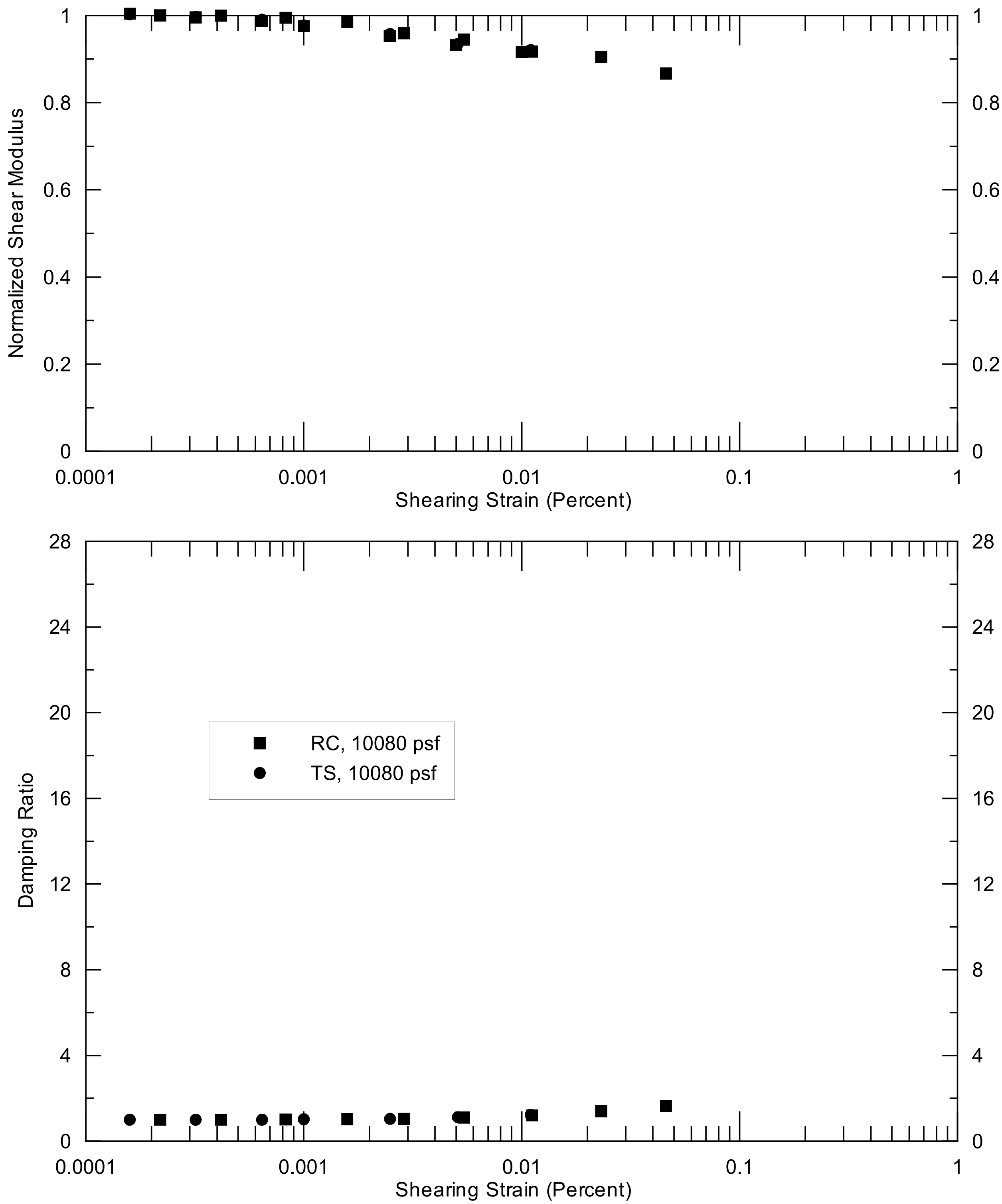


Figure XII-13. Resonant Column and Torsional Shear Results for Specimen UTA-23-I



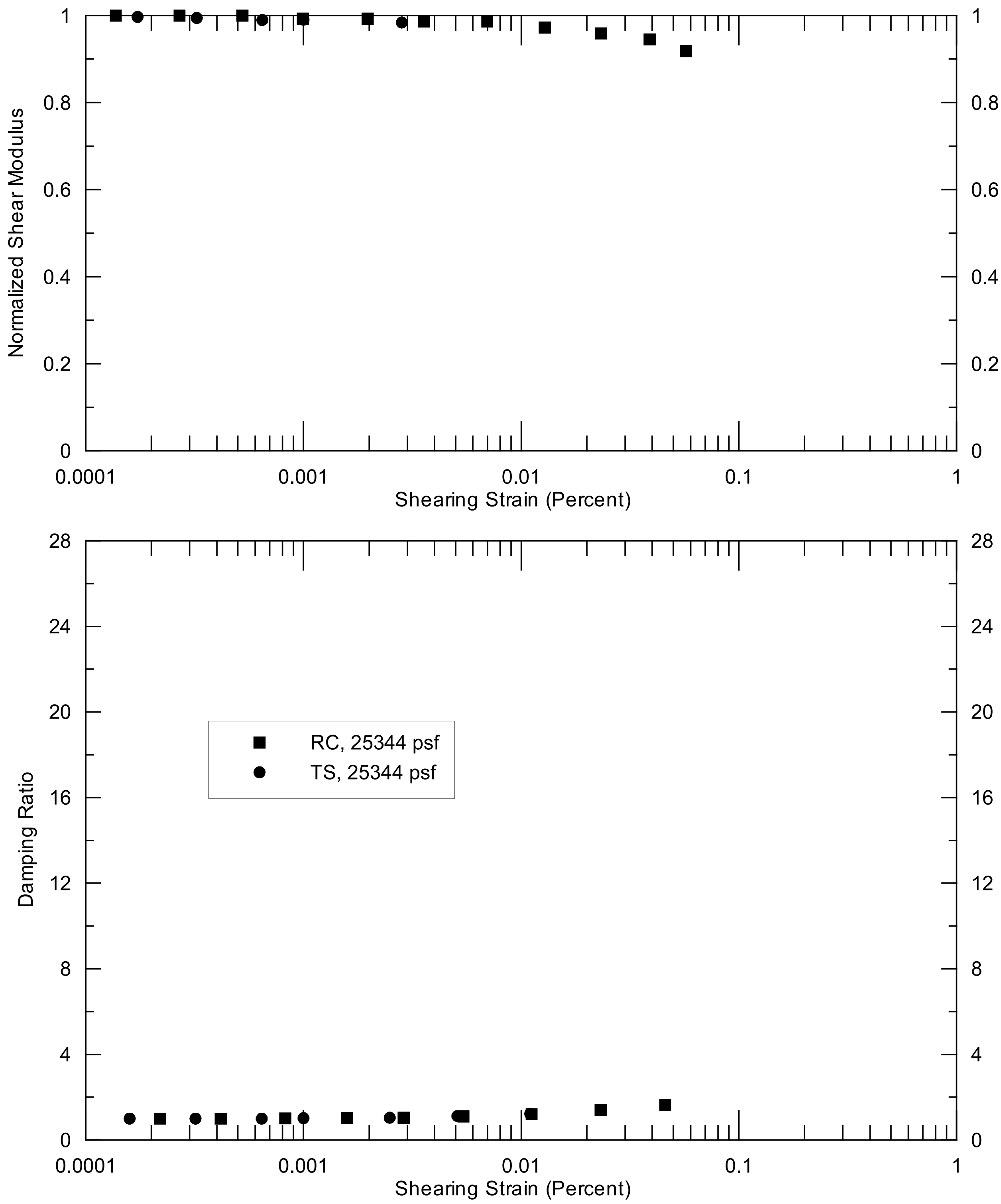
DTN: MO0203DHRSSWHB.001

Figure XII-14. Resonant Column and Torsional Shear Results for Specimen UTA-23-J



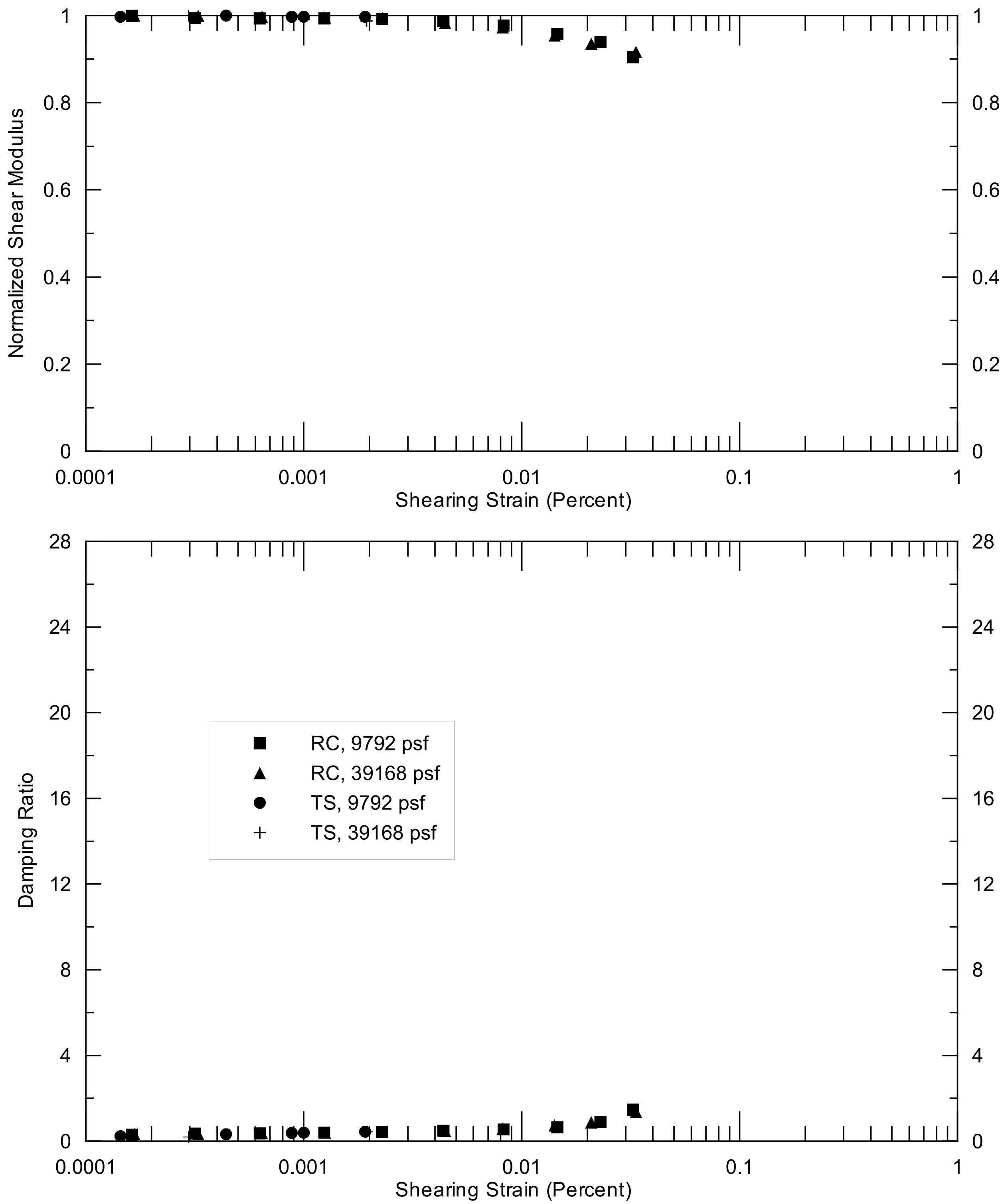
DTN: MO0203DHRSSWHB.001

Figure XII-15. Resonant Column and Torsional Shear Results for Specimen UTA-23-Q



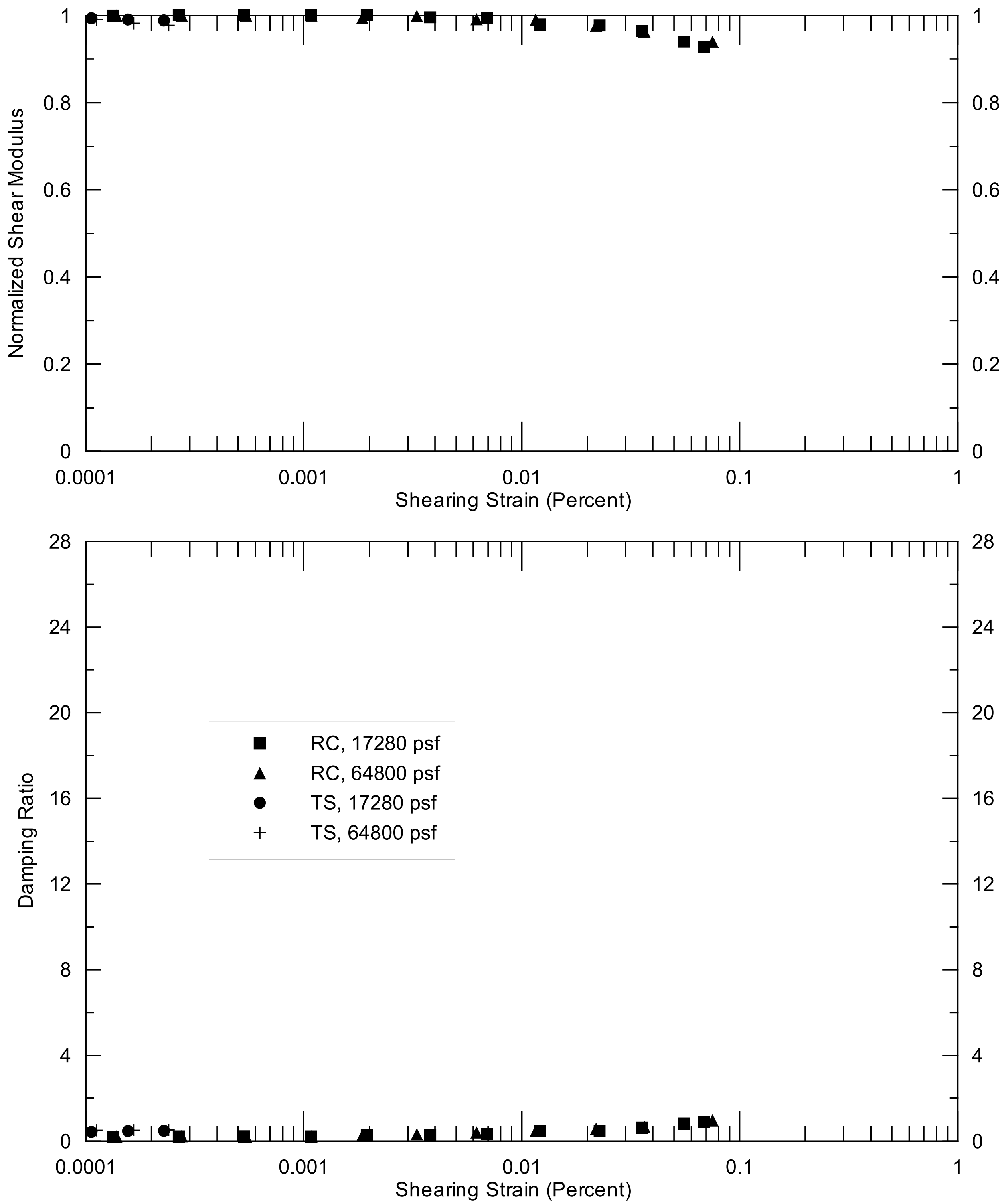
DTN: MO0203DHRSSWHB.001

Figure XII-16. Resonant Column and Torsional Shear Results for Specimen UTA-23-R



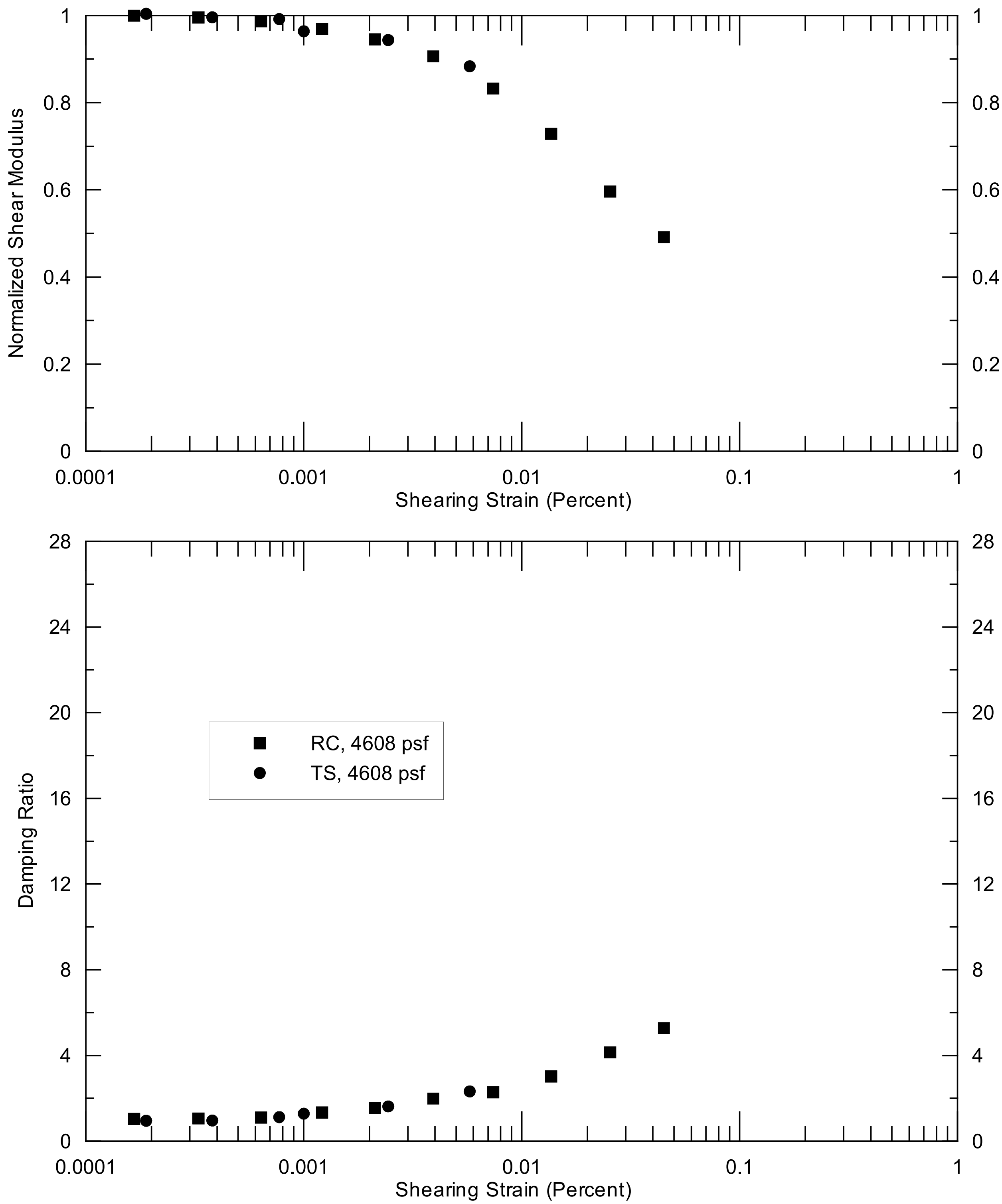
DTN: MO0203DHRSSWHB.001

Figure XII-17. Resonant Column and Torsional Shear Results for Specimen UTA-23-S



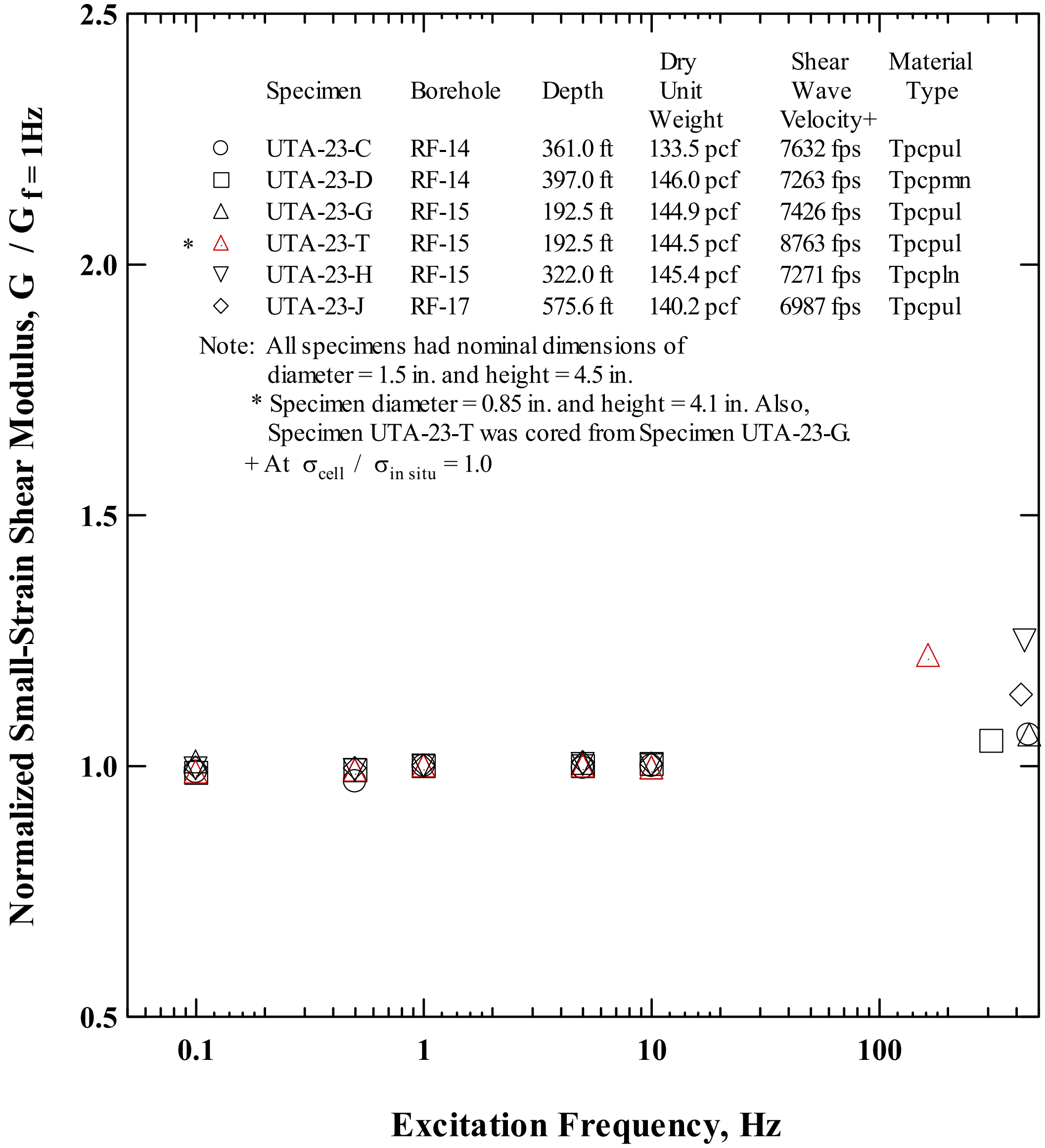
DTN: MO0203DHRSSWHB.001

Figure XII-18. Resonant Column and Torsional Shear Results for Specimen UTA-23-T



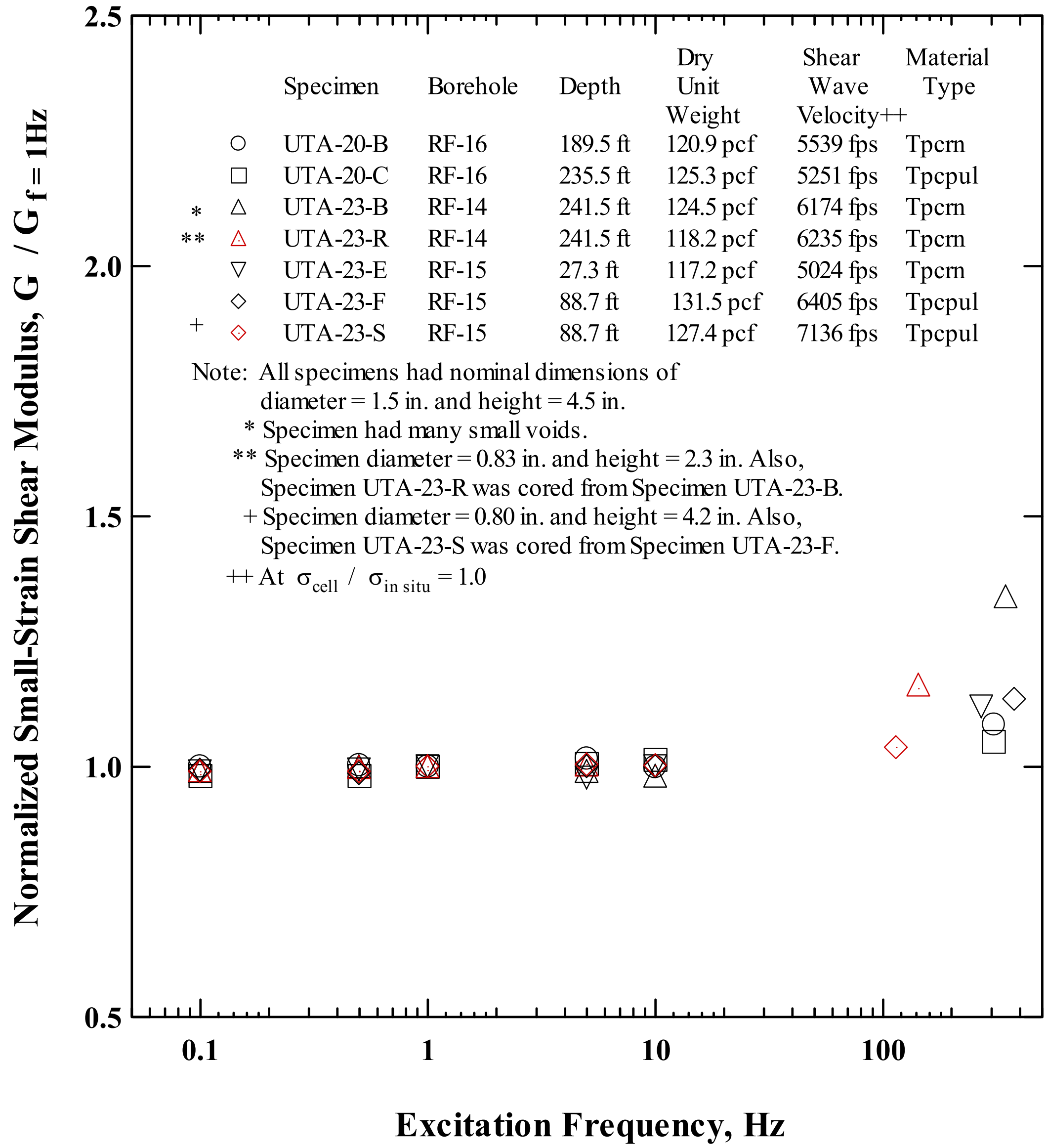
DTN: MO0203DHRSSWHB.001

Figure XII-19. Resonant Column and Torsional Shear Results for Specimen UTA-23-X



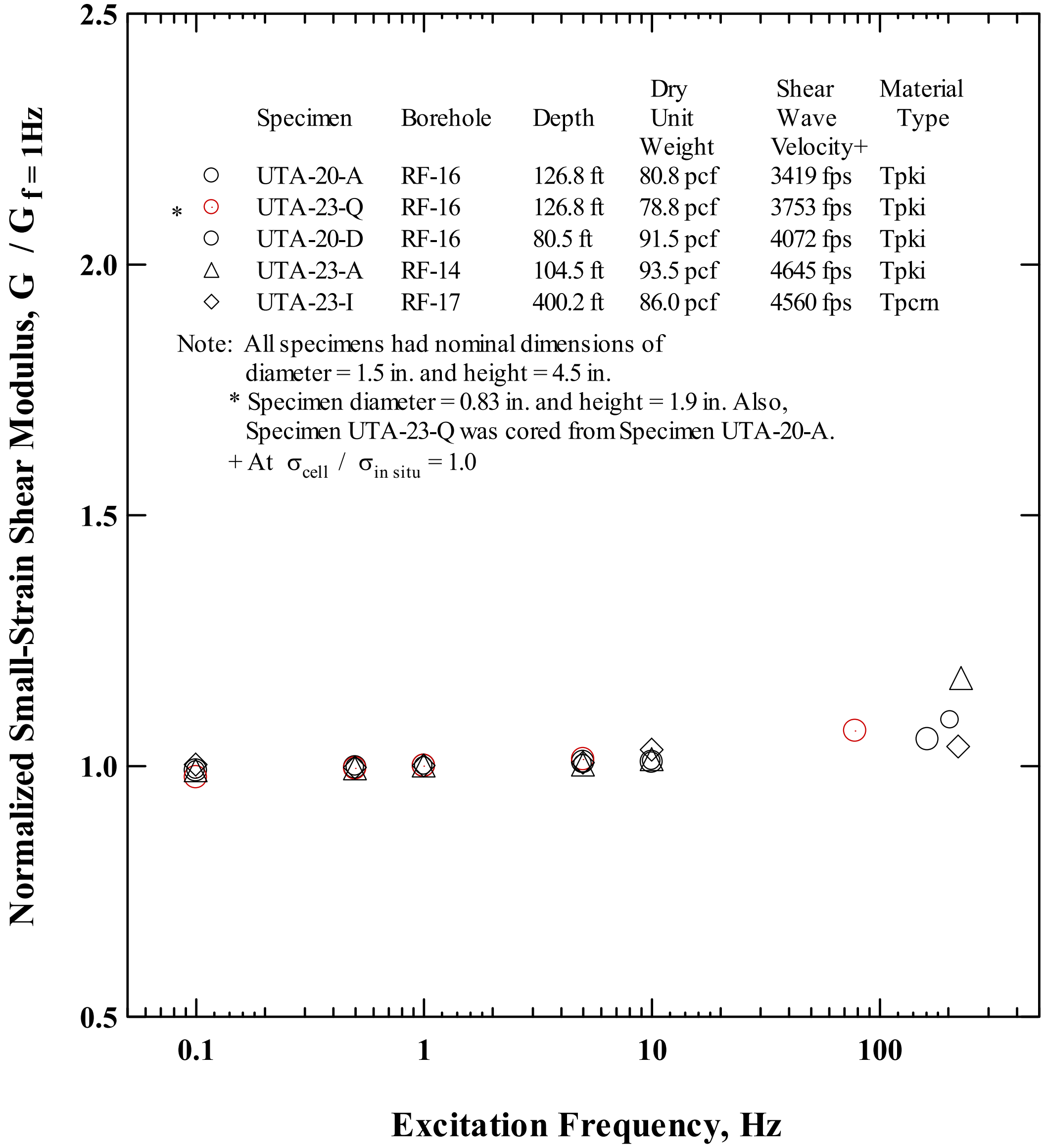
(Wong, 2002e, Appendix 42, page 65)

Figure XII-20. Variation in Normalized Small-Strain Shear Modulus with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 133 pcf (2.13 g/cm3) and 147 pcf (2.36 g/cm3).



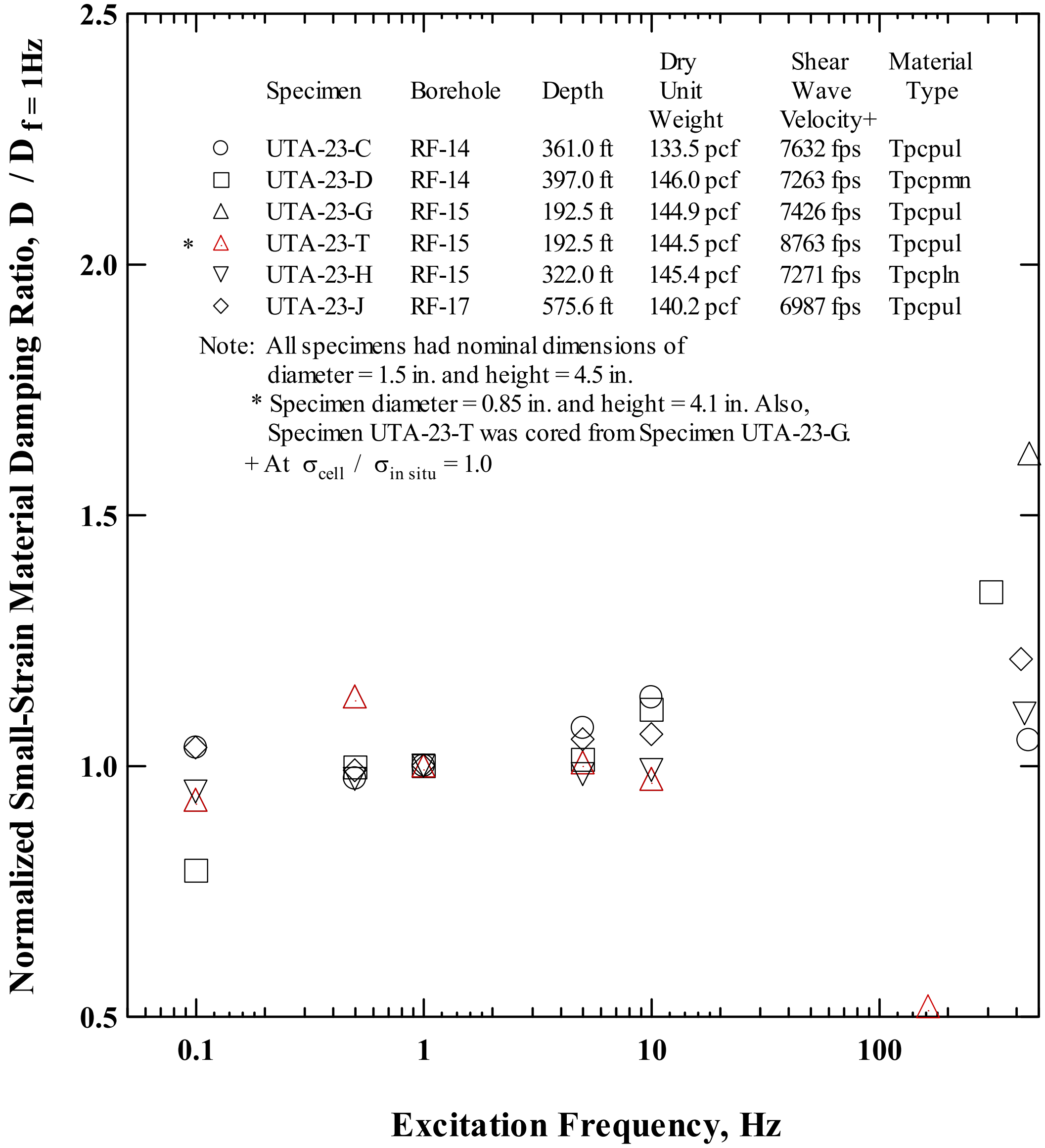
(Wong, 2002e, Appendix 42, page 66)

Figure XII-21. Variation in Normalized Small-Strain Shear Modulus with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 117 pcf (1.88 g/cm3) and 132 pcf (2.12 g/cm3).



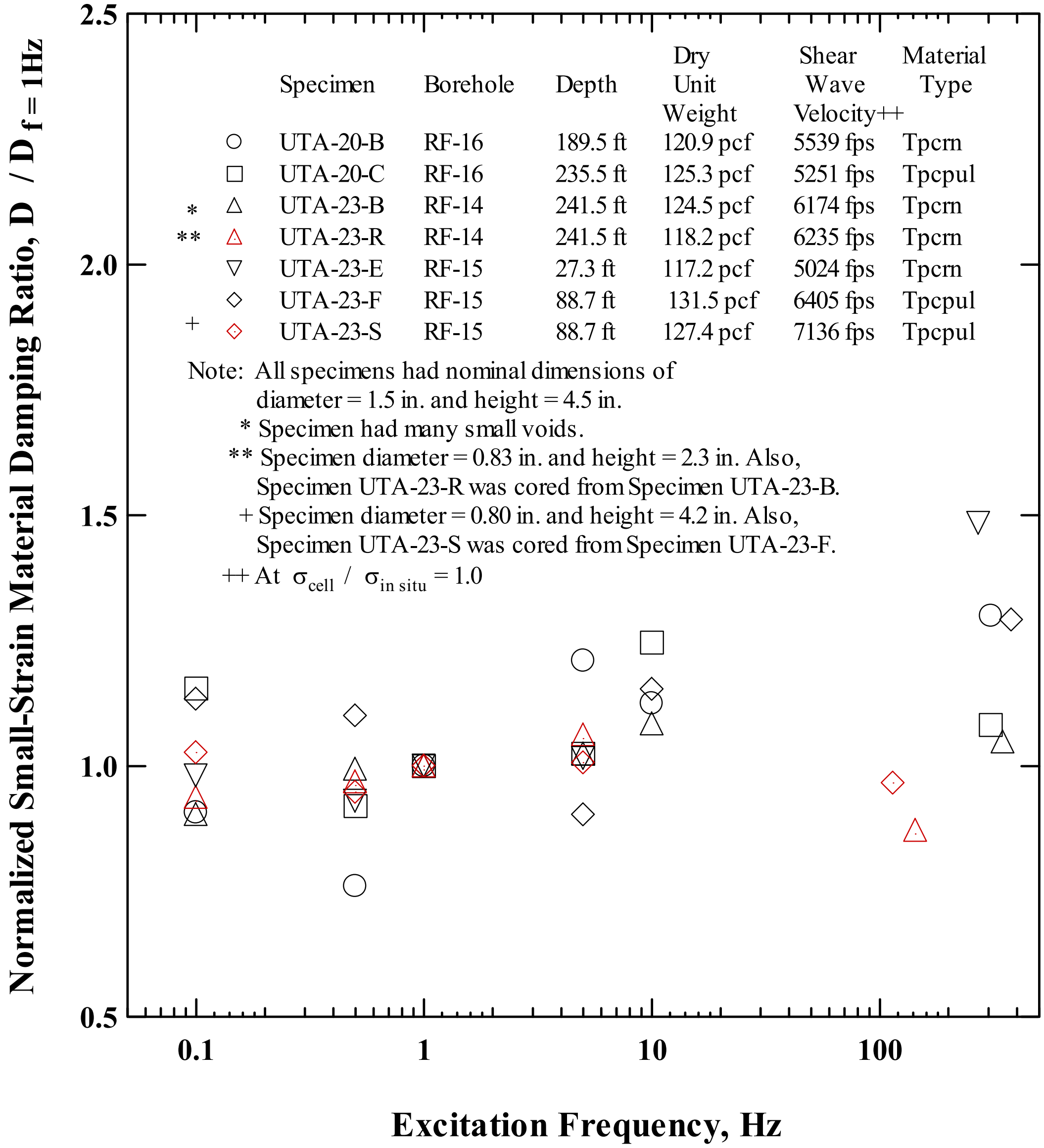
(Wong, 2002e, Appendix 42, page 67)

Figure XII-22. Variation in Normalized Small-Strain Shear Modulus with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 78 pcf (1.25 g/cm3) and 94 pcf (1.51 g/cm3).



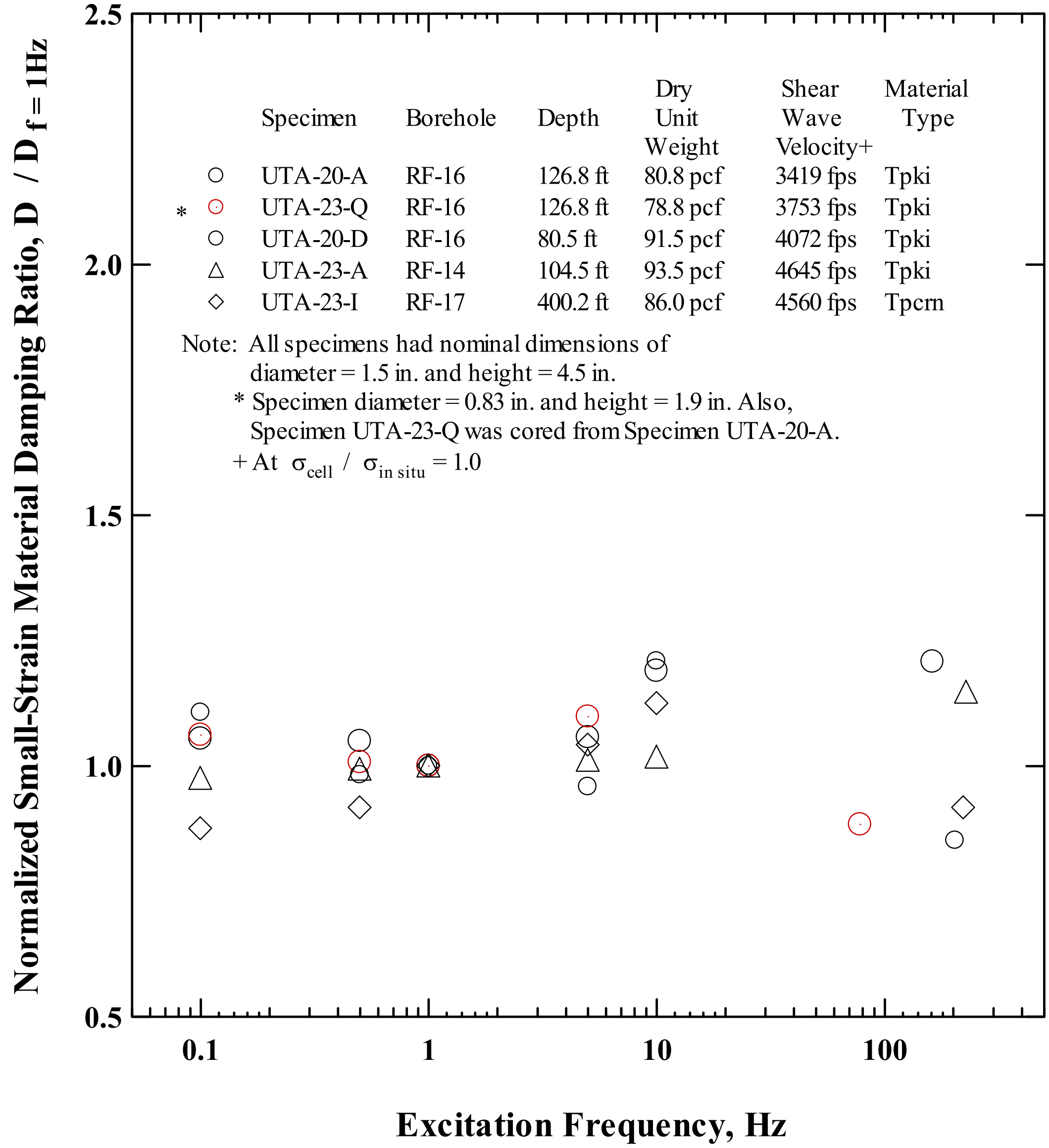
(Wong, 2002e, Appendix 42, page 68)

Figure XII-23. Variation in Normalized Small-Strain Material Damping Ratio with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 133 pcf (2.13 g/cm3) and 147 pcf (2.36 g/cm3).



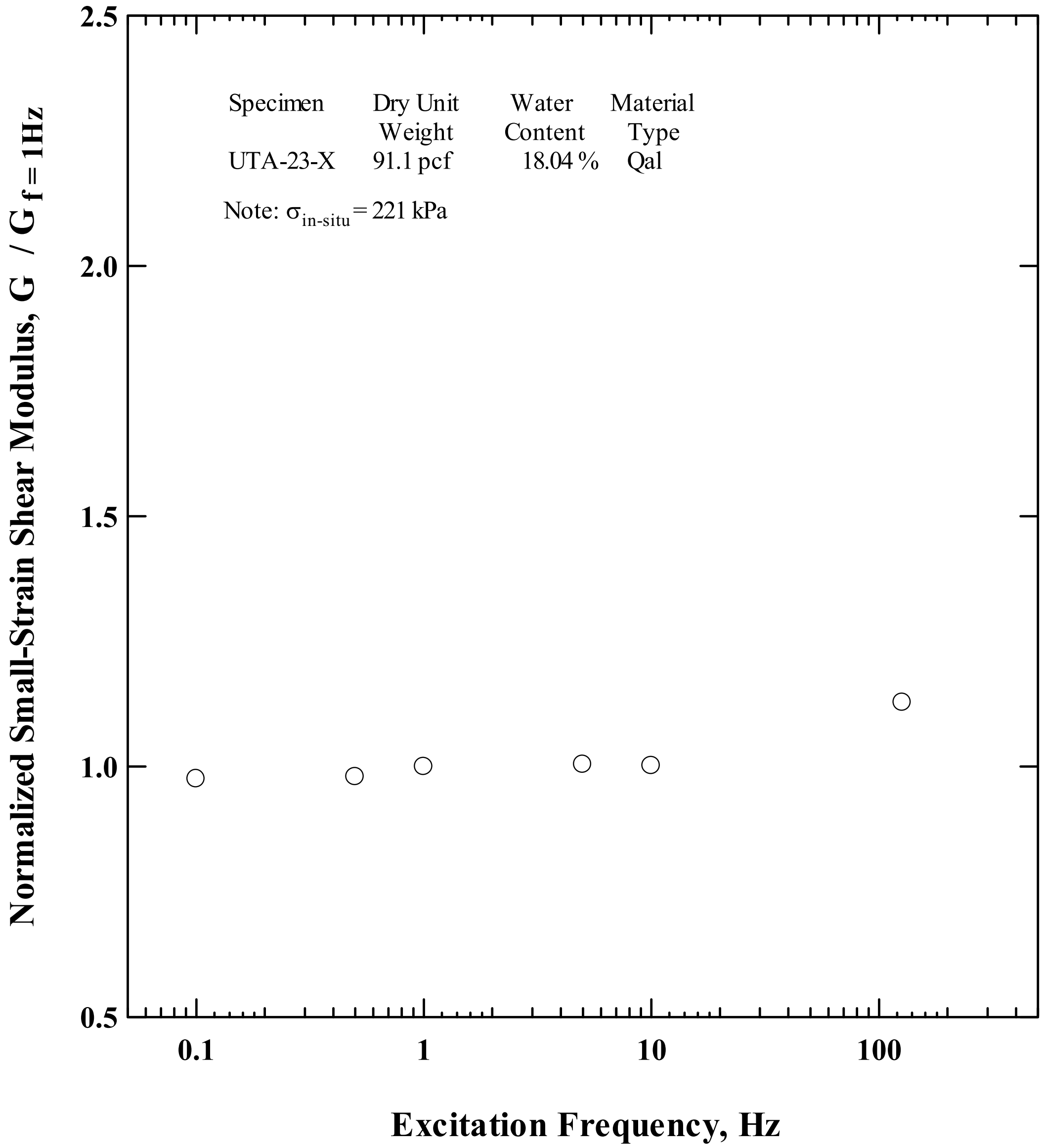
(Wong, 2002e, Appendix 42, page 69)

Figure XII-24. Variation in Normalized Small-Strain Material Damping Ratio with Excitation Frequency in Intact Tuff Specimens with a Dry Unit Weight Between 117 pcf (1.88 g/cm3) and 132 pcf (2.12 g/cm3).



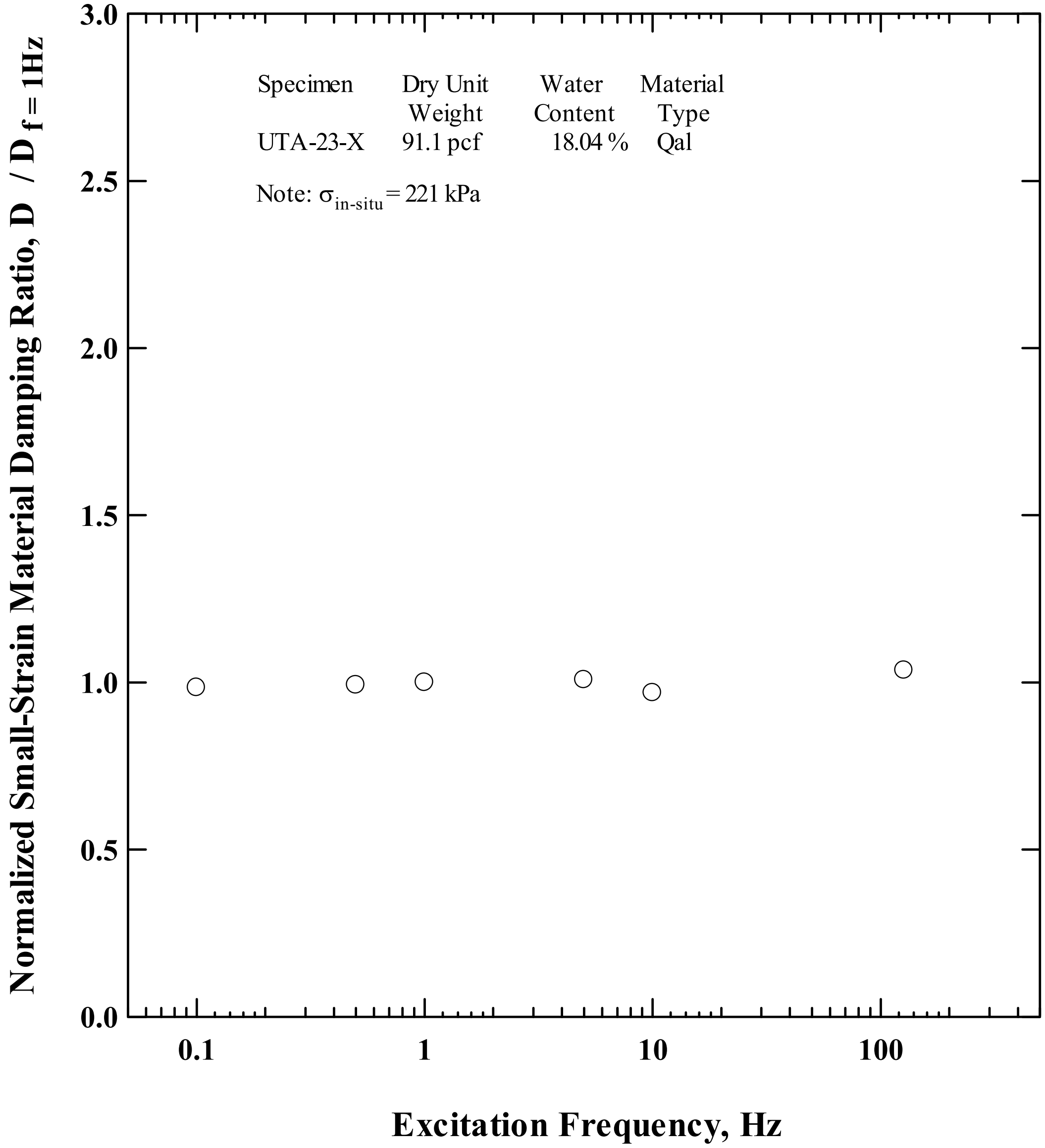
(Wong, 2002e, Appendix 42, page 70)

Figure XII-25. Variation in Normalized Small-Strain Material Damping Ratio with Excitation Frequency of Intact Tuff Specimens with a Dry Unit Weight Between 78 pcf (1.25 g/cm3) and 94 pcf (1.51 g/cm3).



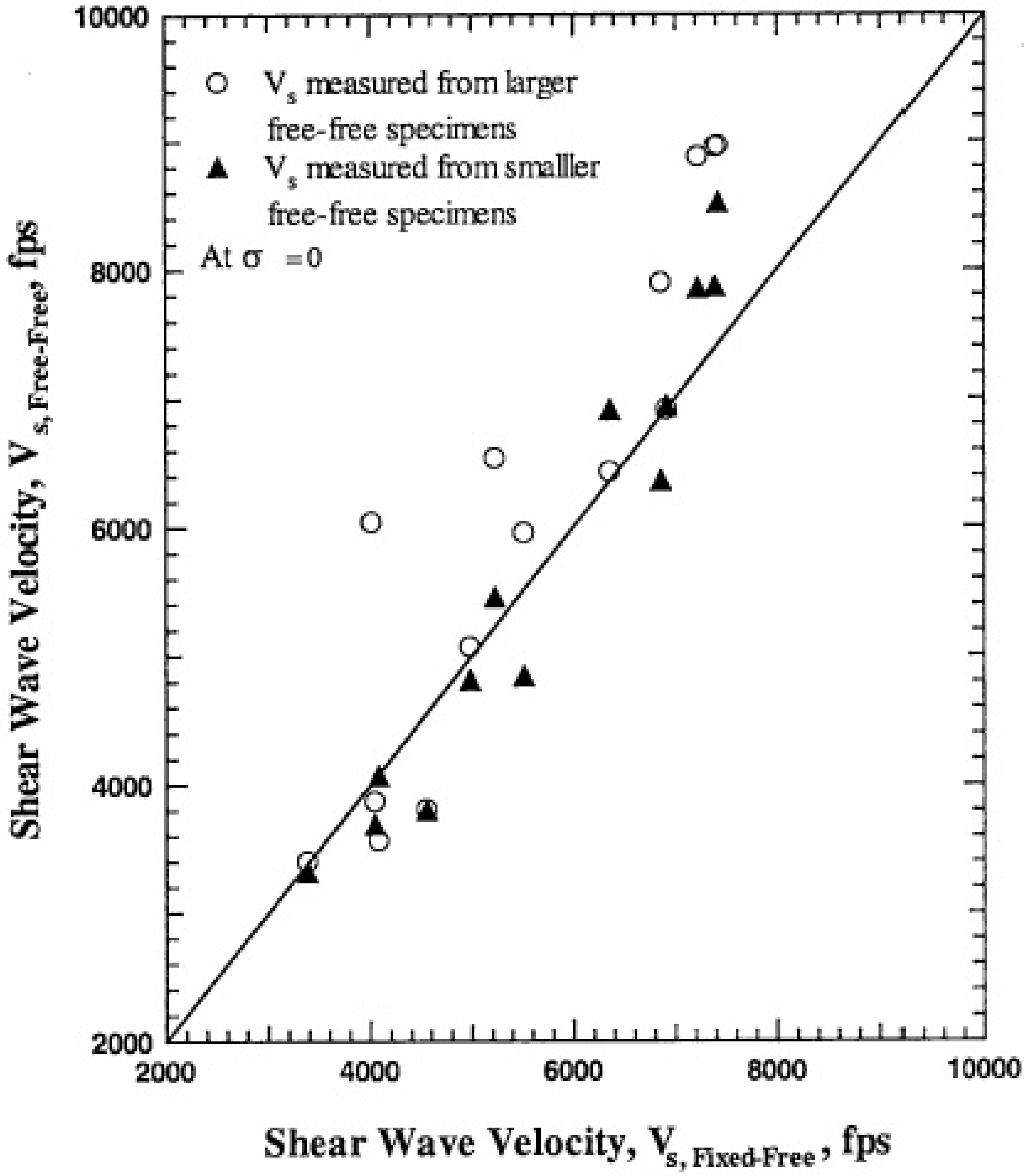
(Wong 2002e, Appendix 42, page 71)

Figure XII-26. Variation in Small-Strain Shear Modulus with Excitation Frequency of Reconstituted Quaternary Alluvium Specimen Recovered from Borehole UE-25 RF#17



(Wong 2002e, Appendix 42, page 72)

Figure XII-27. Variation in Small-Strain Material Damping Ratio with Excitation Frequency of Reconstituted Quaternary Alluvium Specimen Recovered from Borehole UE-25 RF#17



(Wong 2002e, Appendix 42, page 77)

Figure XII-28. Comparison of Small-Strain Shear-Wave Velocity Measured with Fixed-Free and Free-Free Resonant Columns

Table XII-1a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-A.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	31500	1510	3387	1.10
18	2520	120.8	31484	1509	3387	0.85
35	5040	241.6	31648	1517	3396	0.70
70	10080	483.2	32094	1539	3419	0.72
140	20160	966.5	32183	1543	3419	0.73
280	40320	1932.9	32691	1567	3431	0.61

Table XII-1b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-A; Effective Confining Pressure, σ_o' = 70 psi (10.1 ksf = 483 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.16E-04	32076	1.00	2.07E-04	0.70
4.33E-04	32034	1.00	4.14E-04	0.71
8.62E-04	31993	1.00	8.26E-04	0.70
1.63E-03	31988	1.00	1.56E-03	0.69
3.19E-03	31789	0.99	3.02E-03	0.80
6.06E-03	31563	0.98	5.76E-03	0.81
1.09E-02	31133	0.97	1.03E-02	1.00
1.98E-02	30356	0.95	1.83E-02	1.24
3.28E-02	29214	0.91	2.98E-02	1.57

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve
[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-1c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-A; Effective Confining Pressure, σ_o' = 70 psi (10.1 ksf = 483 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
8.00E-05	30570	1.00	0.60	8.10E-05	30400	1.00	0.39
1.50E-04	30290	1.00	0.57	1.51E-04	30210	0.99	0.56
4.01E-04	30300	1.00	0.46	4.01E-04	30200	0.99	0.51
9.39E-04	30200	0.99	0.58	9.39E-04	30100	0.99	0.58
1.00E-03	30100	0.99	0.52	9.98E-04	30050	0.99	0.58
1.73E-03	30050	1.00	0.60	1.71E-03	30050	0.99	0.64

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Table XII-1d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-A; Effective Confining Pressure, so' = 280 psi (40.3 ksf = 1933 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
9.34E-05	32721	1.00	8.95E-05	0.69
4.80E-05	32724	1.00	4.60E-05	0.68
1.83E-04	32612	1.00	1.75E-04	0.68
3.50E-04	32599	1.00	3.35E-04	0.70
6.64E-04	32200	0.98	6.32E-04	0.74
1.22E-03	31998	0.98	1.16E-03	0.86
2.42E-03	31602	0.97	2.28E-03	0.91
4.79E-03	31206	0.95	4.49E-03	1.01
8.84E-03	30424	0.93	8.22E-03	1.17
1.64E-02	29279	0.89	1.50E-02	1.45
2.77E-02	27385	0.84	2.49E-02	1.75

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-1e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-A; Effective Confining Pressure, σ_o' = 280 psi (40.3 ksf = 1933 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.04E-04	28500	1.01	0.80	4.04E-04	28000	1.00	0.78
9.56E-04	28070	0.99	0.88	9.58E-04	28080	1.00	0.98
1.03E-03	28000	0.99	0.95	1.03E-03	28000	1.00	0.94
1.79E-03	27730	0.98	1.02	1.79E-03	27760	0.99	1.08

DTN: MO0203DHRSSWHB.001

Table XII-2a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-B

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	115000	5513	5522	0.70
29	4176	200.2	115670	5545	5539	0.63
58	8352	400.4	115700	5547	5539	0.62
115	16560	793.9	115670	5545	5539	0.64
230	33120	1587.8	115620	5543	5538	0.63
460	66240	3175.5	115730	5548	5540	0.62

Table XII-2b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-B; Effective Confining Pressure, σ_o' = 115 psi (16.6 ksf = 794 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
1.23E-05	115710	1.00	1.19E-05	0.61
2.37E-05	115700	1.00	2.28E-05	0.63
4.61E-05	115690	1.00	4.43E-05	0.63
8.77E-05	115690	1.00	8.43E-05	0.64
1.62E-04	115700	1.00	1.56E-04	0.65
2.87E-04	114950	0.99	2.74E-04	0.71
5.44E-04	114220	0.99	5.20E-04	0.73
9.96E-04	113470	0.98	9.46E-04	0.82
1.65E-03	112010	0.97	1.56E-03	0.87

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-2c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-B; Effective Confining Pressure, σ_o' = 115 psi (16.6 ksf = 794 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.80E-04	107500	1.00	0.62	3.71E-04	107000	1.00	0.66
2.60E-04	106600	1.00	0.57	2.60E-04	106100	1.00	0.61
4.93E-04	104900	0.98	0.70	4.95E-04	105000	0.99	0.67

DTN: MO0203DHRSSWHB.001

Table XII-2d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-B; Effective Confining Pressure, σ_o' = 460 psi (66.2 ksf = 3176 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
7.60E-06	116000	1.00	7.36E-06	0.52
1.48E-05	116000	1.00	1.43E-05	0.52
2.92E-05	116000	1.00	2.83E-05	0.53
5.90E-05	115000	0.99	5.71E-05	0.52
1.16E-04	115000	0.99	1.12E-04	0.53
2.03E-04	114000	0.98	1.96E-04	0.54
3.76E-04	113000	0.97	3.63E-04	0.55
1.18E-03	112000	0.97	1.14E-03	0.55
2.20E-03	110000	0.95	2.12E-03	0.62
3.95E-03	109000	0.94	3.78E-03	0.70
7.24E-03	107000	0.92	6.87E-03	0.86
1.20E-02	104000	0.90	1.13E-02	1.01
1.49E-02	101000	0.87	1.36E-02	1.49

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-2e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-B; Effective Confining Pressure, σ_o' = 460 psi (66.2 ksf = 3176 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.71E-04	105900	1.00	0.66	3.58E-04	106400	1.00	0.62
1.82E-04	106800	1.00	0.60	1.82E-04	106700	1.00	0.62
3.60E-04	106180	1.00	0.68	3.60E-04	106180	1.00	0.69
4.80E-04	105700	0.99	0.72	4.78E-04	106500	1.00	0.67

DTN: MO0203DHRSSWHB.001

Table XII-3a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-C

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	109000	5225	5233	0.60
38	5472	262.3	109130	5232	5236	0.57
75	10800	517.7	109160	5233	5236	0.55
150	21600	1035.5	109810	5264	5251	0.48
300	43200	2071.0	109890	5268	5252	0.46
450	64800	3106.5	110620	5303	5268	0.46

Table XII-3b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-C; Effective Confining Pressure, σ_o' = 150 psi (21.6 ksf = 1035 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.33E-05	109200	1.00	2.27E-05	0.40
4.62E-05	109110	1.00	4.50E-05	0.43
9.10E-05	109200	1.00	8.87E-05	0.41
1.74E-04	109200	1.00	1.70E-04	0.43
3.34E-04	108510	0.99	3.25E-04	0.47
5.95E-04	107800	0.99	5.76E-04	0.51
1.08E-03	106990	0.98	1.05E-03	0.57
1.94E-03	106410	0.97	1.87E-03	0.66
3.27E-03	104900	0.96	3.13E-03	0.72
5.79E-03	103530	0.95	5.49E-03	0.86
9.09E-03	102180	0.94	8.53E-03	1.05
1.37E-02	99564	0.91	1.26E-02	1.43
1.72E-02	95542	0.88	1.49E-02	2.43

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-3c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-C; Effective Confining Pressure, σ_o' = 150 psi (21.6 ksf = 1035 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.49E-04	100800	1.00	0.42	2.48E-04	100800	1.00	0.45
5.35E-04	100200	1.00	0.50	5.35E-04	100200	1.00	0.52

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Table XII-3d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-C; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
2.23E-05	111000	1.00	2.17E-05	0.44
4.38E-05	111000	1.00	4.26E-05	0.42
8.65E-05	111000	1.00	8.41E-05	0.45
1.66E-04	110000	0.99	1.61E-04	0.47
3.20E-04	110000	0.99	3.11E-04	0.49
5.98E-04	109000	0.99	5.79E-04	0.53
1.16E-03	109000	0.98	1.12E-03	0.56
2.20E-03	107000	0.97	2.12E-03	0.62
3.95E-03	106000	0.96	3.79E-03	0.70
7.24E-03	104000	0.94	6.86E-03	0.86
1.20E-02	101000	0.91	1.13E-02	1.01
1.49E-02	98300	0.89	1.34E-02	1.69

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-3e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-C; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.48E-04	100800	0.99	0.43	2.48E-04	100800	1.00	0.43
5.31E-04	101600	1.00	0.49	5.35E-04	102000	1.01	0.49

DTN: MO0203DHRSSWHB.001

Table XII-4a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-D

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	50500	2421	4050	0.77
14	2016	96.6	50525	2422	4052	0.57
28	4032	193.3	51031	2446	4072	0.52
56	8064	386.6	51035	2447	4072	0.52
110	15840	759.4	50983	2444	4071	0.53
220	31680	1518.7	50514	2422	4051	0.52

Table XII-4b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-D; Effective Confining Pressure, σ_o' = 56 psi (8.1 ksf = 387 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
7.88E-05	50988	1.00	7.65E-05	0.47
1.58E-04	50995	1.00	1.53E-04	0.49
3.13E-04	50988	1.00	3.03E-04	0.52
6.12E-04	50985	1.00	5.91E-04	0.54
1.11E-03	50544	0.99	1.07E-03	0.56
2.04E-03	50488	0.99	1.96E-03	0.65
3.39E-03	49996	0.98	3.23E-03	0.81
5.54E-03	49070	0.96	5.21E-03	1.00
9.25E-03	47607	0.93	8.58E-03	1.24

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-4c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-D; Effective Confining Pressure, σ_o' = 56 psi (8.1 ksf = 387 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.58E-04	46230	1.00	0.48	2.58E-04	46200	1.00	0.52
5.15E-04	46330	1.00	0.49	5.15E-04	46400	1.00	0.58
8.59E-04	46220	1.00	0.60	8.59E-04	46300	1.00	0.58
1.00E-03	46200	1.00	0.65	1.00E-03	46300	1.00	0.68
1.20E-03	45900	0.99	0.72	1.20E-03	46000	0.99	0.71

DTN: MO0203DHRSSWHB.001

Table XII-4d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-D; Effective Confining Pressure, σ_o' = 220 psi (31.7 ksf = 1519 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
7.64E-05	50506	1.00	7.76E-05	0.59
1.53E-04	50512	1.00	1.48E-04	0.54
3.05E-04	50514	1.00	3.10E-04	0.59
5.92E-04	50514	1.00	5.71E-04	0.58
1.08E-03	50023	0.99	1.04E-03	0.62
2.06E-03	50025	0.99	1.98E-03	0.66
3.89E-03	49046	0.97	3.71E-03	0.78
6.74E-03	48068	0.95	6.35E-03	0.98
1.06E-02	46631	0.92	9.85E-03	1.20

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-4e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-D; Effective Confining Pressure, σ_o' = 220 psi (31.7 ksf = 1519 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.25E-04	46930	1.00	0.51	4.25E-04	46700	1.00	0.51
6.82E-04	46800	1.00	0.56	6.82E-04	46800	1.00	0.61
1.00E-03	46650	1.00	0.62	1.00E-03	46700	1.00	0.62

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Table XII-5a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-A

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	61700	2958	4086	0.99
16	2304	110.5	63477	3043	4566	0.99
33	4752	227.8	63477	3043	4566	0.99
66	9504	455.6	65697	3149	4645	1.00
132	19008	911.2	65623	3146	4643	0.97
264	38016	1822.5	65673	3148	4645	0.94

Table XII-5b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-A; Effective Confining Pressure, σ_o' = 66 psi (9.5 ksf = 455.6 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
2.31E-05	65143	1.00	2.19E-05	0.84
4.58E-05	65140	1.00	4.34E-05	0.89
9.08E-05	65062	1.00	8.58E-05	0.93
1.78E-04	65000	1.00	1.68E-04	0.95
3.22E-04	65050	1.00	3.15E-04	1.20
5.20E-04	64900	1.00	4.78E-04	1.39
8.83E-04	64500	0.99	7.87E-04	1.90
1.68E-03	63500	0.97	1.46E-03	2.43
5.14E-03	61740	0.95	4.77E-03	3.20

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-5c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-A; Effective Confining Pressure, σ_o' = 66 psi (9.5 ksf = 455.6 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
6.40E-05	54800	1.00	0.90	6.40E-05	54700	1.00	0.91
1.26E-04	54730	1.00	0.98	1.26E-04	54640	1.00	1.00
2.30E-04	54740	1.00	1.12	2.30E-04	54600	1.00	1.14
4.62E-04	54700	1.00	1.40	4.62E-04	54500	1.00	1.42
7.07E-04	54630	1.00	1.65	7.07E-04	54430	1.00	1.67

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Table XII-5d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-A; Effective Confining Pressure, σ_o' = 264 psi (38.0 ksf = 1822 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.40E-05	65679	1.00	2.27E-05	0.86
4.67E-05	65629	1.00	4.42E-05	0.86
9.20E-05	65620	1.00	8.67E-05	0.95
1.67E-04	65200	0.99	1.57E-04	1.01
2.96E-04	65100	0.99	2.75E-04	1.19
4.58E-04	65000	0.99	4.16E-04	1.56
1.08E-03	64500	0.98	9.76E-04	2.10

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-5e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-A; Effective Confining Pressure, σ_o' = 264 psi (38.0 ksf = 1822 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
6.20E-05	55800	1.00	0.87	6.20E-05	55700	1.00	0.88
1.22E-04	55680	1.00	0.92	1.22E-04	55700	1.00	0.93
2.28E-04	55650	1.00	1.10	2.28E-04	55700	1.00	1.11
4.50E-04	55620	1.00	1.35	4.50E-04	55600	1.00	1.38
6.80E-04	55610	1.00	1.60	6.80E-04	55500	1.00	1.62
9.90E-04	55600	1.00	2.00	9.90E-04	55400	1.00	2.05

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Table XII-6a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-B

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	63500	3044	4022	2.33
44	6336	303.7	143300	6870	6035	1.34
88	12672	607.5	149300	7157	6159	1.33
176	25344	1215.0	150100	7196	6174	1.30
352	50688	2430.0	151870	7281	6209	1.30
450	64800	3106.5	151930	7283	6209	1.29

Table XII-6b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-B; Effective Confining Pressure, σ_o' = 176 psi (25.3 ksf = 1215 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
2.26E-06	151120	1.00	1.97E-06	1.20
3.89E-06	150260	0.99	3.44E-06	1.25
7.56E-06	151100	1.00	6.24E-06	1.30
1.49E-05	150090	0.99	1.26E-05	1.40
2.97E-05	150090	0.99	2.49E-05	1.42
5.55E-05	150090	0.99	4.62E-05	1.43
1.13E-04	149000	0.99	9.39E-05	1.44
8.72E-04	142000	0.94	7.90E-04	1.74
3.31E-03	131950	0.87	3.08E-03	2.10
6.91E-03	126230	0.84	6.61E-03	2.50
1.12E-02	123000	0.81	1.07E-02	2.80

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-6c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-B; Effective Confining Pressure, σ_o' = 176 psi (25.3 ksf = 1215 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.63E-05	129800	1.01	1.54	2.63E-05	127600	1.00	1.55
5.22E-05	129000	0.99	1.57	5.20E-05	127000	1.00	1.58
1.07E-04	127000	0.98	1.59	1.07E-04	124400	0.97	1.60
2.92E-04	122000	0.94	1.60	2.92E-04	121600	0.95	1.61
3.49E-04	120000	0.92	1.65	3.49E-04	119600	0.94	1.66

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Table XII-6d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-B; Effective Confining Pressure, σ_o' = 450 psi (64.8ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
3.87E-06	152790	1.00	3.28E-06	1.20
7.33E-06	152810	1.00	6.35E-06	1.22
1.44E-05	152810	1.00	1.17E-05	1.30
2.92E-05	152970	1.00	2.48E-05	1.31
5.43E-05	152800	1.00	4.55E-05	1.31
1.07E-04	151950	0.99	1.50E-04	1.38
2.28E-04	149370	0.98	1.87E-04	1.40
9.68E-04	144000	0.94	9.01E-04	1.70
6.43E-03	132000	0.86	6.09E-03	2.10
1.15E-02	127000	0.82	1.09E-02	2.40
1.78E-02	123230	0.81	1.68E-02	2.70
2.40E-02	120990	0.79	2.24E-02	3.00

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-6e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-B; Effective Confining Pressure, σ_o' = 450 psi (64.8ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.20E-05	152660	1.00	1.40	5.60E-05	152110		1.41
9.50E-05	149000	0.98	1.40	9.64E-05	149000	0.99	1.42
2.10E-04	148700	0.97	1.42	2.07E-04	147000	0.98	1.43
3.29E-04	147000	0.96	1.45	3.10E-04	146000	0.97	1.47
3.66E-04	146000	0.96	1.54	3.50E-04	145000	0.97	1.55

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Table XII-7a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-C

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	200000	9588	6925	1.80
70	10080	483.2	205870	9869	6984	1.80
140	20160	966.5	242020	11602	7570	1.70
280	40320	1932.9	276820	13271	7632	1.66
450	64800	3106.5	280450	13445	7682	1.98

Table XII-7b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-C; Effective Confining Pressure, σ_o' = 280psi (40.3ksf = 1933kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
1.33E-06	279300	1.00	1.26E-06	0.89
2.49E-06	277780	0.99	2.24E-06	1.73
4.84E-06	279290	1.00	4.35E-06	1.76
1.00E-05	278050	1.00	7.52E-06	1.27
1.92E-05	278070	1.00	1.77E-05	1.28
3.62E-05	277770	0.99	3.19E-05	1.31
7.31E-05	276570	0.99	6.45E-05	1.42
1.46E-04	274150	0.98	1.31E-04	1.62
2.72E-04	269330	0.96	2.26E-04	1.80

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-7c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-C; Effective Confining Pressure, σ_o' = 280psi (40.3ksf = 1933kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.54E-05	254000	1.00	1.35	3.54E-05	251000	1.00	1.36
6.62E-05	254000	1.00	1.38	6.70E-05	251000	1.00	1.37
1.34E-04	253700	1.00	1.50	1.35E-04	250000	1.00	1.51
2.92E-04	245000	0.98	1.80	2.92E-04	244800	0.98	1.82

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Table XII-7d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-C; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.31E-06	280470	1.00	2.03E-06	2.15
4.37E-06	280470	1.00	3.59E-06	3.34
8.74E-06	279230	1.00	7.50E-06	2.57
1.76E-05	278940	0.99	1.60E-05	1.25
3.30E-05	279260	1.00	2.85E-05	1.29
6.69E-05	277730	0.99	5.69E-05	1.40
1.38E-04	275300	0.98	1.23E-04	1.65
2.72E-04	271700	0.97	2.26E-04	2.00
4.19E-04	268000	0.96	3.11E-04	2.20

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-7e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-C; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.79E-05	251000	1.00	1.39	1.80E-05	250000	1.00	1.39
3.62E-05	250000	1.00	1.42	3.64E-05	250000	1.00	1.43
6.60E-05	250000	1.00	1.49	6.70E-05	249000	1.00	1.50
1.33E-04	247000	0.98	1.70	1.34E-04	246700	0.99	1.71
2.91E-04	244000	0.97	2.00	2.90E-04	243500	0.97	2.03

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Table XII-8a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-D

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	230000	11026	7426	1.35
70	10080	483.2	239370	11475	7214	0.86
170	24480	1173.6	241050	11556	7234	0.93
340	48960	2347.1	243190	11658	7263	1.09
450	64800	3106.5	245370	11763	7299	1.00

Table XII-8b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-D; Effective Confining Pressure, σ_o' = 340 psi (49.0 ksf = 2347 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
1.23E-05	243400	1.00	1.19E-05	0.61
2.37E-05	243156	1.00	2.28E-05	0.63
4.61E-05	243156	1.00	4.43E-05	0.63
8.77E-05	241690	1.00	8.43E-05	0.64
1.62E-04	241690	1.00	1.56E-04	0.65
2.87E-04	241696	0.99	2.74E-04	0.71
5.44E-04	240260	0.99	5.20E-04	0.73
9.96E-04	238532	0.98	9.46E-04	0.82
1.65E-03	235611	0.97	1.56E-03	0.87

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-8c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-D; Effective Confining Pressure, σ_o' = 340 psi (49.0 ksf = 2347 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.20E-05	230000	1.00	0.42	1.20E-05	229000	1.00	0.42
1.99E-05	229800	1.00	0.43	1.99E-05	228500	1.00	0.44
3.87E-05	228000	0.99	0.44	3.95E-05	228400	1.00	0.47
7.37E-05	228200	0.99	0.47	7.95E-05	228200	0.99	0.50
1.47E-04	228100	0.99	0.49	1.47E-04	228100	0.99	0.52
3.22E-04	228000	0.99	0.52	3.22E-04	228000	0.99	0.55

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Table XII-8d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-D; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
7.60E-06	246300	1.00	7.36E-06	0.52
1.48E-05	246000	1.00	1.43E-05	0.52
2.92E-05	246000	1.00	2.83E-05	0.53
5.90E-05	245000	0.99	5.71E-05	0.52
1.16E-04	245000	0.99	1.12E-04	0.53
2.03E-04	244000	0.98	1.96E-04	0.54
3.76E-04	243000	0.97	3.63E-04	0.55
1.18E-03	242000	0.97	1.14E-03	0.55
2.20E-03	241000	0.95	2.12E-03	0.62
3.95E-03	239000	0.94	3.78E-03	0.70
7.24E-03	237000	0.92	6.87E-03	0.86
1.20E-02	234000	0.90	1.13E-02	1.01
1.49E-02	231000	0.87	1.36E-02	1.49
1.82E-02	230000	0.87	1.60E-02	2.19

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-8e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-D; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.97E-05	231000	1.00	0.40	1.97E-05	231000	1.00	0.40
3.85E-05	230800	1.00	0.40	3.85E-05	230800	1.00	0.41
7.25E-05	230000	0.99	0.42	7.25E-05	230300	0.99	0.42
1.45E-04	230000	0.99	0.43	1.45E-04	230000	0.99	0.43

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Table XII-9a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-E

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	91500	4386	4987	0.63
5	648	31.1	92280	4424	5024	0.48
9	1296	62.1	92155	4418	5021	0.42
18	2592	124.3	92275	4424	5024	0.44
36	5184	248.5	92274	4424	5023	0.42
72	10368	497.0	92280	4424	5023	0.41

Table XII-9b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-E; Effective Confining Pressure, σ_o' = 18 psi (2.6 ksf = 124 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
2.52E-05	92273	1.00	2.47E-05	0.35
5.00E-05	92272	1.00	4.88E-05	0.42
9.83E-05	92845	1.01	9.59E-05	0.39
1.97E-04	92168	1.00	1.92E-04	0.41
3.80E-04	92252	1.00	3.72E-04	0.36
6.83E-04	91494	0.99	6.60E-04	0.55
1.26E-03	90827	0.98	1.21E-03	0.67
2.30E-03	90257	0.98	2.18E-03	0.84
3.93E-03	88840	0.96	3.68E-03	1.10
6.89E-03	86212	0.93	6.33E-03	1.39

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-9c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-E; Effective Confining Pressure, σ_o' = 18 psi (2.6 ksf = 124 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.60E-05	81000	1.00	0.30	4.60E-05	80960	1.00	0.31
8.60E-05	80900	1.00	0.31	8.60E-05	80900	1.00	0.32
1.50E-04	80800	1.00	0.32	1.60E-04	80880	1.00	0.33
3.05E-04	80840	1.00	0.36	3.05E-04	80800	1.00	0.37
4.59E-04	80700	1.00	0.40	4.59E-04	80700	1.00	0.40

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Table XII-9d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-E; Effective Confining Pressure, σ_o' = 72 psi (10.4 ksf = 497 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
2.82E-05	92231	1.00	2.76E-05	0.32
5.48E-05	92214	1.00	5.35E-05	0.37
1.09E-04	92215	1.00	1.06E-04	0.36
2.08E-04	92295	1.00	1.96E-04	0.37
4.20E-04	91614	0.99	4.10E-04	0.39
7.72E-04	91526	0.99	7.53E-04	0.40
1.42E-03	90862	0.99	1.38E-03	0.46
2.46E-03	89531	0.97	2.37E-03	0.59
4.10E-03	87555	0.95	3.92E-03	0.75
6.79E-03	85601	0.93	6.34E-03	1.10
1.17E-02	84306	0.91	1.09E-02	1.28

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-9e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-E; Effective Confining Pressure, σ_o' = 72 psi (10.4 ksf = 497 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.80E-05	82240	1.00	0.29	7.80E-05	82000	1.00	0.30
1.48E-04	81700	1.00	0.31	1.48E-04	81700	1.00	0.32
2.96E-04	81400	0.99	0.33	2.98E-04	81300	0.99	0.34
4.46E-04	81100	0.99	0.41	4.50E-04	81000	0.99	0.40
6.40E-04	81000	0.99	0.46	6.40E-04	80900	0.99	0.47

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Table XII-10a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-F

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	167000	8006	6368	0.40
17	2448	117.4	167700	8039	6383	0.39
34	4896	234.7	167900	8049	6387	0.38
68	9792	469.4	168870	8096	6405	0.34
136	19584	938.9	169660	8133	6418	0.33
272	39168	1877.7	169980	8149	6422	0.33

Table XII-10b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-F; Effective Confining Pressure, σ_o' = 68 psi (9.8 ksf = 469 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
1.25E-05	168710	1.00	1.23E-05	0.36
2.47E-05	168690	1.00	2.42E-05	0.37
4.93E-05	168700	1.00	4.84E-05	0.35
9.79E-05	168690	1.00	9.57E-05	0.37
1.93E-04	168700	1.00	1.89E-04	0.36
3.62E-04	168700	1.00	3.54E-04	0.37
6.97E-04	167960	1.00	6.80E-04	0.40
1.26E-03	167980	1.00	1.22E-03	0.49
2.05E-03	166920	0.99	1.98E-03	0.58
3.62E-03	166000	0.98	3.44E-03	0.70
5.71E-03	163400	0.97	5.41E-03	0.85

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-10c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-F; Effective Confining Pressure, σ_o' = 68 psi (9.8 ksf = 469 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.10E-05	148000	1.00	0.26	2.10E-05	147500	1.00	0.27
4.30E-05	147000	0.99	0.28	4.30E-05	146800	1.00	0.29
8.20E-05	146600	0.99	0.31	8.20E-05	146300	0.99	0.32
1.62E-04	146200	0.99	0.35	1.62E-04	145500	0.99	0.36
3.49E-04	146000	0.99	0.40	3.49E-04	145000	0.98	0.41

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Table XII-10d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-F; Effective Confining Pressure, σ_o' = 272 psi (39.2 ksf = 1878 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
2.97E-05	170780	1.00	2.92E-05	0.30
1.48E-05	170830	1.00	1.45E-05	0.29
5.87E-05	170820	1.00	5.76E-05	0.29
1.16E-04	170830	1.00	1.14E-04	0.29
2.28E-04	170790	1.00	2.24E-04	0.30
4.20E-04	170650	1.00	4.12E-04	0.30
8.56E-04	169920	0.99	8.39E-04	0.32
1.59E-03	168870	0.99	1.55E-03	0.37
3.34E-03	167980	0.98	3.25E-03	0.51
5.88E-05	170670	1.00	5.77E-05	0.29
6.61E-03	164410	0.96	6.30E-03	0.76
9.46E-03	161960	0.95	8.92E-03	0.97

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-10e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-F; Effective Confining Pressure, σ_o' =272 psi (39.2 ksf = 1878 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.30E-05	170000	1.00	0.22	2.30E-05	170000	1.00	0.23
4.72E-05	169500	1.00	0.23	4.72E-05	169500	1.00	0.24
2.10E-04	169000	1.00	0.25	2.07E-04	169000	1.00	0.26
1.33E-04	168800	0.99	0.28	1.34E-04	168500	0.99	0.28
2.24E-04	168500	0.99	0.29	2.24E-04	168300	0.99	0.30
3.55E-04	168300	0.99	0.31	3.50E-04	168100	0.99	0.32

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Table XII-11a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-G

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	247570	11868	7398	0.50
30	4320	207.1	248640	11920	7414	0.51
60	8640	414.2	248710	11923	7415	0.48
120	17280	828.4	249540	11963	7426	0.48
240	34560	1656.8	249960	11983	7431	0.47
450	64800	3106.5	251140	12040	7444	0.46

Table XII-11b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-G; Effective Confining Pressure, σ_o' = 120 psi (17.3 ksf = 828 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
5.98E-06	249870	1.00	5.78E-06	0.56
1.19E-05	249620	1.00	1.15E-05	0.53
1.19E-05	249630	1.00	1.15E-05	0.53
2.37E-05	249610	1.00	2.30E-05	0.53
4.73E-05	249630	1.00	4.63E-05	0.53
9.43E-05	249600	1.00	9.12E-05	0.54
1.78E-04	249670	1.00	1.72E-04	0.55
6.95E-04	248530	0.99	6.70E-04	0.60
1.29E-03	247470	0.99	1.24E-03	0.69
2.30E-03	245310	0.98	2.18E-03	0.88
3.52E-03	242090	0.97	3.27E-03	1.20

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-11c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-G; Effective Confining Pressure, σ_o' =120 psi (17.3 ksf = 828 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.24E-05	235000	1.01	0.42	5.24E-05	232900	1.00	0.43
1.06E-04	232200	0.99	0.43	1.06E-04	231500	1.00	0.44
1.56E-04	231500	0.99	0.47	1.56E-04	231000	0.99	0.48
2.28E-04	231000	0.99	0.48	2.28E-04	230600	0.99	0.49

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Table XII-11d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-G; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
5.29E-06	251140	1.00	5.09E-06	0.61
1.05E-05	251170	1.00	1.01E-05	0.58
2.09E-05	251110	1.00	2.01E-05	0.59
4.13E-05	251400	1.00	3.98E-05	0.60
8.30E-05	251110	1.00	7.99E-05	0.61
1.54E-04	251120	1.00	1.48E-04	0.62
3.11E-04	250010	1.00	3.00E-04	0.63
6.16E-04	250280	1.00	5.92E-04	0.64
1.17E-03	248950	0.99	1.12E-03	0.69
2.14E-03	246820	0.98	2.04E-03	0.79
3.48E-03	244630	0.97	3.27E-03	1.00

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-11e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-G; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.93E-05	240000	1.00	0.47	2.93E-05	239600	1.00	0.48
5.50E-05	238400	1.00	0.48	5.50E-05	238000	1.00	0.49
1.12E-04	237000	0.99	0.50	1.12E-04	236700	0.99	0.51
1.66E-04	235000	0.98	0.51	1.66E-04	234000	0.98	0.52
2.40E-04	234000	0.98	0.52	2.40E-04	233000	0.98	0.53

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Table XII-12a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-H

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	238000	11410	7230	1.01
50	7200	345.2	238470	11432	7238	1.00
100	14400	690.3	239570	11485	7254	0.99
200	28800	1380.7	240740	11541	7271	0.98
400	57600	2761.3	246420	11813	7355	1.03
450	64800	3106.5	246490	11817	7356	1.10

Table XII-12b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-H; Effective Confining Pressure, σ_o' = 200 psi (28.8 ksf = 1381 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
3.99E-06	240840	1.00	3.79E-06	0.82
7.80E-06	240840	1.00	7.31E-06	1.07
1.54E-05	240850	1.00	1.44E-05	1.15
3.08E-05	240840	1.00	2.87E-05	1.13
6.15E-05	240820	1.00	5.74E-05	1.12
1.14E-04	240870	1.00	1.06E-04	1.15
2.32E-04	239720	1.00	2.16E-04	1.15
4.60E-04	239710	1.00	4.28E-04	1.17
8.89E-04	238640	0.99	8.22E-04	1.28
1.65E-03	235340	0.98	1.52E-03	1.36
2.74E-03	232080	0.96	2.49E-03	1.56

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-12c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-H; Effective Confining Pressure, σ_o' = 200 psi (28.8 ksf = 1381 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.54E-05	189900	1.00	1.10	3.54E-05	189900	1.00	1.11
6.67E-05	189900	1.00	1.11	6.67E-05	188600	1.00	1.12
2.00E-04	189500	1.00	1.12	2.00E-04	188500	0.99	1.13
2.85E-04	189400	1.00	1.13	2.90E-04	188000	0.99	1.14

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Table XII-12d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-H; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
4.48E-06	246500	1.00	4.23E-06	0.95
8.72E-06	246520	1.00	8.17E-06	1.04
1.72E-05	246520	1.00	1.62E-05	1.05
3.43E-05	245420	1.00	3.23E-05	1.03
6.83E-05	245390	1.00	6.41E-05	1.03
1.26E-04	245400	1.00	1.19E-04	1.04
1.27E-04	245430	1.00	1.19E-04	1.05
2.56E-04	245390	1.00	2.39E-04	1.07
5.01E-04	244270	0.99	4.69E-04	1.09
9.46E-04	243170	0.99	8.82E-04	1.15
1.72E-03	239840	0.97	1.59E-03	1.35

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-12e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-H; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.69E-05	204000	1.01	0.91	1.69E-05	199800	1.00	0.91
3.50E-05	198500	0.99	0.92	3.50E-05	198000	1.00	0.93
6.50E-05	197100	0.98	0.94	6.50E-05	197000	0.99	0.95
1.24E-04	195500	0.97	0.98	1.24E-04	196000	0.99	1.00
1.93E-04	195600	0.97	1.02	1.93E-04	195300	0.98	1.04

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Table XII-13a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-I

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	55665	2669	4559	0.25
62	8928	428.0	55728	2672	4561	0.24
125	18000	862.9	55715	2671	4559	0.26
250	36000	1725.8	55766	2673	4560	0.21
450	64800	3106.5	55770	2674	4562	0.22

Table XII-13b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-I; Effective Confining Pressure, σ_o' = 250 psi (36.0 ksf = 1726 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
6.01E-05	56273	1.00	5.95E-05	0.20
1.14E-04	55722	0.99	1.13E-04	0.22
2.39E-04	55725	0.99	2.36E-04	0.23
4.36E-04	55776	0.99	4.30E-04	0.22
9.02E-04	55206	0.98	8.82E-04	0.23
1.65E-03	55215	0.98	1.62E-03	0.22
3.08E-03	54727	0.97	3.03E-03	0.27
5.76E-03	54276	0.96	5.65E-03	0.31
1.10E-02	53740	0.95	1.08E-02	0.36
1.91E-02	52806	0.94	1.85E-02	0.47
2.87E-02	51833	0.92	2.77E-02	0.59

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve
[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-13c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-I; Effective Confining Pressure, σ_o' = 250 psi (36.0 ksf = 1726 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.99E-05	54010	1.00	0.18	6.00E-05	53450	1.00	0.19
1.21E-04	53900	1.00	0.19	1.21E-04	53500	1.00	0.19
2.26E-04	53500	0.99	0.20	2.26E-04	53400	1.00	0.21
3.05E-04	53440	0.99	0.21	3.05E-04	53360	1.00	0.22
6.79E-04	53400	0.99	0.22	6.80E-04	53300	1.00	0.23

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Table XII-13d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-I; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
6.26E-05	55769	1.00	6.17E-05	0.23
1.11E-04	55770	1.00	1.10E-04	0.22
2.27E-04	55318	0.99	2.23E-04	0.23
4.09E-04	54765	0.98	3.85E-04	0.23
7.95E-04	54764	0.98	7.80E-04	0.24
1.49E-03	54315	0.97	1.47E-03	0.29
2.97E-03	53833	0.97	2.91E-03	0.32
5.59E-03	53338	0.96	5.46E-03	0.36
1.08E-02	52369	0.94	1.06E-02	0.38
2.00E-02	52361	0.94	1.95E-02	0.43
3.17E-02	51829	0.93	3.07E-02	0.53

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-13e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-I; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.22E-04	53900	1.01	0.22	1.22E-04	53900	1.01	0.23
2.31E-04	53200	0.99	0.24	2.31E-04	53200	0.99	0.25
4.66E-04	53000	0.99	0.26	4.66E-04	53000	0.99	0.27
6.96E-04	52600	0.98	0.27	6.96E-04	52500	0.98	0.28
1.02E-03	52300	0.98	0.28	1.02E-03	52200	0.97	0.29

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Table XII-14a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-J

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	202000	9684	6869	1.30
90	12960	621.3	202580	9712	6887	1.16
180	25920	1242.6	205740	9863	6939	1.15
360	51840	2485.2	208720	10006	6987	1.14
450	64800	3106.5	208840	10012	6988	1.14

Table XII-14b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-J; Effective Confining Pressure, σ_o' = 360 psi (51.8 ksf = 2485 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
4.37E-06	208690	1.00	4.04E-06	1.28
8.60E-06	208700	1.00	8.12E-06	1.14
1.72E-05	207710	1.00	1.60E-05	1.14
3.41E-05	208680	1.00	3.18E-05	1.15
6.88E-05	208660	1.00	6.73E-05	1.14
1.28E-04	208670	1.00	1.20E-04	1.14
2.61E-04	207720	1.00	2.43E-04	1.16
5.23E-04	207680	1.00	4.87E-04	1.15
1.04E-03	207680	1.00	9.68E-04	1.15
2.06E-03	206680	0.99	1.92E-03	1.16

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-14c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-J; Effective Confining Pressure, σ_o' = 360 psi (51.8 ksf = 2485 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.79E-05	185000	1.00	1.15	1.80E-05	185000	1.00	1.16
3.60E-05	182200	0.99	1.16	3.60E-05	182000	0.99	1.16
6.80E-05	181400	0.99	1.15	6.85E-05	181300	0.99	1.17
1.35E-04	181000	0.99	1.16	1.35E-04	181000	0.99	1.17
2.00E-04	181000	0.99	1.17	2.00E-04	180800	0.99	1.18

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Table XII-14d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-J; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
4.32E-06	208750	1.00	4.07E-06	0.98
8.38E-06	208720	1.00	7.72E-06	1.33
1.65E-05	209730	1.00	1.53E-05	1.19
3.27E-05	209760	1.00	3.04E-05	1.19
6.59E-05	208750	1.00	6.12E-05	1.21
1.23E-04	208930	1.00	1.14E-04	1.22
2.51E-04	208710	1.00	2.33E-04	1.21
5.00E-04	208700	1.00	4.64E-04	1.22
9.95E-04	207700	1.00	9.25E-04	1.20
1.95E-03	206950	0.99	1.80E-03	1.23
3.48E-03	205930	0.99	3.21E-03	1.35

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-14e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-J; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.10E-05	190300	1.00	1.20	2.10E-05	190000	1.00	1.21
4.08E-05	189400	1.00	1.21	4.08E-05	189200	1.00	1.23
7.40E-05	188000	0.99	1.22	7.40E-05	187600	0.99	1.24
1.50E-04	187600	0.99	1.23	1.50E-04	186000	0.98	1.24
2.18E-04	187000	0.98	1.24	2.18E-04	185000	0.98	1.25

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Table XII-15a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-Q

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	32915	1578	3576	1.41
18	2520	120.8	34160	1638	3643	1.32
35	5040	241.6	35159	1686	3696	1.24
70	10080	483.2	36283	1739	3753	1.22

Table XII-15b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-Q; Effective Confining Pressure, σ_o' = 70 psi (10.1 ksf = 483 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
4.17E-04	36188	1.00	3.95E-04	1.00
2.19E-04	36205	1.00	2.04E-04	1.00
8.24E-04	36010	1.00	7.69E-04	1.01
1.58E-03	35641	0.98	1.47E-03	1.03
2.88E-03	34719	0.96	2.66E-03	1.04
5.43E-03	34183	0.94	4.97E-03	1.10
1.12E-02	33201	0.92	1.02E-02	1.20
2.31E-02	32754	0.91	2.11E-02	1.40
4.59E-02	31375	0.87	4.16E-02	1.63

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-15c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-Q; Effective Confining Pressure, σ_o' = 70 psi (10.1 ksf = 483 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.59E-04	34470	1.00	1.00	1.59E-04	34210	1.00	1.00
3.19E-04	34170	1.00	1.00	3.19E-04	34030	1.00	1.00
6.42E-04	33910	0.99	1.00	6.43E-04	33800	0.99	1.00
1.00E-03	33490	0.98	1.01	1.00E-03	33341	0.98	1.02
2.48E-03	32700	0.95	1.03	2.49E-03	32680	0.96	1.04
5.00E-03	32000	0.93	1.10	5.09E-03	31900	0.93	1.12
1.00E-02	31430	0.92	1.21	1.10E-02	31420	0.92	1.23

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Table XII-16a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-R

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	144760	6940	6231	0.25
44	6336	303.7	145030	6953	6235	0.26
88	12672	607.5	145160	6959	6231	0.28
176	25344	1215.0	145370	6969	6235	0.27

Table XII-16b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-R; Effective Confining Pressure, σ_o' = 176 psi (25.3 ksf = 1215 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
2.69E-04	145390	1.00	2.65E-04	0.25
1.37E-04	145390	1.00	1.35E-04	0.25
5.24E-04	145390	1.00	5.15E-04	0.26
9.94E-04	144380	0.99	9.77E-04	0.28
1.97E-03	144380	0.99	1.93E-03	0.31
3.58E-03	143360	0.99	3.50E-03	0.33
6.98E-03	143380	0.99	6.82E-03	0.37
1.28E-02	141360	0.97	1.25E-02	0.44
2.33E-02	139410	0.96	2.25E-02	0.56
3.89E-02	137410	0.95	3.72E-02	0.72
5.71E-02	133530	0.92	5.40E-02	0.92

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-16c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-R; Effective Confining Pressure, σ_o' = 176 psi (25.3 ksf = 1215 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.07E-05	125000	1.00	0.25	4.07E-05	125000	1.00	0.25
8.60E-05	125000	1.00	0.26	8.60E-05	124800	1.00	0.27
1.73E-04	124800	1.00	0.28	1.73E-04	124600	1.00	0.29
3.22E-04	124600	1.00	0.29	3.23E-04	124300	0.99	0.30
6.47E-04	124000	0.99	0.30	6.47E-04	123700	0.99	0.31
1.00E-03	123900	0.99	0.31	1.00E-03	123800	0.99	0.32
2.82E-03	123100	0.98	0.33	2.83E-03	123000	0.98	0.34

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Table XII-17a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-S

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	210000	10067	6368	0.40
17	2448	117.4	210480	10090	7130	0.34
34	4896	234.7	210500	10091	7408	0.35
68	9792	469.4	210880	10110	7136	0.34
136	19584	938.9	208590	10000	7096	0.34
272	39168	1877.7	208840	10012	6422	0.33

Table XII-17b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-S; Effective Confining Pressure, σ_o' = 68 psi (9.8 ksf = 469 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
8.19E-05	211290	1.00	8.08E-05	0.30
1.62E-04	211070	1.00	1.59E-04	0.30
3.17E-04	209980	0.99	3.10E-04	0.35
6.28E-04	209800	0.99	6.14E-04	0.36
1.24E-03	209790	0.99	1.21E-03	0.40
2.29E-03	209600	0.99	2.23E-03	0.44
4.37E-03	208470	0.99	4.24E-03	0.49
8.25E-03	206290	0.98	7.98E-03	0.55
1.46E-02	202330	0.96	1.40E-02	0.64
2.30E-02	198360	0.94	2.17E-02	0.89
3.24E-02	190970	0.90	2.96E-02	1.47

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-17c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-S; Effective Confining Pressure, σ_o' = 68 psi (9.8 ksf = 469 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.52E-05	201100	1.00	0.22	1.52E-05	201000	1.00	0.23
1.44E-04	200000	1.00	0.23	1.44E-04	199999	1.00	0.24
4.40E-04	200000	1.00	0.32	4.40E-04	200000	1.00	0.33
8.80E-04	200000	1.00	0.38	8.80E-04	200000	1.00	0.39
1.00E-03	200000	1.00	0.39	1.00E-03	200000	1.00	0.40
1.91E-03	200000	1.00	0.44	1.91E-03	200000	1.00	0.46

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Table XII-17d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-S; Effective Confining Pressure, σ_o' = 272 psi (39.2 ksf = 1878 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
8.28E-05	208860	1.00	8.17E-05	0.30
1.67E-04	208870	1.00	1.63E-04	0.33
3.28E-04	208670	1.00	3.22E-04	0.32
6.42E-04	208300	1.00	6.27E-04	0.37
1.25E-03	207900	1.00	1.22E-03	0.39
2.29E-03	207570	0.99	2.23E-03	0.42
4.44E-03	205360	0.98	4.32E-03	0.47
8.18E-03	203200	0.97	7.89E-03	0.58
1.42E-02	199240	0.95	1.35E-02	0.73
2.09E-02	195320	0.94	1.98E-02	0.88
3.34E-02	191420	0.92	3.00E-02	1.36

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-17e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-S; Effective Confining Pressure, σ_o' = 272 psi (39.2 ksf = 1878 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.45E-05	202200	1.00	0.17	2.02E+05	202000	1.00	0.18
2.96E-04	202000	1.00	0.19	2.96E-04	201200	1.97	0.19
1.00E-03	200300	0.99	0.37	1.00E-03	200000	0.99	0.38
1.94E-03	199600	0.99	0.44	1.00E-03	199500	0.99	0.50

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Table XII-18a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-T

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	247570	11868	7398	0.50
30	4320	207.1	344310	16506	8752	0.24
60	8640	414.2	344800	16530	8757	0.24
120	17280	828.4	345320	16555	8763	0.23
240	34560	1656.8	342860	16437	8729	0.22
450	64800	3106.5	342970	16442	8728	0.22

Table XII-18b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-T; Effective Confining Pressure, σ_o' = 120 psi (17.3 ksf = 828 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
1.33E-04	345290	1.00	1.30E-04	0.21
6.59E-05	344940	1.00	6.47E-05	0.21
2.67E-04	345780	1.00	2.61E-04	0.22
5.31E-04	345760	1.00	5.24E-04	0.21
5.32E-04	345760	1.00	5.25E-04	0.22
1.08E-03	345800	1.00	1.06E-03	0.22
1.94E-03	345790	1.00	1.91E-03	0.26
3.79E-03	343910	1.00	3.73E-03	0.28
6.94E-03	343570	1.00	6.80E-03	0.33
1.21E-02	338170	0.98	1.18E-02	0.47
2.28E-02	337750	0.98	2.21E-02	0.49
3.56E-02	333190	0.96	3.43E-02	0.62
5.54E-02	324520	0.94	5.27E-02	0.82
6.84E-02	320060	0.93	6.47E-02	0.89

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-18c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-T; Effective Confining Pressure, σ_o' = 120 psi (17.3 ksf = 828 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.24E-05	285000	1.00	0.42	5.24E-05	282900	1.00	0.43
1.06E-04	282000	0.99	0.43	1.06E-04	281500	1.00	0.44
1.56E-04	281000	0.99	0.47	1.56E-04	281000	0.99	0.48
2.28E-04	281000	0.99	0.48	2.28E-04	280600	0.99	0.49

DTN: MO0203DHRSSWHB.001

Table XII-18d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-T; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average⁺ Shearing Strain, %	Material Damping Ratio^x, D, %
6.95E-05	343170	1.00	6.86E-05	0.22
1.38E-04	343170	1.00	1.36E-04	0.22
1.38E-04	343180	1.00	1.36E-04	0.22
2.75E-04	343150	1.00	2.71E-04	0.23
5.43E-04	343210	1.00	5.36E-04	0.21
1.09E-03	343180	1.00	1.07E-03	0.22
1.85E-03	341030	0.99	1.82E-03	0.25
3.30E-03	342790	1.00	3.23E-03	0.32
6.20E-03	340140	0.99	6.05E-03	0.40
1.16E-02	339770	0.99	1.13E-02	0.47
2.19E-02	335160	0.98	2.12E-02	0.57
3.65E-02	330670	0.96	3.50E-02	0.67
7.52E-02	322430	0.94	7.08E-02	0.97

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-18e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-T; Effective Confining Pressure, σ_o' = 450 psi (64.8 ksf = 3106 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.93E-05	290000	1.00	0.47	2.93E-05	289600	1.00	0.48
5.50E-05	288400	1.00	0.48	5.50E-05	288000	1.00	0.49
1.12E-04	287400	0.99	0.50	1.12E-04	286700	0.99	0.51
1.66E-04	285000	0.98	0.51	1.66E-04	284000	0.98	0.52
2.40E-04	284000	0.98	0.52	2.40E-04	283300	0.98	0.53

DTN: MO0203DHRSSWHB.001

Table XII-19a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-X

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio, Dmin, %	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)		
8	1152	55.2	1098	53	573	2.17	0.81
16	2304	110.5	1875	90	749	1.59	0.81
32	4608	220.9	2854	137	923	1.29	0.81

Table XII-19b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-X; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
8.56E-05	2852	1.00	8.04E-05	1.02
1.66E-04	2851	1.00	1.55E-04	1.04
3.28E-04	2839	1.00	3.06E-04	1.06
6.37E-04	2813	0.99	5.90E-04	1.10
1.21E-03	2765	0.97	1.12E-03	1.34
2.12E-03	2696	0.95	1.93E-03	1.54
3.93E-03	2585	0.91	3.49E-03	1.99
7.40E-03	2374	0.83	6.46E-03	2.28
1.37E-02	2077	0.73	1.14E-02	3.02
2.55E-02	1699	0.60	2.01E-02	4.14
4.49E-02	1402	0.49	3.34E-02	5.27

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XII-19c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-X; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.89E-04	2500	1.00	0.95	1.89E-04	2499	1.00	0.96
3.80E-04	2480	1.00	0.96	3.80E-04	2478	1.00	0.98
7.71E-04	2470	0.99	1.12	7.71E-04	2465	0.99	1.14
1.00E-03	2400	0.96	1.28	1.00E-03	2395	0.96	1.30
2.44E-03	2350	0.94	1.62	2.44E-03	2320	0.93	1.63
5.77E-03	2200	0.88	2.32	5.79E-03	2180	0.88	2.34

DTN: MO0203DHRSSWHB.001

ATTACHMENT XIII

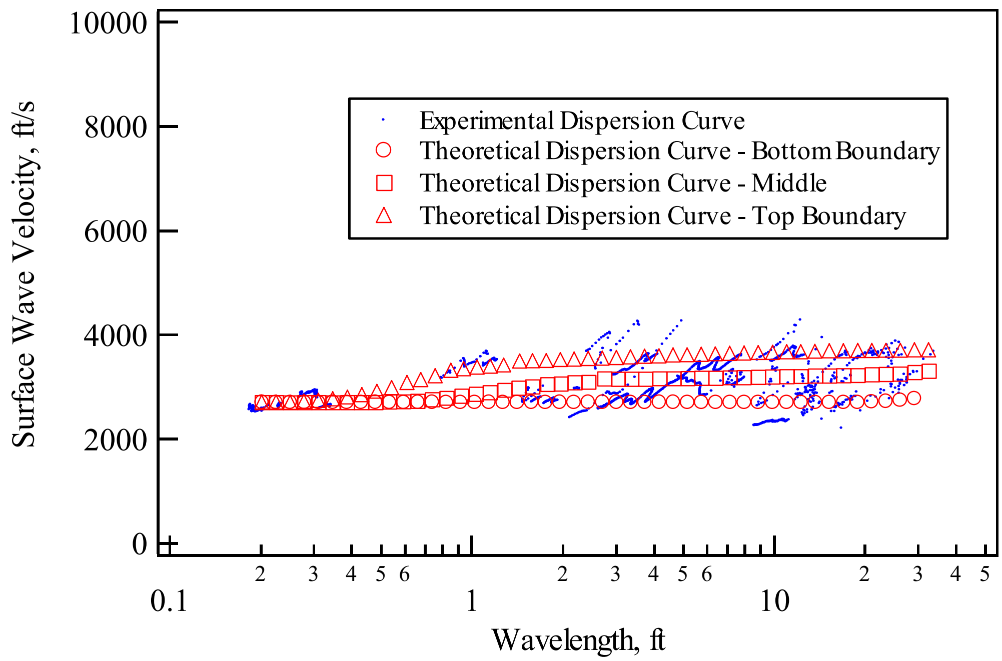
SASW VELOCITY PLOTS – ESF

ATTACHMENT XIII

SASW VELOCITY PLOTS – ESF

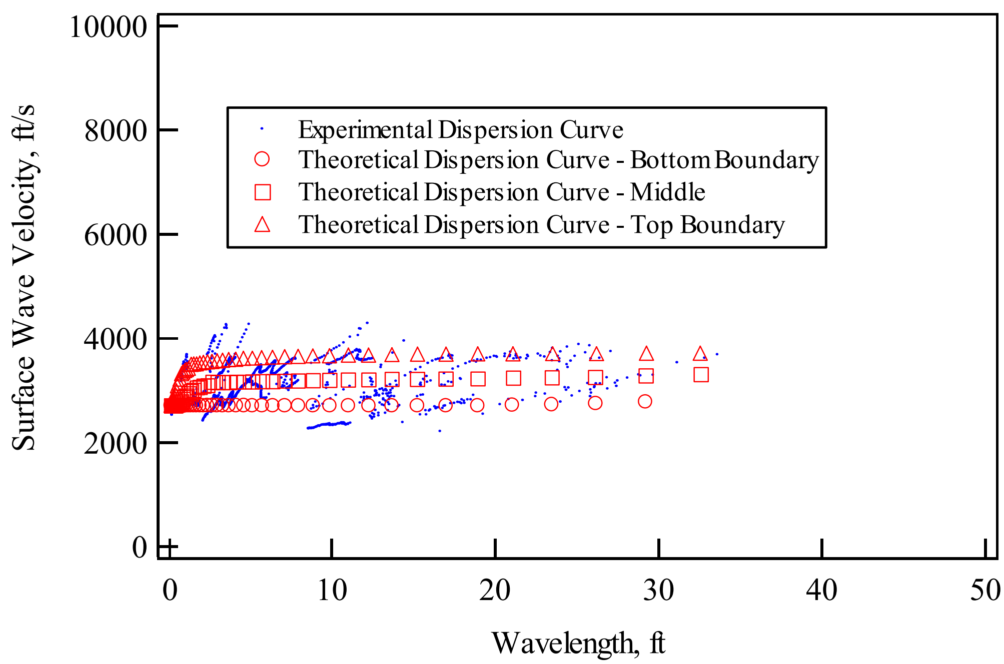
As discussed in Section 6.3.2, this attachment presents interpretive results of five SASW surveys performed in the Exploration Studies Facility (ESF). Each figure contains dispersion curves (both experimental and theoretical in linear and semi-log space) and the resulting shear-wave and compression-wave velocity profiles.

A detailed description of each analysis can be found in the associated appendix in scientific notebook SN-M&O-SCI-040-V1 (Wong 2002a).



(Wong, 2002e, Appendix 28)

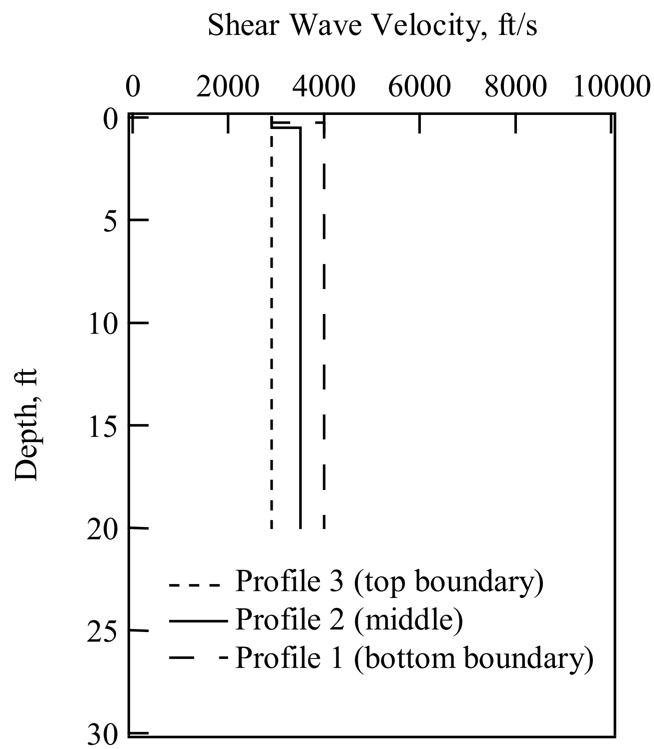
a. SASW-T1 Dispersion Curves (Log Plot)



(Wong, 2002e, Appendix 28)

b. SASW-T1 Dispersion Curves (Linear Plot)

Figure XIII-1. SASW-T1 Results



DTN: MO0206SASWROCK.000

c. SASW-T1 Shear Wave Velocity Profile

Location: SASW-T1 Profile 3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	20	5425	2900	0.25	145

Location: SASW-T1 Profile 2

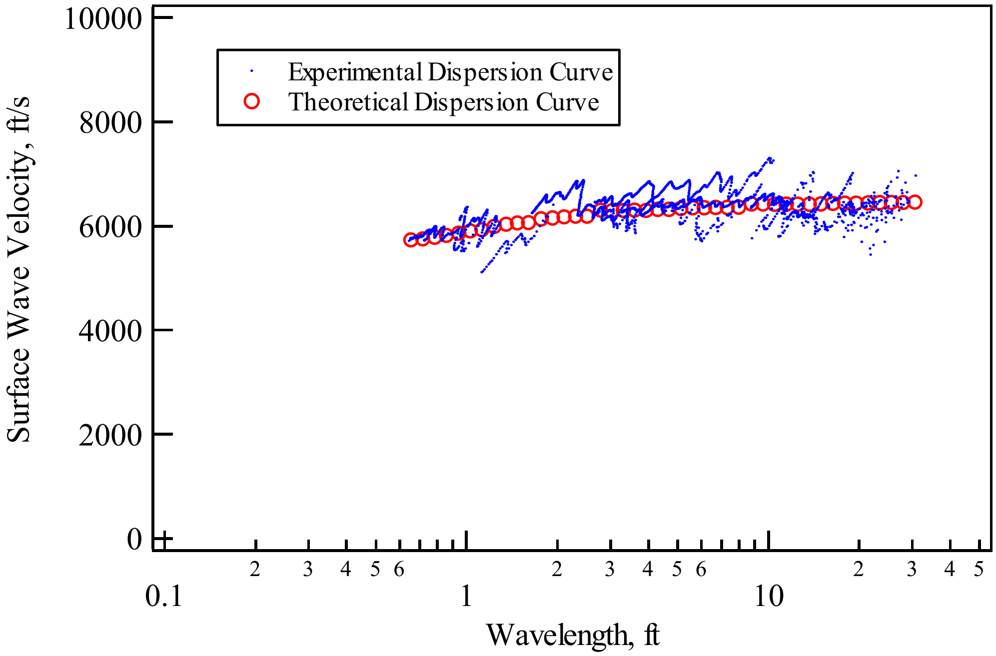
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	5425	2900	0.25	145
2	19.5	6548	3500	0.25	145

Location: SASW-T1 Profile 1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.3	5425	2900	0.25	145
2	19.7	7483	4000	0.25	145

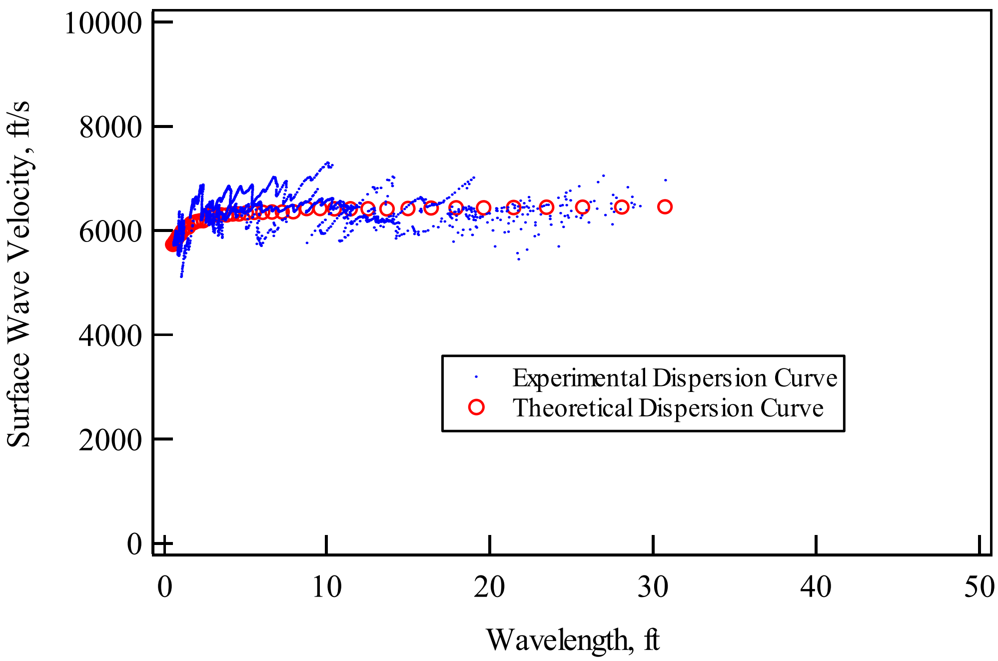
DTN: MO0206SASWROCK.000
* Poisson's ratio and mass density from Wong (2002a, Appendix 28)

Figure XIII-1. SASW-T1 Results (continued)



(Wong, 2002e, Appendix 29)

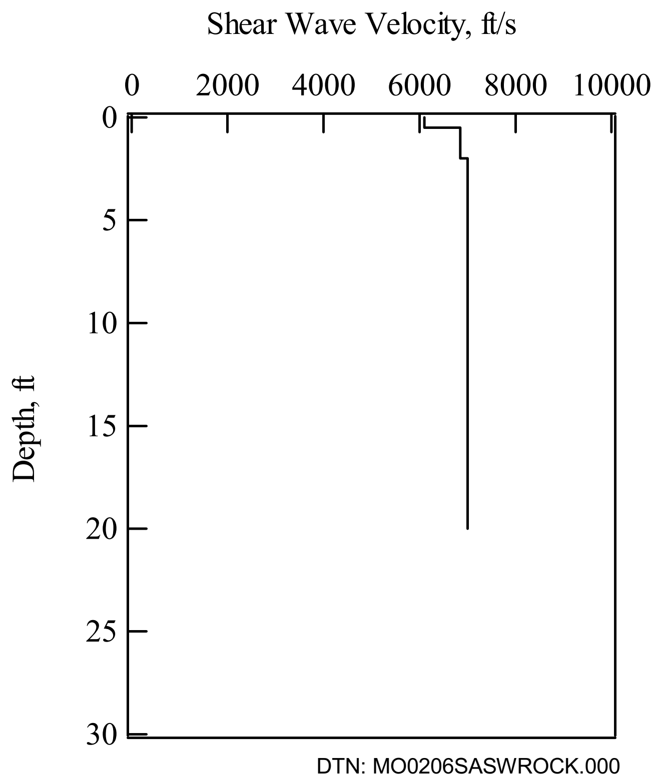
a. SASW-T2 Dispersion Curves (Log Plot)



(Wong, 2002e, Appendix 29)

b. SASW-T2 Dispersion Curves (Linear Plot)

Figure XIII-2. SASW-T2 Results



c. SASW-T2 Shear Wave Velocity Profile

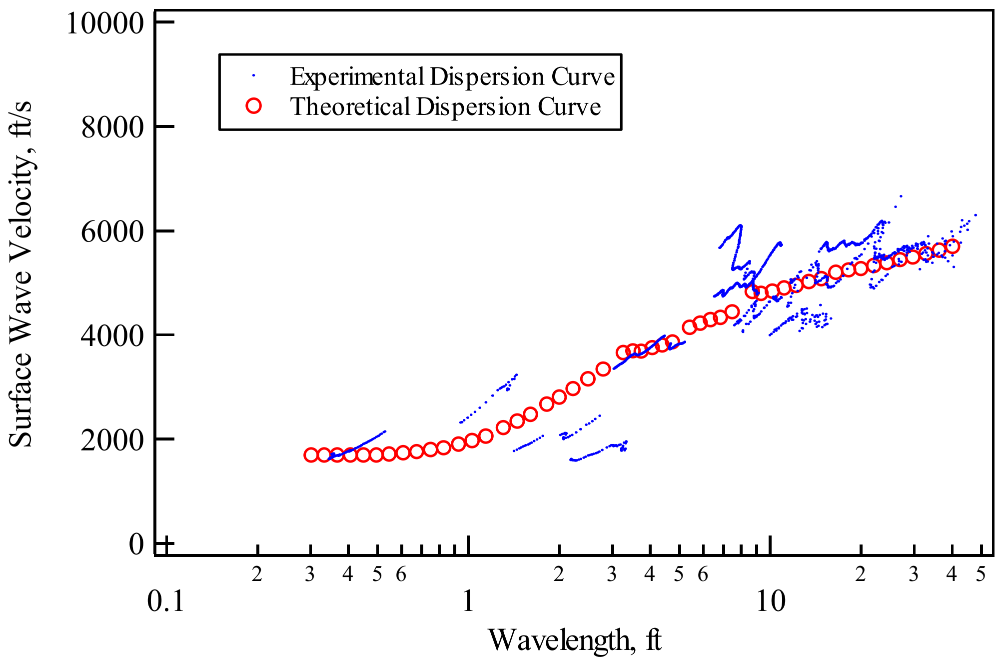
Location: SASW-T2

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	11412	6100	0.25	145
2	1.5	12815	6850	0.25	145
3	18	13096	7000	0.25	145

DTN: MO0206SASWROCK.000

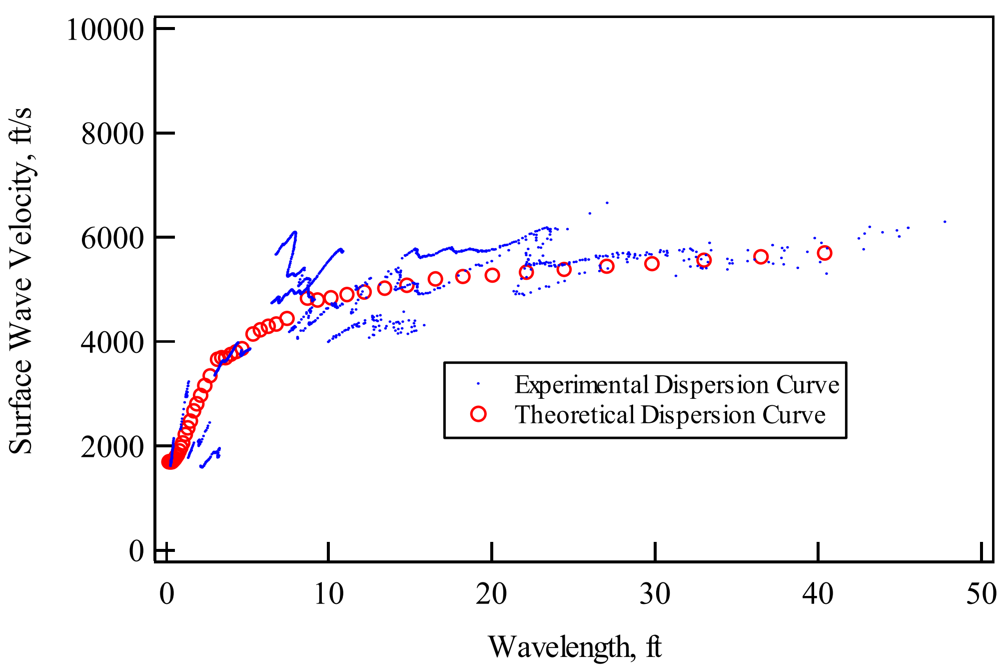
* Poisson's ratio and mass density from Wong (2002a, Appendix 29)

Figure XIII-2. SASW-T2 Results (continued)



(Wong, 2002e, Appendix 30)

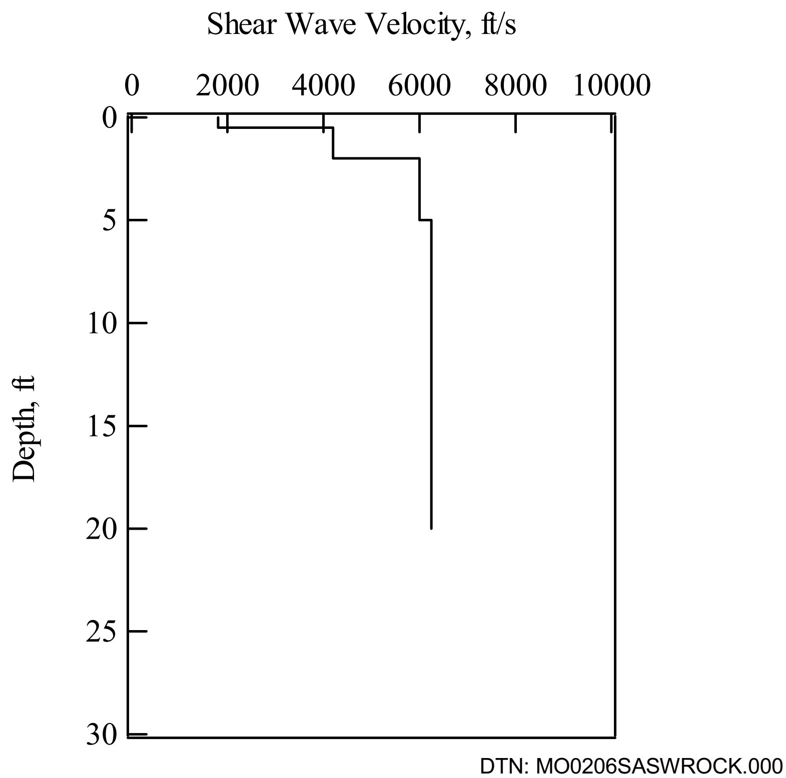
a. SASW-T3 Dispersion Curves (Log Plot)



(Wong, 2002e, Appendix 30)

b. SASW-T3 Dispersion Curves (Linear Plot)

Figure XIII-3. SASW-T3 Results



c. SASW-T3 Shear Wave Velocity Profile

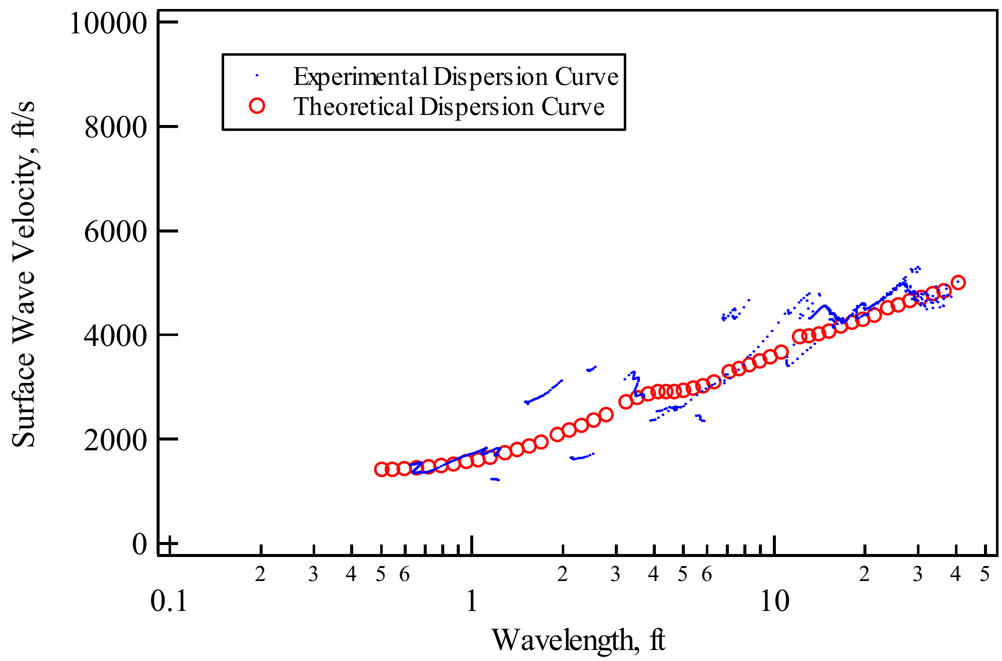
Location: SASW-T3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	3368	1800	0.25	145
2	1.5	7858	4200	0.25	145
3	3	11225	6000	0.25	145
4	15	11693	6250	0.25	145

DTN: MO0206SASWROCK.000

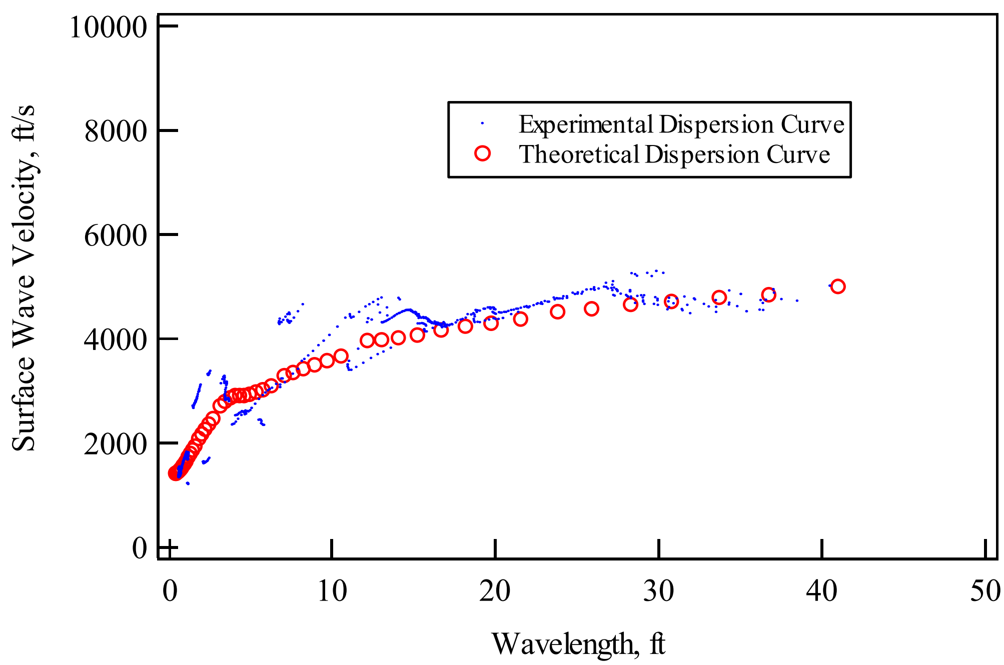
* Poisson's ratio and mass density from Wong (2002a, Appendix 30)

Figure XIII-3. SASW-T3 Results (continued)



(Wong, 2002e, Appendix 31)

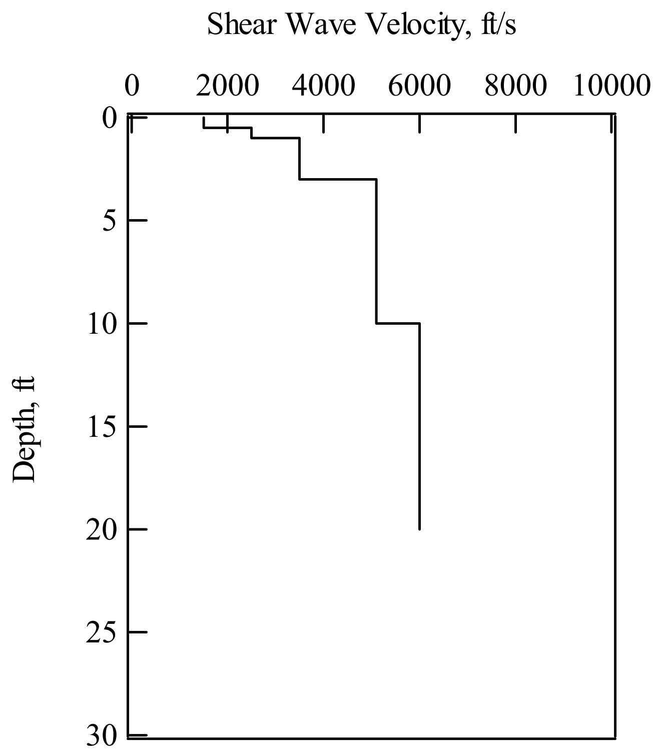
a. SASW-T4 Dispersion Curves (Log Plot)



(Wong, 2002e, Appendix 31)

b. SASW-T4 Dispersion Curves (Linear Plot)

Figure XIII-4. SASW-T4 Results



DTN: MO0206SASWROCK.000

c. SASW-T4 Shear Wave Velocity Profile

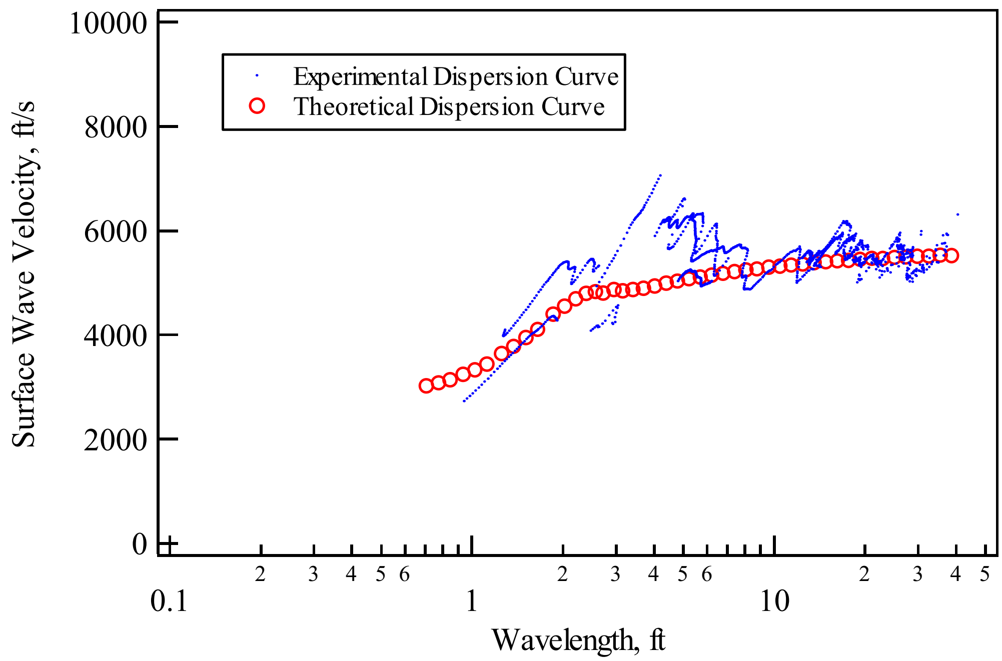
Location: SASW-T4

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	2806	1500	0.25	145
2	0.5	4677	2500	0.25	145
3	2	6548	3500	0.25	145
4	7	9541	5100	0.25	145
5	10	11225	6000	0.25	145

DTN: MO0206SASWROCK.000

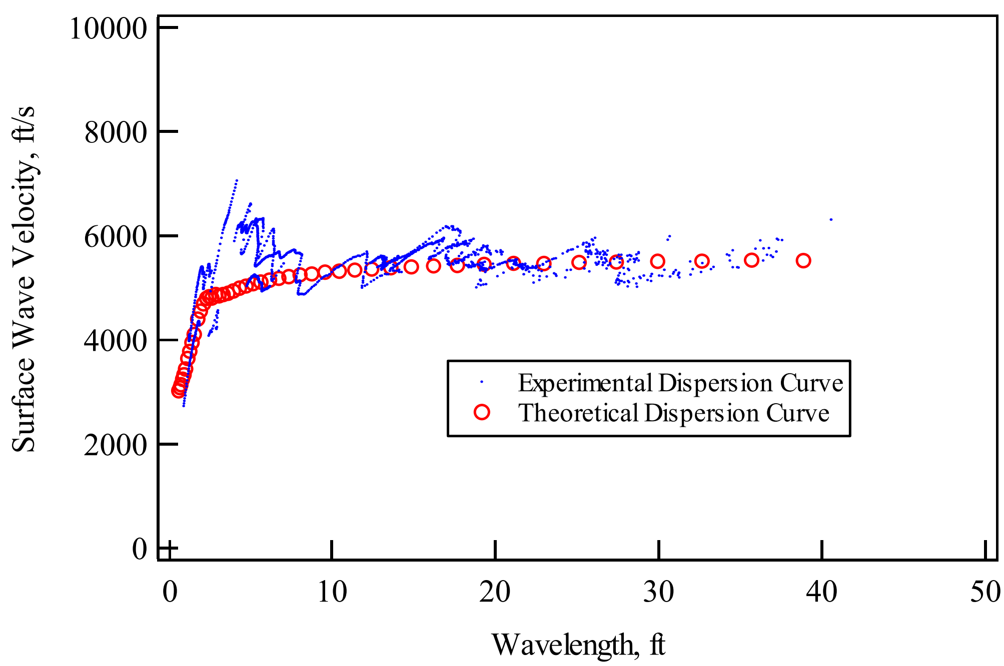
* Poisson's ratio and mass density from Wong (2002a, Appendix 31)

Figure XIII-4. SASW-T4 Results (continued)



(Wong, 2002e, Appendix 32)

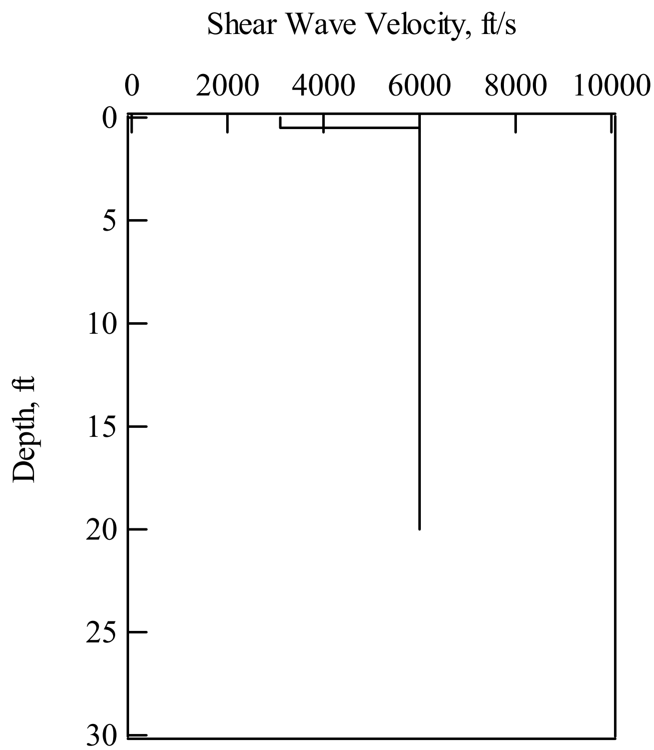
a. SASW-T5 Dispersion Curves (Log Plot)



(Wong, 2002e, Appendix 32)

b. SASW-T5 Dispersion Curves (Linear Plot)

Figure XIII-5. SASW-T5 Results



DTN: MO0206SASWROCK.000

c. SASW-T5 Shear Wave Velocity Profile

Location: SASW-T5

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	5800	3100	0.25	145
2	19.5	11225	6000	0.25	145

DTN: MO0206SASWROCK.000

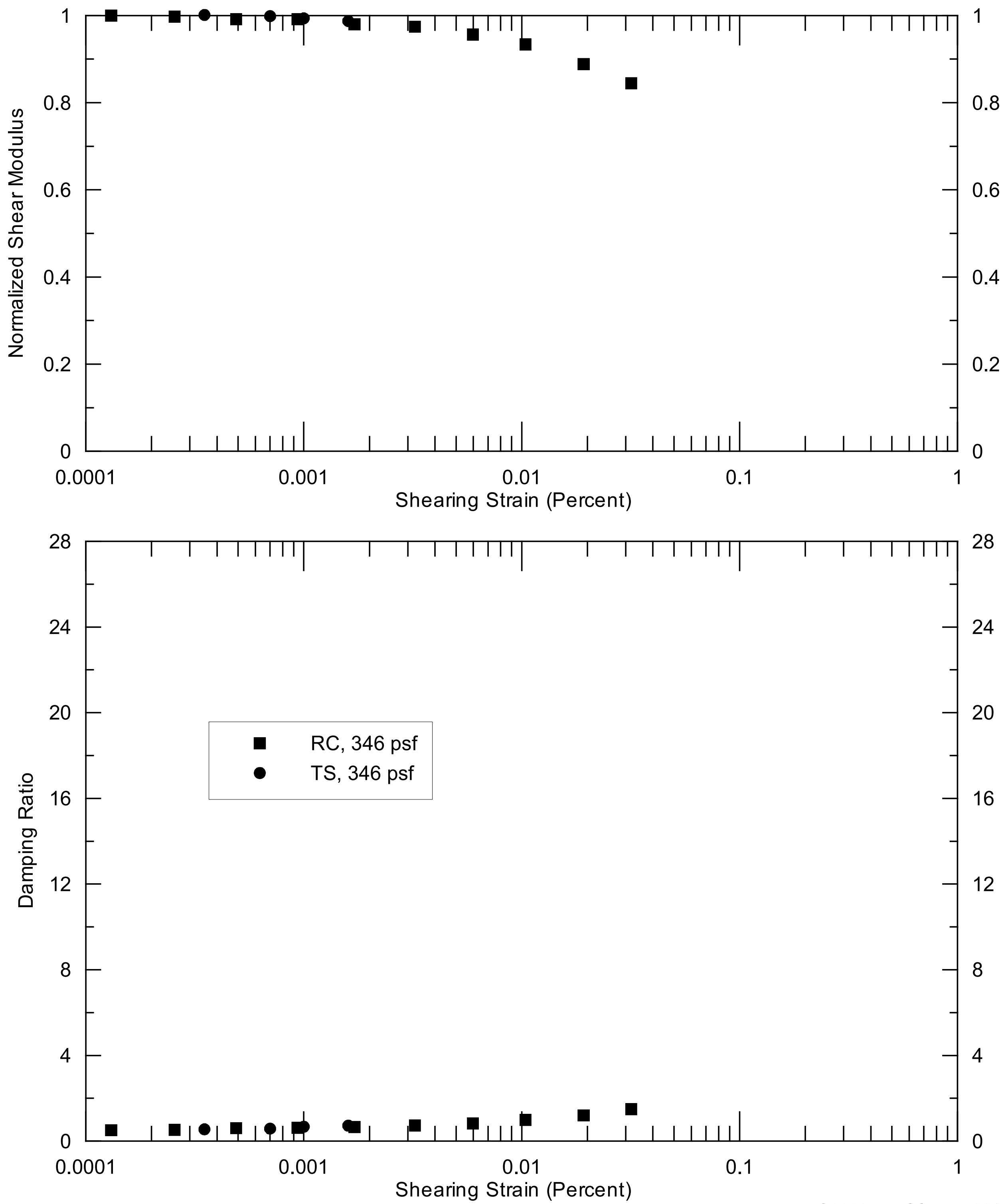
* Poisson's ratio and mass density from Wong (2002a, Appendix 32)

Figure XIII-5. SASW-T5 Results (continued)

ATTACHMENT XIV

GEOTECHNICAL LABORATORY DYNAMIC TESTING – ESF

As discussed in Section 6.3.3, this attachment presents the results of resonant column and torsional shear (RCTS) tests performed on samples taken by coring into the walls of the ESF North Ramp. Seven figures are followed by five tables. The data on these tables is found in DTN: MO0203DHRSSWHB.001.



DTN: MO0203DHRSSWHB.001

Figure XIV-1. Resonant Column and Torsional Shear Results for Specimen UTA-20-F

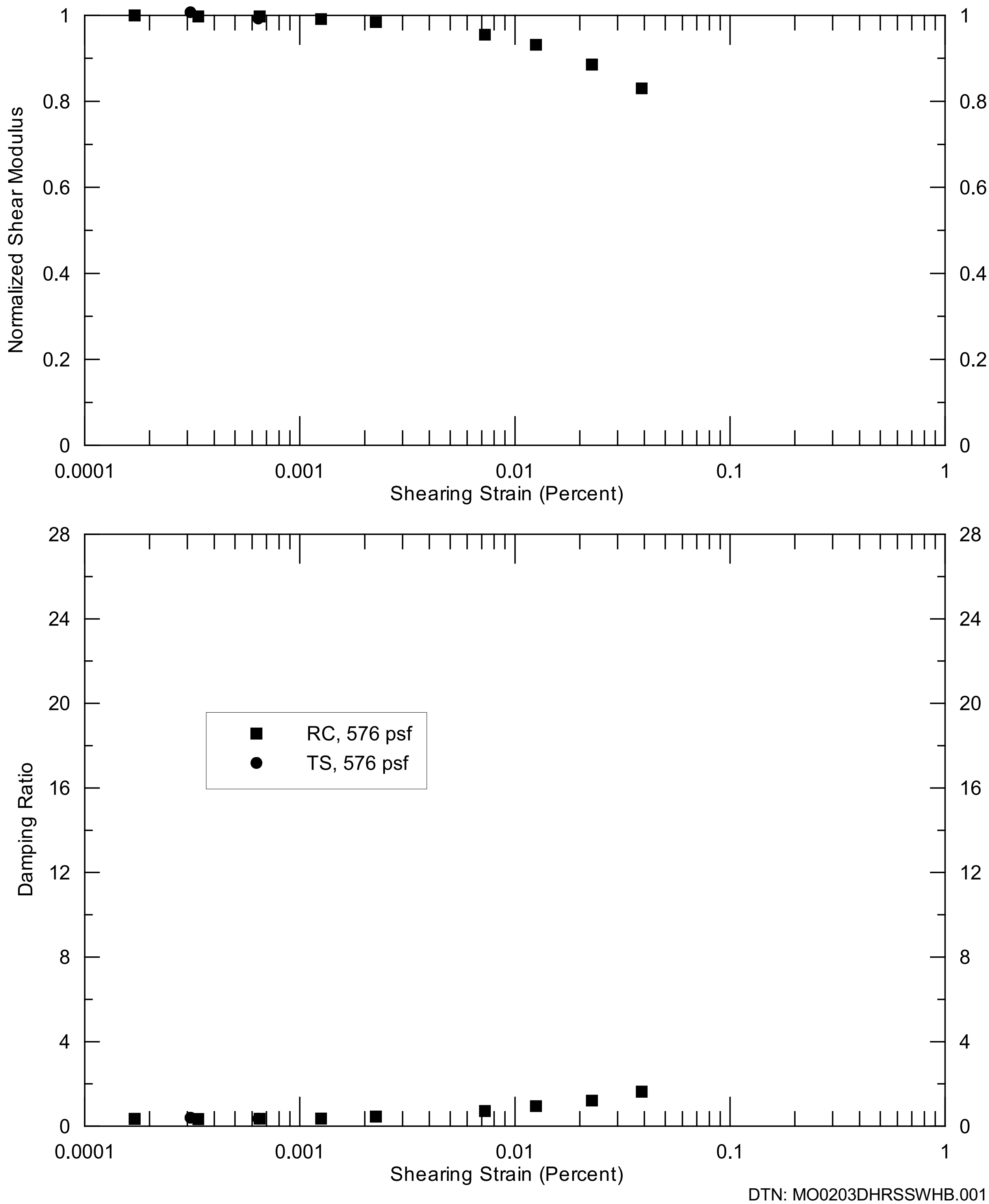


Figure XIV-2. Resonant Column and Torsional Shear Results for Specimen UTA-20-G

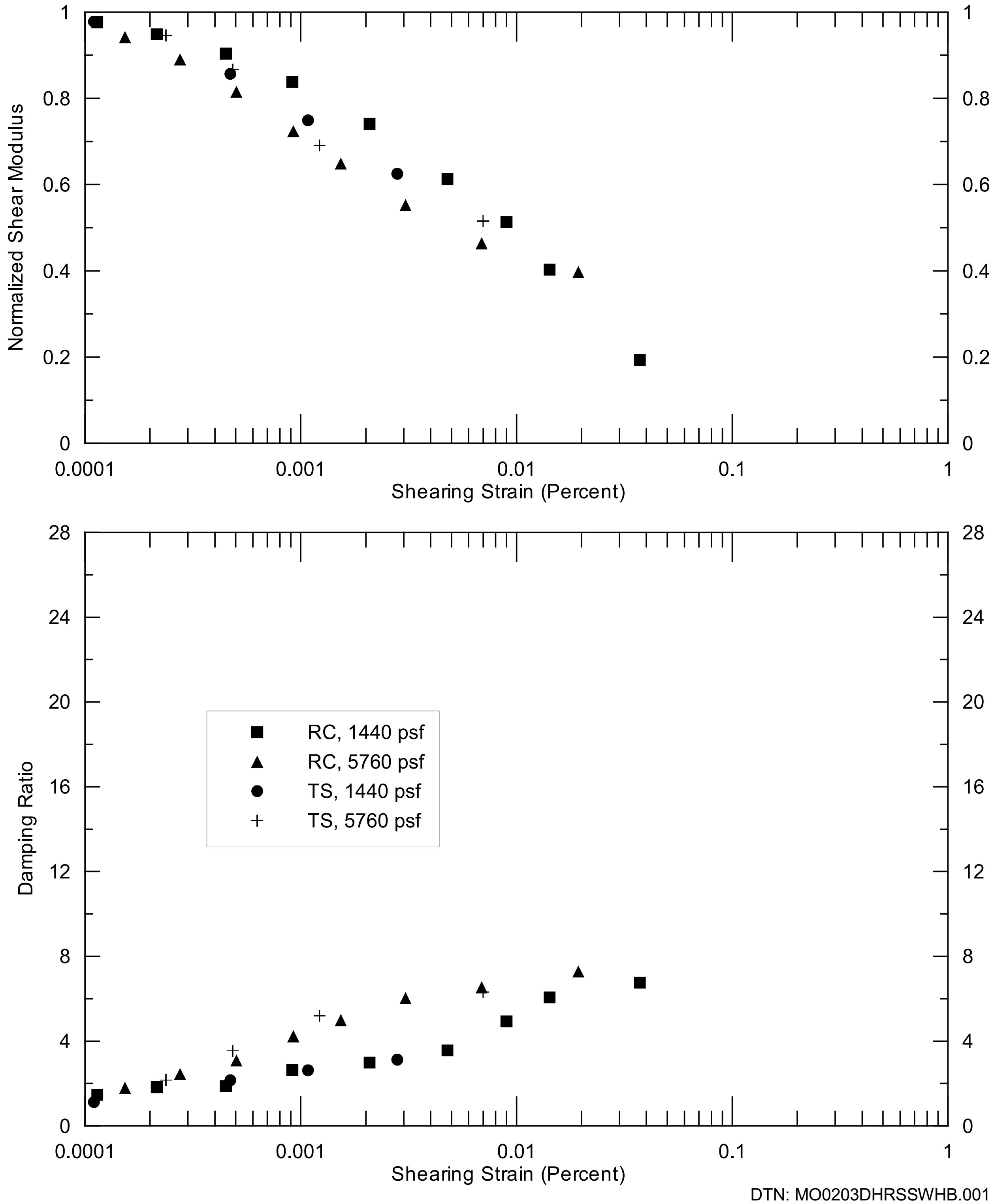


Figure XIV-3. Resonant Column and Torsional Shear Results for Specimen UTA-20-I

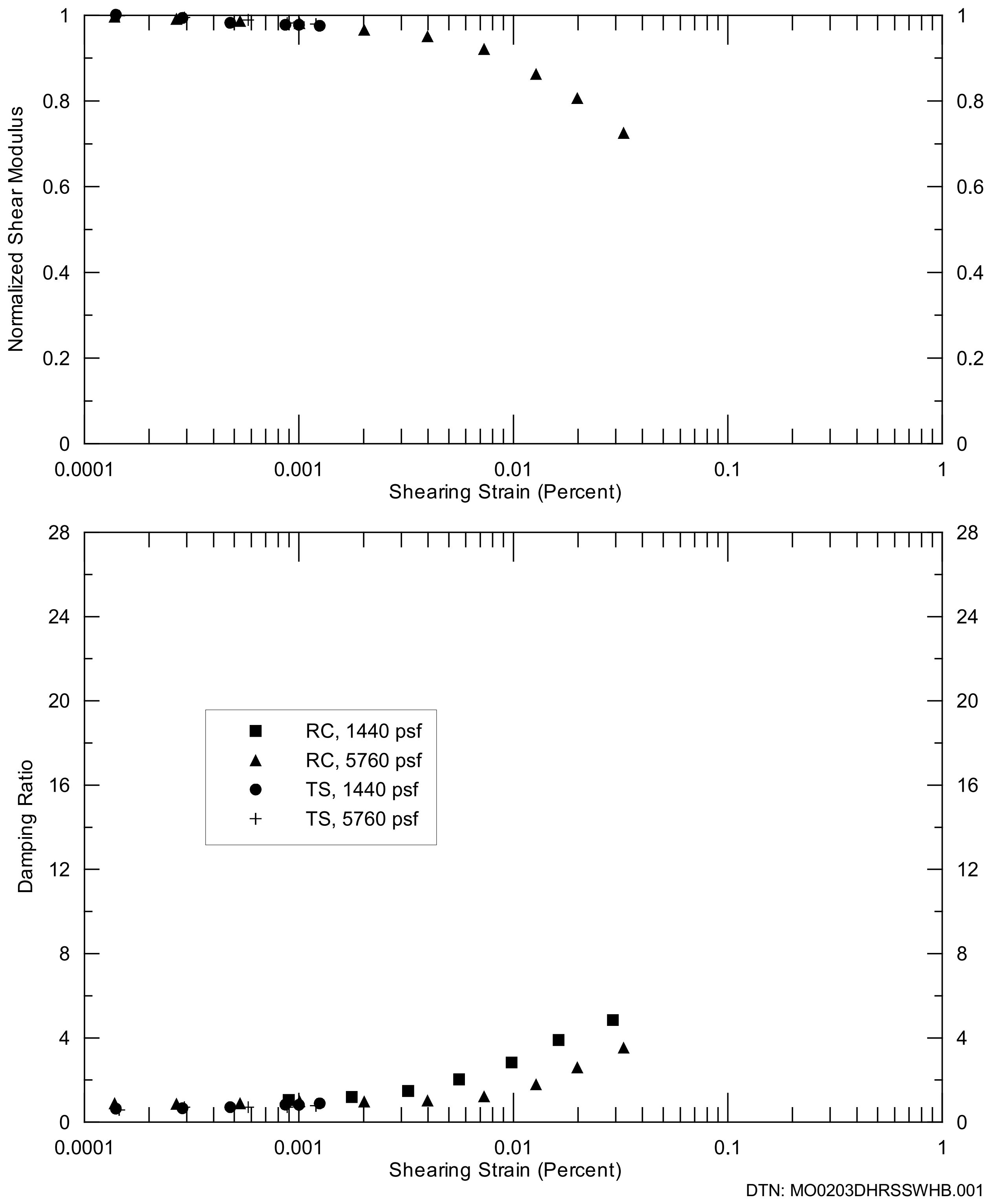
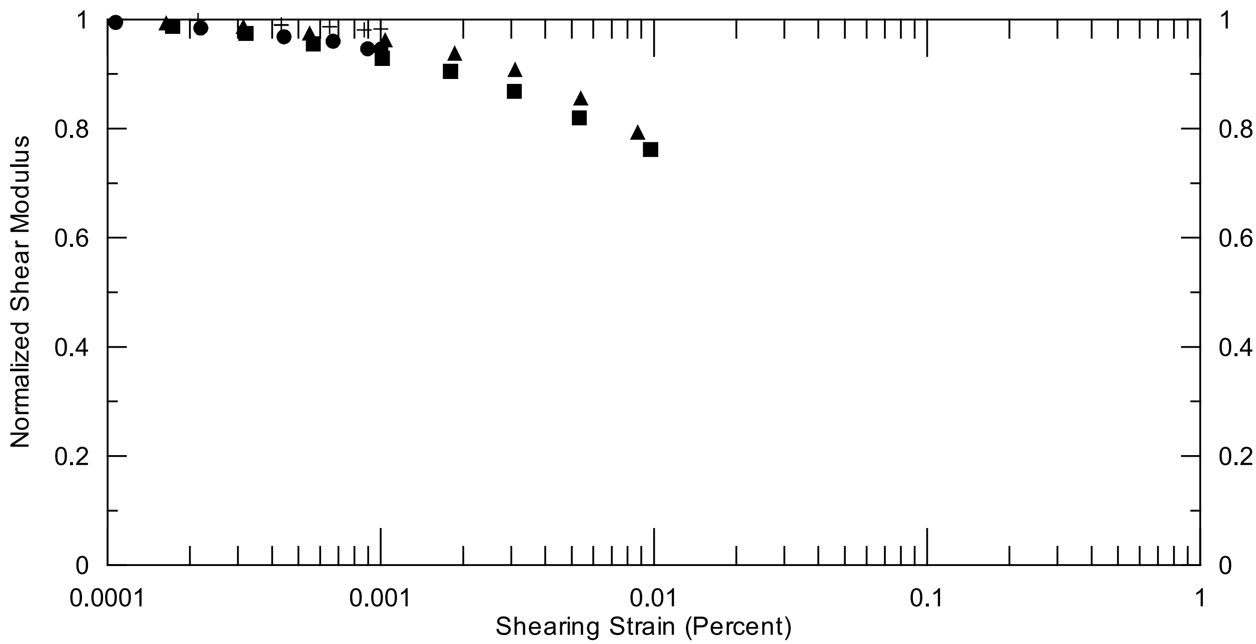
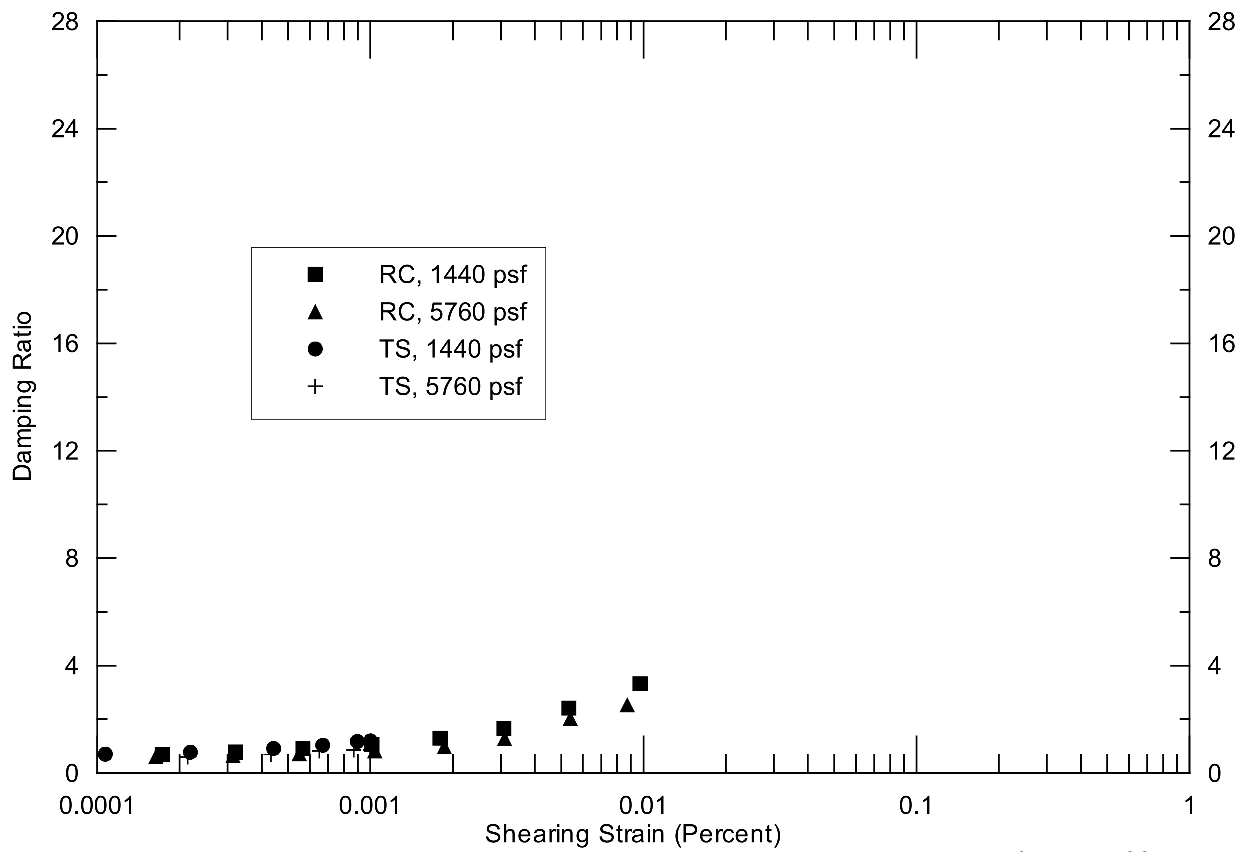


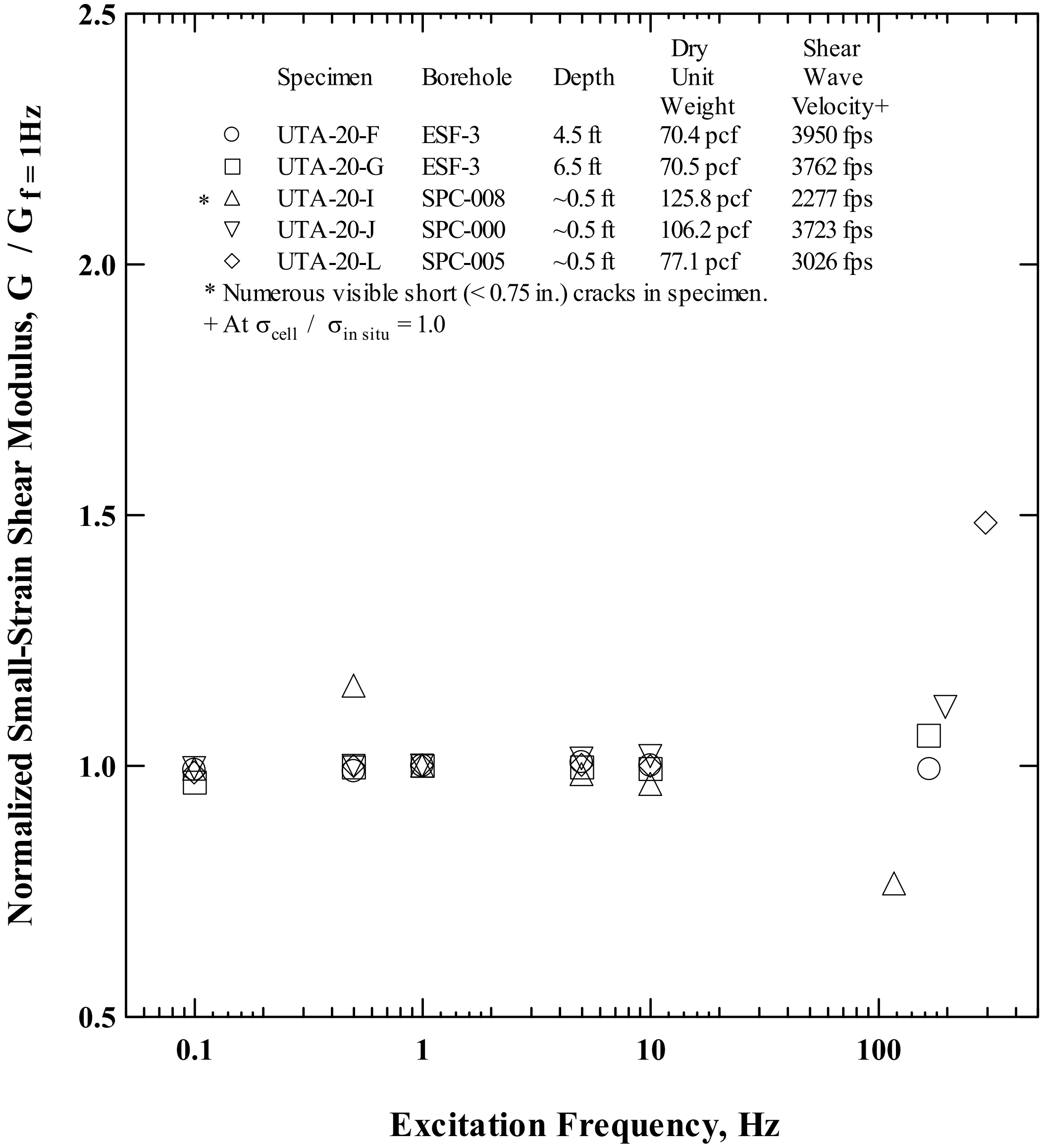
Figure XIV-4. Resonant Column and Torsional Shear Results for Specimen UTA-20-J





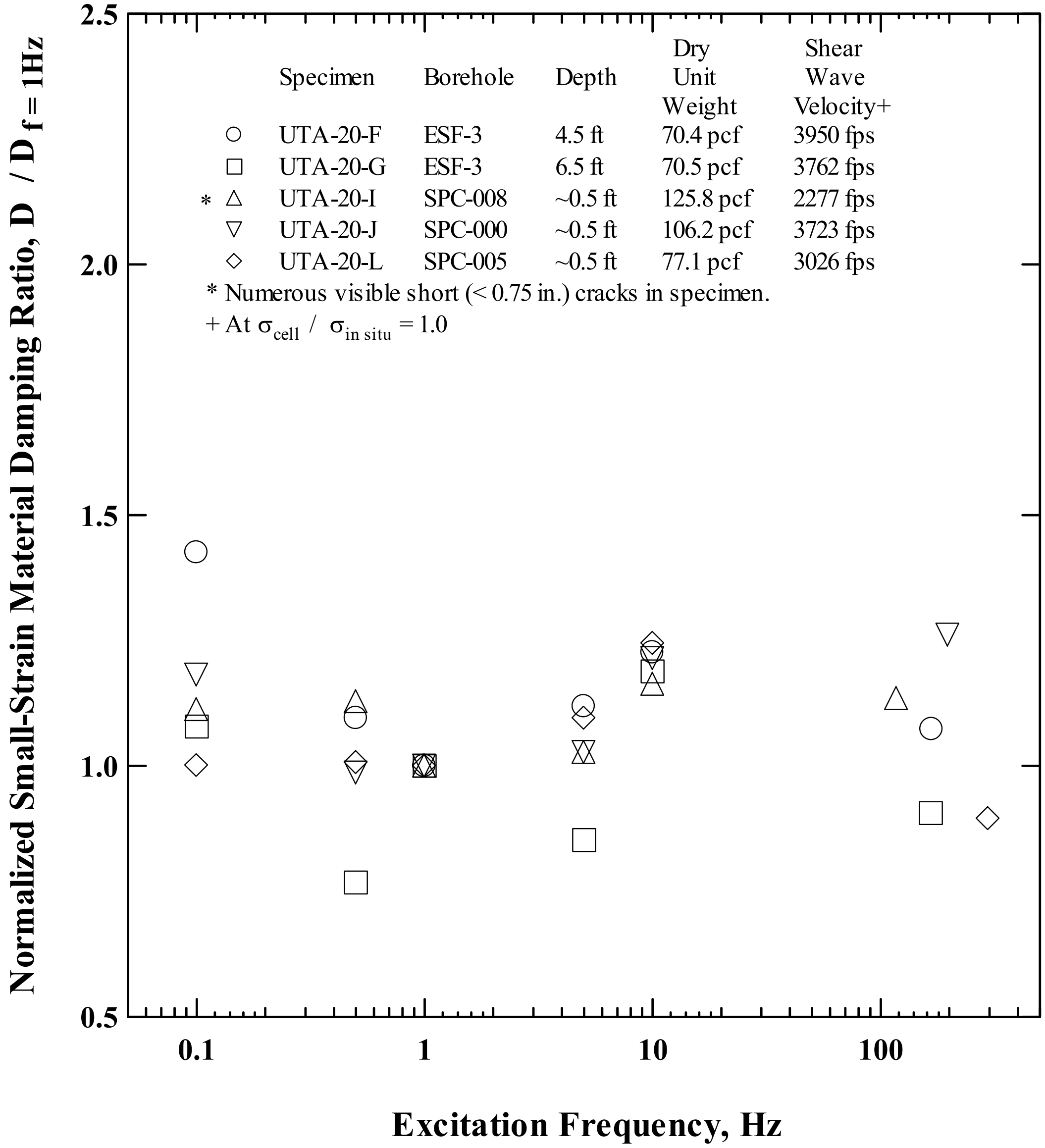
DTN: MO0203DHRSSWHB.001

Figure XIV-5. Resonant Column and Torsional Shear Results for Specimen UTA-20-L



(Wong 2002e, Appendix 42, page 75)

Figure XIV-6. Variation in Normalized Small-Strain Shear Modulus with Excitation Frequency of Intact Tuff Specimens from the North Portal Area of the Access Tunnel



(Wong 2002e, Appendix 42, page 76)

Figure XIV-7. Variation in Normalized Small-Strain Material Damping Ratio with Excitation Frequency of Intact Tuff Specimens from the North Portal Area of the Access Tunnel

Table XIV-1a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-F.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_s	Low-Amplitude Material Damping Ratio, Dmin, %
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	
UNCONFINED	0	0	36000	1726	3931	0.85
0.6	86	4.1	36125	1732	3936	0.52
1.2	173	8.3	36173	1734	3938	0.51
2.4	346	16.6	36393	1745	3950	0.50

Table XIV-1b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-F; Effective Confining Pressure, σ_o' = 2.4 psi (0.35 ksf = 17 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
1.31E-04	36374	1.00	1.27E-04	0.51
2.55E-04	36290	1.00	2.47E-04	0.53
4.89E-04	36073	0.99	4.71E-04	0.60
9.35E-04	36071	0.99	8.96E-04	0.62
1.71E-03	35649	0.98	1.64E-03	0.66
3.24E-03	35438	0.97	3.10E-03	0.73
5.97E-03	34801	0.96	5.67E-03	0.82
1.04E-02	33967	0.93	9.82E-03	0.99
1.92E-02	32325	0.89	1.71E-02	1.20
3.18E-02	30726	0.84	2.91E-02	1.49

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XIV-1c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-F; Effective Confining Pressure, σ_o' = 2.4 psi (0.35 ksf = 17 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.50E-04	36000	1.00	0.55	3.50E-04	35800	0.99	0.47
7.00E-04	35900	1.00	0.58	7.00E-04	35800	0.99	0.55
1.00E-03	35700	0.99	0.67	1.00E-03	35500	0.98	0.69
1.60E-03	35500	0.99	0.72	1.60E-03	35400	0.98	0.71

DTN: MO0203DHRSSWHB.001

Table XIV-2a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-G.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio, Dmin, %
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	
UNCONFINED	0	0	35200	1687	3758	0.66
1	144	6.9	35208	1688	3759	0.38
2	288	13.8	35252	1690	3761	0.38
4	576	27.6	35263	1690	3762	0.35

Table XIV-2b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-G; Effective Confining Pressure, σ_o' = 4 psi (0.58 ksf = kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
1.71E-04	35389	1.00	1.70E-04	0.35
8.66E-05	35396	1.00	8.48E-05	0.35
3.37E-04	35309	1.00	3.30E-04	0.34
6.51E-04	35312	1.00	6.37E-04	0.35
1.26E-03	35091	0.99	1.23E-03	0.36
2.26E-03	34840	0.98	2.19E-03	0.45
7.25E-03	33799	0.95	6.93E-03	0.72
1.25E-02	32971	0.93	1.18E-02	0.95
2.28E-02	31347	0.89	2.12E-02	1.21
3.89E-02	29383	0.83	3.52E-02	1.64

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XIV-2c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-G; Effective Confining Pressure, σ_o' = 4 psi (0.58 ksf = 28 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
6.41E-04	32520	0.99	0.35	6.41E-04	32700	1.00	0.33
3.10E-04	33000	1.01	0.40	3.11E-04	33000	1.00	0.38

DTN: MO0203DHRSSWHB.001

Table XIV-3a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-I.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio, Dmin, %
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	
UNCONFINED	0	0	18350	880	2155	2.82
3	360	17.3	18975	910	2192	2.46
5	720	34.5	20373	977	2272	2.00
10	1440	69.0	20468	981	2277	2.20
20	2880	138.1	7202	345	1351	2.64
40	5760	276.1	8113	389	1434	3.06
80	11520	552.3	19152	918	2203	2.58

Table XIV-3b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-I; Effective Confining Pressure, σ_o' = 10 psi (1.4 ksf = 69 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
4.08E-05	21309	1.03	3.94E-05	1.39
1.14E-04	20211	0.98	1.04E-04	1.47
2.15E-04	19640	0.95	1.93E-04	1.82
4.49E-04	18706	0.90	4.01E-04	1.88
9.13E-04	17350	0.84	7.91E-04	2.64
2.08E-03	15340	0.74	1.75E-03	2.99
4.79E-03	12685	0.61	4.14E-03	3.56
8.99E-03	10626	0.51	6.80E-03	4.93
1.42E-02	8335	0.40	1.02E-02	6.06
3.72E-02	3996	0.19	2.58E-02	6.76

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

DTN: MO0203DHRSSWHB.001

Table XIV-3c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-I; Effective Confining Pressure, σ_o' = 10 psi (1.4 ksf = 69 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.67E-05	31340	1.02	0.80	2.67E-05	31780	1.03	0.82
1.10E-04	29990	0.98	1.12	1.10E-04	30100	0.97	0.97
4.71E-04	26270	0.86	2.15	4.71E-04	25930	0.84	2.03
1.08E-03	22970	0.75	2.62	1.08E-03	22670	0.73	2.42
2.80E-03	19170	0.63	3.12	2.80E-03	19000	0.61	2.89

Table XIV-3d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-I; Effective Confining Pressure, σ_o' = 40 psi (5.8 ksf = 276 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
8.75E-05	9852	1.00	7.26E-05	1.81
1.53E-04	9282	0.94	1.38E-04	1.79
2.76E-04	8770	0.89	2.39E-04	2.44
5.03E-04	8029	0.81	4.19E-04	3.09
9.23E-04	7131	0.72	7.25E-04	4.22
1.53E-03	6391	0.65	1.16E-03	4.98
3.06E-03	5442	0.55	3.22E-03	6.02
6.89E-03	4569	0.46	7.28E-03	6.53
1.94E-02	3911	0.40	1.31E-02	7.28

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XIV-3e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-I; Effective Confining Pressure, σ_o' = 40 psi (5.8 ksf = 276 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.43E-05	15640	1.05	2.25	5.43E-05	15210	1.04	2.25
2.37E-04	14040	0.95	2.16	2.37E-04	13940	0.96	2.23
4.83E-04	12860	0.87	3.54	4.83E-04	12600	0.86	3.45
1.22E-03	10250	0.69	5.19	1.22E-03	10060	0.69	4.92
7.00E-03	7647	0.52	6.31	7.00E-03	7624	0.52	5.93

DTN: MO0203DHRSSWHB.001

Table XIV-4a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-J.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio, Dmin, %
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	
UNCONFINED	0	0	47200	2263	3703	1.19
3	360	17.3	47459	2275	3712	0.92
5	720	34.5	47788	2291	3725	0.95
10	1440	69.0	47735	2288	3723	0.90
20	2880	138.1	45281	2171	3625	0.88
40	5760	276.1	45428	2178	3631	0.85
80	11520	552.3	45955	2203	3652	0.80
160	23040	1104.5	45881	2200	3648	0.81

Table XIV-4b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing S from RC Tests of Specimen UTA-20-J; Effective Confining Pressure, σ_o' = 10 psi (1.4 ksf = 69 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
8.96E-04	47140	1.01	9.11E-04	1.05
1.76E-03	46668	0.99	1.79E-03	1.19
3.23E-03	45959	0.98	3.29E-03	1.48
5.58E-03	44555	0.95	5.68E-03	2.03
9.81E-03	42262	0.90	8.62E-03	2.83
1.62E-02	39150	0.83	1.37E-02	3.90
2.91E-02	35322	0.75	2.32E-02	4.85

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

DTN: MO0203DHRSSWHB.001

Table XIV-4c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-J; Effective Confining Pressure, σ_o' = 10 psi (1.4 ksf = 69 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.54E-05	43100	1.00	0.83	7.54E-05	43240	1.00	0.66
1.40E-04	43210	1.00	0.64	1.69E-04	42900	1.00	0.64
2.86E-04	42890	0.99	0.66	2.86E-04	42828	0.99	0.74
4.78E-04	42400	0.98	0.71	4.78E-04	42500	0.99	0.81
8.64E-04	42200	0.98	0.83	8.64E-04	42200	0.98	0.83
1.00E-03	42200	0.98	0.82	1.00E-03	42240	0.98	0.84
1.25E-03	42100	0.98	0.89	1.25E-03	42100	0.98	0.89

Table XIV-4d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-J; Effective Confining Pressure, σ_o' = 40 psi (5.8 ksf = 276 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
6.98E-05	45840	1.00	7.09E-05	0.85
1.38E-04	45740	1.00	1.31E-04	0.90
2.68E-04	45498	0.99	2.54E-04	0.87
5.31E-04	45272	0.99	5.03E-04	0.89
1.01E-03	45037	0.98	9.47E-04	1.00
2.01E-03	44337	0.97	1.89E-03	0.99
3.98E-03	43641	0.95	3.73E-03	1.03
7.30E-03	42273	0.92	6.77E-03	1.23
1.27E-02	39598	0.86	1.14E-02	1.80
1.99E-02	37012	0.81	1.70E-02	2.60
3.27E-02	33295	0.73	2.66E-02	3.54

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XIV-4e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-J; Effective Confining Pressure, σ_o' =40 psi (5.8 ksf = 276 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.70E-05	42000	1.00	0.51	7.70E-05	42000	1.00	0.43
1.45E-04	41900	1.00	0.58	1.45E-04	42100	1.00	0.60
2.92E-04	41730	0.99	0.71	2.92E-04	41800	0.99	0.70
5.80E-04	41500	0.99	0.71	5.80E-04	41500	0.99	0.72
8.80E-04	41200	0.98	0.71	8.80E-04	41600	0.99	0.77
1.00E-03	41300	0.98	0.72	1.00E-03	41400	0.98	0.73
1.20E-03	41090	0.98	0.78	1.20E-03	41200	0.98	0.80

DTN: MO0203DHRSSWHB.001

Table XIV-5a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-20-L.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %
UNCONFINED	0	0	21200	1016	2948	0.93
3	360	17.3	21454	1028	2967	0.71
5	720	34.5	21859	1048	2995	0.70
10	1440	69.0	22314	1070	3026	0.64
20	2880	138.1	23306	1117	3092	0.59
40	5760	276.1	24353	1167	3161	0.60
80	11520	552.3	25599	1227	3240	0.61
160	23040	1104.5	27508	1319	3357	0.59

Table XIV-5b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing S from RC Tests of Specimen UTA-20-L; Effective Confining Pressure, σ_o' = 10 psi (1.4 ksf = 69 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
2.36E-05	21868	1.00	2.26E-05	0.73
4.54E-05	21888	1.00	4.37E-05	0.62
9.00E-05	21723	0.99	8.65E-05	0.64
1.73E-04	21602	0.99	1.66E-04	0.68
3.21E-04	21320	0.97	3.06E-04	0.78
5.66E-04	20902	0.96	5.35E-04	0.91
1.01E-03	20327	0.93	9.49E-04	1.06
1.80E-03	19802	0.91	1.66E-03	1.29
3.08E-03	18995	0.87	2.79E-03	1.66
5.33E-03	17930	0.82	4.61E-03	2.41
9.71E-03	16663	0.76	8.27E-03	3.32

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

DTN: MO0203DHRSSWHB.001

Table XIV-5c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-L; Effective Confining Pressure, σ_o' = 10psi (1.4ksf = 69kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.60E-05	14555	1.01	0.87	5.70E-05	14470	1.00	0.70
1.07E-04	14400	0.99	0.70	1.08E-04	14430	1.00	0.72
2.19E-04	14250	0.98	0.77	2.19E-04	14190	0.98	0.77
4.42E-04	14020	0.97	0.91	4.40E-04	14098	0.98	0.91
6.69E-04	13900	0.96	1.03	6.69E-04	13930	0.96	1.03
8.96E-04	13700	0.95	1.17	8.96E-04	13720	0.95	1.14
1.00E-03	13690	0.95	1.19	1.00E-03	13740	0.95	1.20

Table XIV-5d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-20-L; Effective Confining Pressure, σ_o' = 40 psi (5.8 ksf = 276 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
2.13E-05	23928	1.00	2.06E-05	0.58
4.18E-05	23930	1.00	4.03E-05	0.59
8.24E-05	23924	1.00	7.94E-05	0.59
1.64E-04	23776	0.99	1.58E-04	0.61
3.14E-04	23628	0.99	3.02E-04	0.64
5.49E-04	23330	0.97	5.20E-04	0.71
1.04E-03	23035	0.96	9.86E-04	0.83
1.87E-03	22454	0.94	1.76E-03	0.99
3.10E-03	21739	0.91	2.87E-03	1.29
5.39E-03	20480	0.86	4.62E-03	2.02
8.72E-03	18994	0.79	7.50E-03	2.54

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XIV-5e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-20-L; Effective Confining Pressure, σ_o' =40 psi (5.8 ksf = 276 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.45E-05	14500	1.00	0.51	5.45E-05	14500	1.00	0.43
2.14E-04	14450	1.00	0.59	1.45E-04	14470	1.00	0.64
4.32E-04	14330	0.99	0.68	2.92E-04	14380	0.99	0.66
6.50E-04	14280	0.99	0.82	6.50E-04	14320	0.99	0.76
8.69E-04	14200	0.98	0.86	8.69E-04	14230	0.98	0.83
1.00E-03	14220	0.98	0.85	1.00E-03	14250	0.98	0.81

DTN: MO0203DHRSSWHB.001

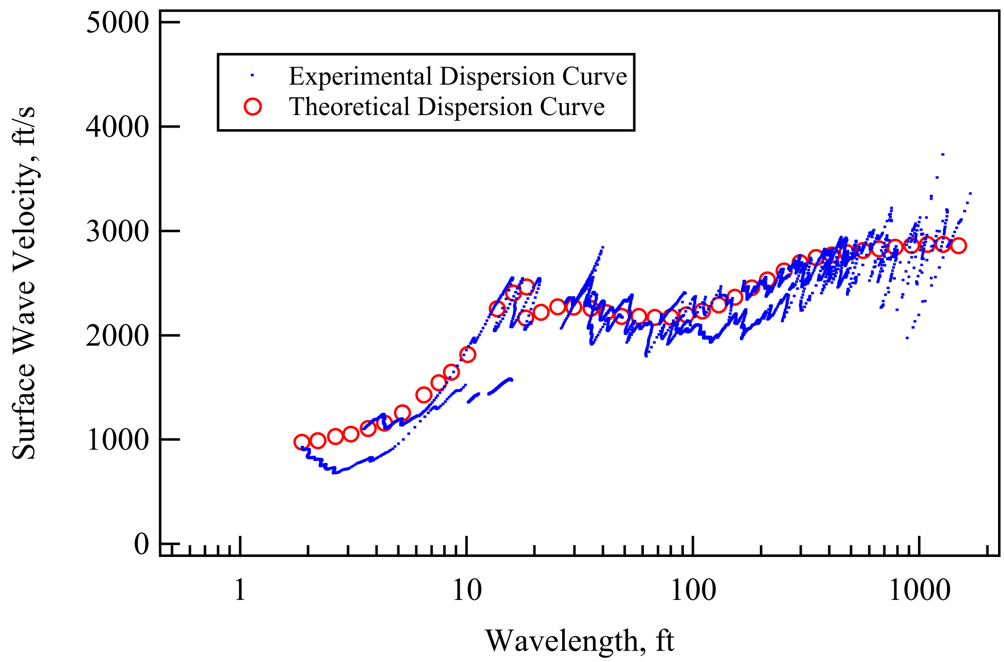
ATTACHMENT XV

SASW VELOCITY PLOTS – YUCCA MOUNTAIN CREST

ATTACHMENT XV

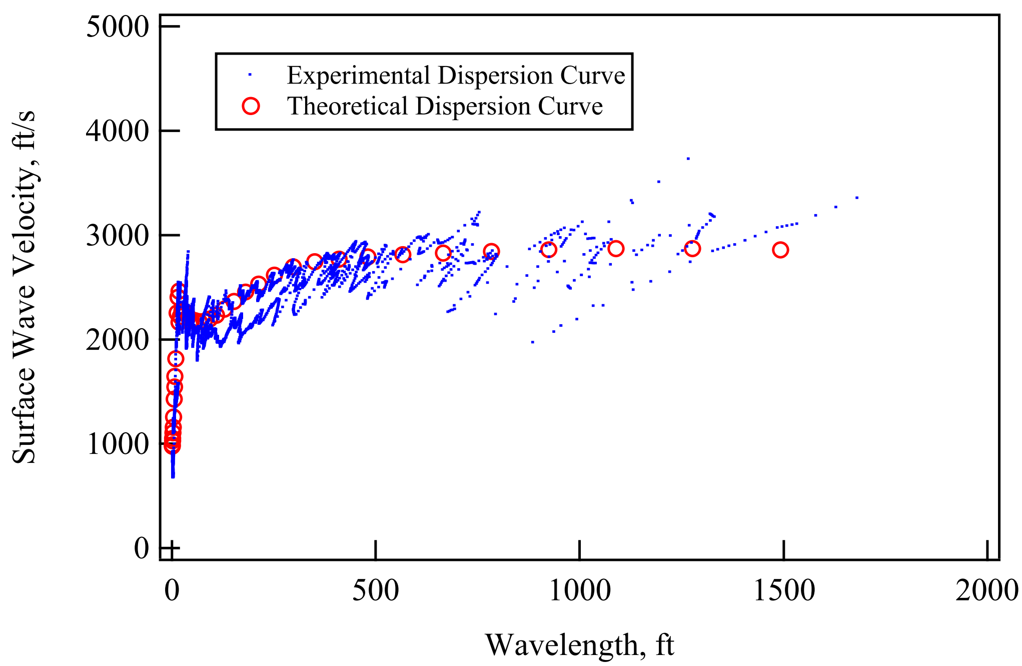
SASW VELOCITY PLOTS – YUCCA MOUNTAIN CREST

As described in Section 6.4.2, this attachment contains 31 figures presenting detailed interpretive results for SASW surveys conducted at the crest of Yucca Mountain. Figures XV-1 through XV-7 are for the seven "C" sites, Figures XV-8 through XV-19 are for the twelve "S" sites, and Figures XV-20 through XV-31 are for the twelve "D" sites. Site D-12 is actually on Exile Hill.
A detailed description of each analysis can be found in the associated appendix in SN-M&O-SCI-023-V1 (Wong 2002d) or SN-M&O-SCI-040-V1 (Wong 2002a).



(Wong, 2002d, Appendix 1, page 8)

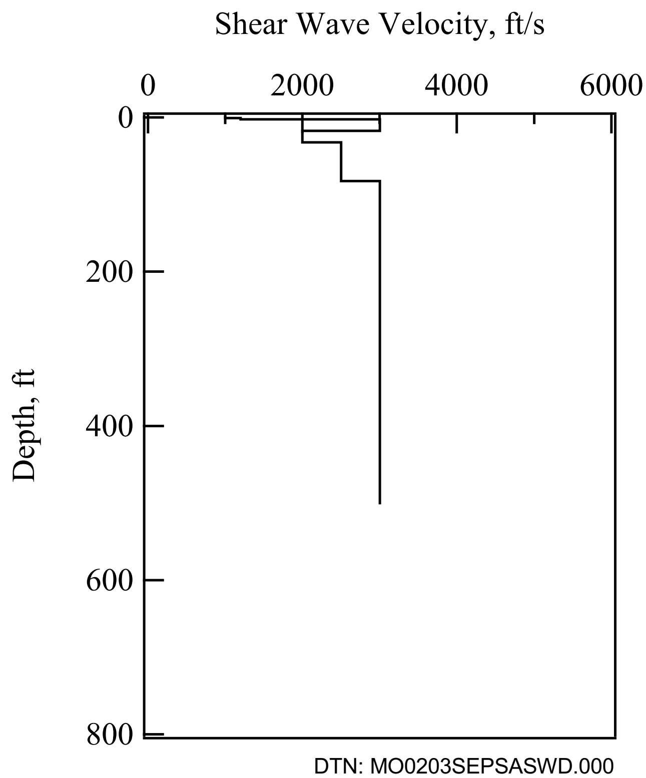
a. SASW C-1 Dispersion Curves (Log Plot)



(Wong, 2002d, Appendix 1, page 8)

b. SASW C-1 Dispersion Curves (Linear Plot)

Figure XV-1. SASW-C1 Results



c. SASW C-1 Shear Wave Velocity Profile

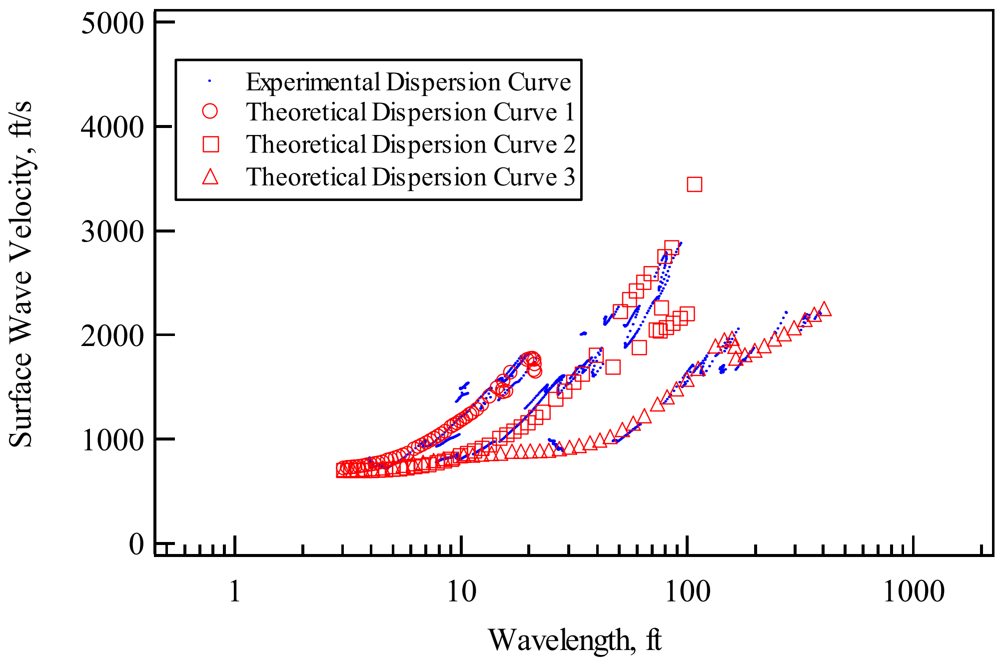
Location: SASW C-1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	1732	1000	0.25	145
2	1.5	2079	1200	0.25	145
3	15	5196	3000	0.25	145
4	15	3464	2000	0.25	145
5	50	4330	2500	0.25	145
6	420	5542	3200	0.25	145

DTN: MO0203SEPSASWD.000

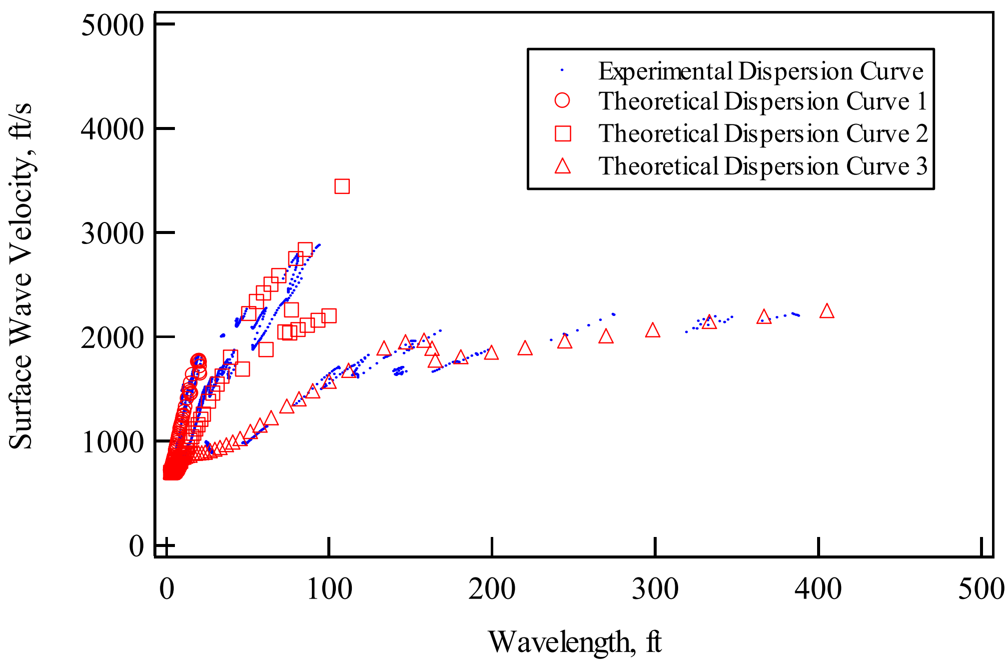
*Poisson's ratio and mass density from Wong (2002d, Appendix 1, page 9)

Figure XV-1. SASW-C1 Results (continued)



(Wong, 2002d, Appendix 2, page 17)

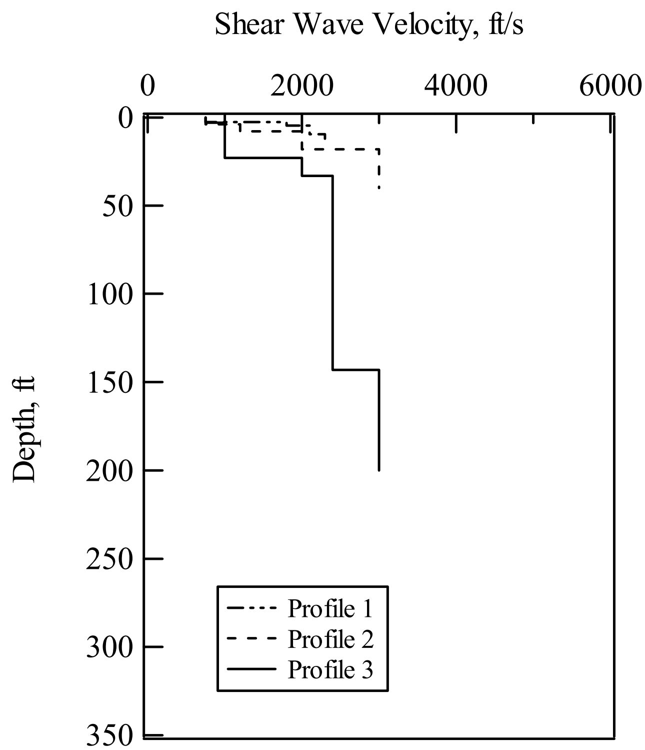
a. SASW C-2 Dispersion Curves (Log Plot)



(Wong, 2002d, Appendix 2, page 17)

b. SASW C-2 Dispersion Curves (Linear Plot)

Figure XV-2. SASW-C2 Results



DTN: MO0203SEPSASWD.000

c. SASW C-2 Shear Wave Velocity Profile

Location: SASW C-2-Profile 1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2.5	1299	750	0.25	145
2	2	3118	1800	0.25	145
3	5	3637	2100	0.25	145
4	3	3984	2300	0.25	145

Location: SASW C-2-Profile 2

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	4	1299	750	0.25	145
2	4	2078	1200	0.25	145
3	10	3464	2000	0.25	145
4	22	5196	3000	0.25	145

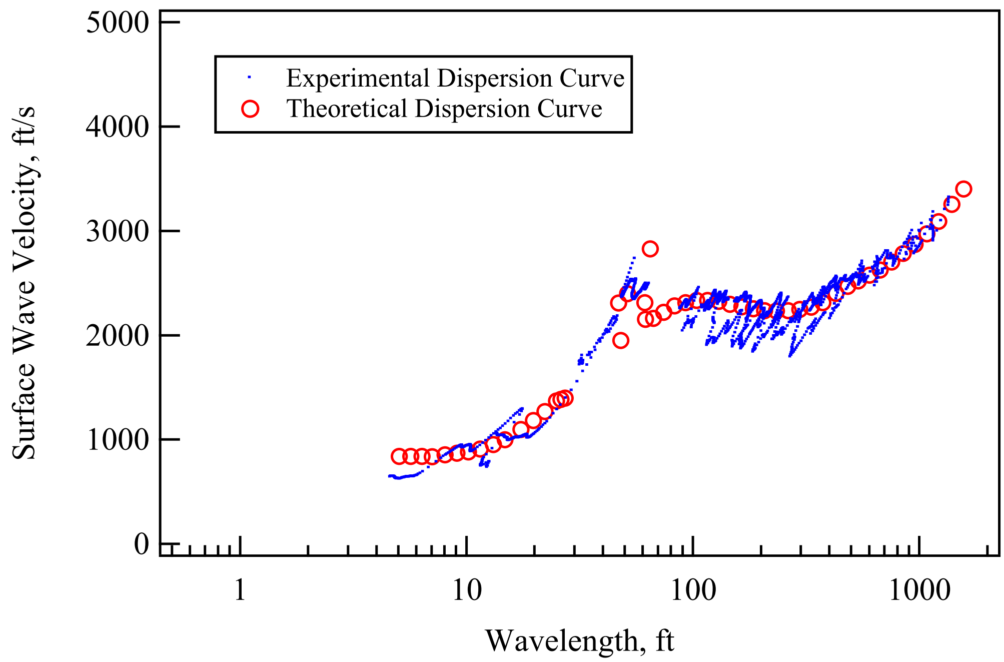
Location: SASW C-2-Profile 3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	3	1299	750	0.25	145
2	20	1732	1000	0.25	145
3	10	3464	2000	0.25	145
4	110	4156	2400	0.25	145
5	57	5196	3000	0.25	145

DTN: MO0203SEPSASWD.000

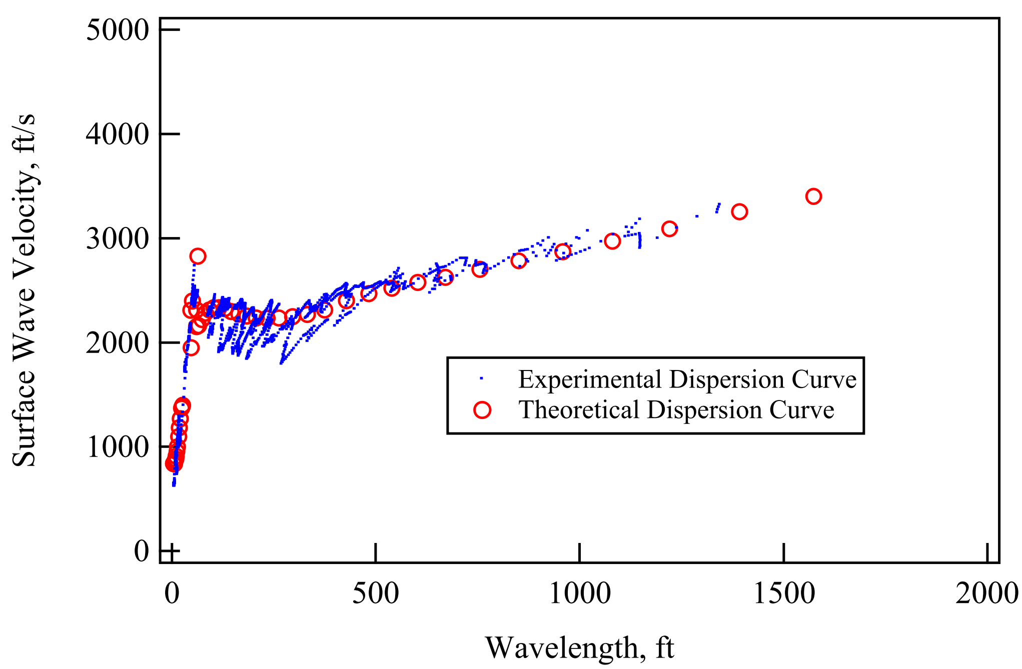
* Poisson's ratio and mass density from Wong (2002d, Appendix 2, page 19)

Figure XV-2. SASW-C2 Results (continued)



Wong, 2002d, Appendix 3, page 28)

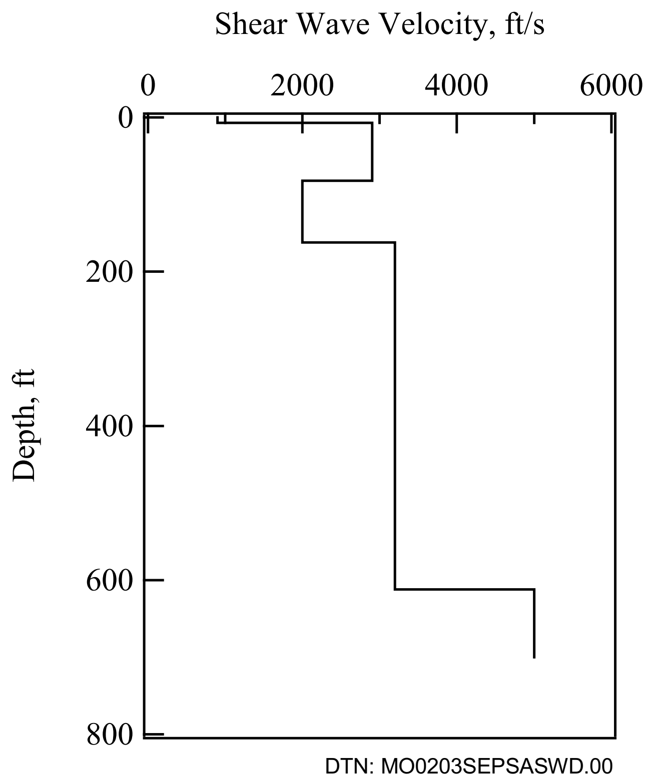
a. SASW C-3 Dispersion Curves (Log Plot)



Wong, 2002d, Appendix 3, page 28)

b. SASW C-3 Dispersion Curves (Linear Plot)

Figure XV-3. SASW-C3 Results



c. SASW C-3 Shear Wave Velocity Profile

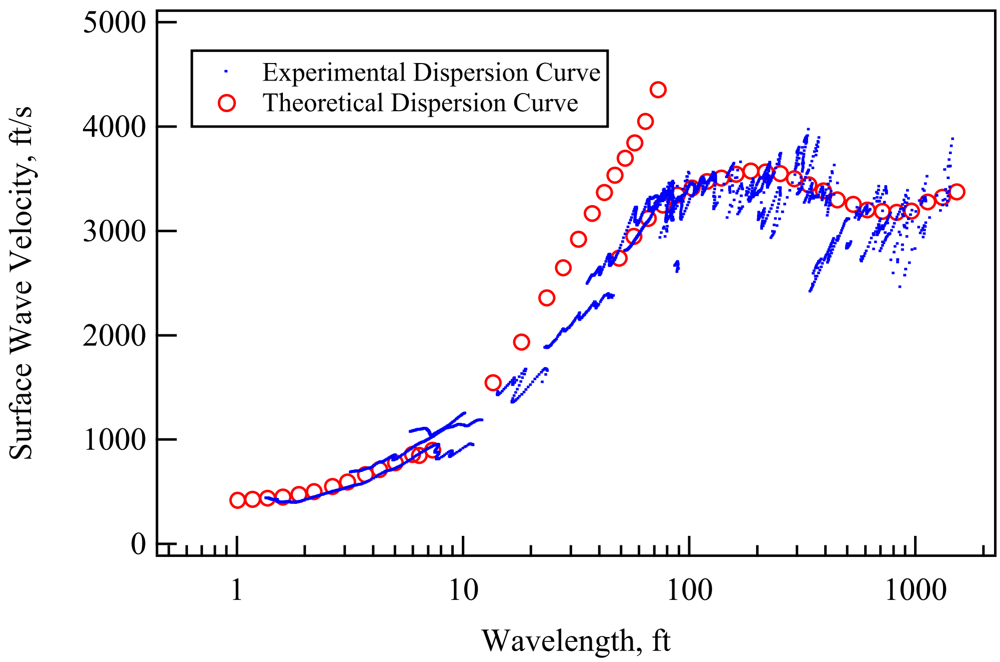
Location: SASW C-3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	7	1559	900	0.25	145
2	75	5022	2900	0.25	145
3	80	3464	2000	0.25	145
4	450	5542	3200	0.25	145
5	88	8660	5000	0.25	145

DTN: MO0203SEPSASWD.000

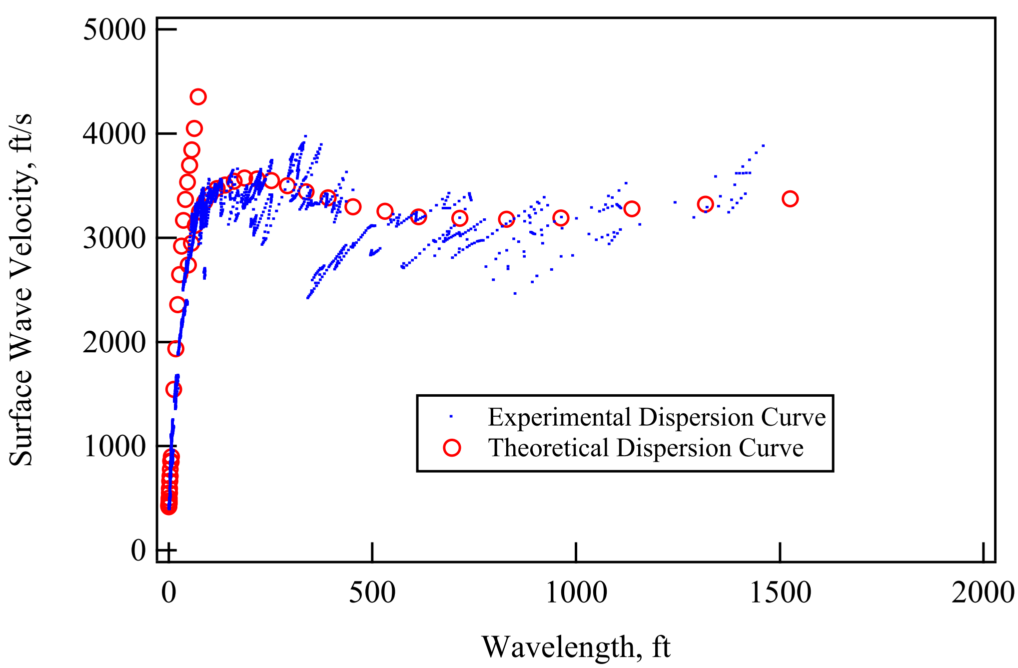
* Poisson's ratio and mass density from Wong (2002d, Appendix 3, page 30)

Figure XV-3. SASW-C3 Results (continued)



Wong, 2002d, Appendix 4, page 39)

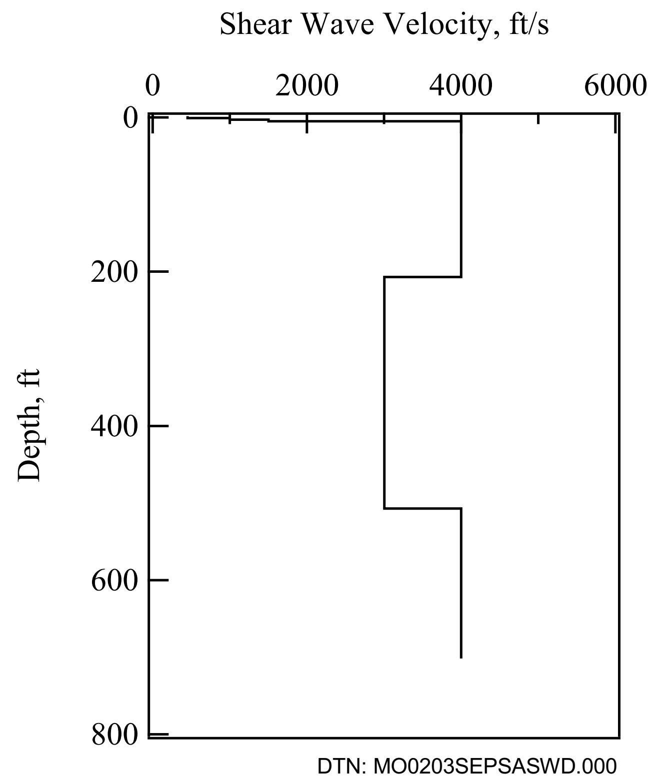
a. SASW C-4 Dispersion Curves (Log Plot)



Wong, 2002d, Appendix 4, page 39)

b. SASW C-4 Dispersion Curves (Linear Plot)

Figure XV-4. SASW-C4 Results



c. SASW C-4 Shear Wave Velocity Profile

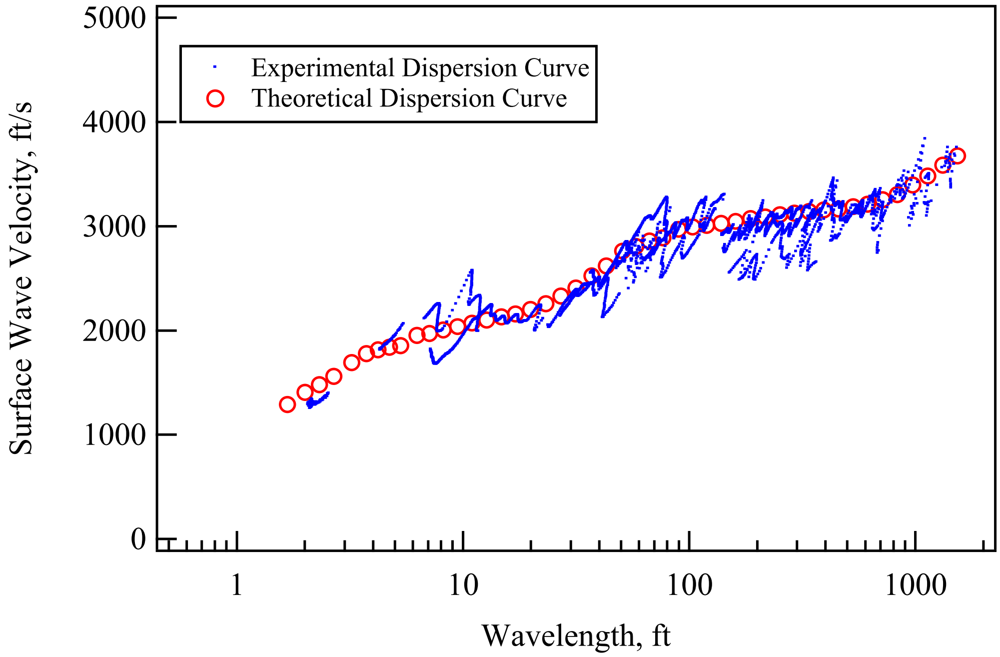
Location: SASW C-4

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	779	450	0.25	145
2	2	1732	1000	0.25	145
3	2	2598	1500	0.25	145
4	200	6928	4000	0.25	145
5	300	5196	3000	0.25	145
6	200	6928	4000	0.25	145

DTN: MO0203SEPSASWD.000

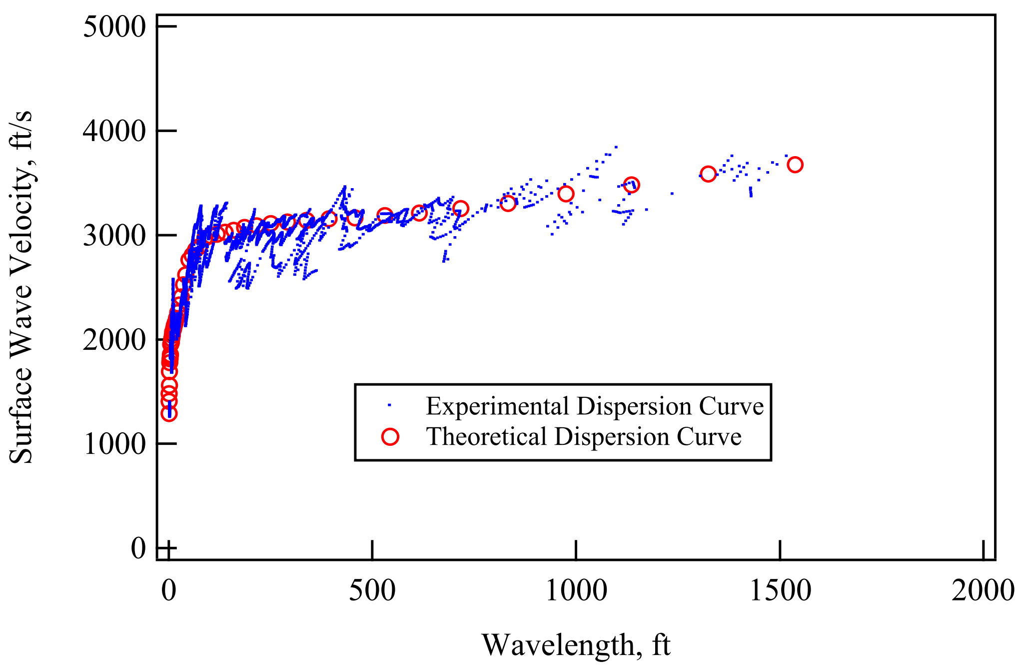
* Poisson's ratio and mass density from Wong (2002d, Appendix 4, page 41)

Figure XV-4. SASW-C4 Results (continued)



(Wong, 2002d, Appendix 5, page 49)

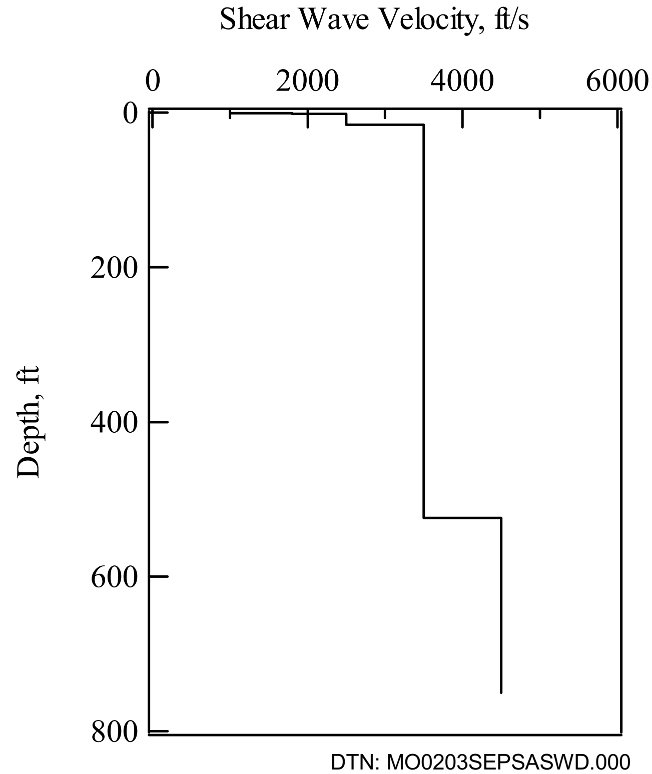
a. SASW C-5 Dispersion Curves (Log Plot)



(Wong, 2002d, Appendix 5, page 49)

b. SASW C-5 Dispersion Curves (Linear Plot)

Figure XV-5. SASW-C5 Results



c. SASW C-5 Shear Wave Velocity Profile

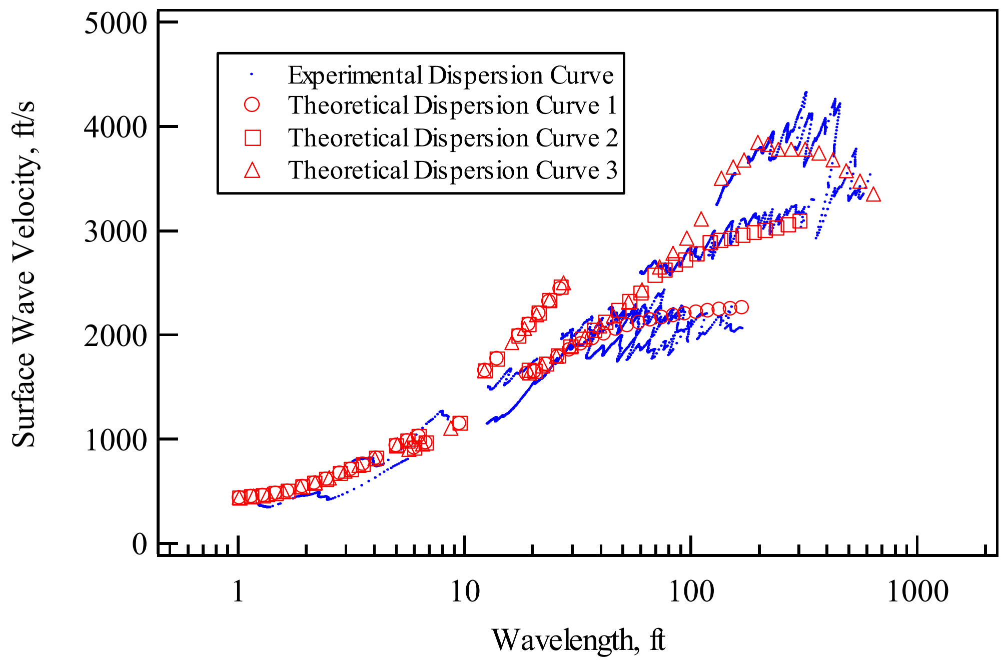
Location: SASW C-5

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.5	1732	1000	0.25	145
2	1	3117	1800	0.25	145
3	14.5	4330	2500	0.25	145
4	508	6062	3500	0.25	145
5	226	7794	4500	0.25	145

DTN: MO0203SEPSASWD.000

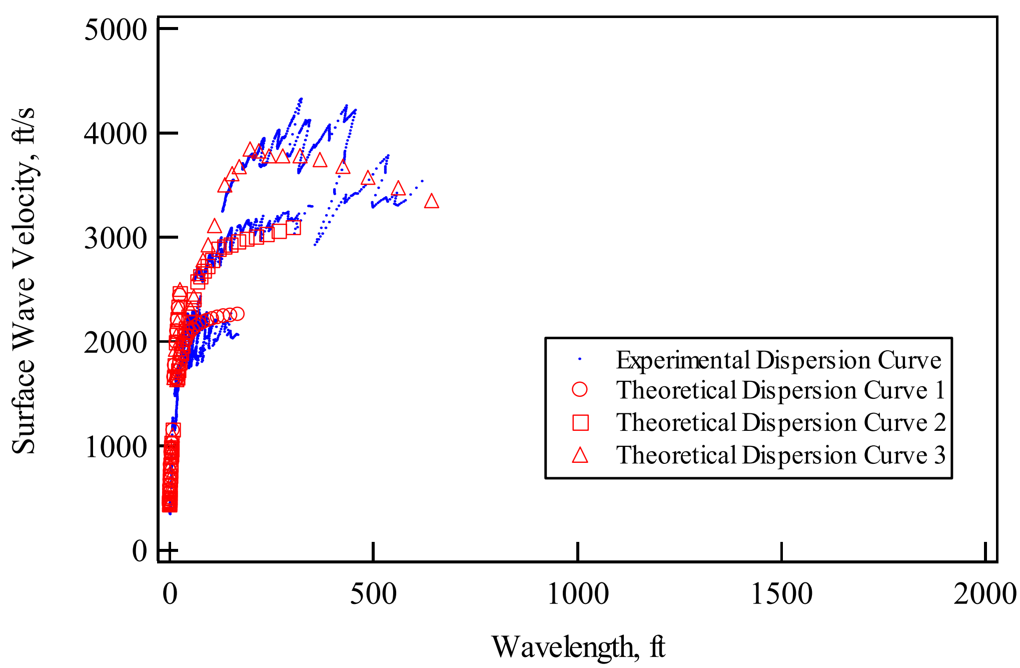
* Poisson's ratio and mass density from Wong (2002d, Appendix 5, page 51)

Figure XV-5. SASW-C5 Results (continued)



(Wong, 2002d, Appendix 6, page 59)

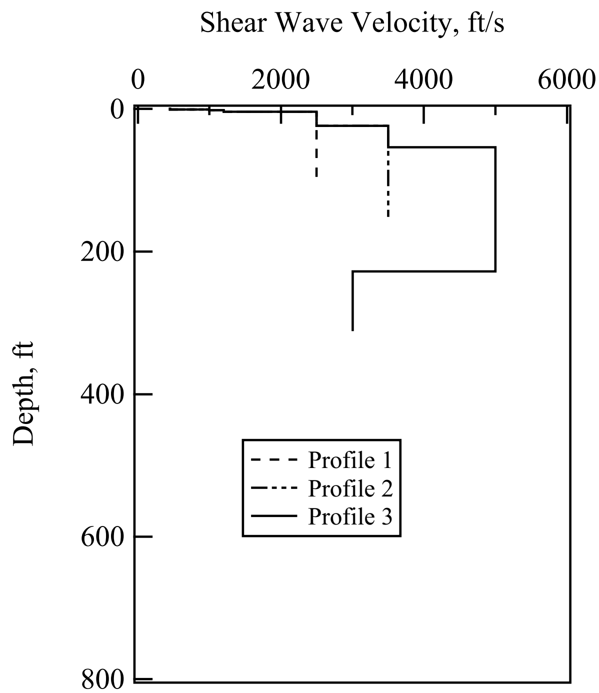
a. SASW C-6 Dispersion Curves (Log Plot)



(Wong, 2002d, Appendix 6, page 59)

b. SASW C-6 Dispersion Curves (Linear Plot)

Figure XV-6. SASW-C6 Results



DTN: MO0203SEPSASWD.000

c. SASW C-6 Shear Wave Velocity Profile

Location: SASW C-6 Profile 1

Layer No.	**Thickness, ft**	**P-Wave Velocity, ft/s**	**S-Wave Velocity, ft/s**	**Poisson's Ratio***	**Mass Density* pcf**
1	0.75	779	450	0.25	145
2	1	1732	1000	0.25	145
3	2	2078	1200	0.25	145
4	96	4330	2500	0.25	145

Location: SASW C-6 Profile 2

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.75	779	450	0.25	145
2	1	1732	1000	0.25	145
3	2	2078	1200	0.25	145
4	20	4330	2500	0.25	145
5	152	6062	3500	0.25	145

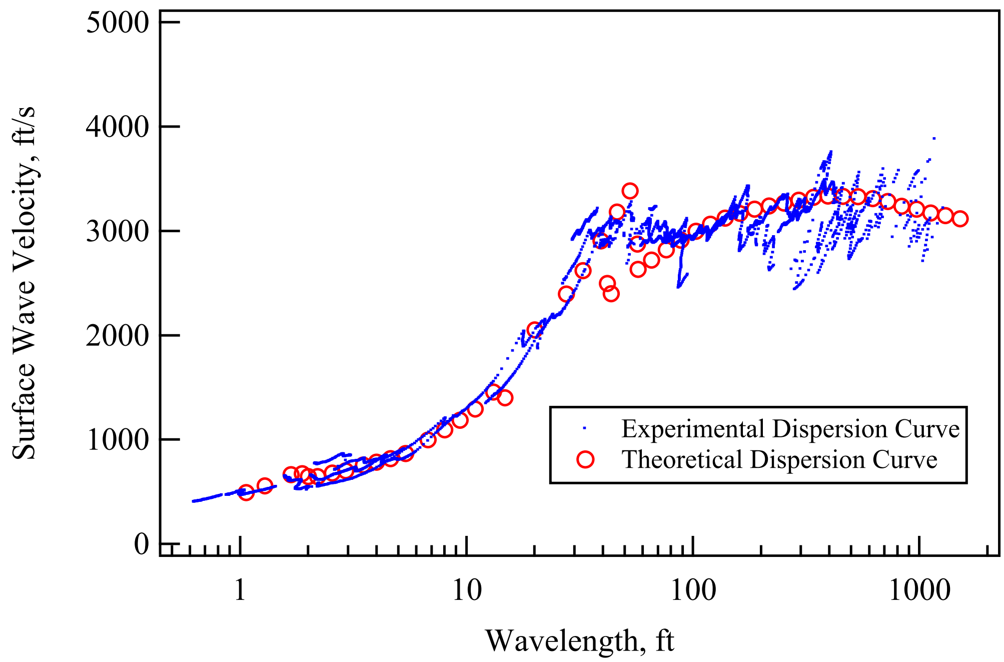
Location: SASW C-6 Profile 3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.75	779	450	0.25	145
2	1	1732	1000	0.25	145
3	2	2078	1200	0.25	145
4	20	4330	2500	0.25	145
5	30	6062	3500	0.25	145
6	175	8660	5000	0.25	145
7	70	5196	3000	0.25	145

DTN: MO0203SEPSASWD.000

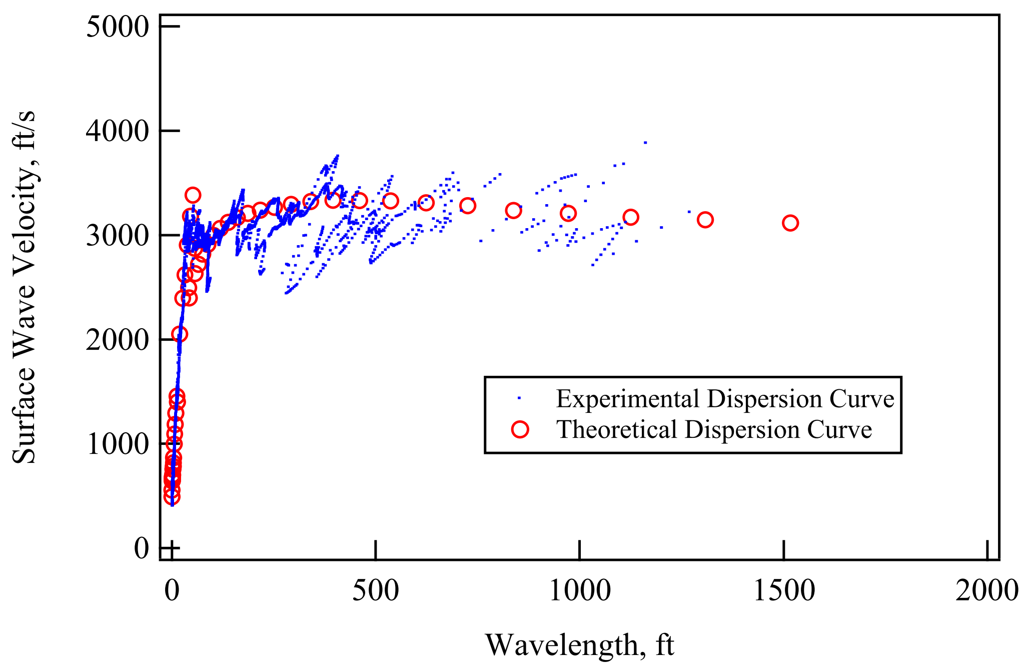
*Poisson's ratio and mass density from Wong (2002d, Appendix 6, page 61)

Figure XV-6. SASW-C6 Results (continued)



(Wong, 2002d, Appendix 7, page 70)

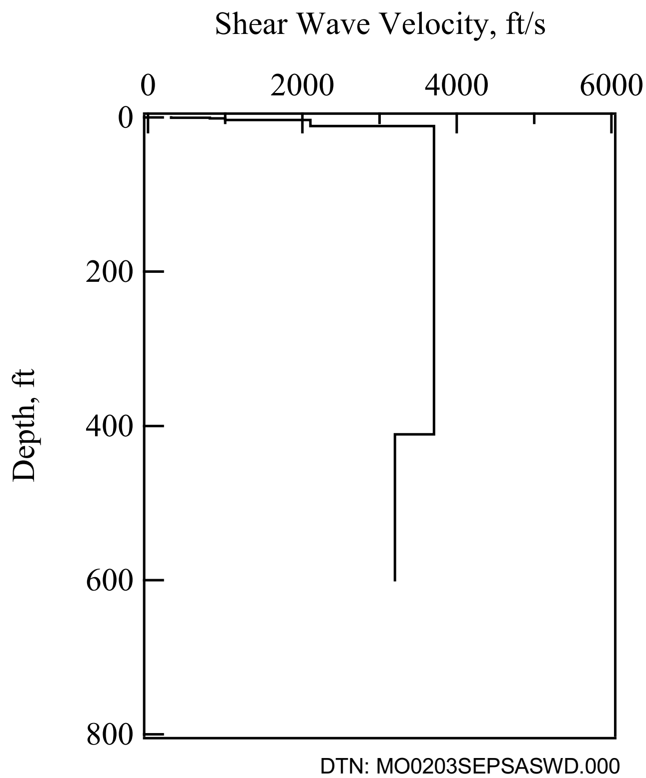
a. SASW C-7 Dispersion Curves (Log Plot)



(Wong, 2002d, Appendix 7, page 70)

b. SASW C-7 Dispersion Curves (Linear Plot)

Figure XV-7. SASW-C7 Results



c. SASW C-7 Shear Wave Velocity Profile

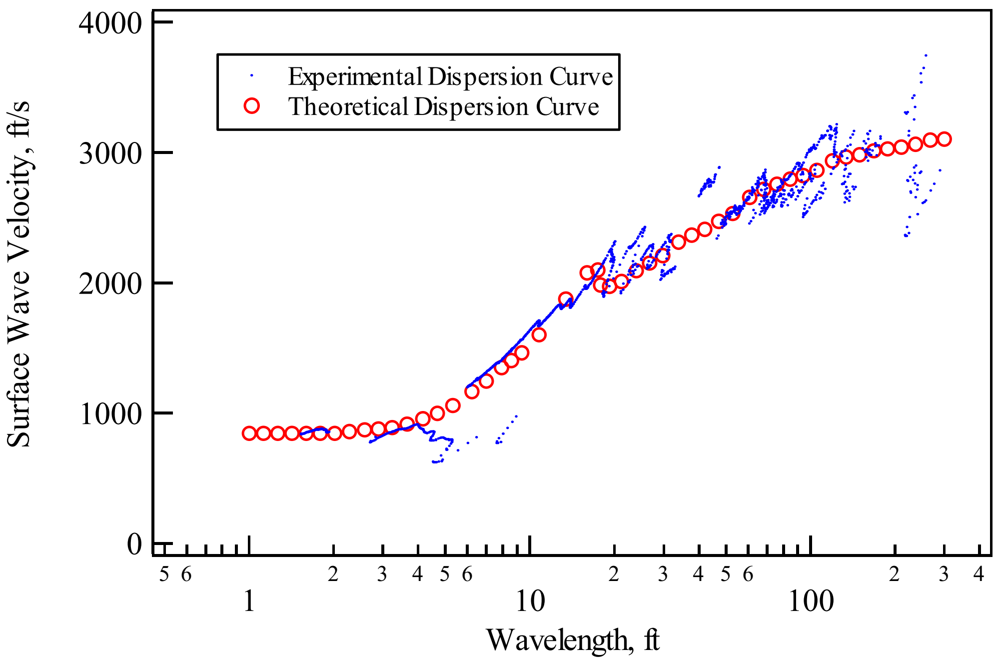
Location: SASW C-7

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.25	519	300	0.25	145
2	1	1385	800	0.25	145
3	2	1732	1000	0.25	145
4	8	3637	2100	0.25	145
5	400	6409	3700	0.25	145
6	190	5542	3200	0.25	145

DTN: MO0203SEPSASWD.000

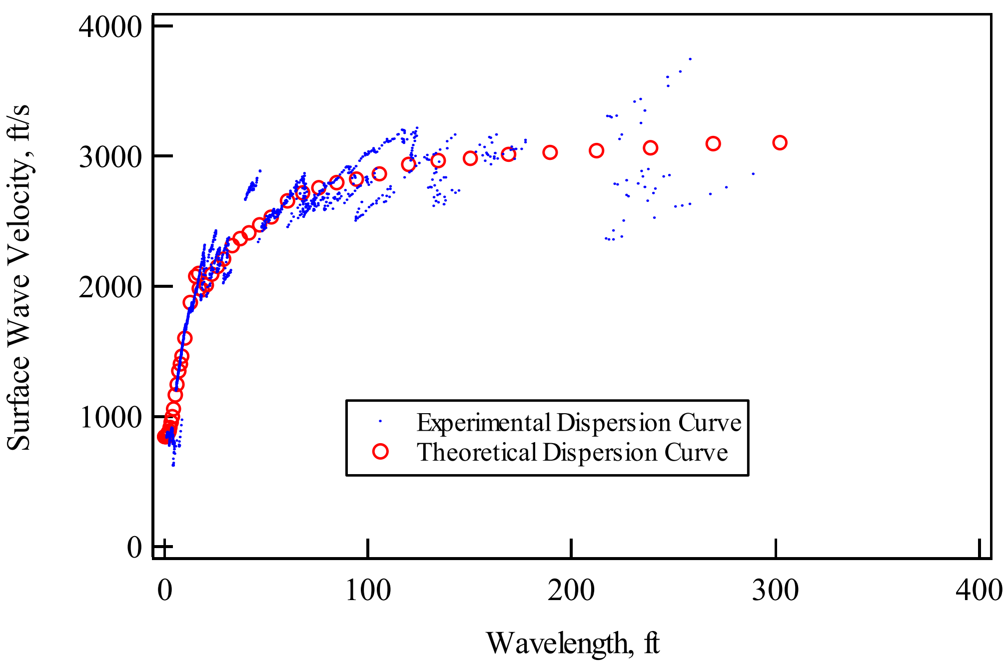
* Poisson's ratio and mass density from Wong (2002d, Appendix 7, page 72)

Figure XV-7. SASW-C7 Results (continued)



(Wong, 2002a, Appendix 1)

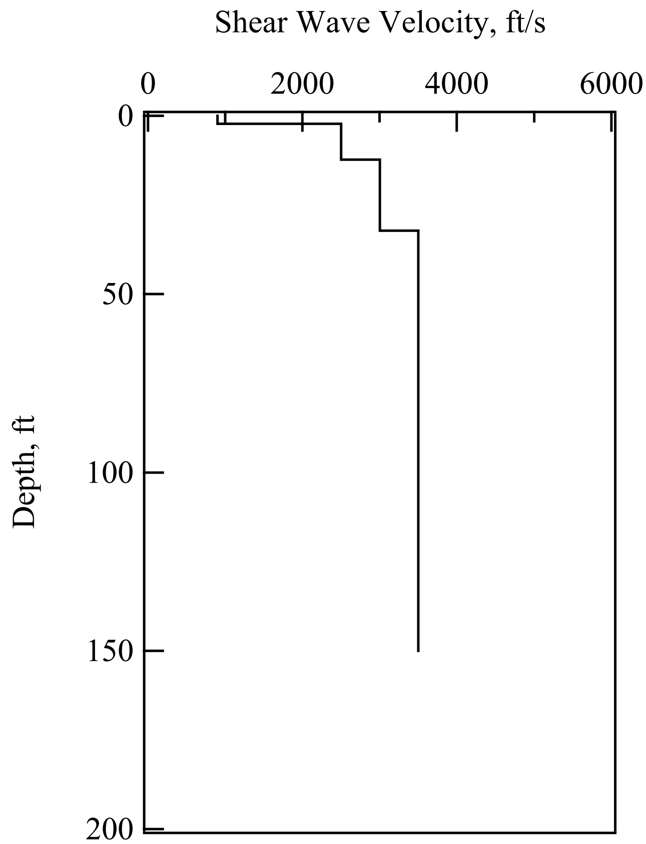
a. SASW-S1 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 1)

b. SASW-S1 Dispersion Curves (Linear Plot)

Figure XV-8. SASW-S1 Results



DTN: MO0110SASWVDYM.000

c. SASW-S1 Shear Wave Velocity Profile

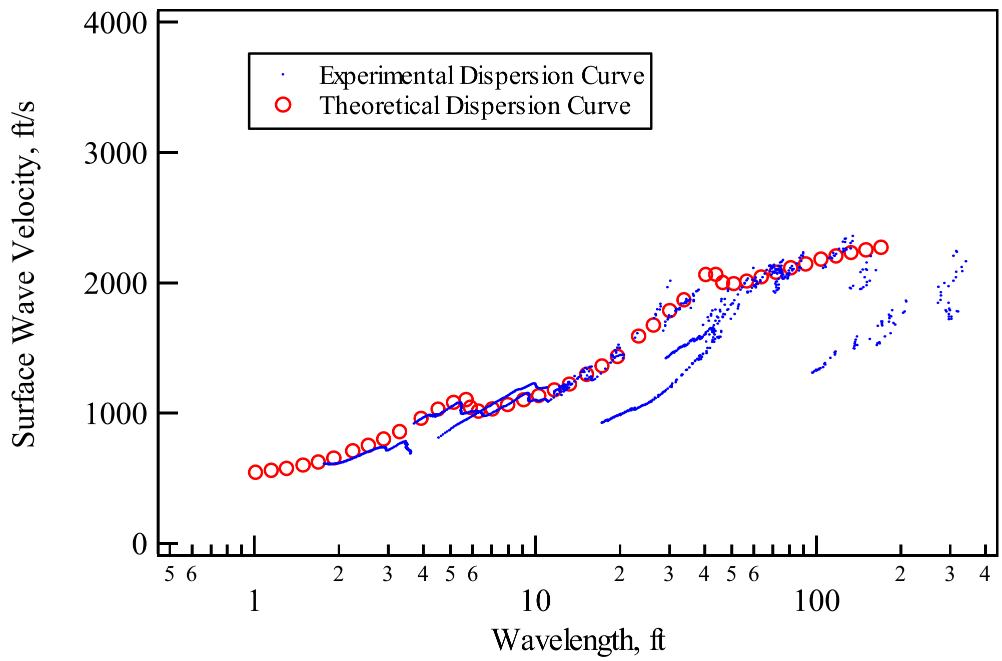
Location: SASW-S1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2.25	1559	900	0.25	145
2	10	4330	2500	0.25	145
3	20	5196	3000	0.25	145
4	118	6062	3500	0.25	145

DTN: MO0110SASWVDYM.000

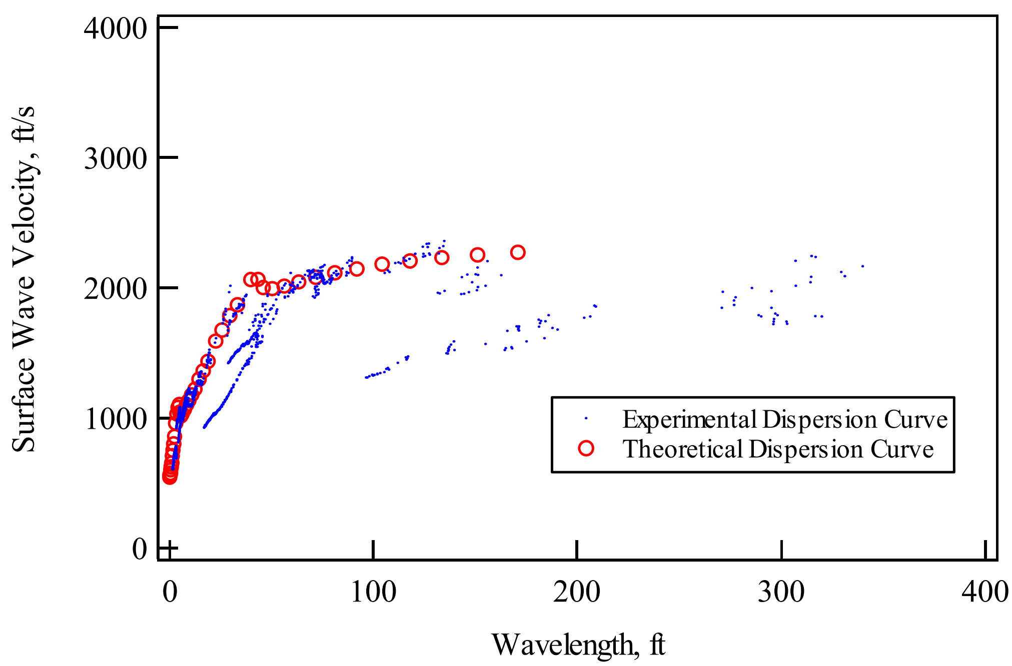
* Poisson's ratio and mass density from Wong (2002a, Appendix 1)

Figure XV-8. SASW-S1 Results (continued)



(Wong, 2002a, Appendix 2)

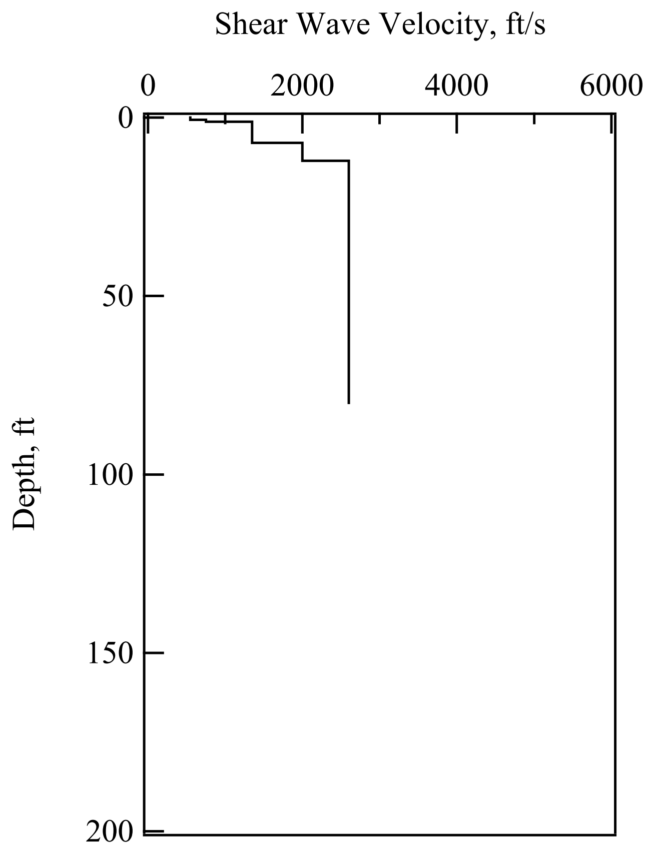
a. SASW-S2 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 2)

b. SASW-S2 Dispersion Curves (Linear Plot)

Figure XV-9. SASW-S2 Results



DTN: MO0110SASWVDYM.000

c. SASW-S2 Shear Wave Velocity Profile

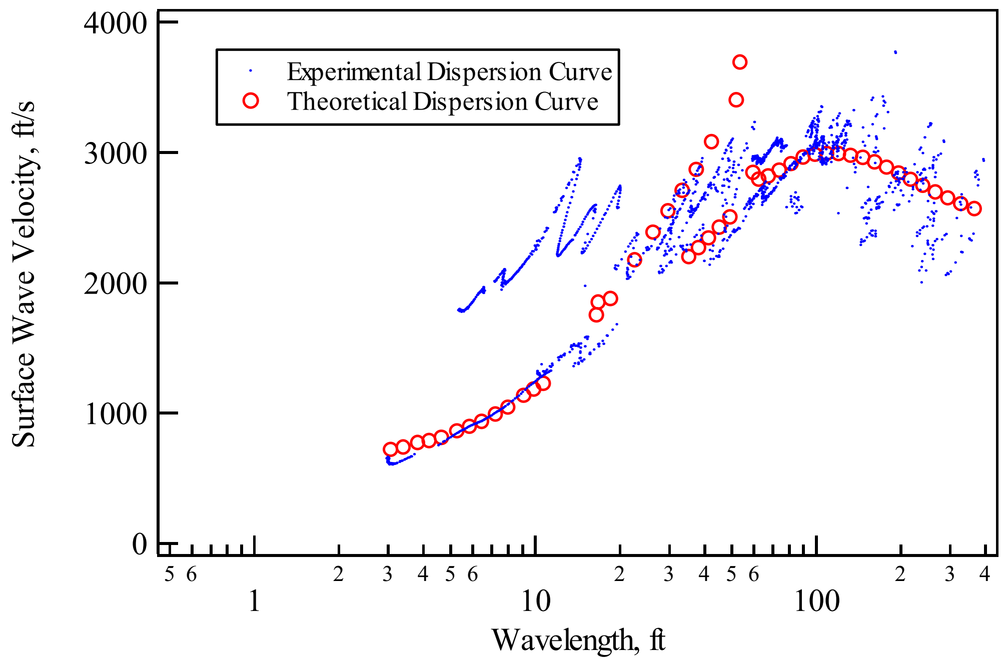
Location: SASW-S2

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	0.6	953	550	0.25	145
2	0.5	1299	750	0.25	145
3	6	2338	1350	0.25	145
4	5	3464	2000	0.25	145
5	67	4503	2600	0.25	145

DTN: MO0110SASWVDYM.000

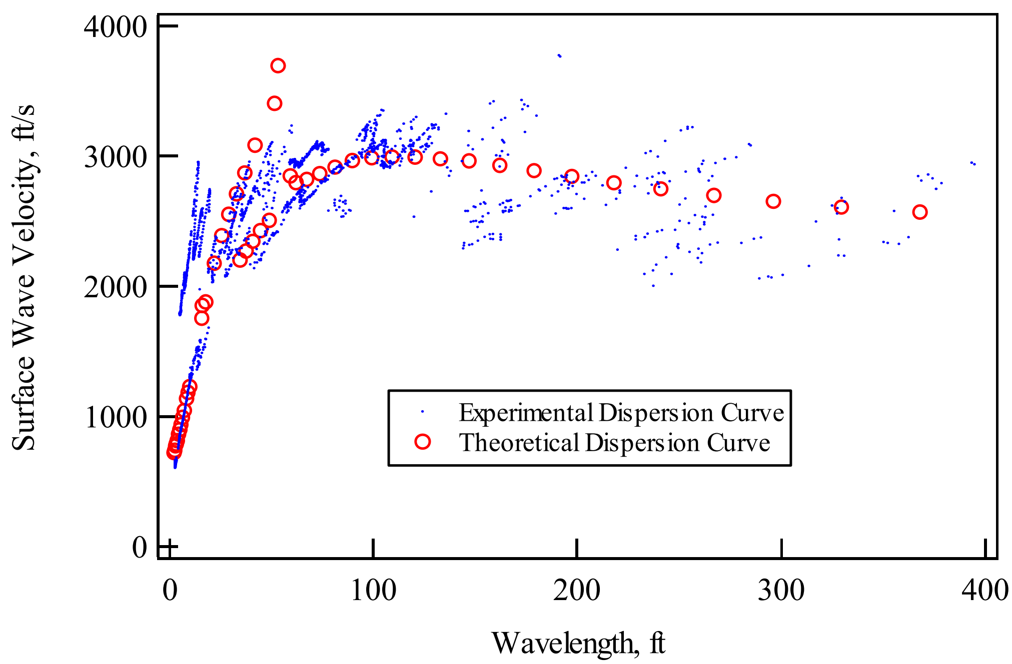
* Poisson's ratio and mass density from Wong (2002a, Appendix 2)

Figure XV-9. SASW-S2 Results (continued)



(Wong, 2002a, Appendix 3)

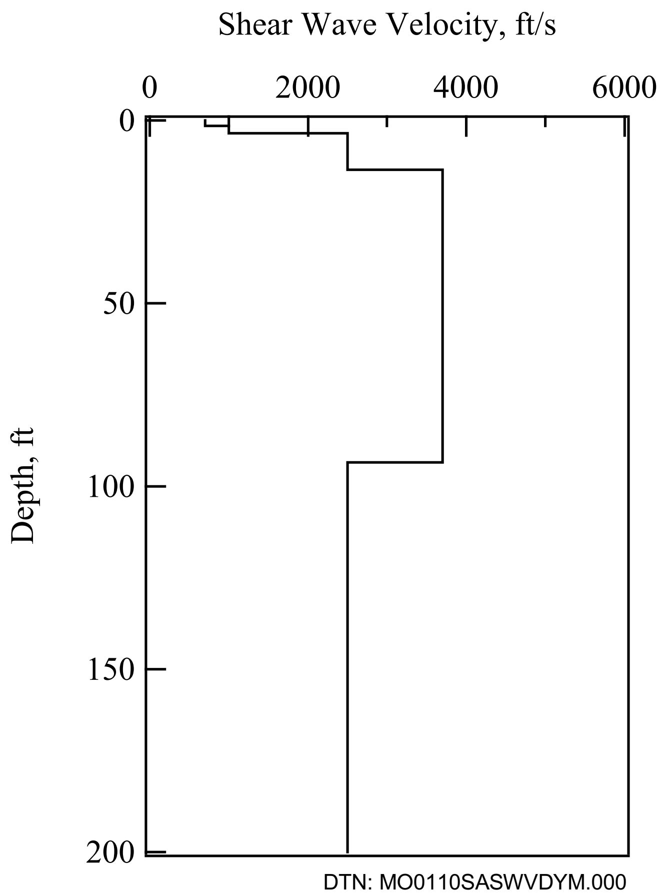
a. SASW-S3 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 3)

b. SASW-S3 Dispersion Curves (Linear Plot)

Figure XV-10. SASW-S3 Results



c. SASW-S3 Shear Wave Velocity Profile

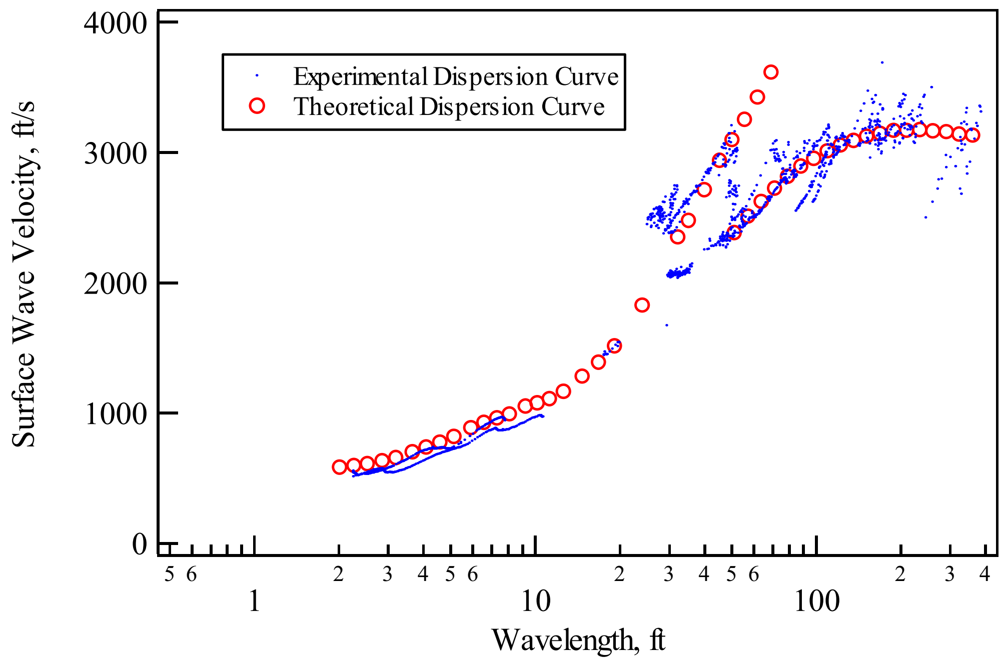
Location: SASW-S3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1.5	1212	700	0.25	145
2	2	1732	1000	0.25	145
3	10	4330	2500	0.25	145
4	80	6409	3700	0.25	145
5	107	4330	2500	0.25	145

DTN: MO0110SASWVDYM.000

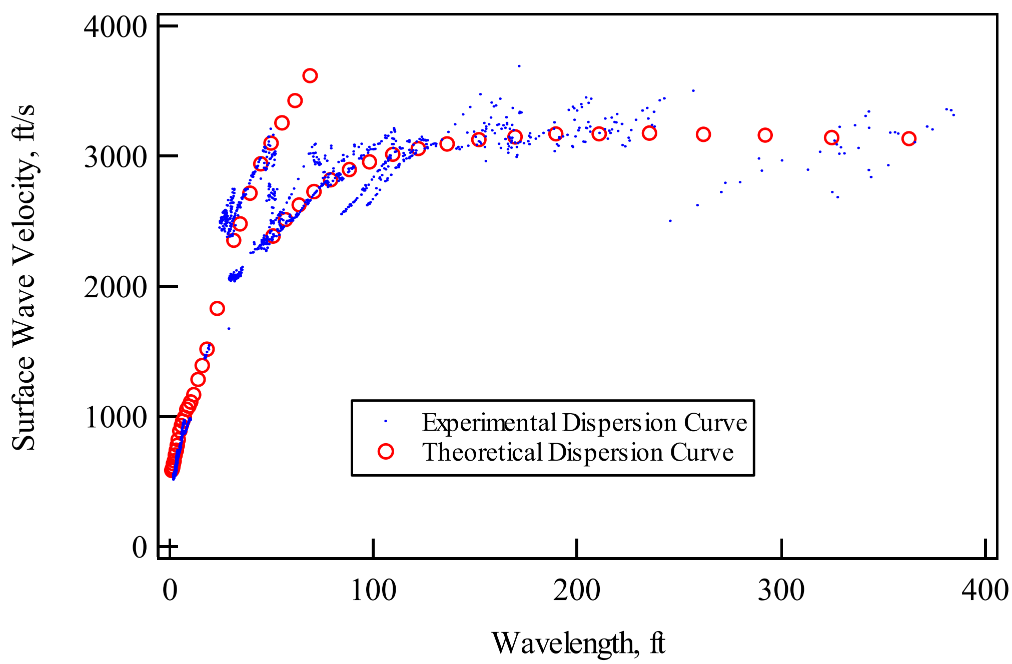
* Poisson's ratio and mass density from Wong (2002a, Appendix 3)

Figure XV-10. SASW-S3 Results (continued)



(Wong, 2002a, Appendix 4)

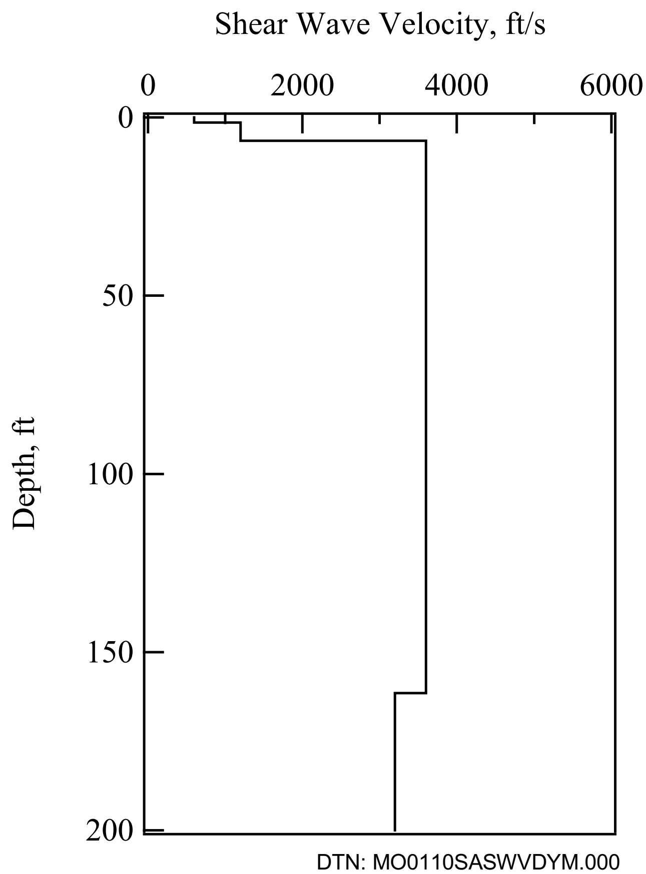
a. SASW-S4 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 4)

b. SASW-S4 Dispersion Curves (Linear Plot)

Figure XV-11. SASW-S4 Results



c. SASW-S4 Shear Wave Velocity Profile

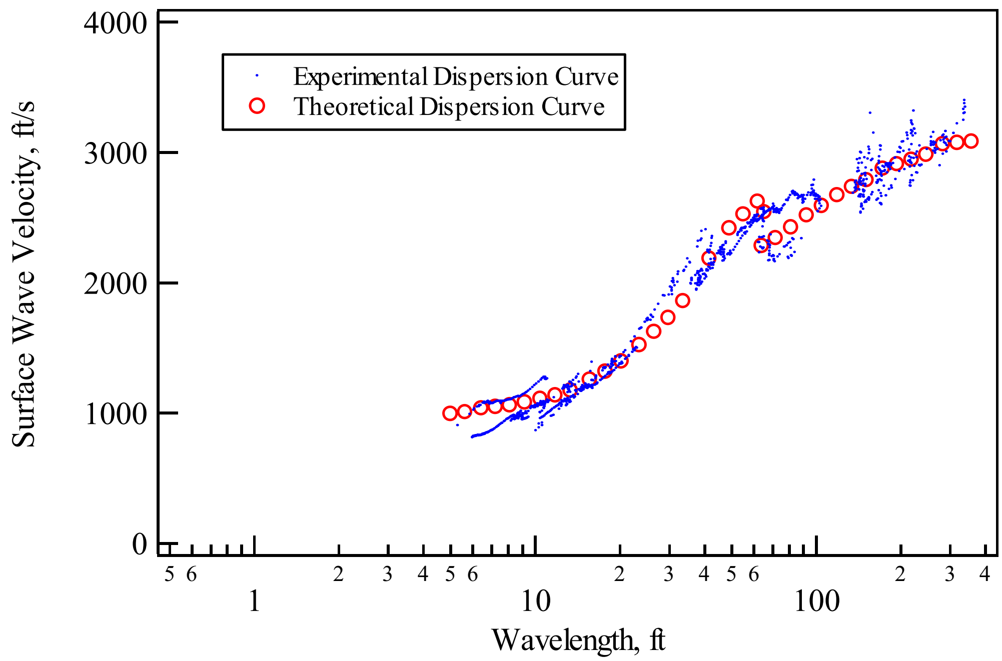
Location: SASW-S4

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1.5	1039	650	0.25	145
2	5	2079	1200	0.25	145
3	155	6235	3600	0.25	145
4	39	5543	3200	0.25	145

DTN: MO0110SASWVDYM.000

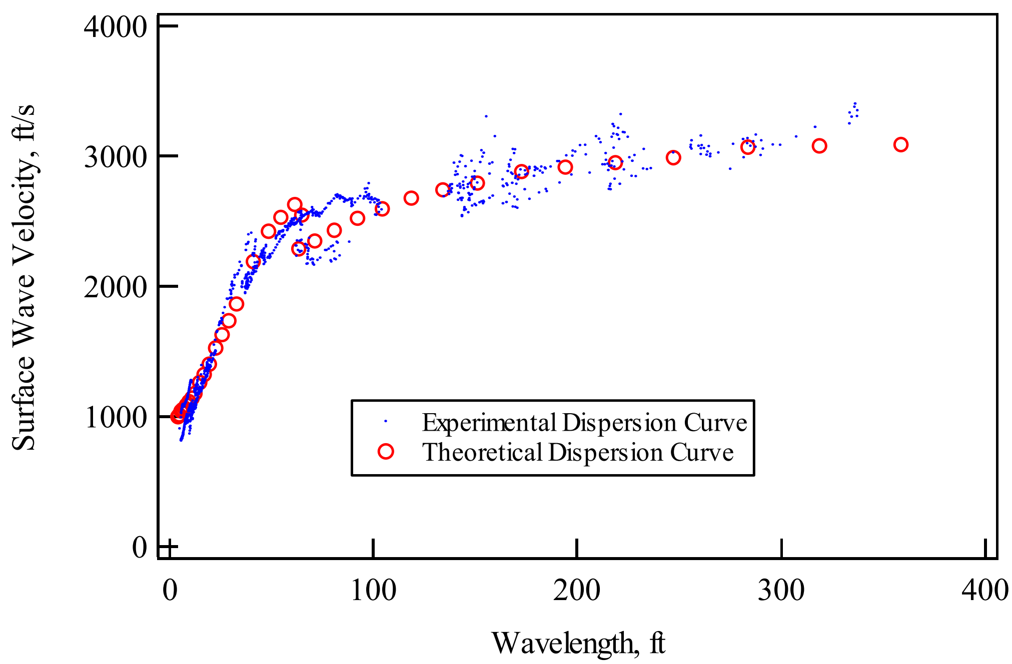
* Poisson's ratio and mass density from Wong (2002a, Appendix 4)

Figure XV-11. SASW-S4 Results (continued)



(Wong, 2002a, Appendix 5)

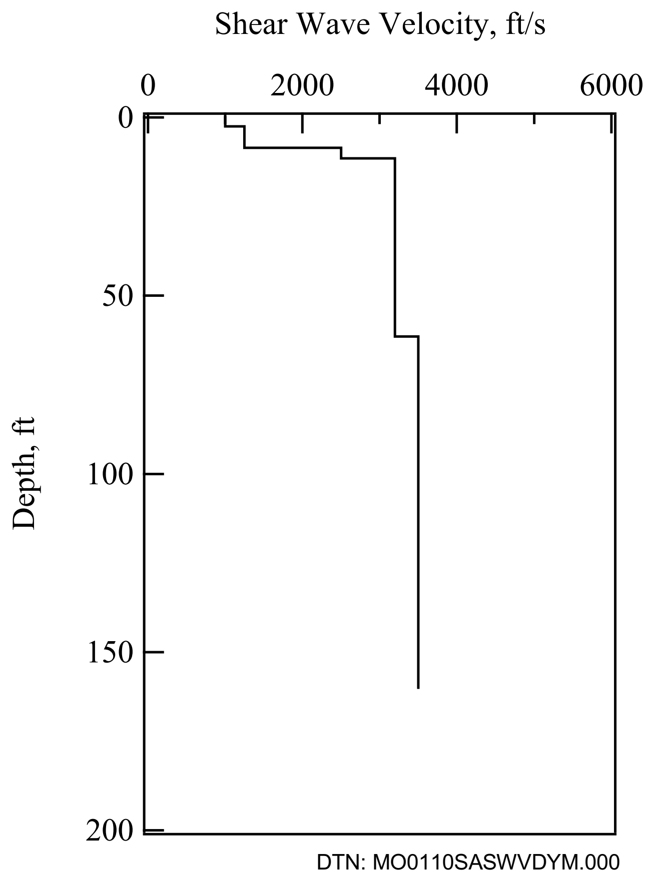
a. SASW-S5 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 5)

b. SASW-S5 Dispersion Curves (Linear Plot)

Figure XV-12. SASW-S5 Results



c. SASW-S5 Shear Wave Velocity Profile

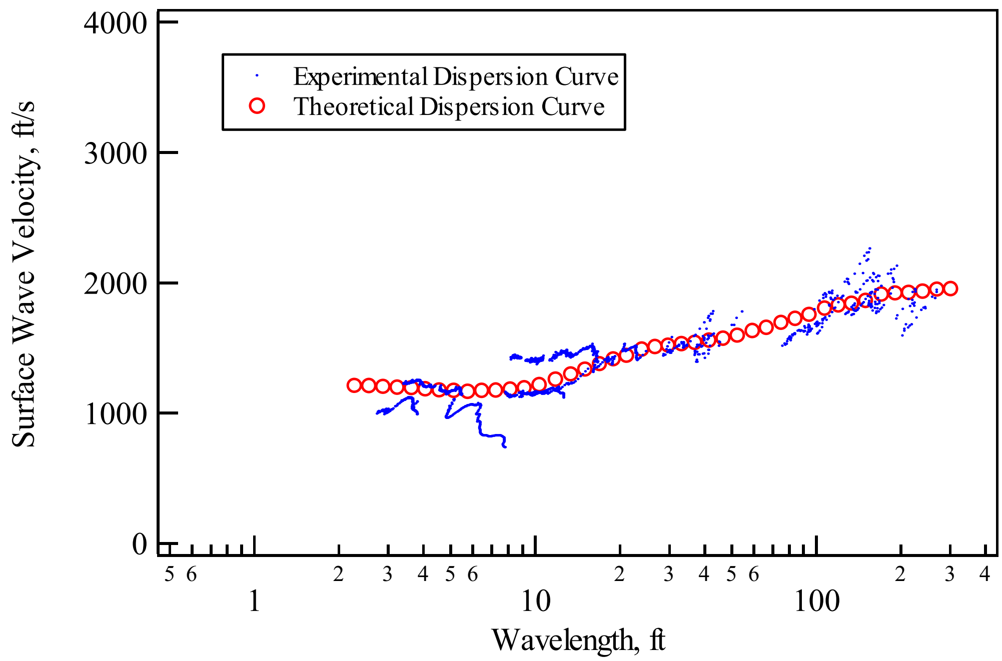
Location: SASW-S5

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2.5	1732	1000	0.25	145
2	6	2165	1250	0.25	145
3	3	4330	2500	0.25	145
4	50	5542	3200	0.25	145
5	98	6062	3500	0.25	145

DTN: MO0110SASWVDYM.000

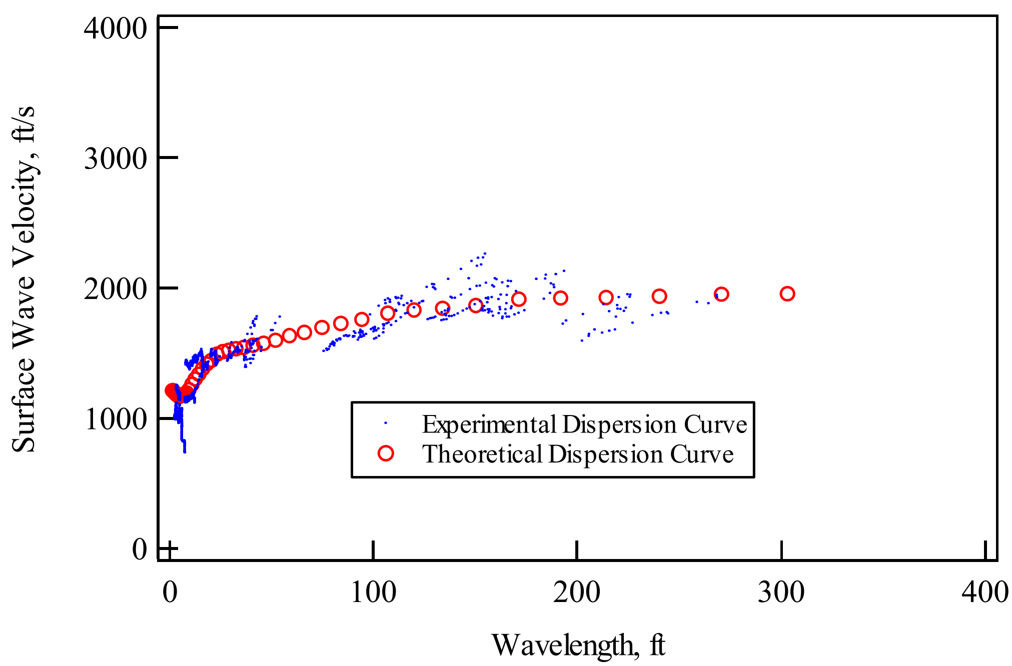
* Poisson's ratio and mass density from Wong (2002a, Appendix 5)

Figure XV-12. SASW-S5 Results (continued)



(Wong, 2002a, Appendix 6)

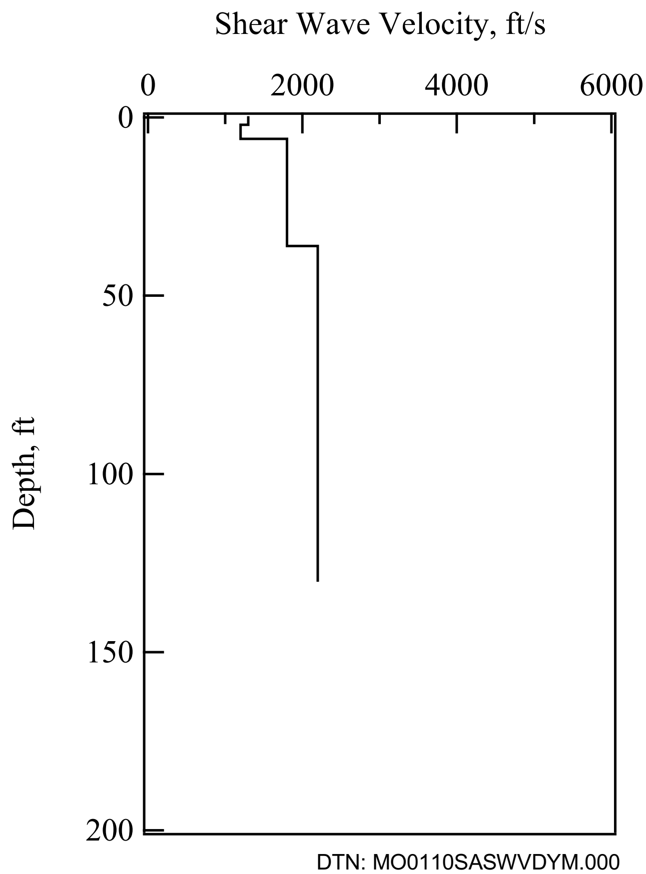
a. SASW-S6 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 6)

b. SASW-S6 Dispersion Curves (Linear Plot)

Figure XV-13. SASW-S6 Results



c. SASW-S6 Shear Wave Velocity Profile

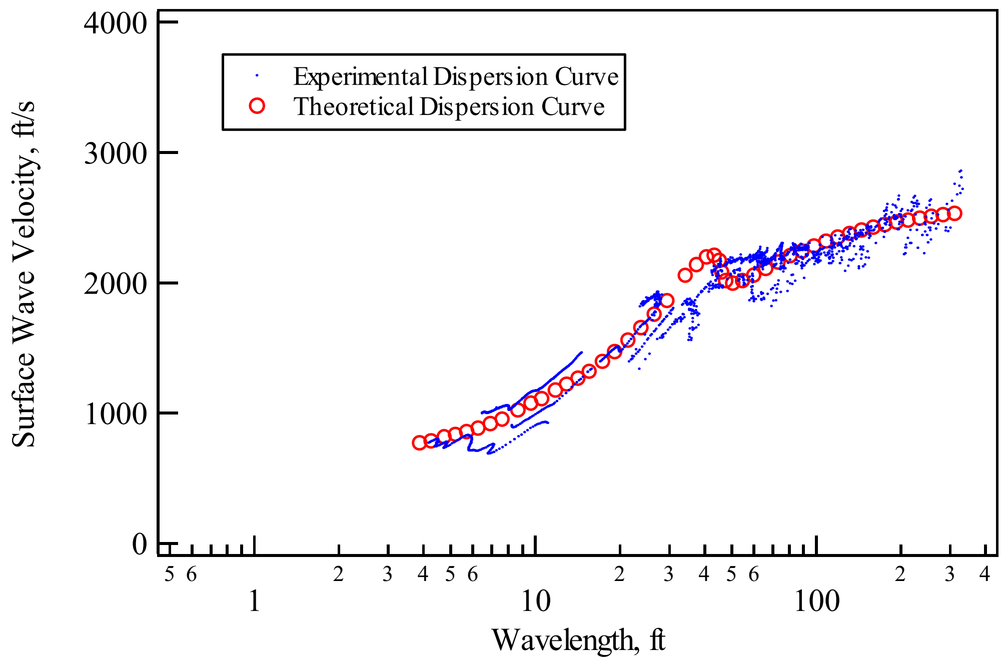
Location: SASW-S6

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	2251	1300	0.25	145
2	4	2078	1200	0.25	145
3	30	3117	1800	0.25	145
4	96	3810	2200	0.25	145

DTN: MO0110SASWVDYM.000

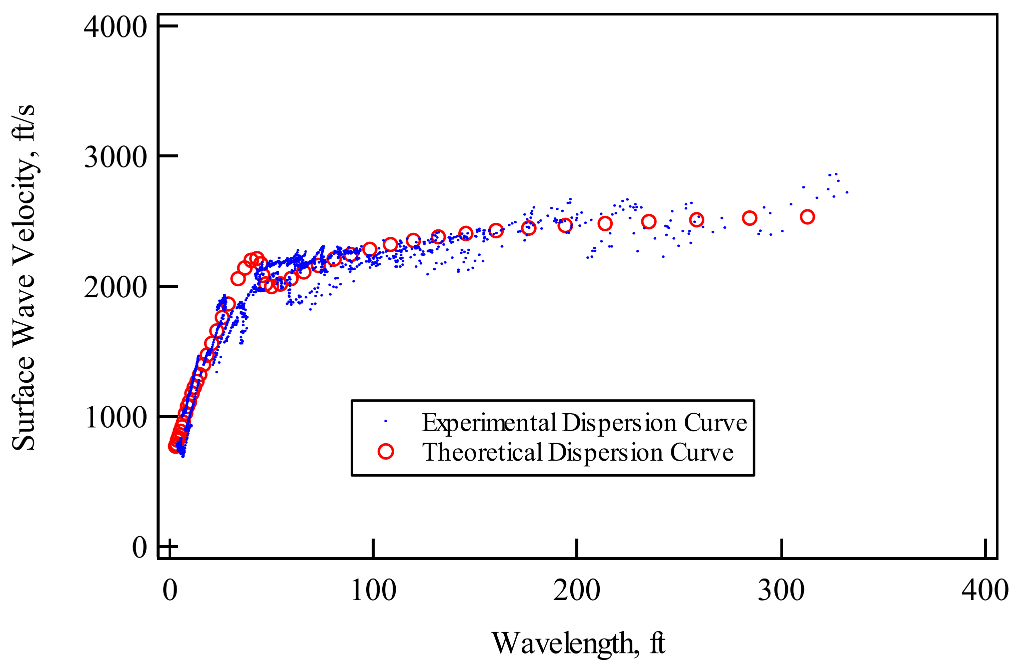
* Poisson's ratio and mass density from Wong (2002a, Appendix 6)

Figure XV-13. SASW-S6 Results (continued)



(Wong, 2002a, Appendix 7)

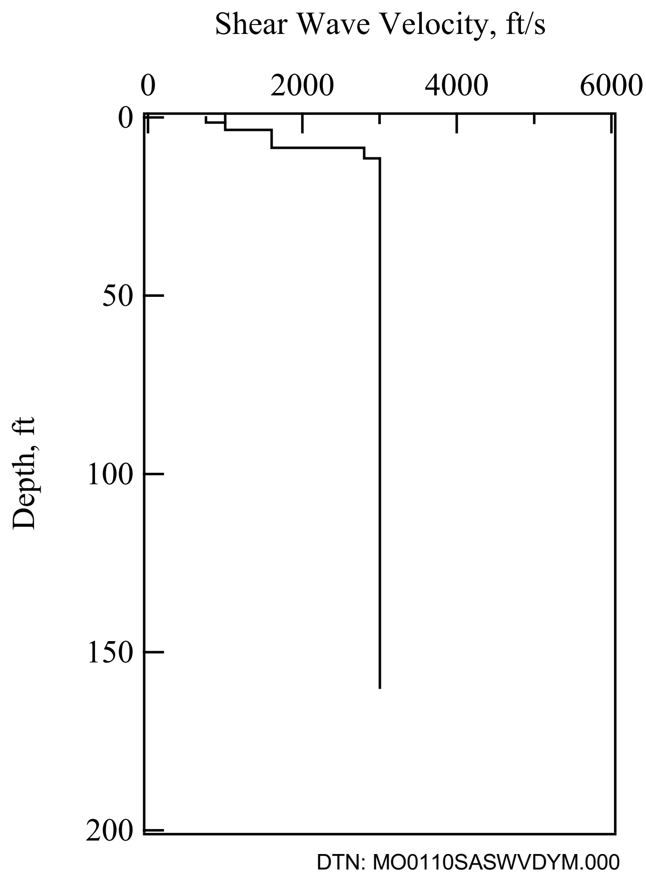
a. SASW-S7 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 7)

b. SASW-S7 Dispersion Curves (Linear Plot)

Figure XV-14. SASW-S7 Results



c. SASW-S7 Shear Wave Velocity Profile

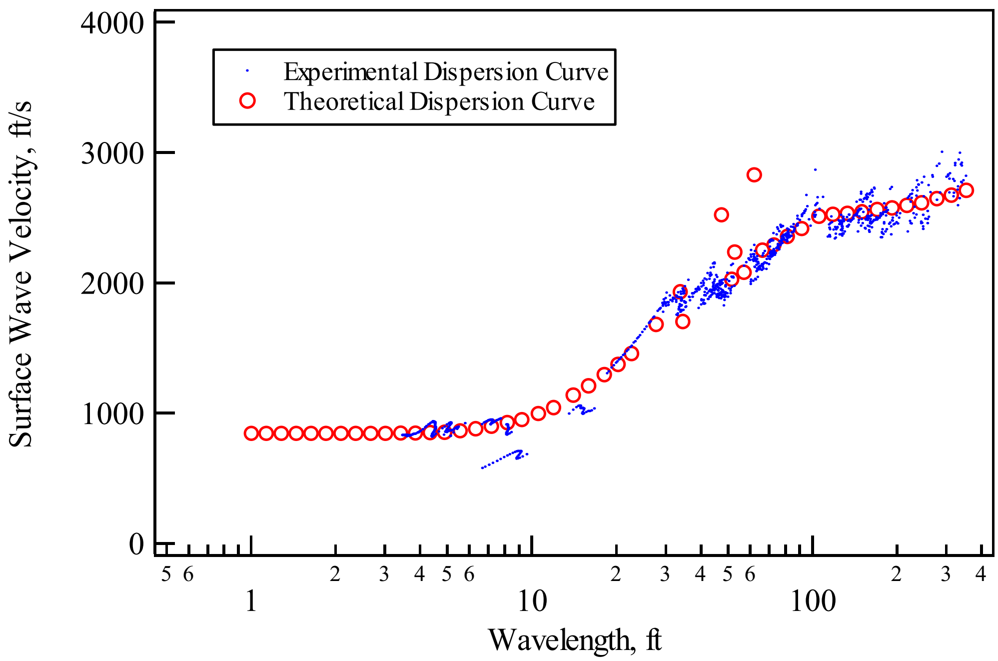
Location: SASW-S7

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1.5	1299	750	0.25	145
2	2	1732	1000	0.25	145
3	5	2771	1600	0.25	145
4	3	4850	2800	0.25	145
5	149	5196	3000	0.25	145

DTN: MO0110SASWVDYM.000

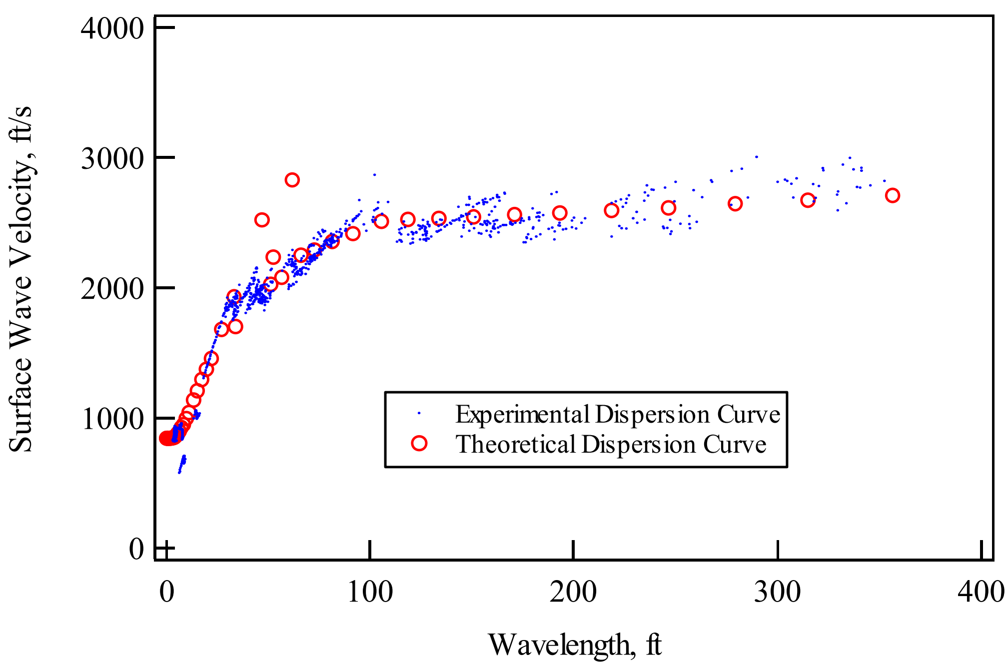
* Poisson's ratio and mass density from Wong (2002a, Appendix 7)

Figure XV-14. SASW-S7 Results (continued)



(Wong, 2002a, Appendix 8)

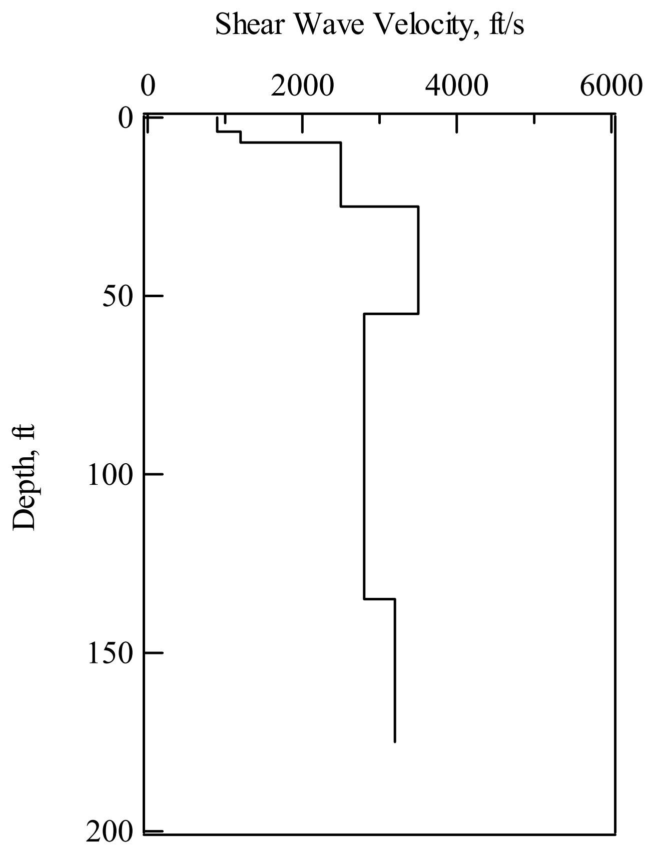
a. SASW-S8 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 8)

b. SASW-S8 Dispersion Curves (Linear Plot)

Figure XV-15. SASW-S8 Results



DTN: MO0110SASWVDYM.000

c. SASW-S8 Shear Wave Velocity Profile

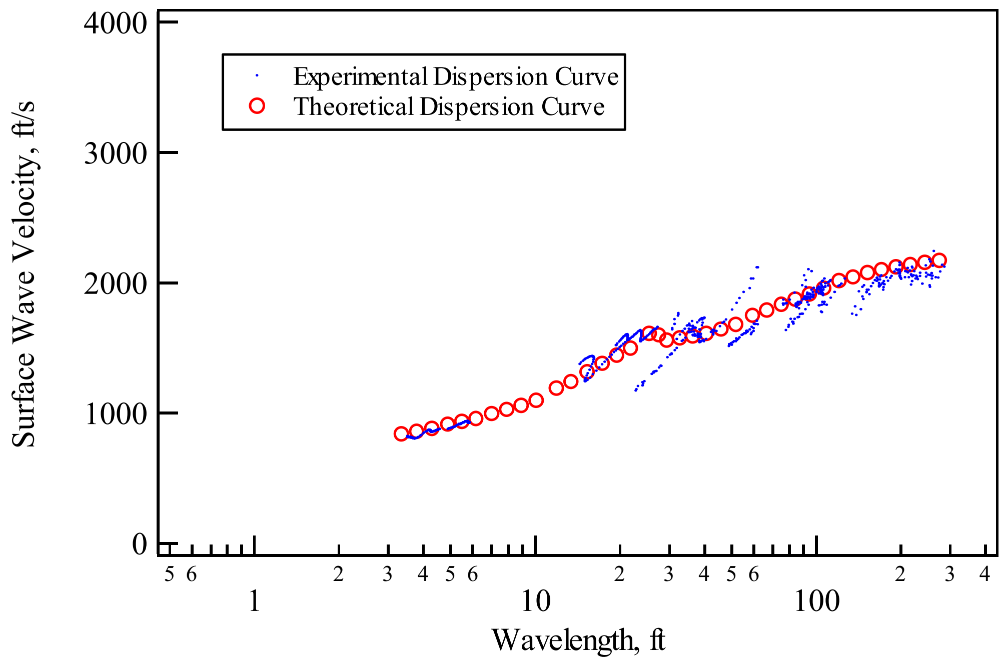
Location: SASW-S8

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	4	1558	900	0.25	145
2	3	2078	1200	0.25	145
3	18	4330	2500	0.25	145
4	30	6062	3500	0.25	145
5	80	4849	2800	0.25	145
6	40	5542	3200	0.25	145

DTN: MO0110SASWVDYM.000

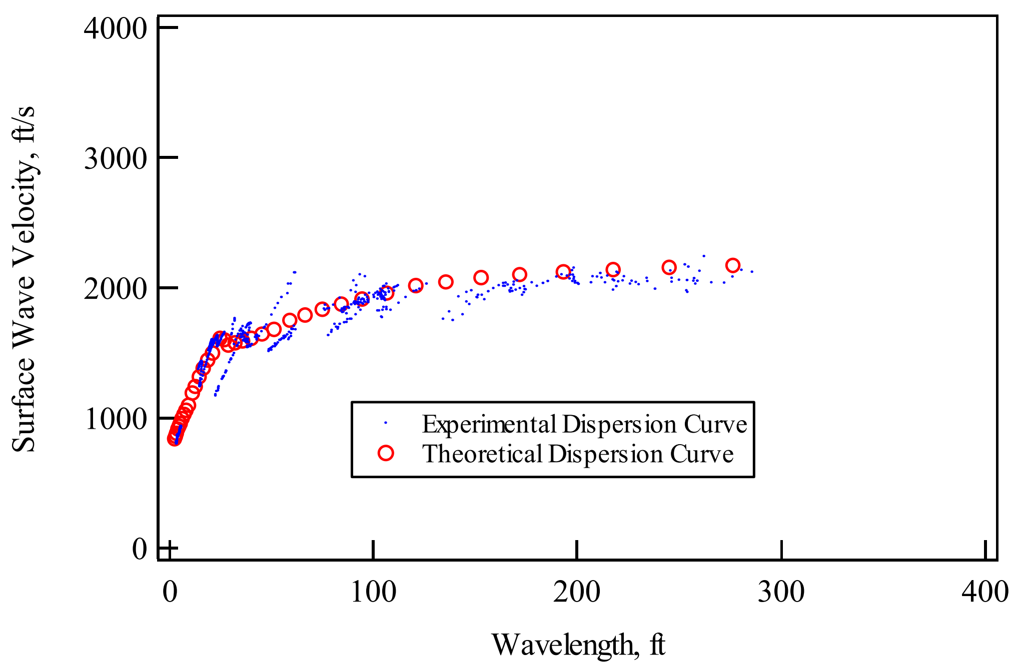
* Poisson's ratio and mass density from Wong (2002a, Appendix 8)

Figure XV-15. SASW-S8 Results (continued)



(Wong, 2002a, Appendix 9)

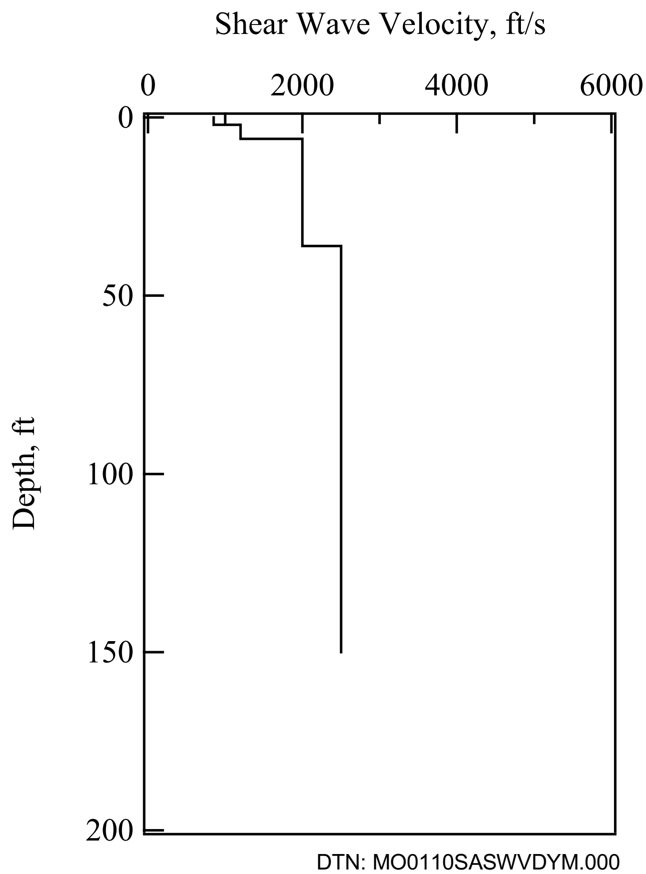
a. SASW-S9 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 9)

b. SASW-S9 Dispersion Curves (Linear Plot)

Figure XV-16. SASW-S9 Results



c. SASW-S9 Shear Wave Velocity Profile

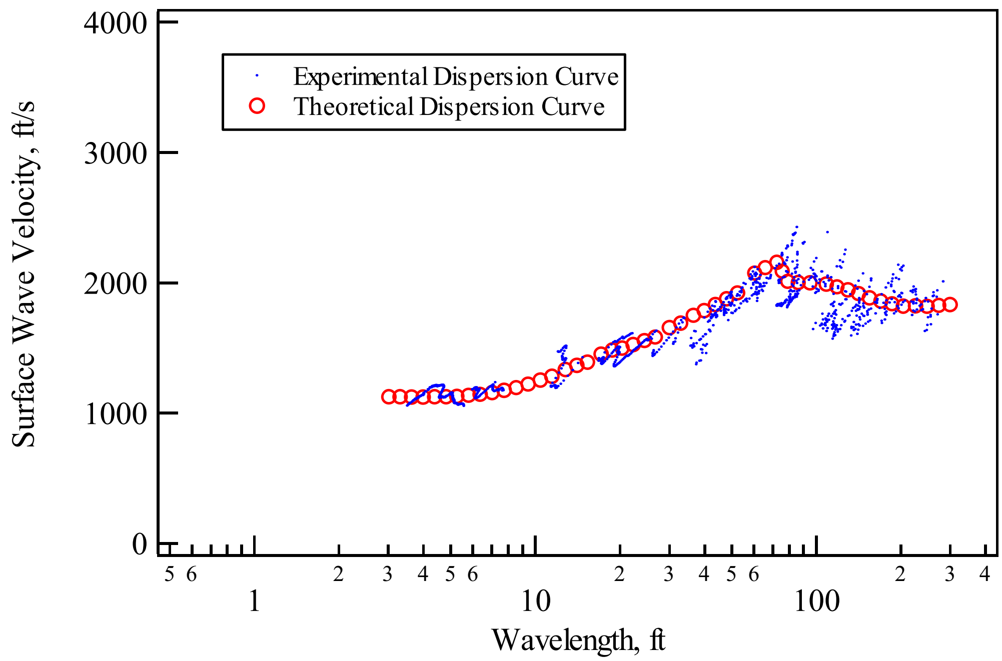
Location: SASW-S9

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	1472	850	0.25	145
2	4	2078	1200	0.25	145
3	30	3464	2000	0.25	145
4	114	4330	2500	0.25	145

DTN: MO0110SASWVDYM.000

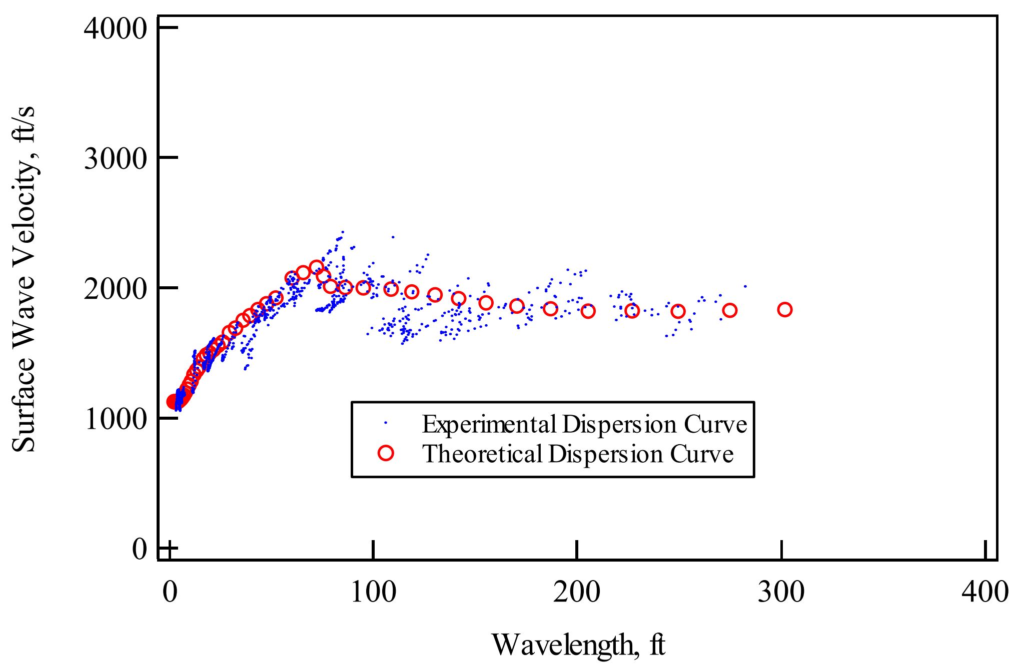
* Poisson's ratio and mass density from Wong (2002a, Appendix 9)

Figure XV-16. SASW-S9 Results (continued)



(Wong, 2002a, Appendix 10)

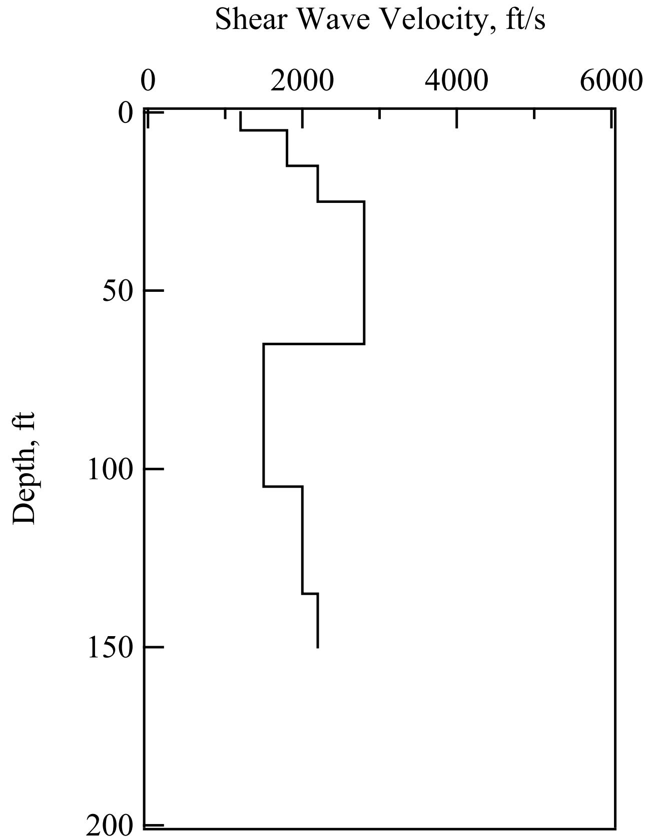
a. SASW-S10 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 10)

b. SASW-S10 Dispersion Curves (Linear Plot)

Figure XV-17. SASW-S10 Results



DTN: MO0110SASWVDYM.000

c. SASW-S10 Shear Wave Velocity Profile

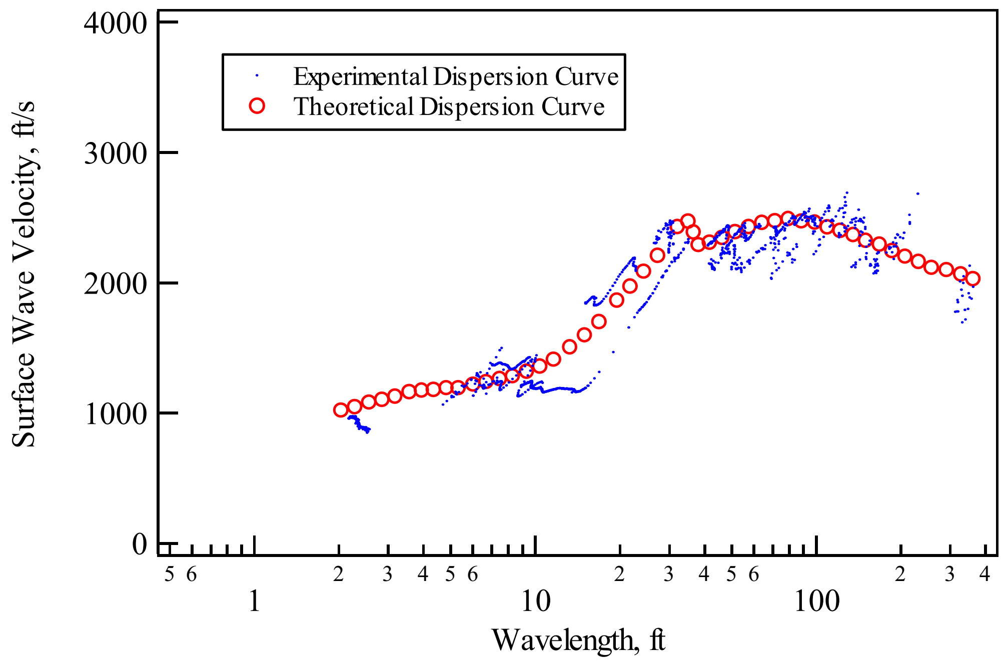
Location: SASW-S10

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	5	2078	1200	0.25	145
2	10	3117	1800	0.25	145
3	10	3810	2200	0.25	145
4	40	4849	2800	0.25	145
5	40	2078	1500	0.25	145
6	30	3464	2000	0.25	145
7	15	3810	2200	0.25	145

DTN: MO0110SASWVDYM.000

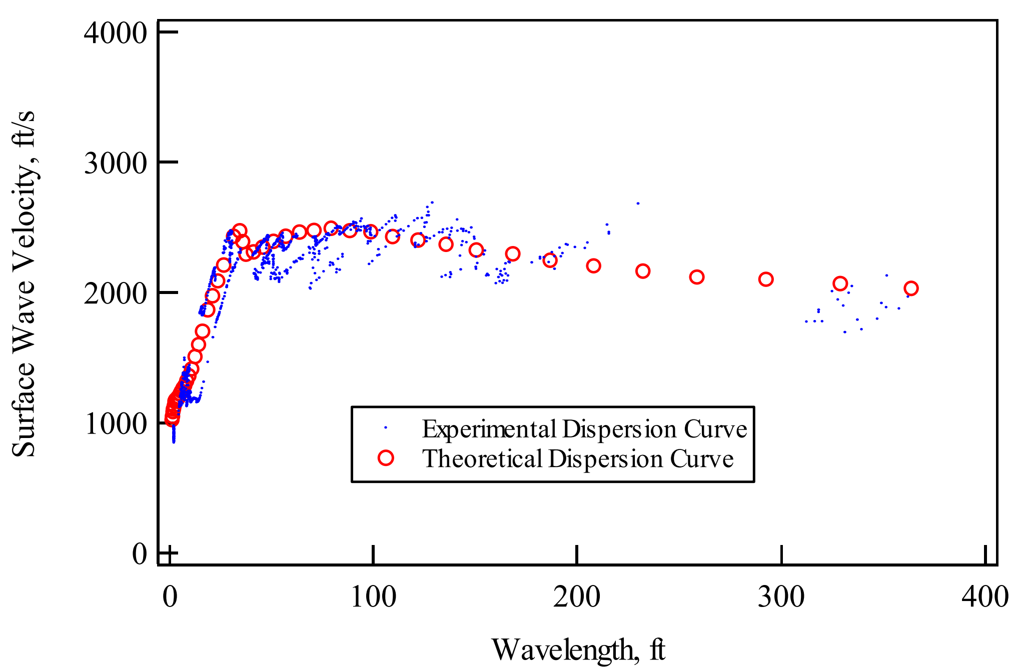
* Poisson's ratio and mass density from Wong (2002a, Appendix 10)

Figure XV-17. SASW-S10 Results (continued)



(Wong, 2002a, Appendix 11)

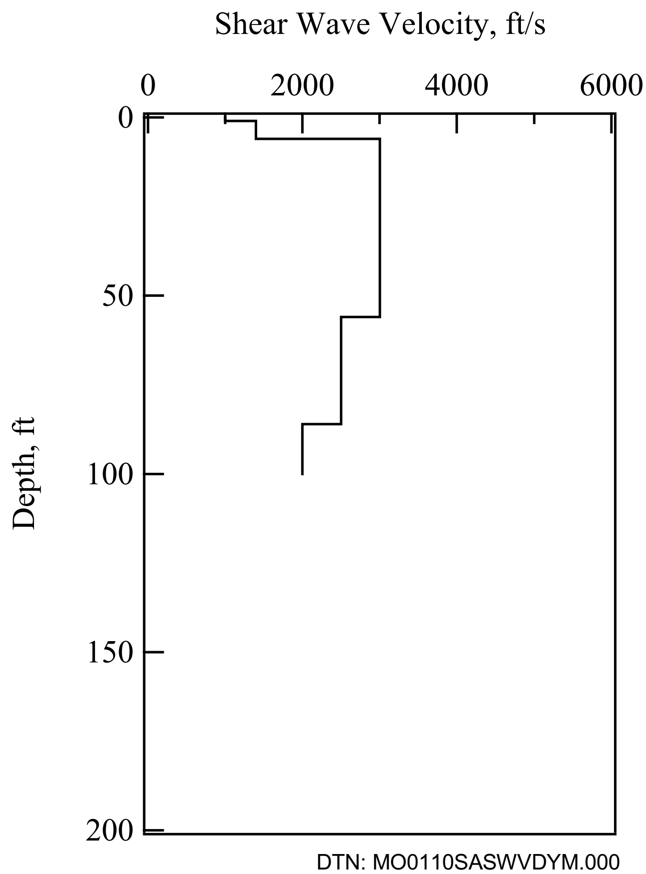
a. SASW-S11 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 11)

b. SASW-S11 Dispersion Curves (Linear Plot)

Figure XV-18. SASW-S11 Results



c. SASW-S11 Shear Wave Velocity Profile

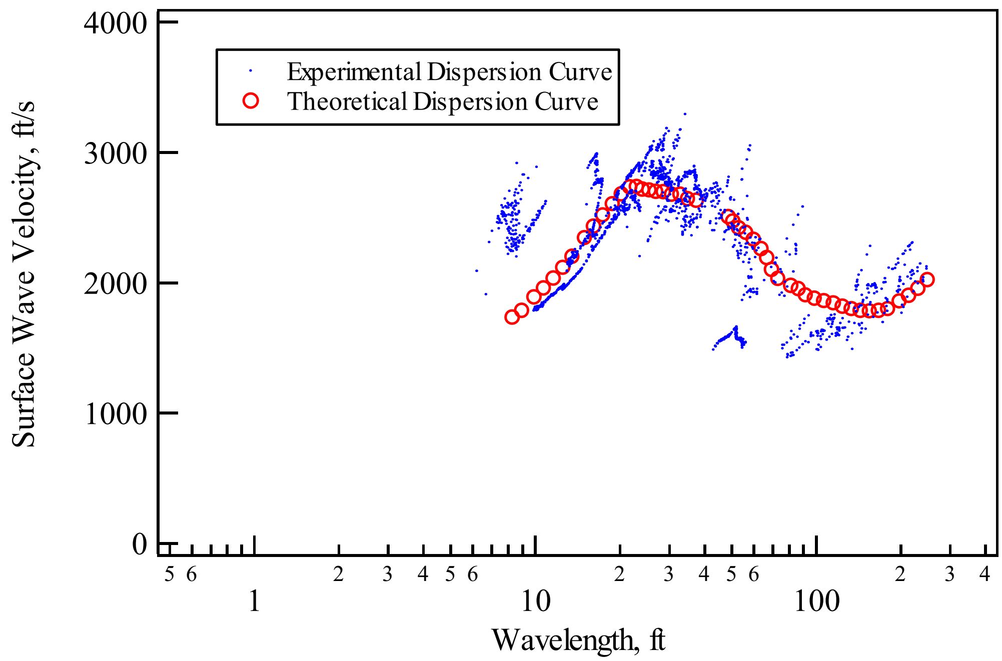
Location: SASW-S11

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	1	1732	1000	0.25	145
2	5	2425	1400	0.25	145
3	50	5196	3000	0.25	145
4	30	4330	2500	0.25	145
5	14	3464	2000	0.25	145

DTN: MO0110SASWVDYM.000

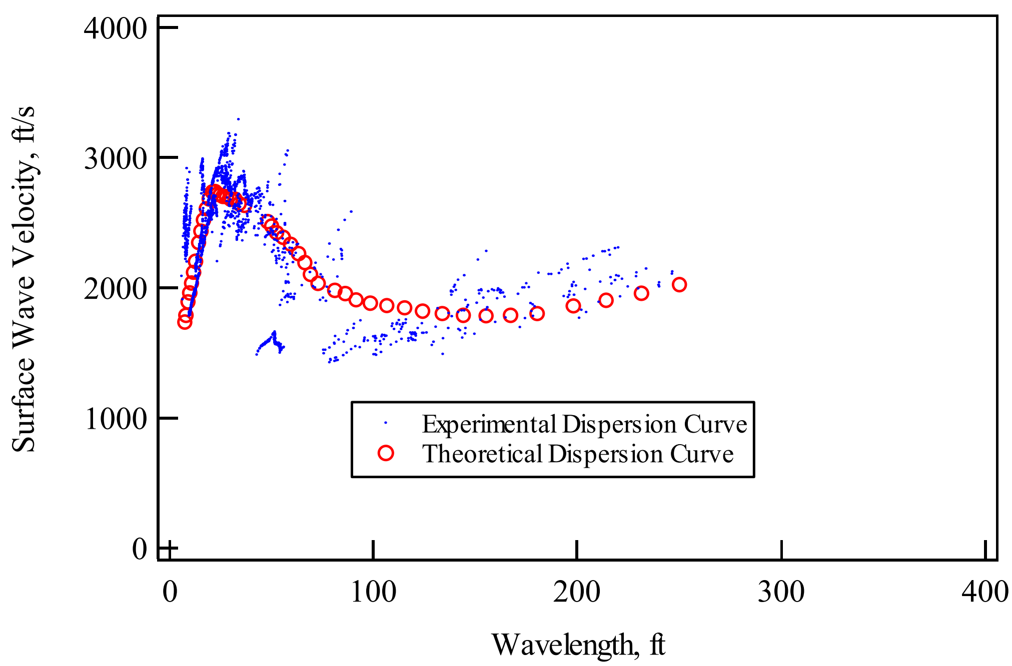
* Poisson's ratio and mass density from Wong (2002a, Appendix 11)

Figure XV-18. SASW-S11 Results (continued)



(Wong, 2002a, Appendix 12)

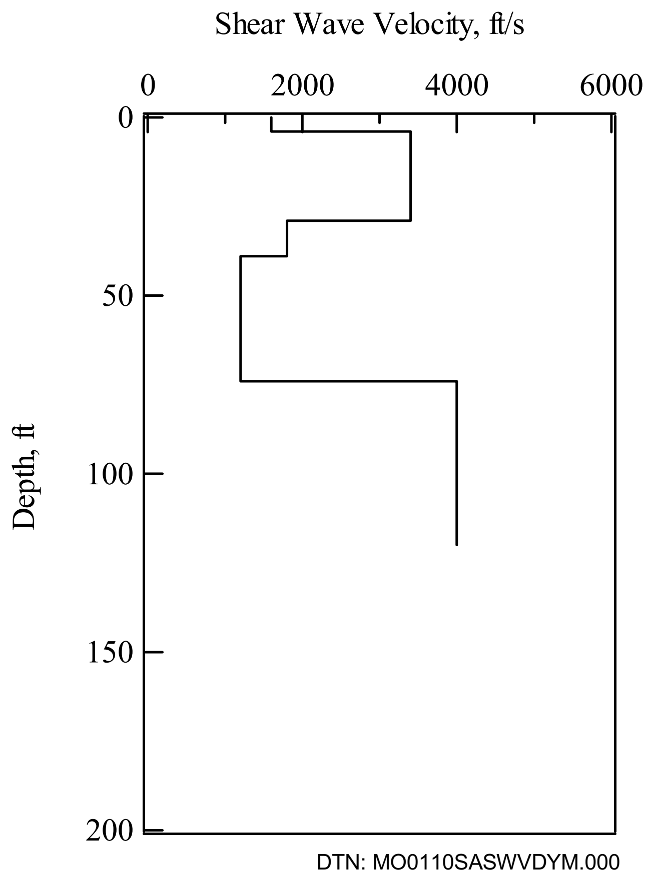
a. SASW-S12 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 12)

b. SASW-S12 Dispersion Curves (Linear Plot)

Figure XV-19. SASW-C12 Results



c. SASW-S12 Shear Wave Velocity Profile

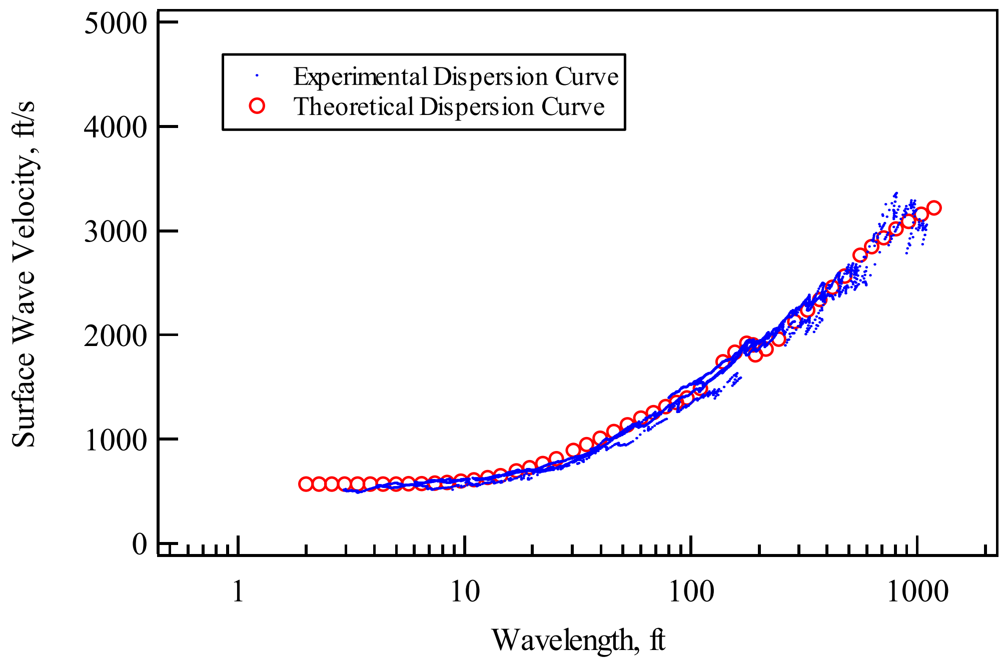
Location: SASW-S12

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	4	2771	1600	0.25	145
2	25	5889	3400	0.25	145
3	10	3117	1800	0.25	145
4	35	2078	1200	0.25	145
5	46	6928	4000	0.25	145

DTN: MO0110SASWVDYM.000

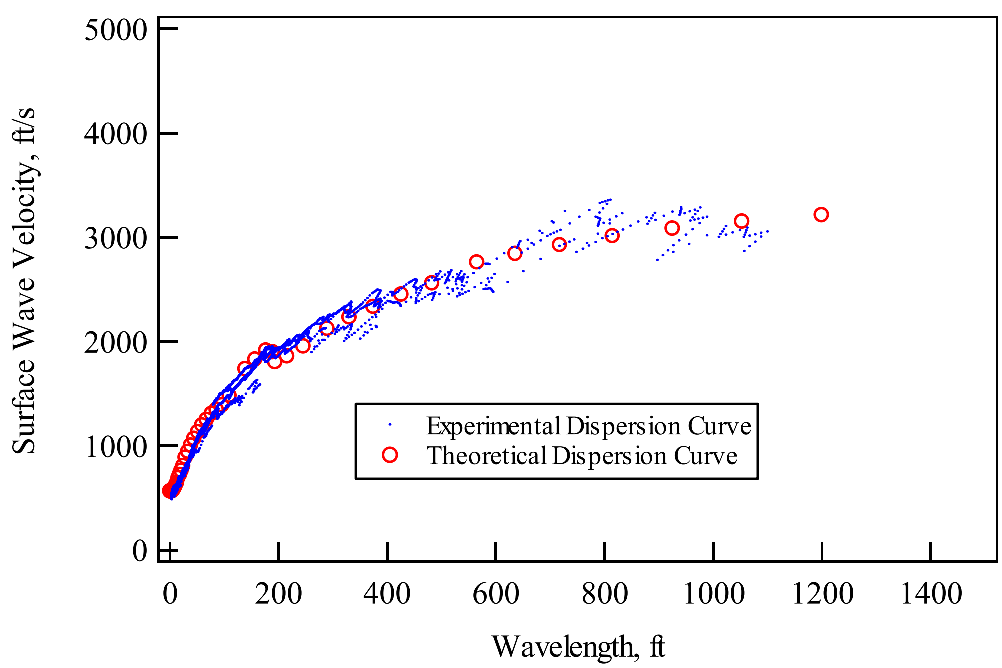
* Poisson's ratio and mass density from Wong (2002a, Appendix 12)

Figure XV-19. SASW-S12 Results (continued)



(Wong, 2002a, Appendix 15)

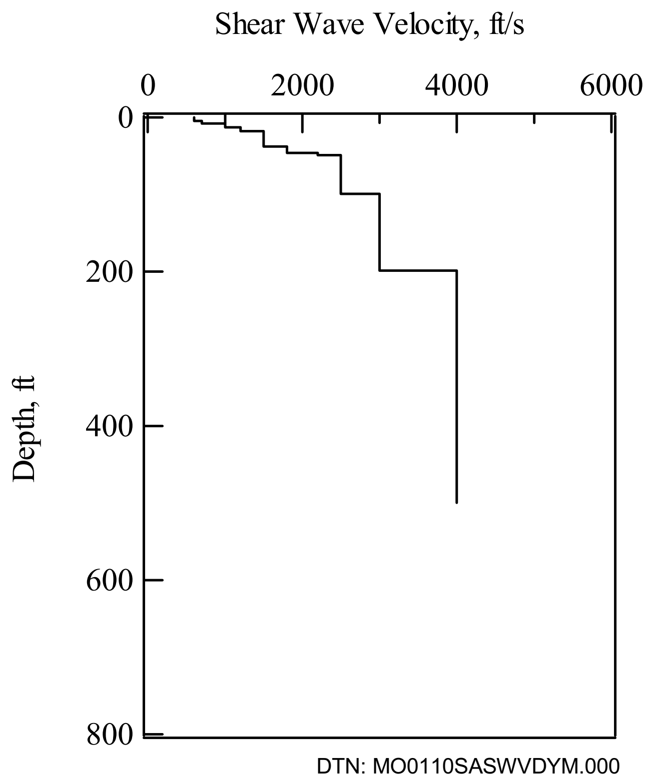
a. SASW-D1 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 15)

b. SASW-D1 Dispersion Curves (Linear Plot)

Figure XV-20. SASW-D1 Results



c. SASW-D1 Shear Wave Velocity Profile

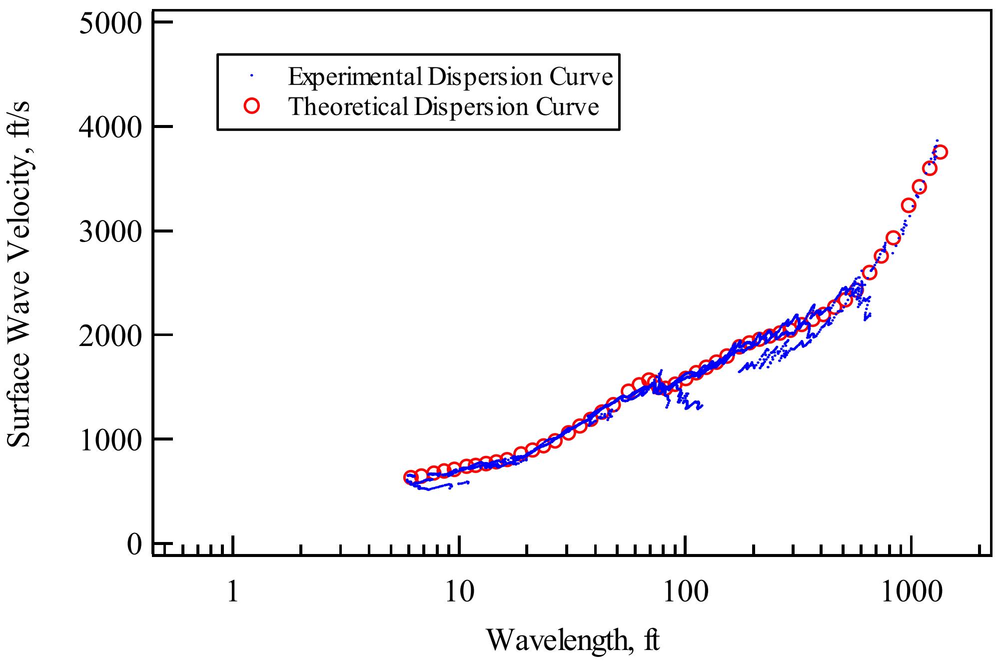
Location: SASW-D1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	5	1039	600	0.25	145
2	3	1212	700	0.25	145
3	5	1732	1000	0.25	145
4	5	2078	1200	0.25	145
5	20	2598	1500	0.25	145
6	8	3118	1800	0.25	145
7	3	3811	2200	0.25	145
8	50	4330	2500	0.25	145
9	100	5196	3000	0.25	145
10	300	6928	4000	0.25	145

DTN: MO0110SASWVDYM.000

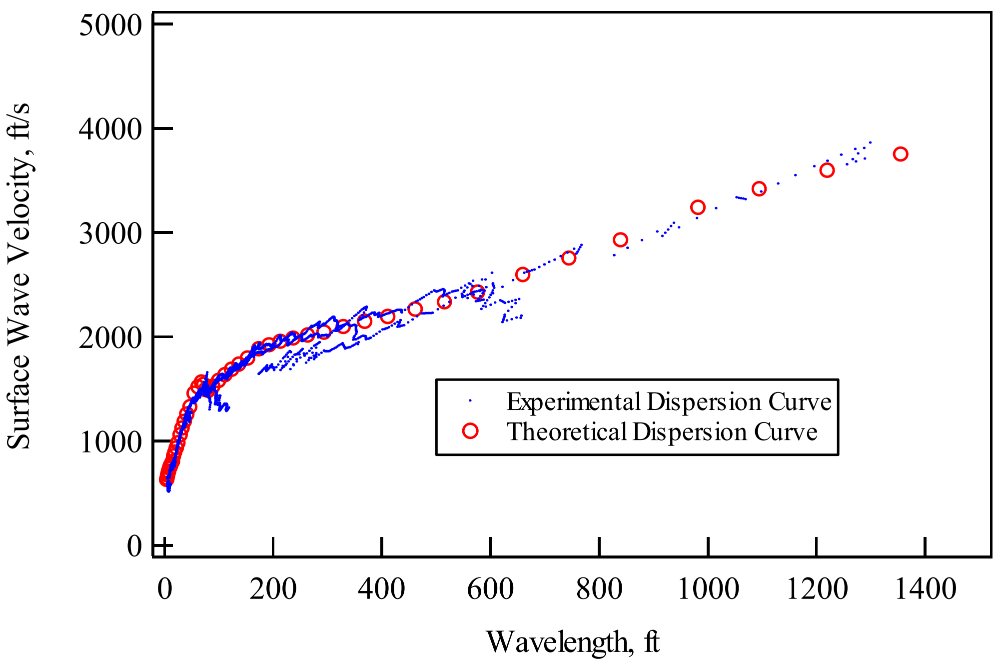
* Poisson's ratio and mass density from Wong (2002a, Appendix 15)

Figure XV-20. SASW-D1 Results (continued)



(Wong, 2002a, Appendix 16)

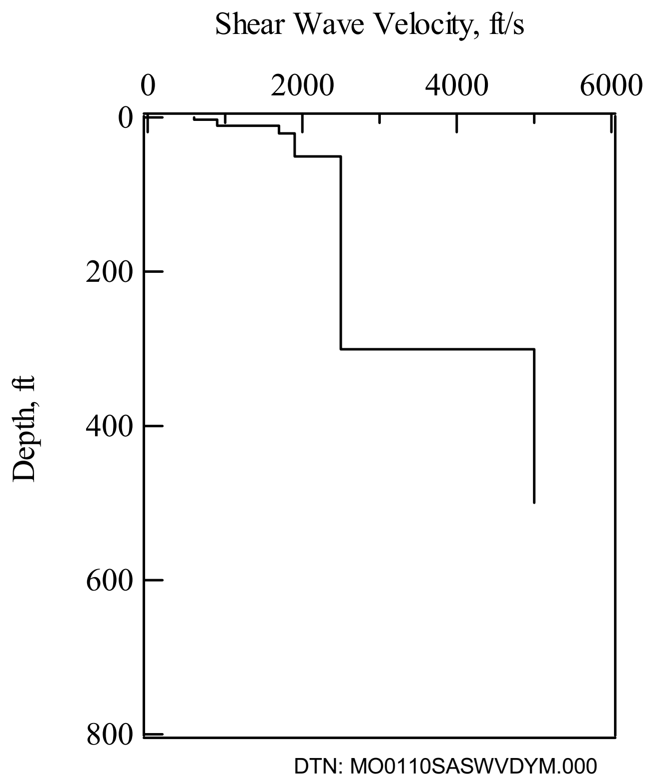
a. SASW-D2 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 16)

b. SASW-D2 Dispersion Curves (Linear Plot)

Figure XV-21. SASW-D2 Results



c. SASW-D2 Shear Wave Velocity Profile

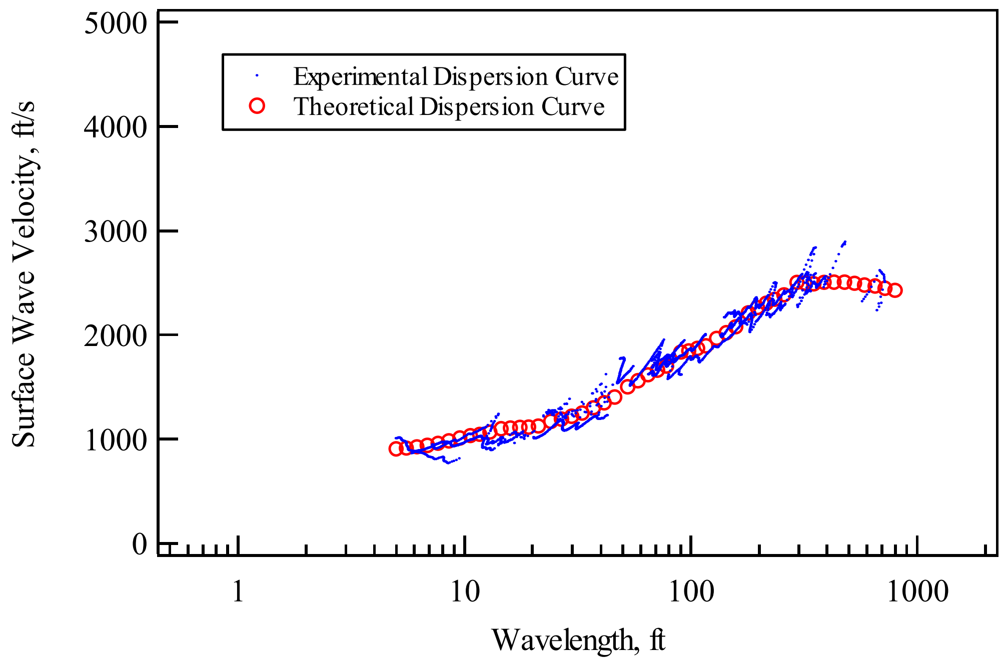
Location: SASW-D2

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	3	1039	600	0.25	145
2	8	1559	900	0.25	145
3	10	2945	1700	0.25	145
4	30	3291	1900	0.25	145
5	250	4330	2500	0.25	145
6	200	8660	5000	0.25	145

DTN: MO0110SASWVDYM.000

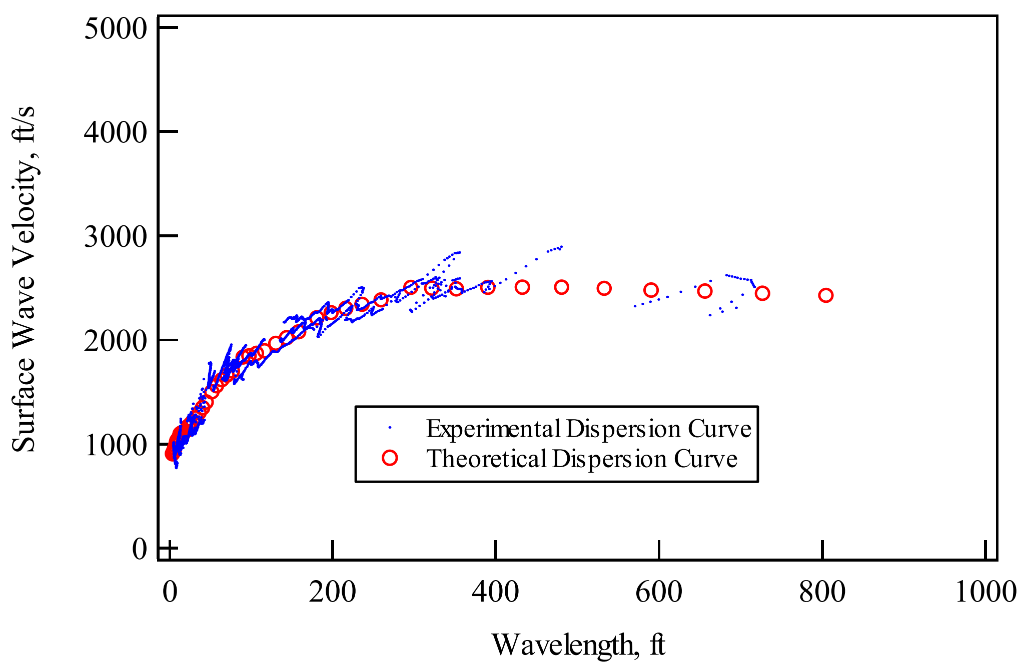
* Poisson's ratio and mass density from Wong (2002a, Appendix 16)

Figure XV-21. SASW-D2 Results (continued)



(Wong, 2002a, Appendix 17)

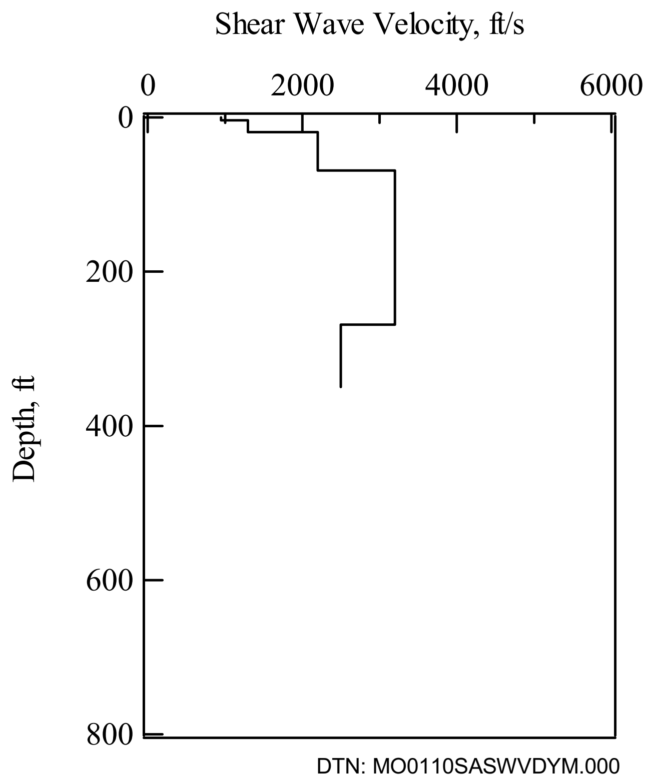
a. SASW-D3 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 17)

b. SASW-D3 Dispersion Curves (Linear Plot)

Figure XV-22. SASW-D3 Results



c. SASW-D3 Shear Wave Velocity Profile

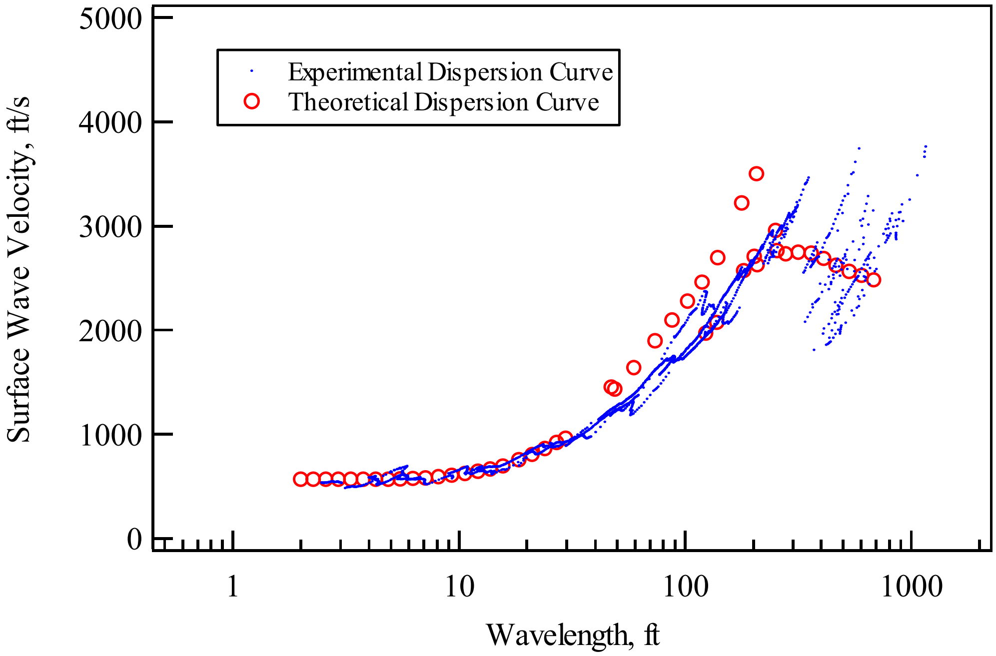
Location: SASW-D3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	4	1646	950	0.25	145
2	15	2252	1300	0.25	145
3	50	3811	2200	0.25	145
4	200	5543	3200	0.25	145
5	81	4330	2500	0.25	145

DTN: MO0110SASWVDYM.000

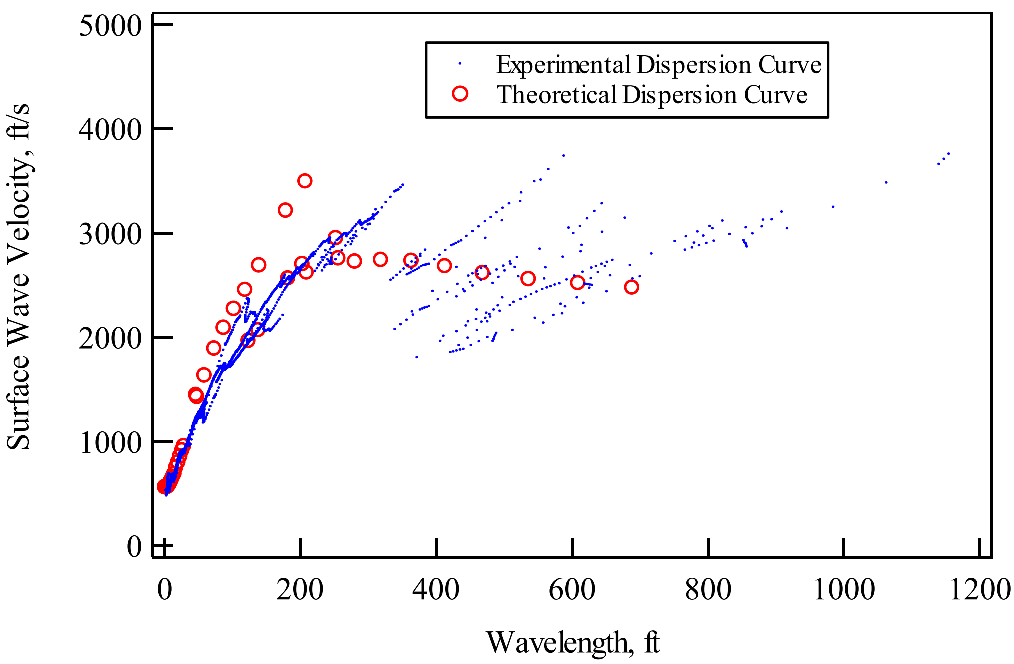
* Poisson's ratio and mass density from Wong (2002a, Appendix 17)

Figure XV-22. SASW-D3 Results (continued)



(Wong, 2002a, Appendix 18)

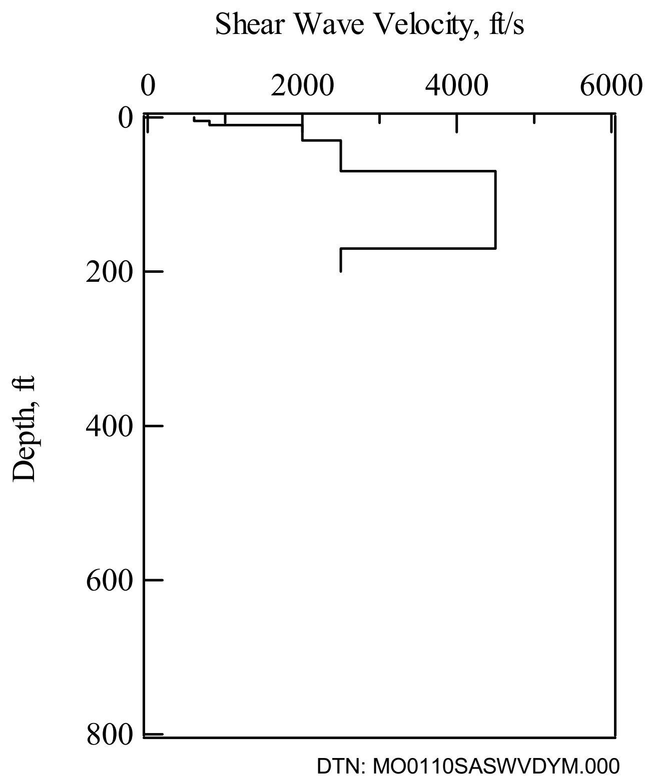
a. SASW-D4 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 18)

b. SASW-D4 Dispersion Curves (Linear Plot)

Figure XV-23. SASW-D4 Results



c. SASW-D4 Shear Wave Velocity Profile

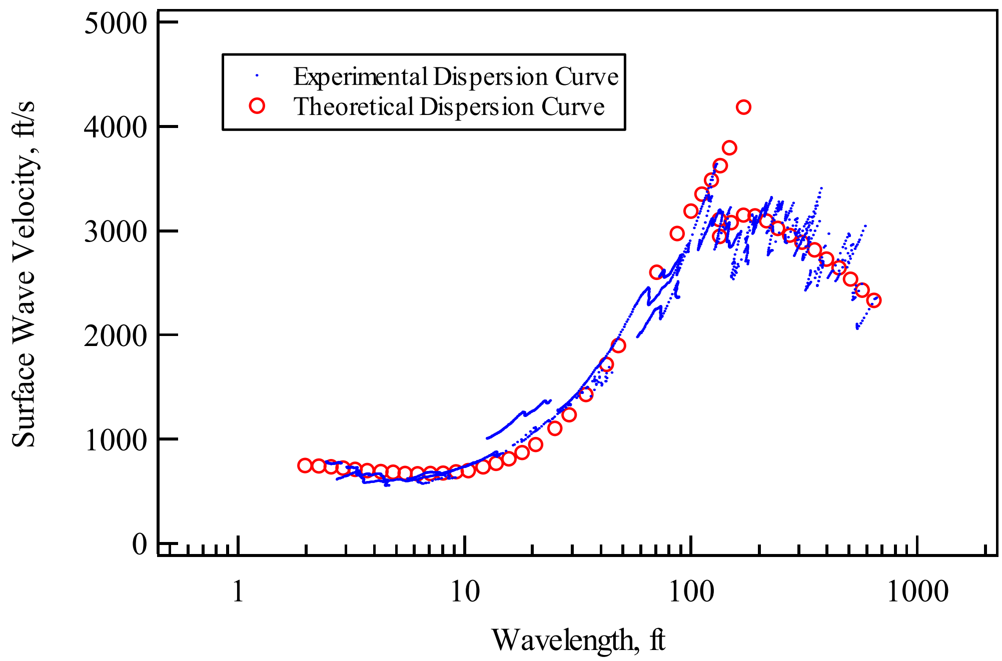
Location: SASW-D4

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	5	1039	600	0.25	145
2	5	1386	800	0.25	145
3	20	3464	2000	0.25	145
4	40	4330	2500	0.25	145
5	100	7794	4500	0.25	145
6	30	4330	2500	0.25	145

DTN: MO0110SASWVDYM.000

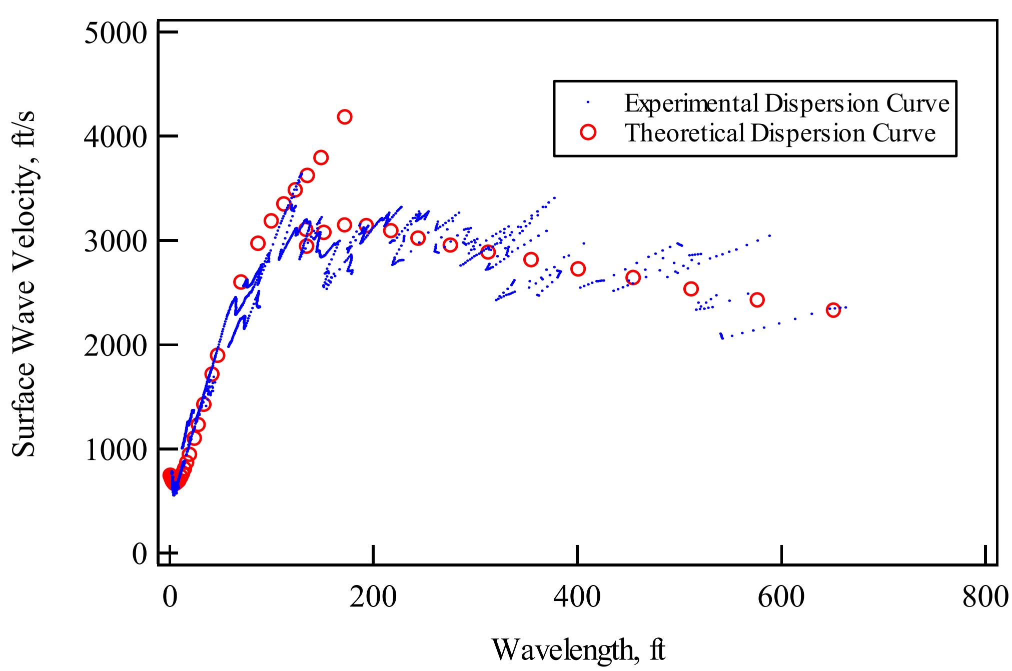
* Poisson's ratio and mass density from Wong (2002a, Appendix 18)

Figure XV-23. SASW-D4 Results (continued)



(Wong, 2002a, Appendix 19)

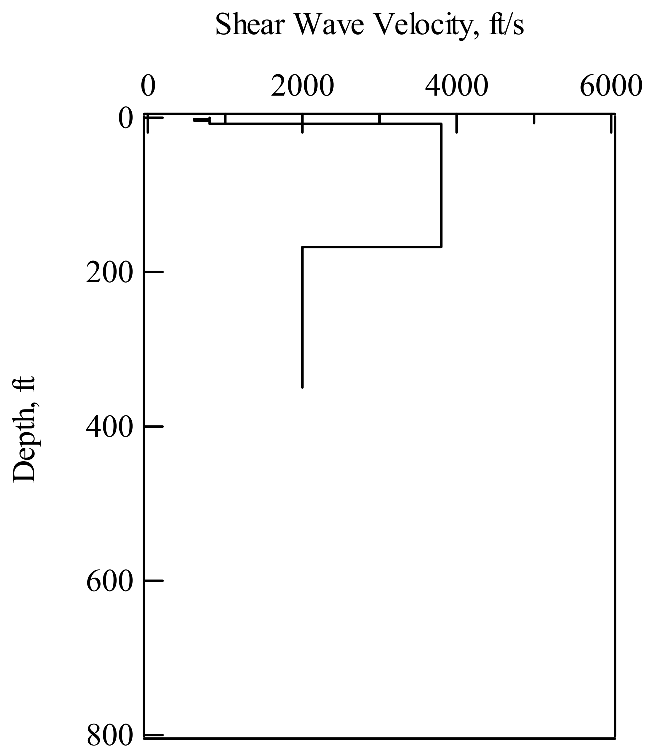
a. SASW-D5 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 19)

b. SASW-D5 Dispersion Curves (Linear Plot)

Figure XV-24. SASW-D5 Results



DTN: MO0110SASWVDYM.000

c. SASW-D5 Shear Wave Velocity Profile

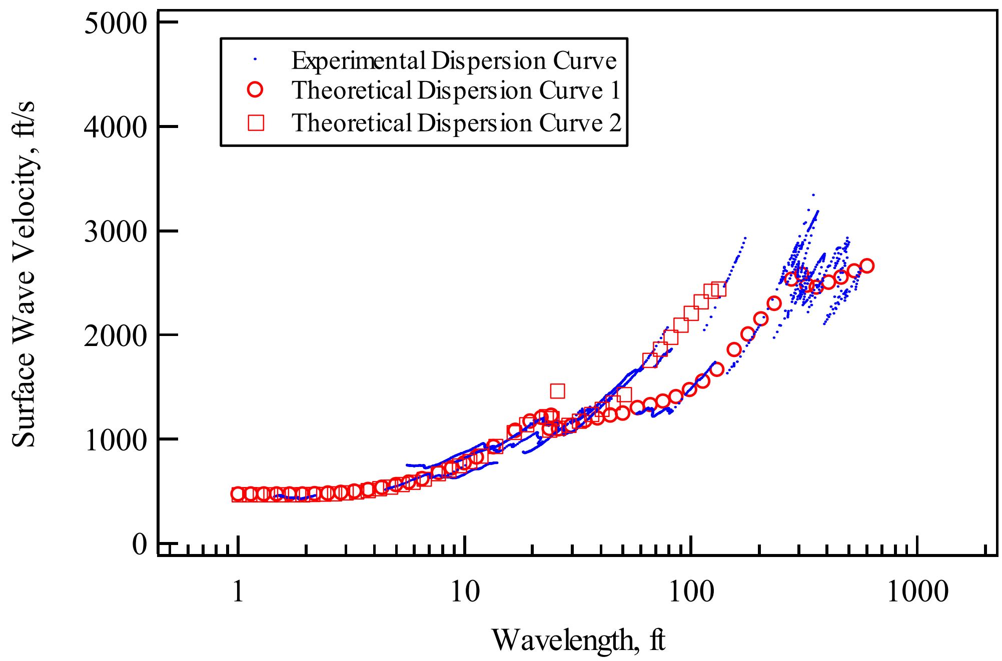
Location: SASW-D5

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	1386	800	0.25	145
2	2	1039	600	0.25	145
3	4	1386	800	0.25	145
4	20	6582	3800	0.25	145
5	40	6582	3800	0.25	145
6	100	6582	3800	0.25	145
7	182	3464	2000	0.25	145

DTN: MO0110SASWVDYM.000

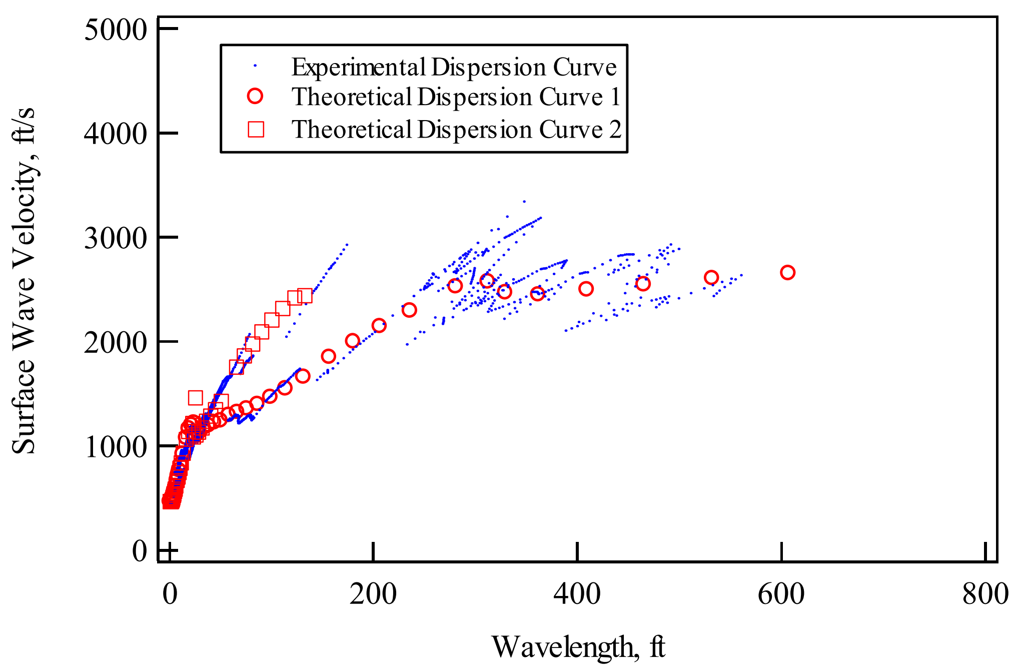
* Poisson's ratio and mass density from Wong (2002a, Appendix 19)

Figure XV-24. SASW-D5 Results (continued)



(Wong, 2002a, Appendix 20)

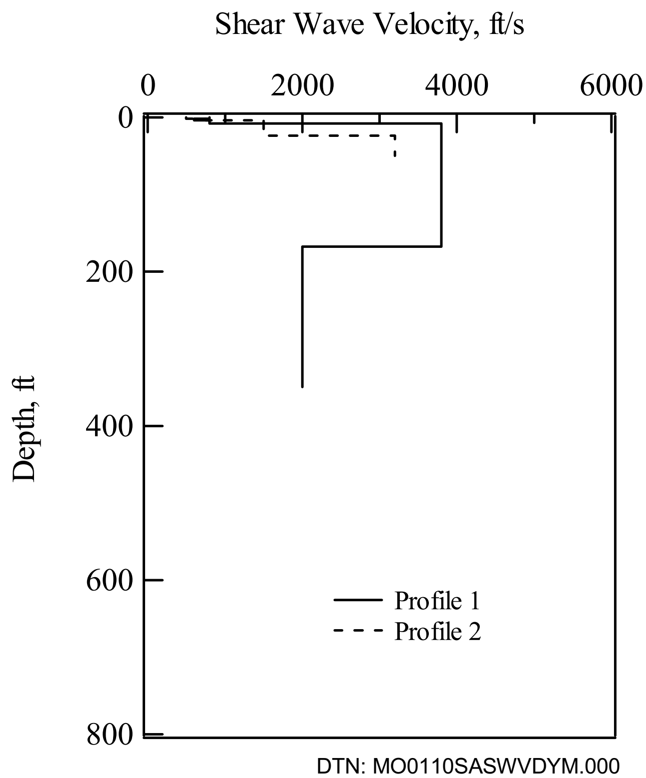
a. SASW-D6 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 20)

b. SASW-D6 Dispersion Curves (Linear Plot)

Figure XV-25. SASW-D6 Results



c. SASW-D6 Shear Wave Velocity Profile

Location: SASW-D6 Profile 1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	1386	800	0.25	145
2	2	1039	600	0.25	145
3	4	1386	800	0.25	145
4	160	6582	3800	0.25	145
5	182	3464	2000	0.25	145

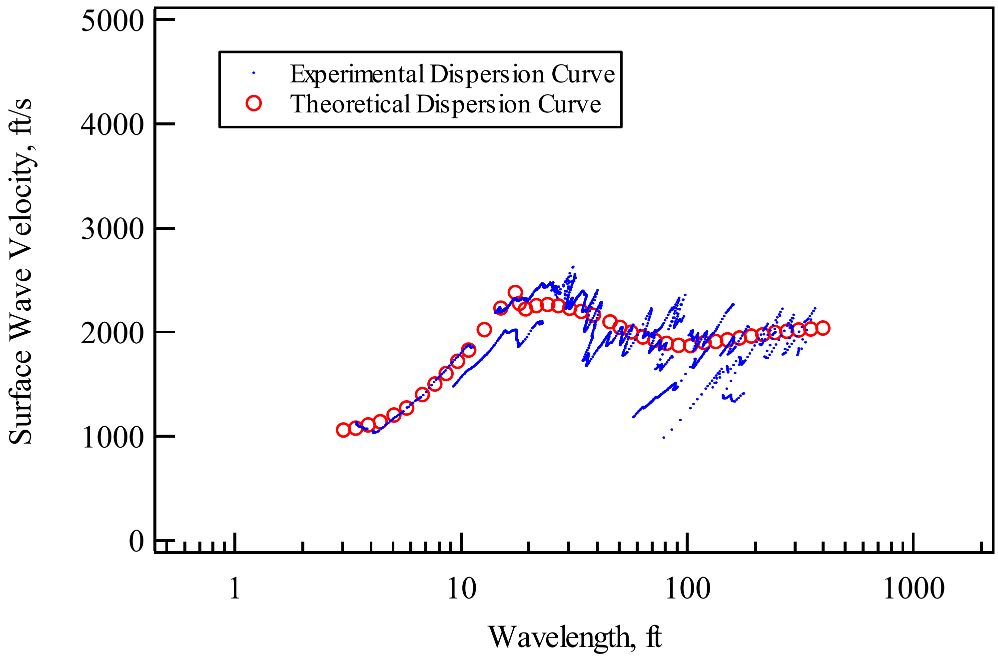
Location: SASW-D6 Profile 2

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	866	500	0.25	145
2	2	1299	750	0.25	145
3	20	2598	1500	0.25	145
4	26	5542	3200	0.25	145

DTN: MO0110SASWVDYM.000

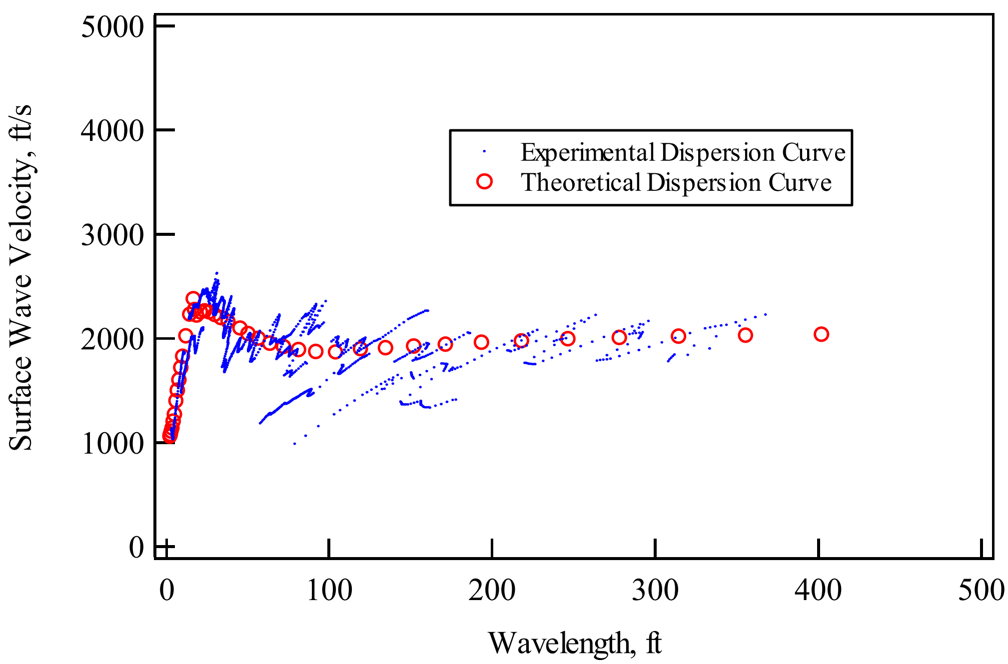
* Poisson's ratio and mass density from Wong (2002a, Appendix 20)

Figure XV-25. SASW-D6 Results (continued)



(Wong, 2002a, Appendix 21)

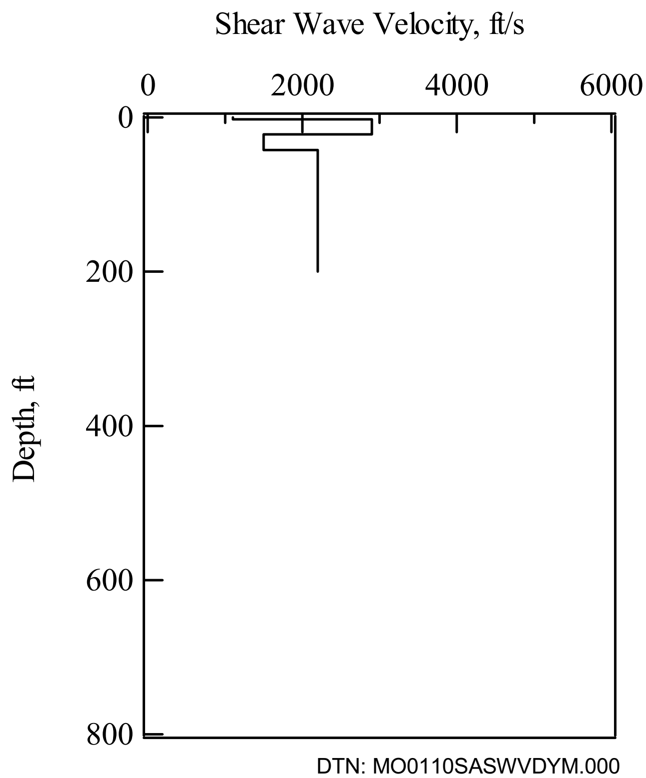
a. SASW-D7 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 21)

b. SASW-D7 Dispersion Curves (Linear Plot)

Figure XV-26. SASW-D7 Results



c. SASW-D7 Shear Wave Velocity Profile

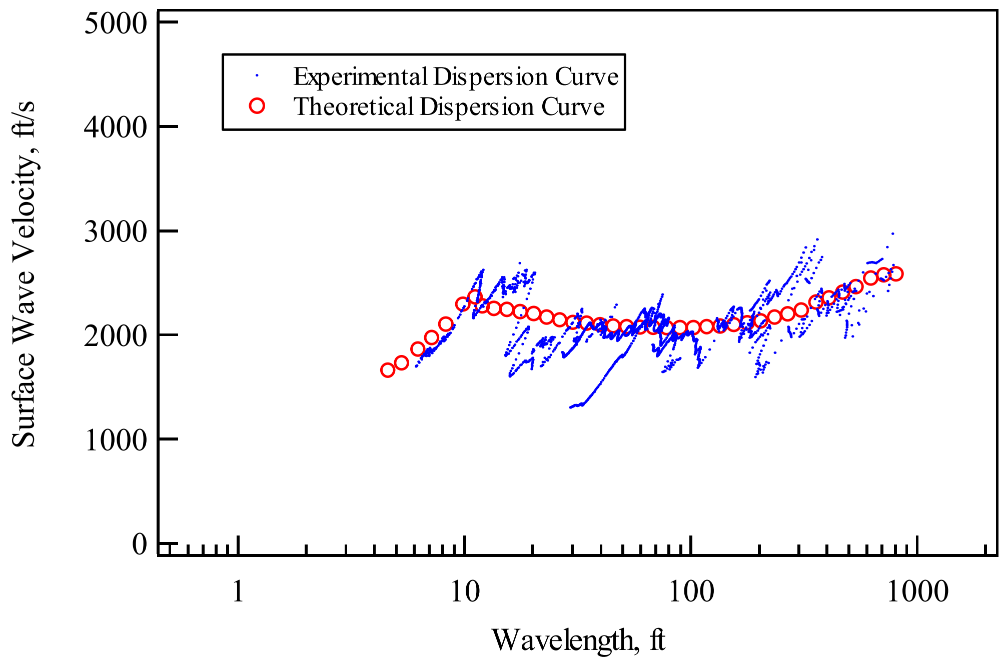
Location: SASW-D7

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2.5	1905	1100	0.25	145
2	20	5023	2900	0.25	145
3	20	2598	1500	0.25	145
4	158	3811	2200	0.25	145

DTN: MO0110SASWVDYM.000

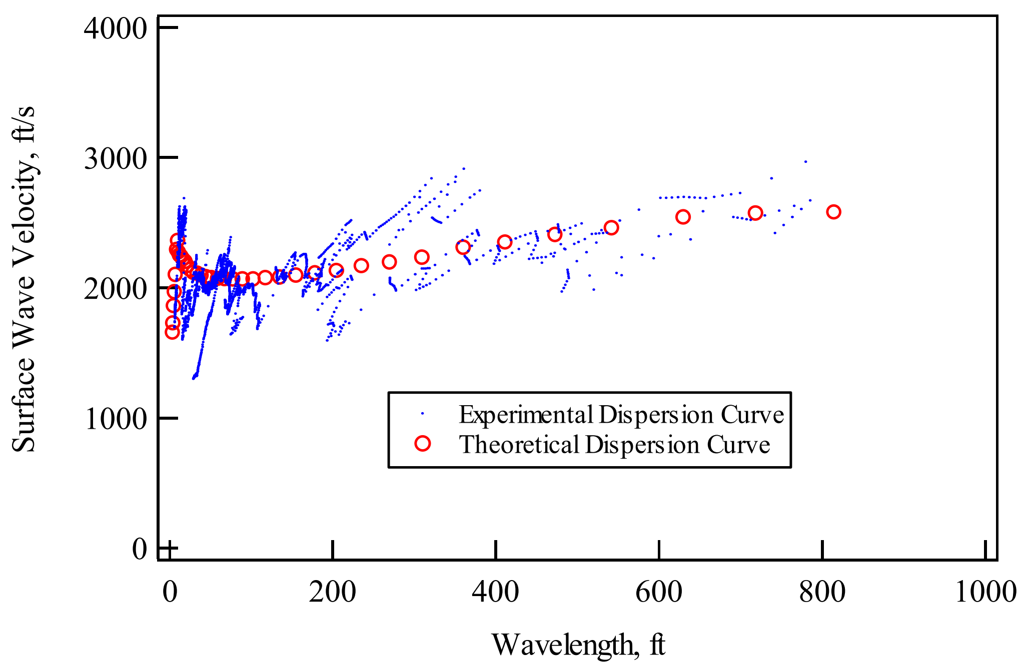
* Poisson's ratio and mass density from Wong (2002a, Appendix 21)

Figure XV-26. SASW-D7 Results (continued)



(Wong, 2002a, Appendix 22)

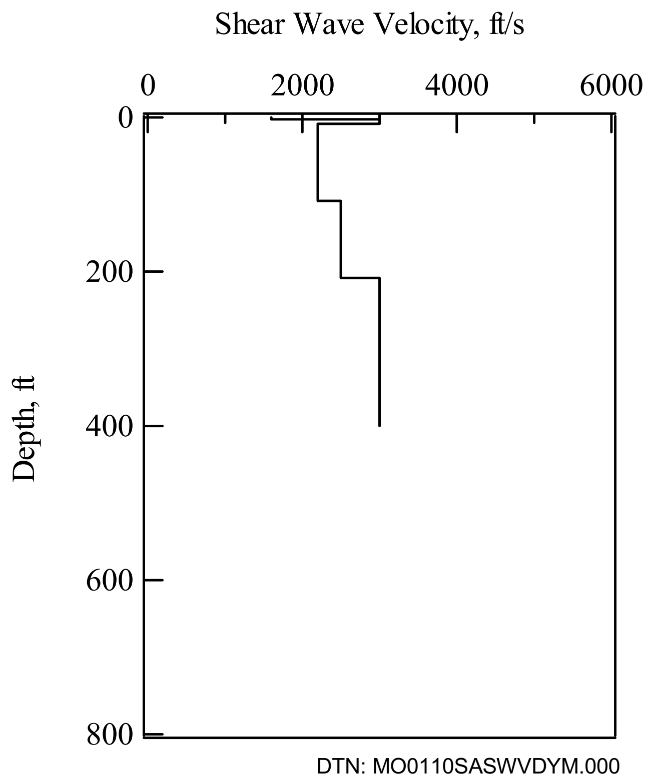
a. SASW-D8 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 22)

b. SASW-D8 Dispersion Curves (Linear Plot)

Figure XV-27. SASW-D8 Results



c. SASW-D8 Shear Wave Velocity Profile

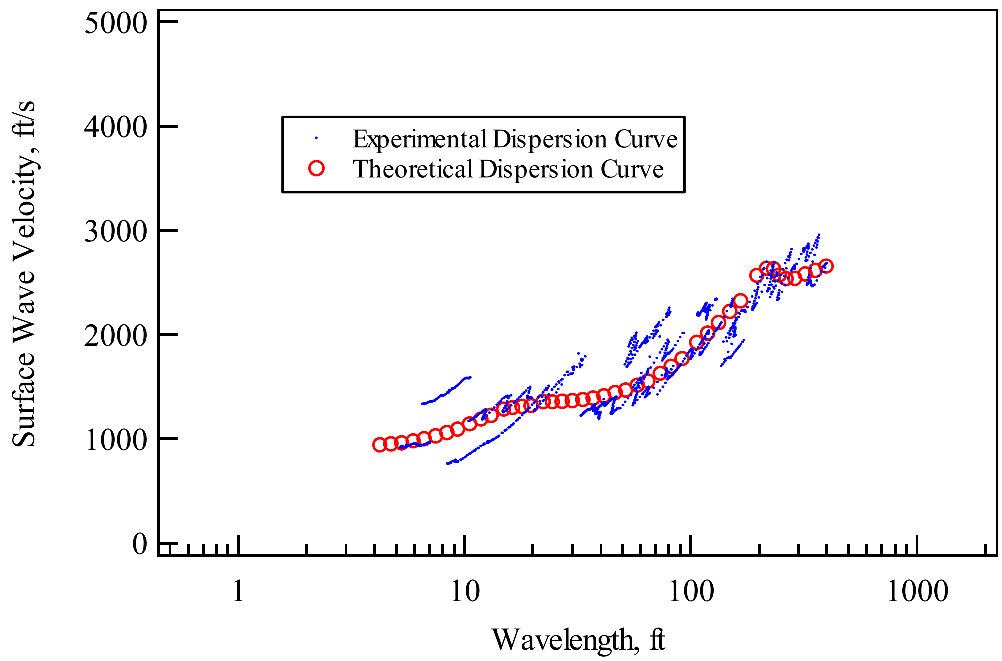
Location: SASW-D8

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2.5	2771	1600	0.25	145
2	6	5196	3000	0.25	145
3	100	3811	2200	0.25	145
4	100	4330	2500	0.25	145
5	192	5196	3000	0.25	145

DTN: MO0110SASWVDYM.000

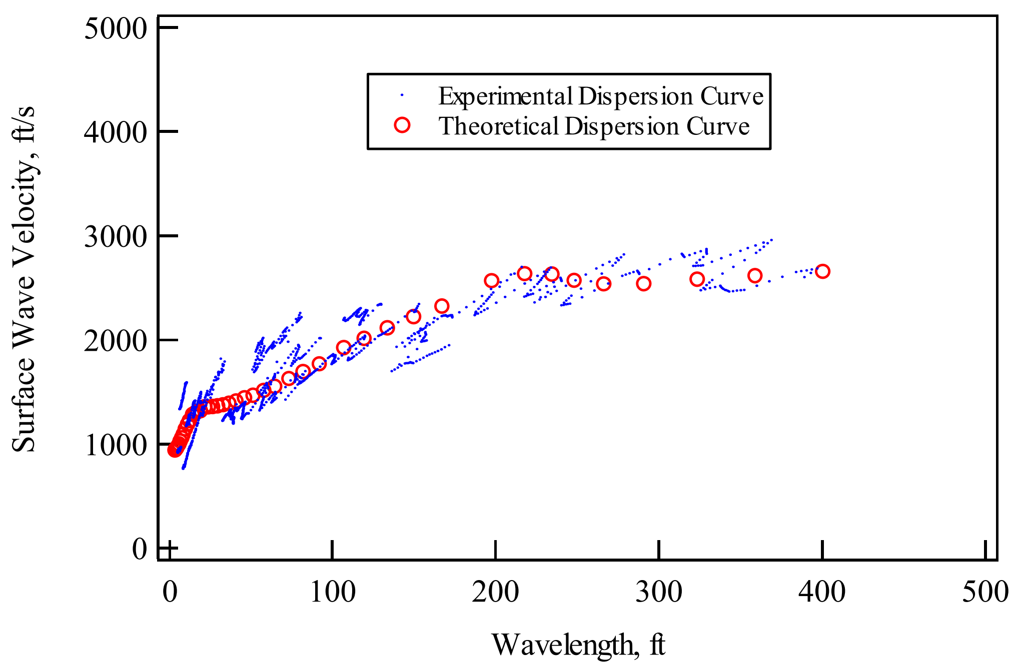
* Poisson's ratio and mass density from Wong (2002a, Appendix 22)

Figure XV-27. SASW-D8 Results (continued)



(Wong, 2002a, Appendix 23)

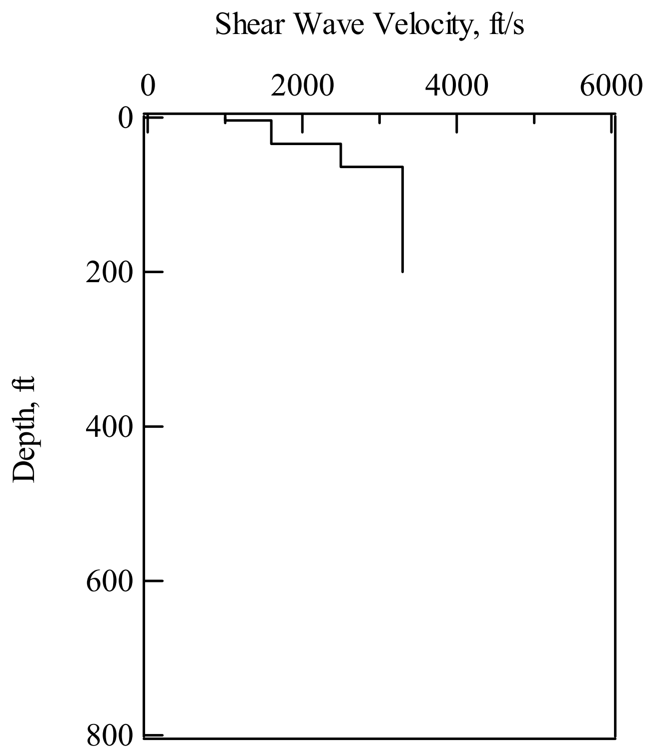
a. SASW-D9 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 23)

b. SASW-D9 Dispersion Curves (Linear Plot)

Figure XV-28. SASW-D9 Results



DTN: MO0110SASWVDYM.000

c. SASW-D9 Shear Wave Velocity Profile

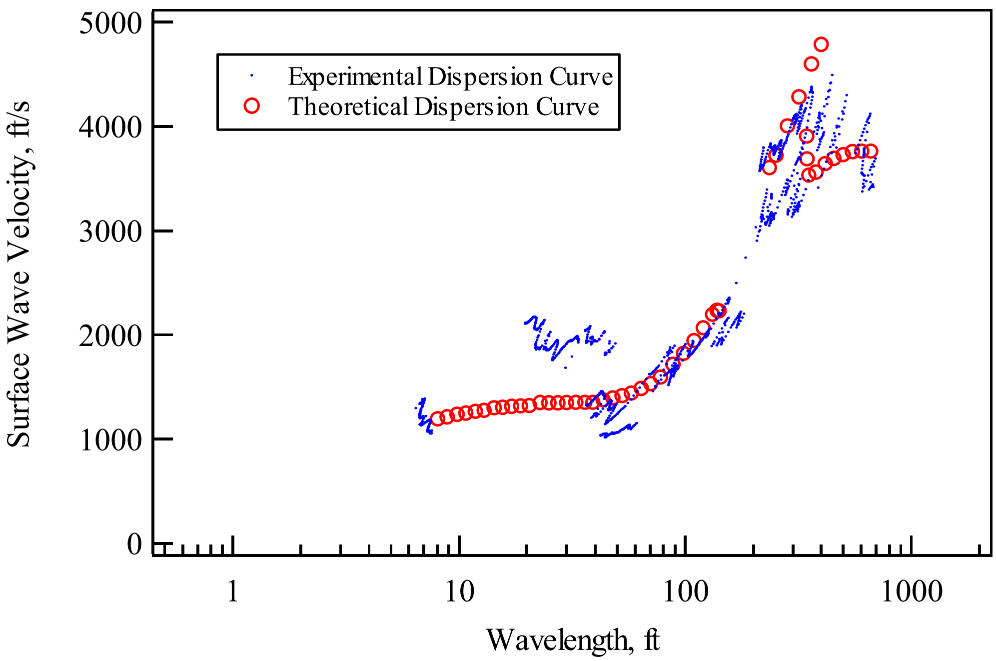
Location: SASW-D9

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	4	1732	1000	0.25	145
2	30	2771	1600	0.25	145
3	30	4330	2500	0.25	145
4	136	5716	3300	0.25	145

DTN: MO0110SASWVDYM.000

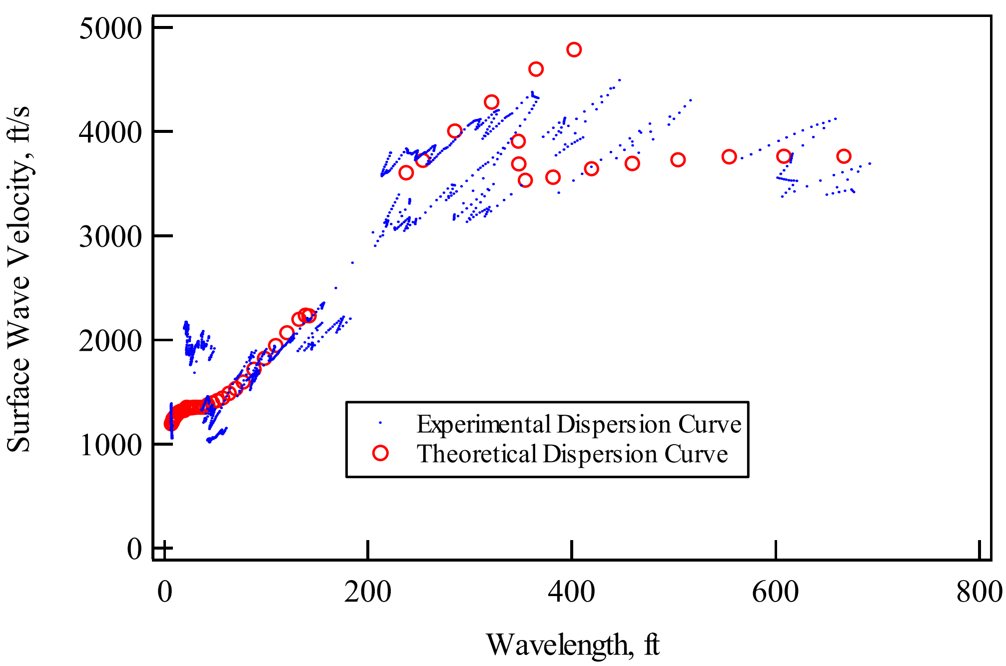
* Poisson's ratio and mass density from Wong (2002a, Appendix 23)

Figure XV-28. SASW-D9 Results (continued)



(Wong, 2002a, Appendix 24)

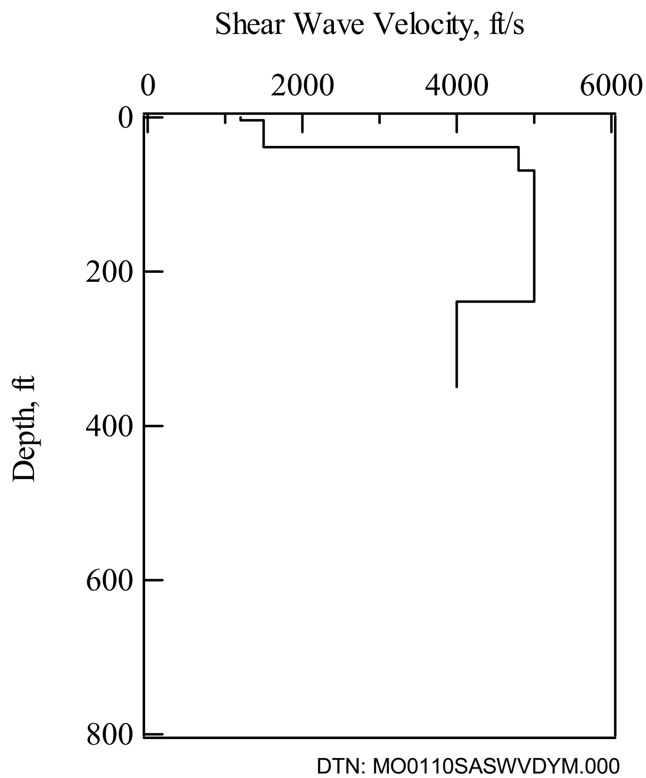
a. SASW-D10 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 24)

b. SASW-D10 Dispersion Curves (Linear Plot)

Figure XV-29. SASW-D10 Results



c. SASW-D10 Shear Wave Velocity Profile

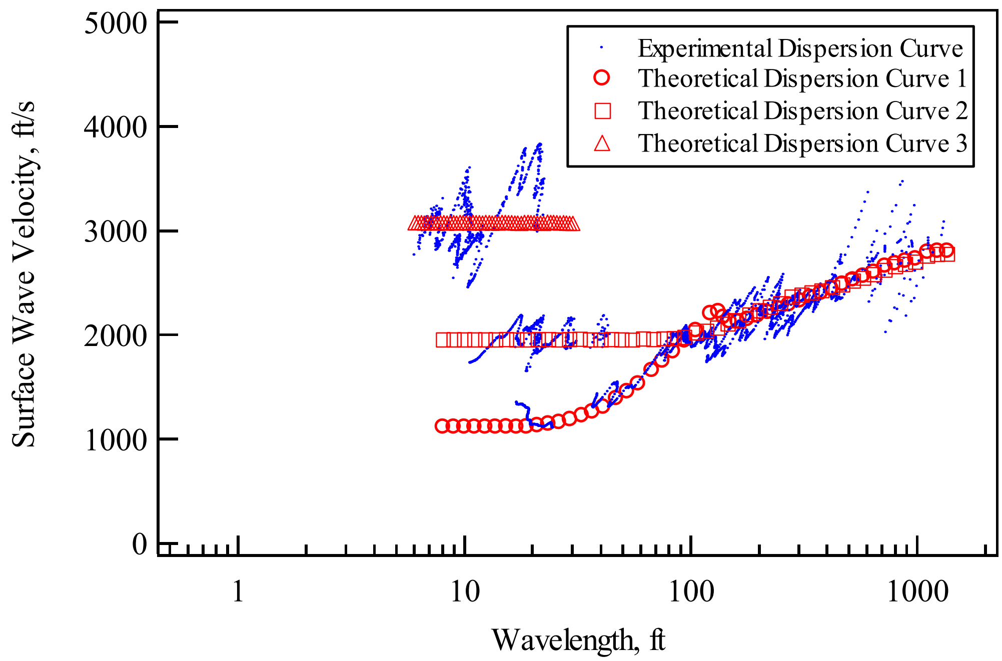
Location: SASW-D10

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	4	2079	1200	0.25	145
2	35	2598	1500	0.25	145
3	30	8314	4800	0.25	145
4	170	8660	5000	0.25	145
5	110	6928	4000	0.25	145

DTN: MO0110SASWVDYM.000

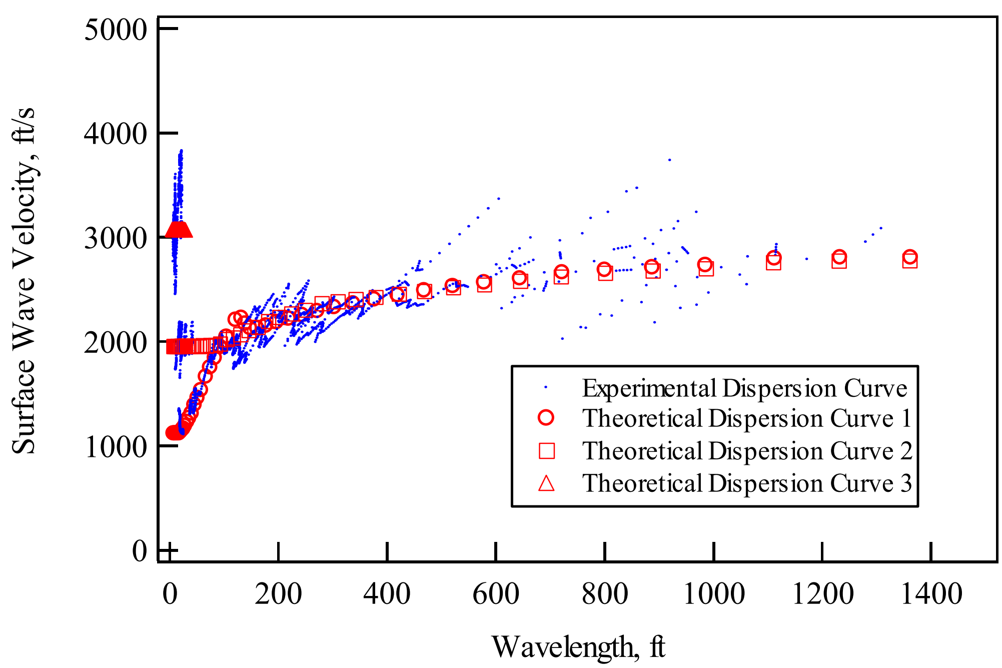
* Poisson's ratio and mass density from Wong (2002a, Appendix 24)

Figure XV-29. SASW-D10 Results (continued)



(Wong, 2002a, Appendix 25)

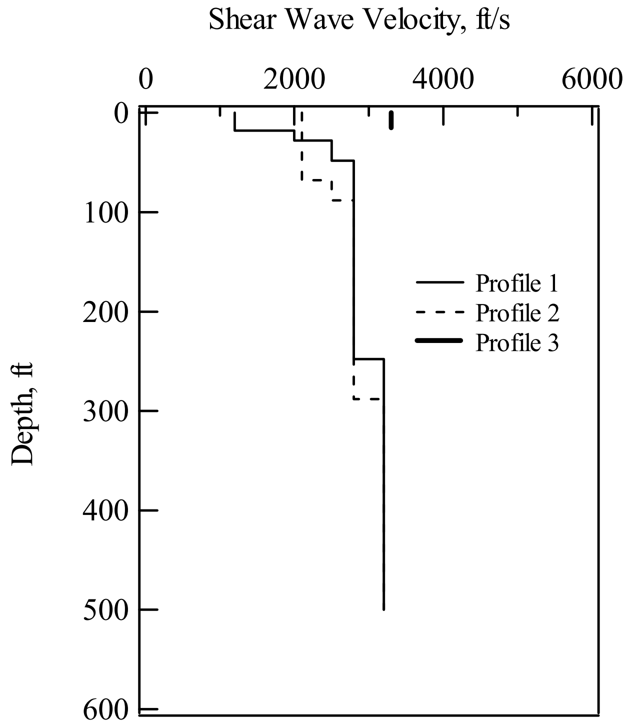
a. SASW-D11 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 25)

b. SASW-D11 Dispersion Curves (Linear Plot)

Figure XV-30. SASW-D11 Results



DTN: MO0110SASWVDYM.000

c. SASW-D11 Shear Wave Velocity Profile

Location: SASW-D11 Profile 1

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	18	2079	1200	0.25	145
2	10	3464	2000	0.25	145
3	20	4330	2500	0.25	145
4	200	4850	2800	0.25	145
5	252	5543	3200	0.25	145

Location: SASW-D11 Profile 2

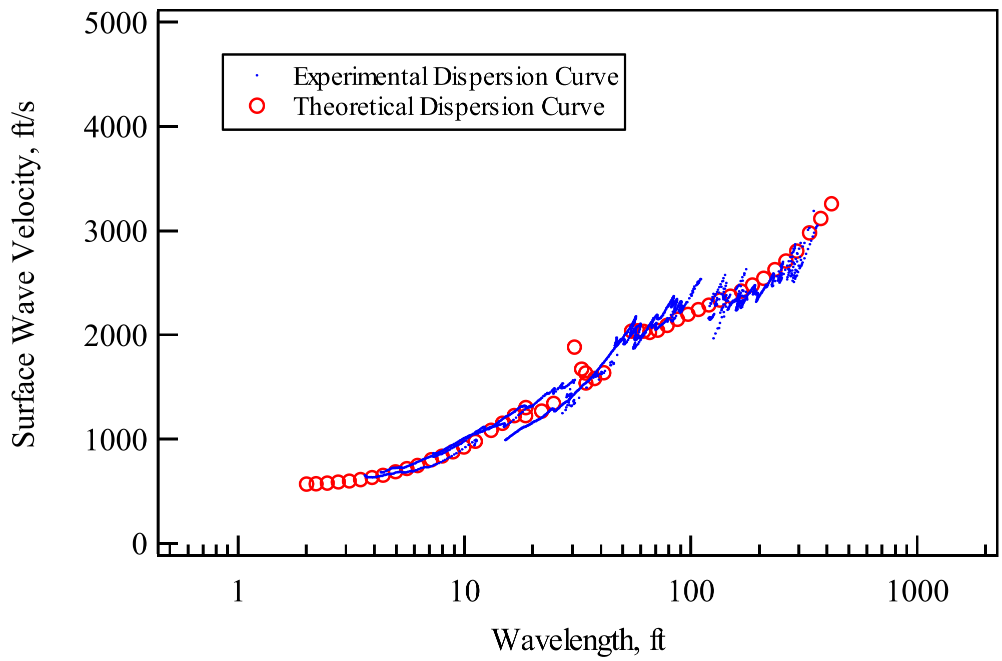
Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	68	3637	2100	0.25	145
2	20	4330	2500	0.25	145
3	200	4850	2800	0.25	145
4	212	5543	3200	0.25	145

Location: SASW-D11 Profile 3

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	20	5716	3300	0.25	145

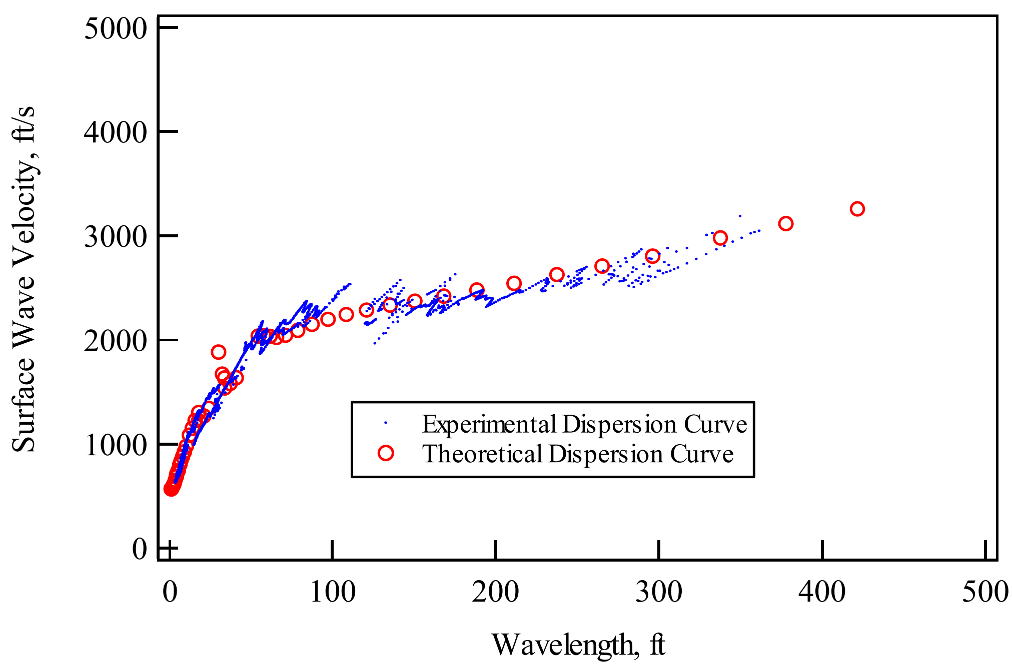
DTN: MO0110SASWVDYM.000

* Poisson's ratio and mass density from Wong (2002a, Appendix 25)



(Wong, 2002a, Appendix 26)

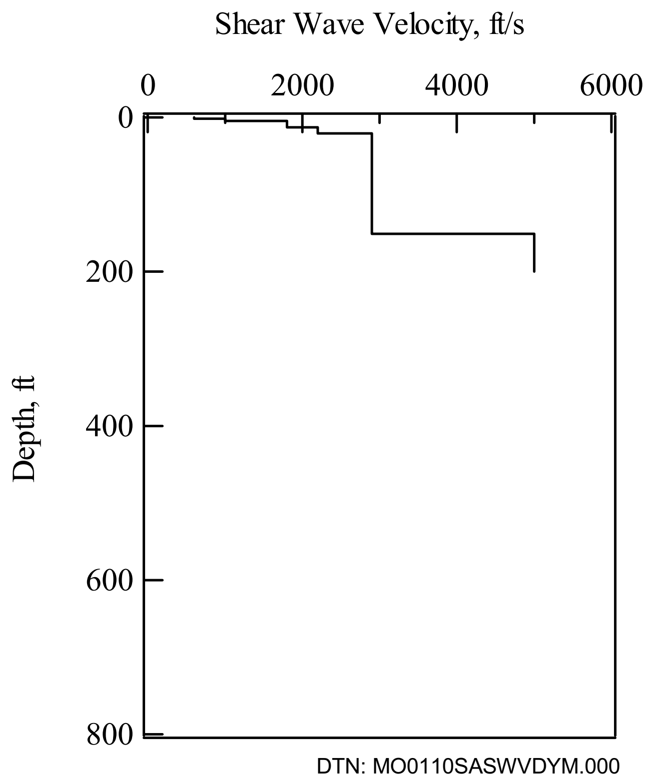
a. SASW-D12 Dispersion Curves (Log Plot)



(Wong, 2002a, Appendix 26)

b. SASW-D12 Dispersion Curves (Linear Plot)

Figure XV-31. SASW-D12 Results



c. SASW-D12 Shear Wave Velocity Profile

Location: SASW-D12

Layer No.	Thickness, ft	P-Wave Velocity, ft/s	S-Wave Velocity, ft/s	Poisson's Ratio*	Mass Density* pcf
1	2	1039	600	0.25	145
2	3	1732	1000	0.25	145
3	8	3118	1800	0.25	145
4	8	3811	2200	0.25	145
5	130	5023	2900	0.25	145
6	49	8660	5000	0.25	145

DTN: MO0110SASWVDYM.000

* Poisson's ratio and mass density from Wong (2002a, Appendix 26)

Figure XV-31. SASW-D12 Results (continued)

APPENDIX XVI

DOWNHOLE SEISMIC VELOCITY PLOTS – YUCCA MOUNTAIN CREST

ATTACHMENT XVI

DOWNHOLE SEISMIC VELOCITY PLOTS – YUCCA MOUNTAIN CREST

As discussed in Section 6.4.3, this attachment contains eight figures presenting the interpreted shear-wave and compression-wave velocity profiles from downhole seismic surveys conducted using eight boreholes that were installed in the past for other purposes. A detailed description of each analysis can be found in SN-M&O-SCI-039-V1 (Redpath 2002).

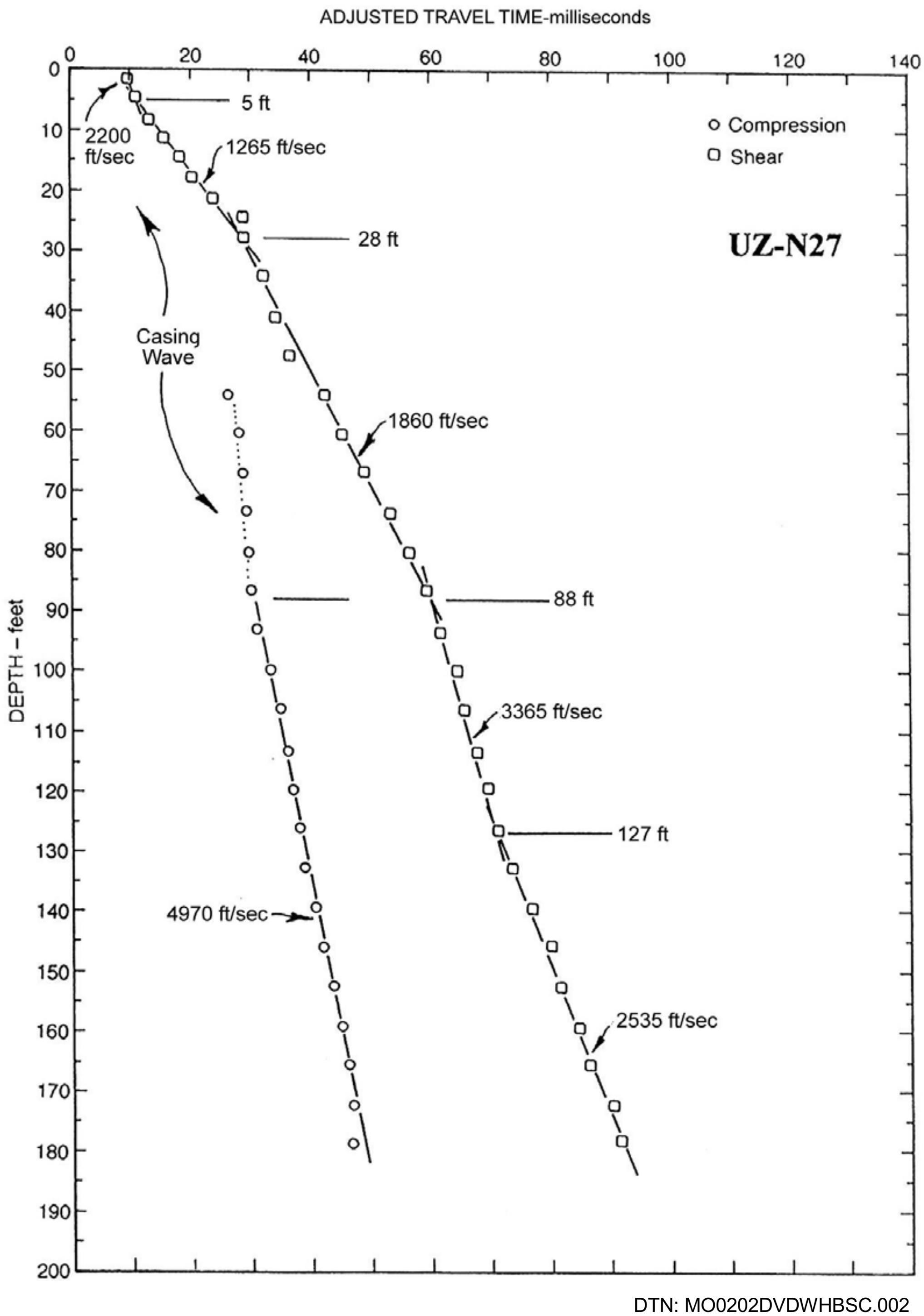


Figure XVI-1. UZ-N27 Downhole Travel Time Versus Depth Plots

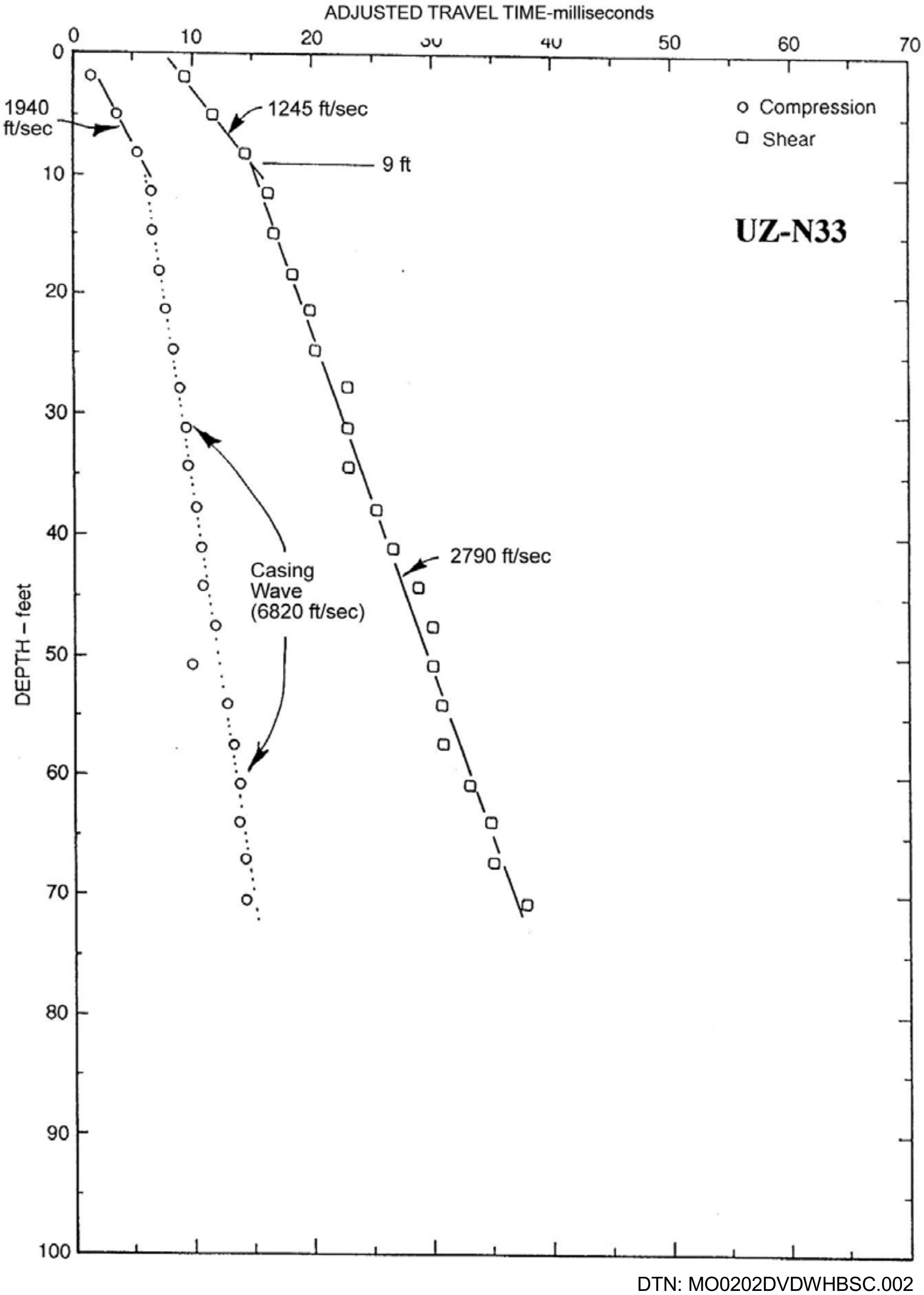


Figure XVI-2. UZ-N33 Downhole Travel Time Versus Depth Plots

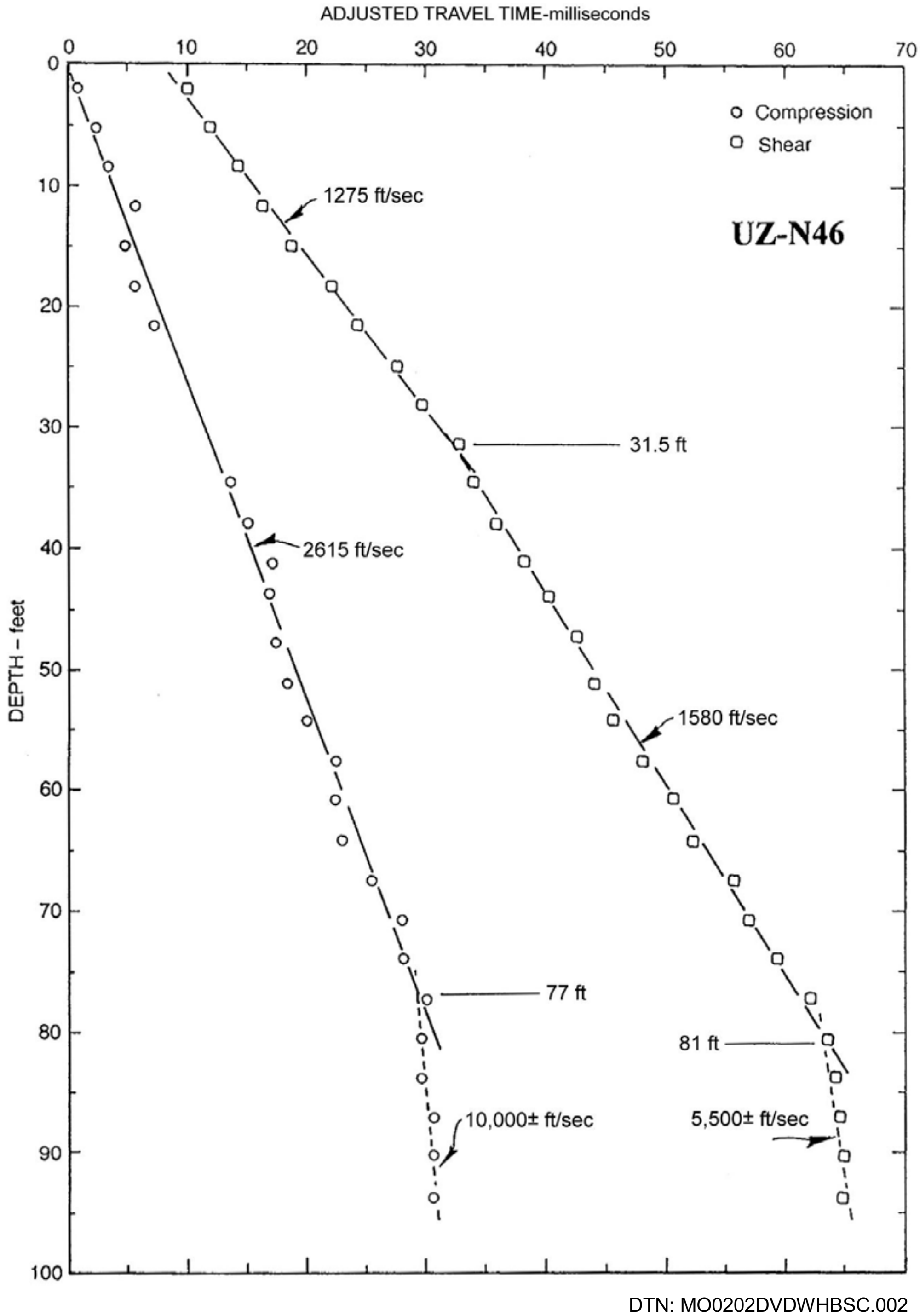
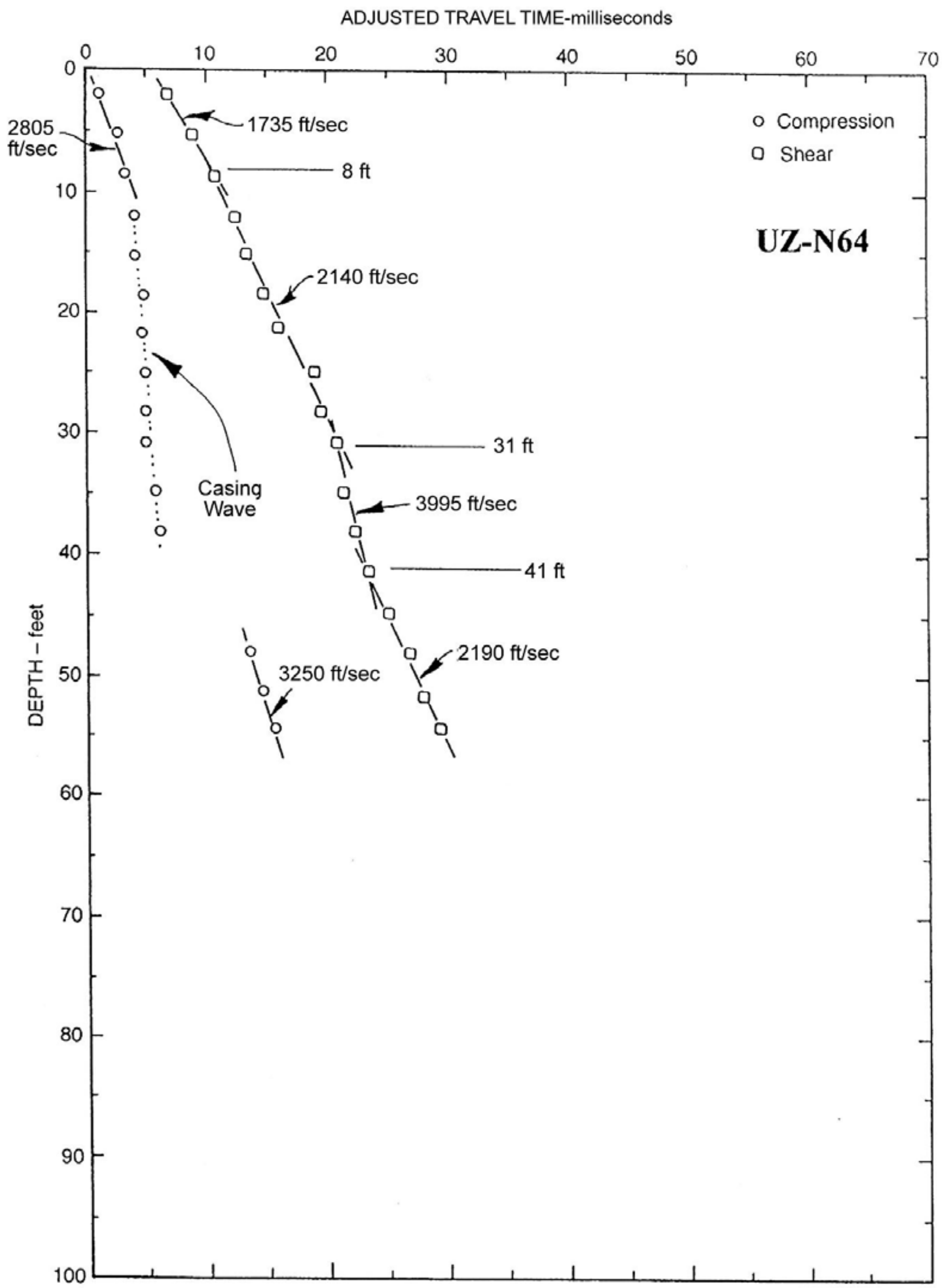
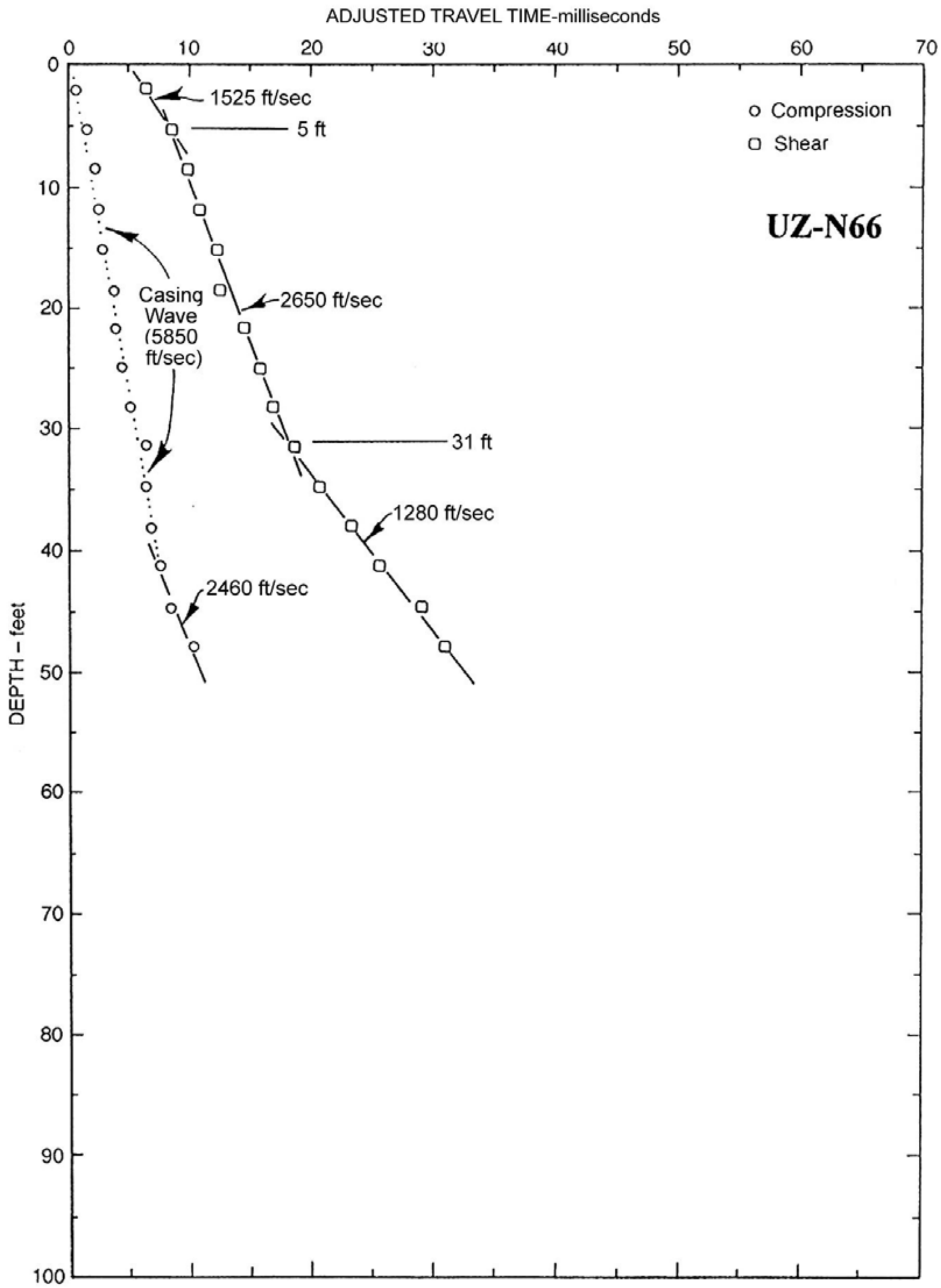


Figure XVI-3. UZ-N46 Downhole Travel Time Versus Depth Plots



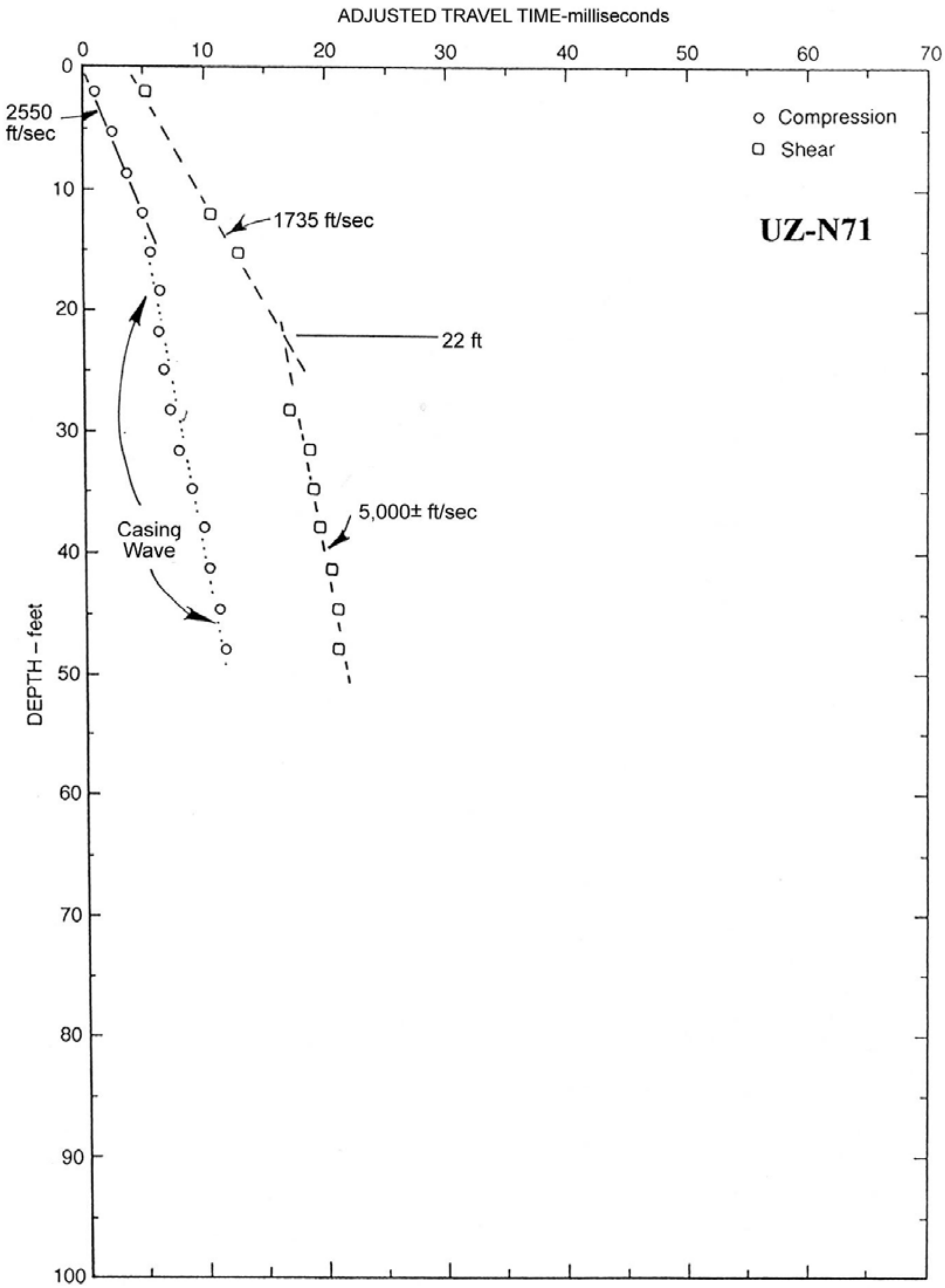
DTN: MO0202DVDWHBSC.002

Figure XVI-4. UZ-N64 Downhole Travel Time Versus Depth Plots



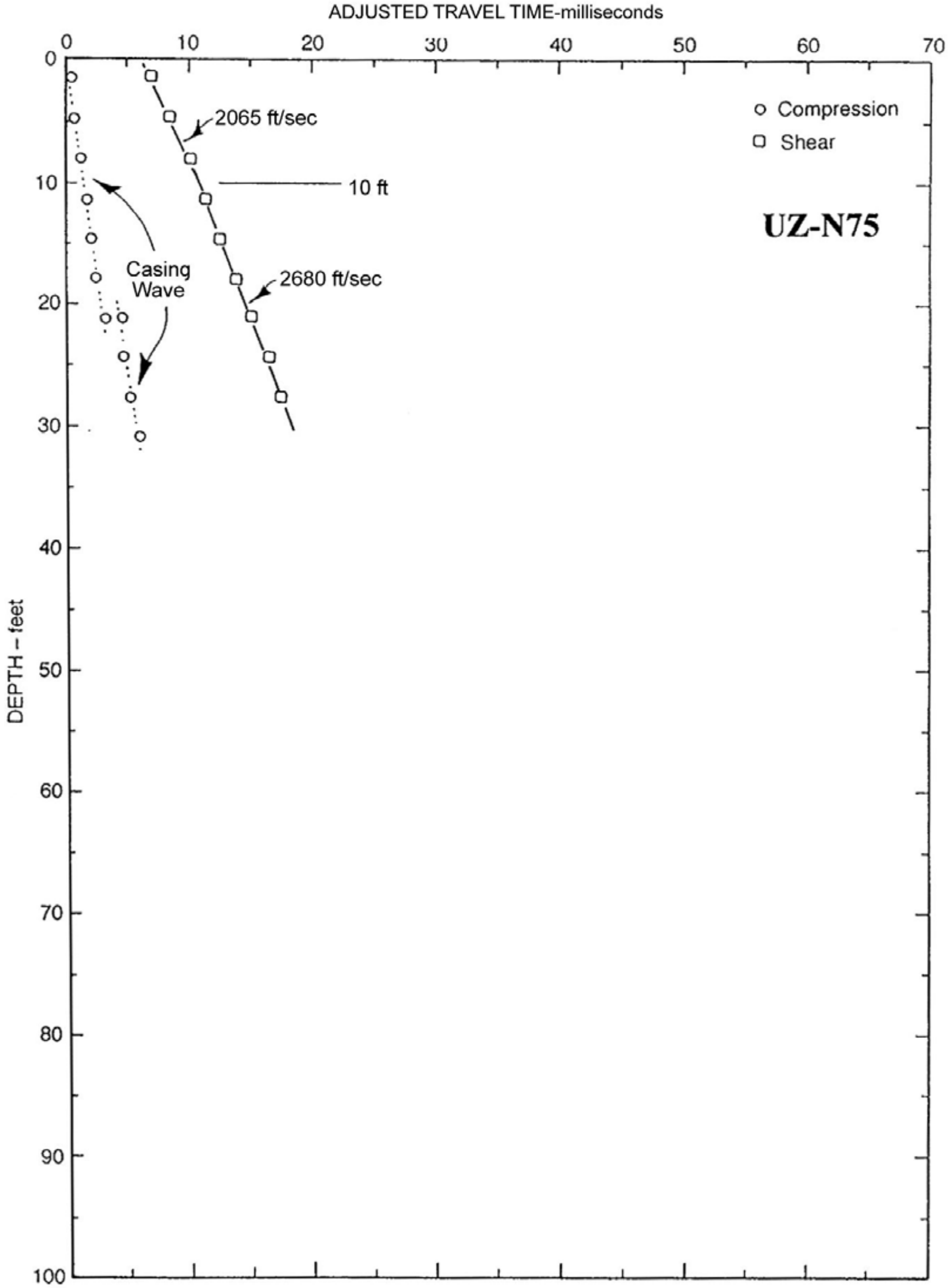
DTN: MO0202DVDWHBSC.002

Figure XVI-5. UZ-N66 Downhole Travel Time Versus Depth Plots



DTN: MO0202DVDWHBSC.002

Figure XVI-6. UZ-N71 Downhole Travel Time Versus Depth Plots



DTN: MO0202DVDWHBSC.002

Figure XVI-7. UZ-N75 Downhole Travel Time Versus Depth Plots

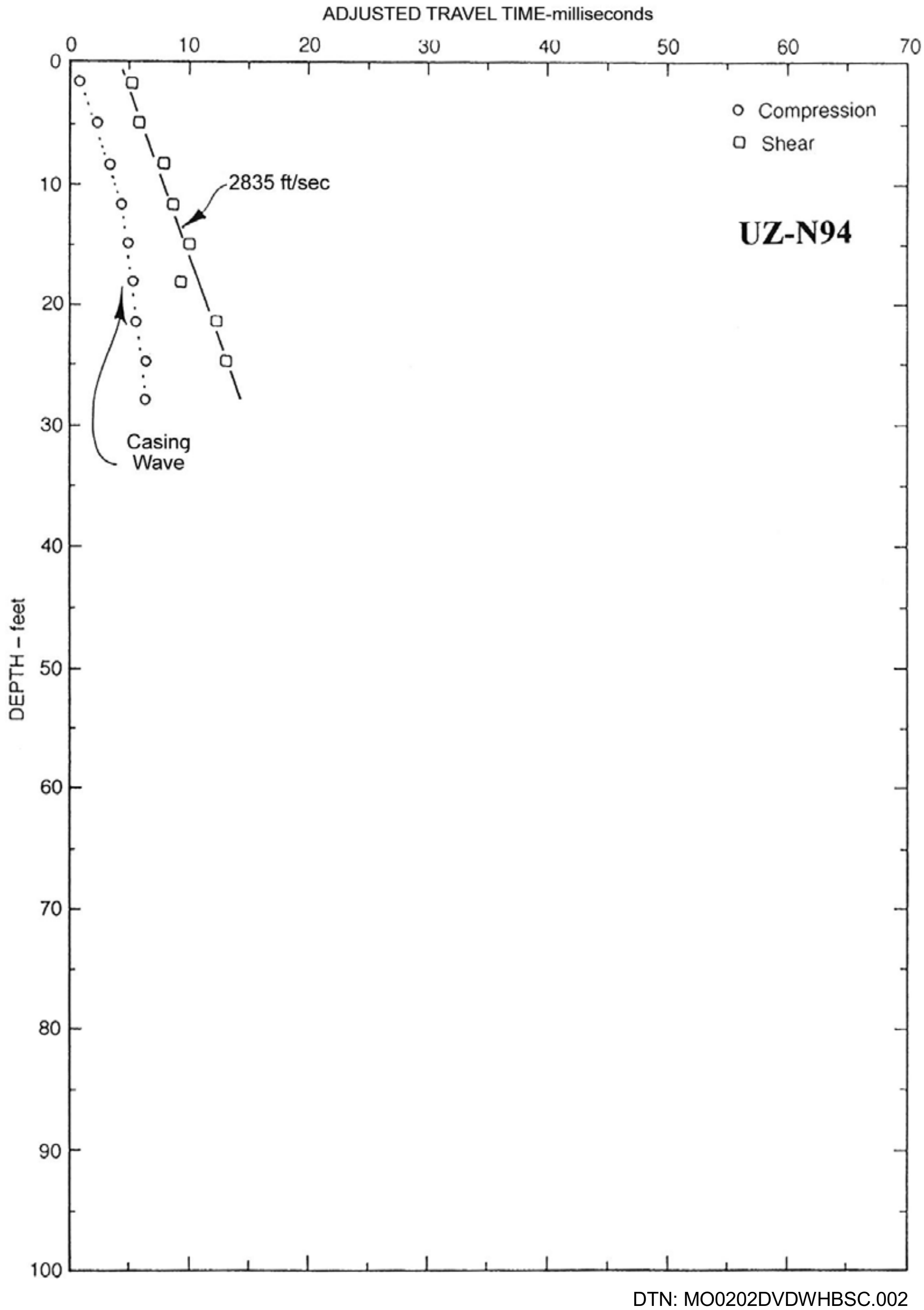


Figure XVI-8. UZ-N94 Downhole Travel Time Versus Depth Plots

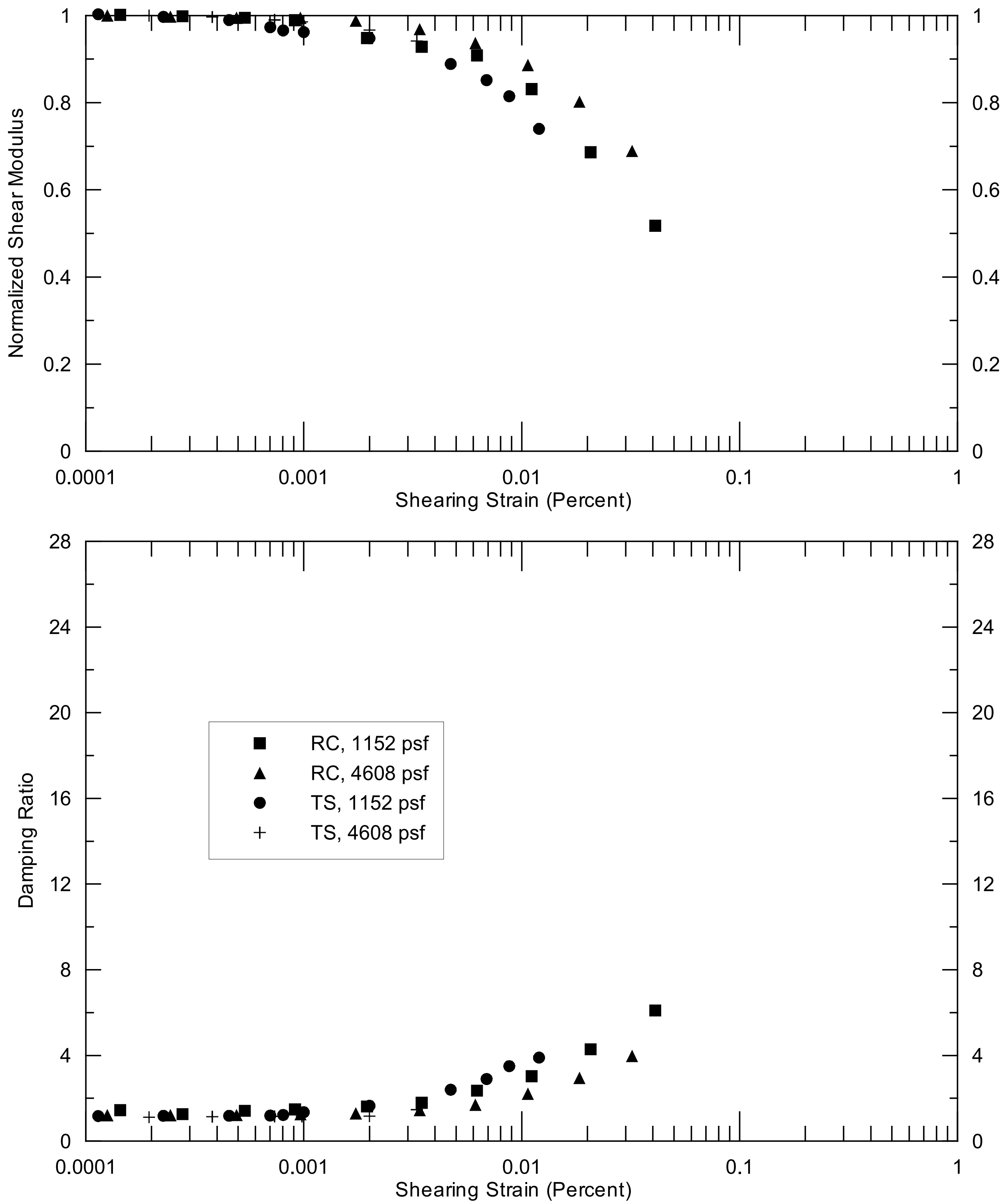
ATTACHMENT XVII

GEOTECHNICAL LABORATORY DYNAMIC TESTING – FRAN RIDGE

ATTACHMENT XVII

GEOTECHNICAL LABORATORY DYNAMIC TESTING – FRAN RIDGE

As discussed in Section 6.5.3, this attachment presents the results of resonant column and torsional shear (RCTS) tests on compacted samples of material from the Fran Ridge Borrow Area, a potential borrow site to provide material for constructing an engineered fill at a potential WHB site. Twelve figures are followed by 10 tables. Each table spans two pages. The data on these tables is found in DTN: MO0203DHRSSWHB.001.



DTN: MO0203DHRSSWHB.001

Figure XVII-1. Resonant Column and Torsional Shear Results for Specimen UTA-23-K

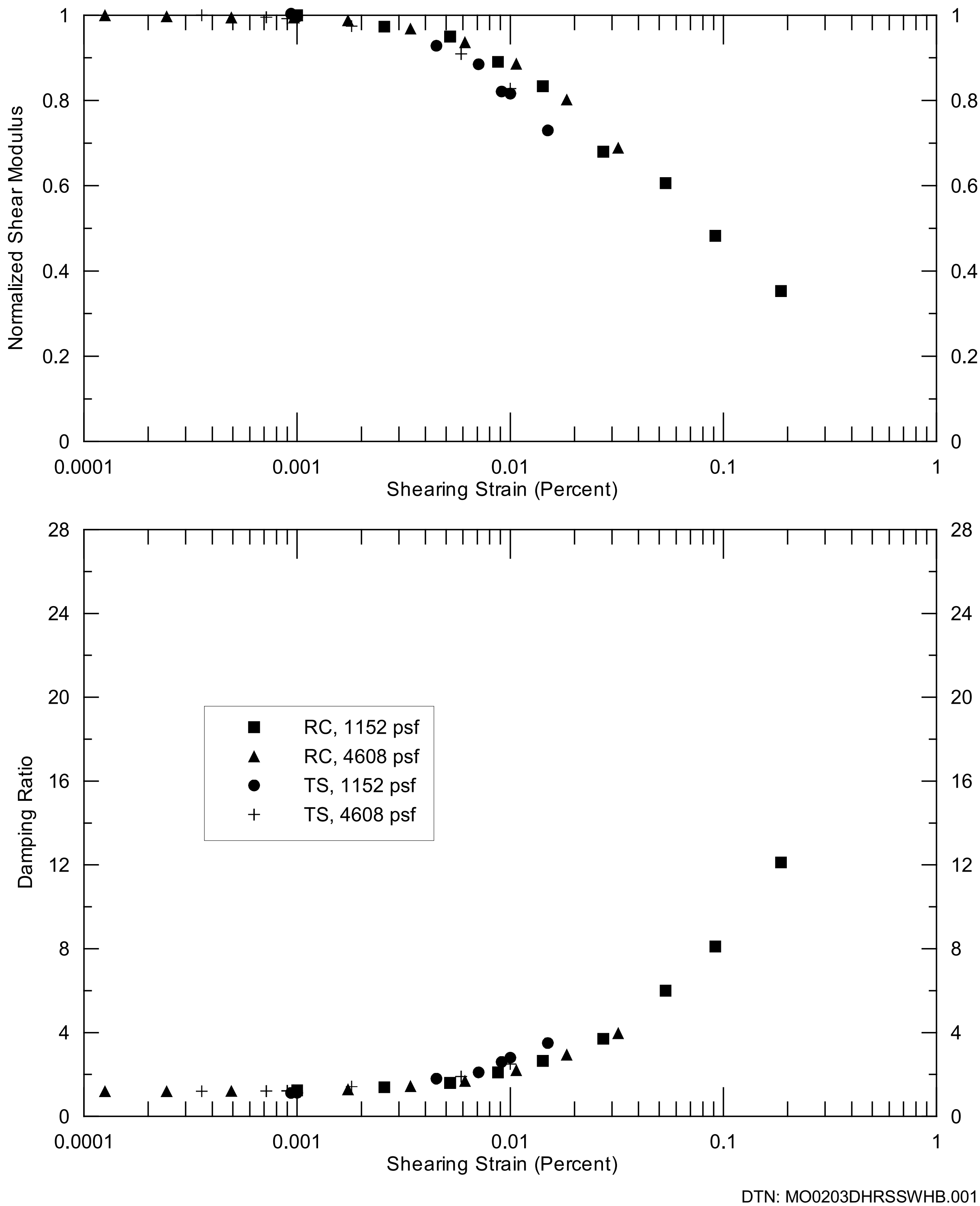
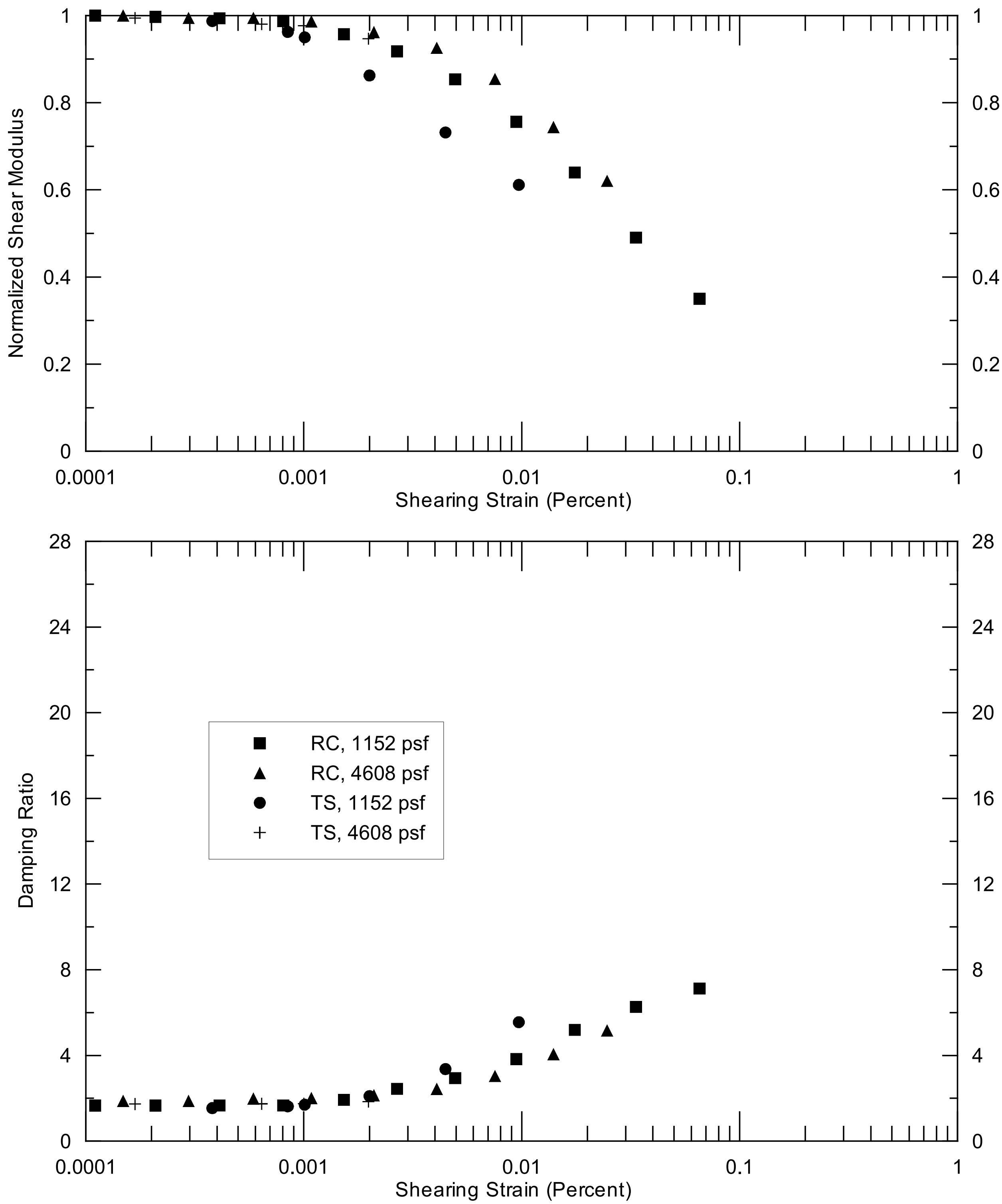


Figure XVII-2. Resonant Column and Torsional Shear Results for Specimen UTA-23-L



DTN: MO0203DHRSSWHB.001

Figure XVII-3. Resonant Column and Torsional Shear Results for Specimen UTA-23-M

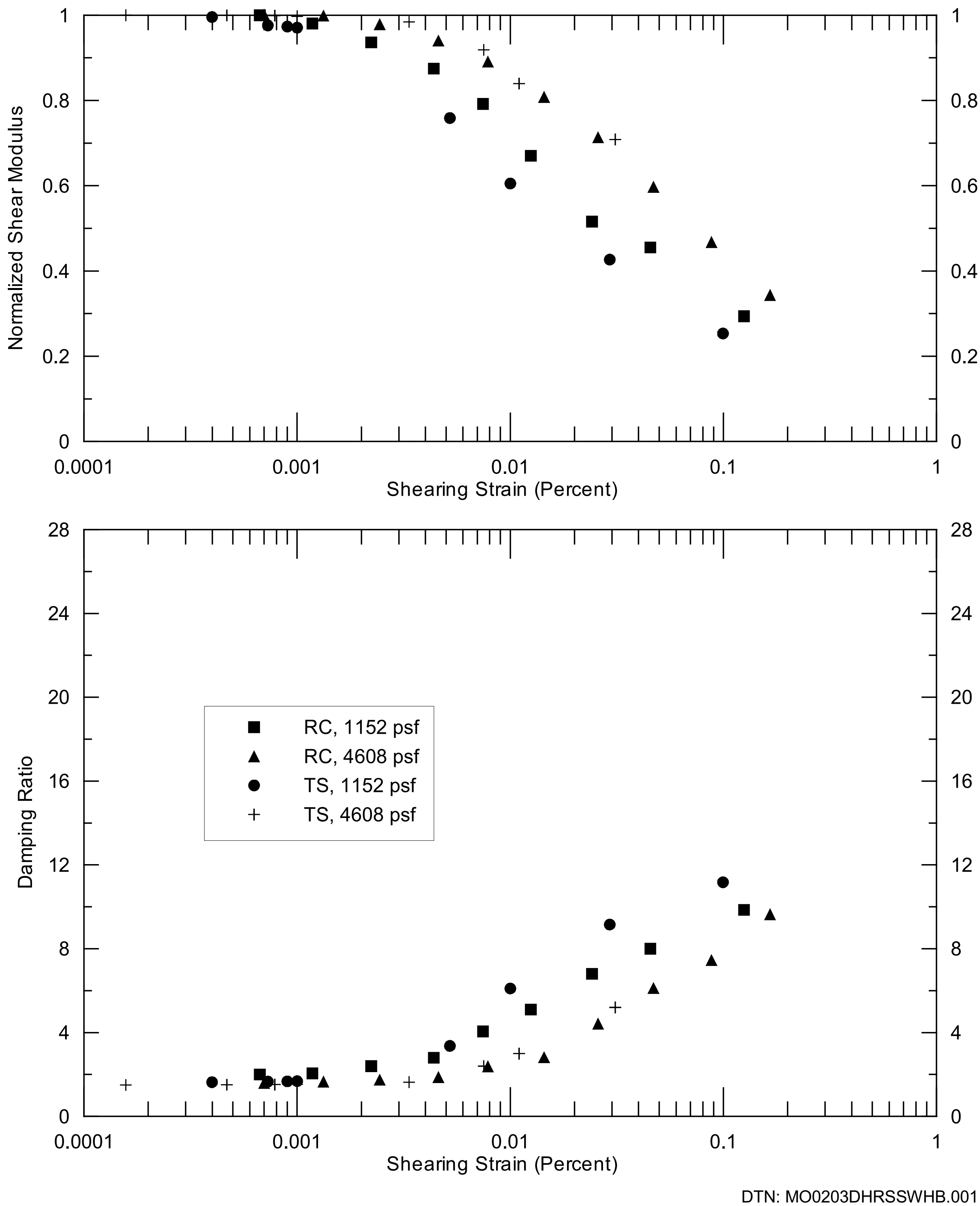
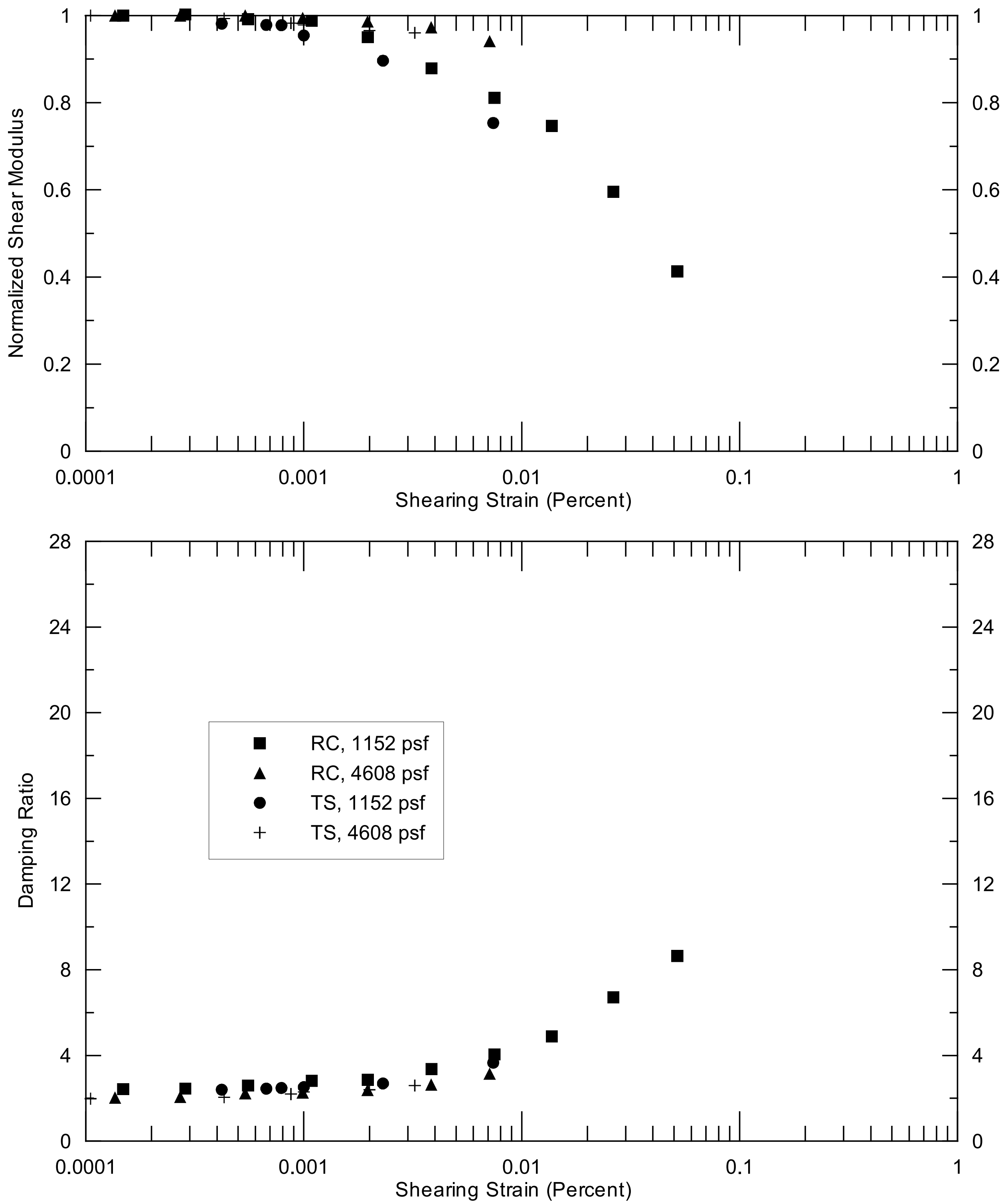
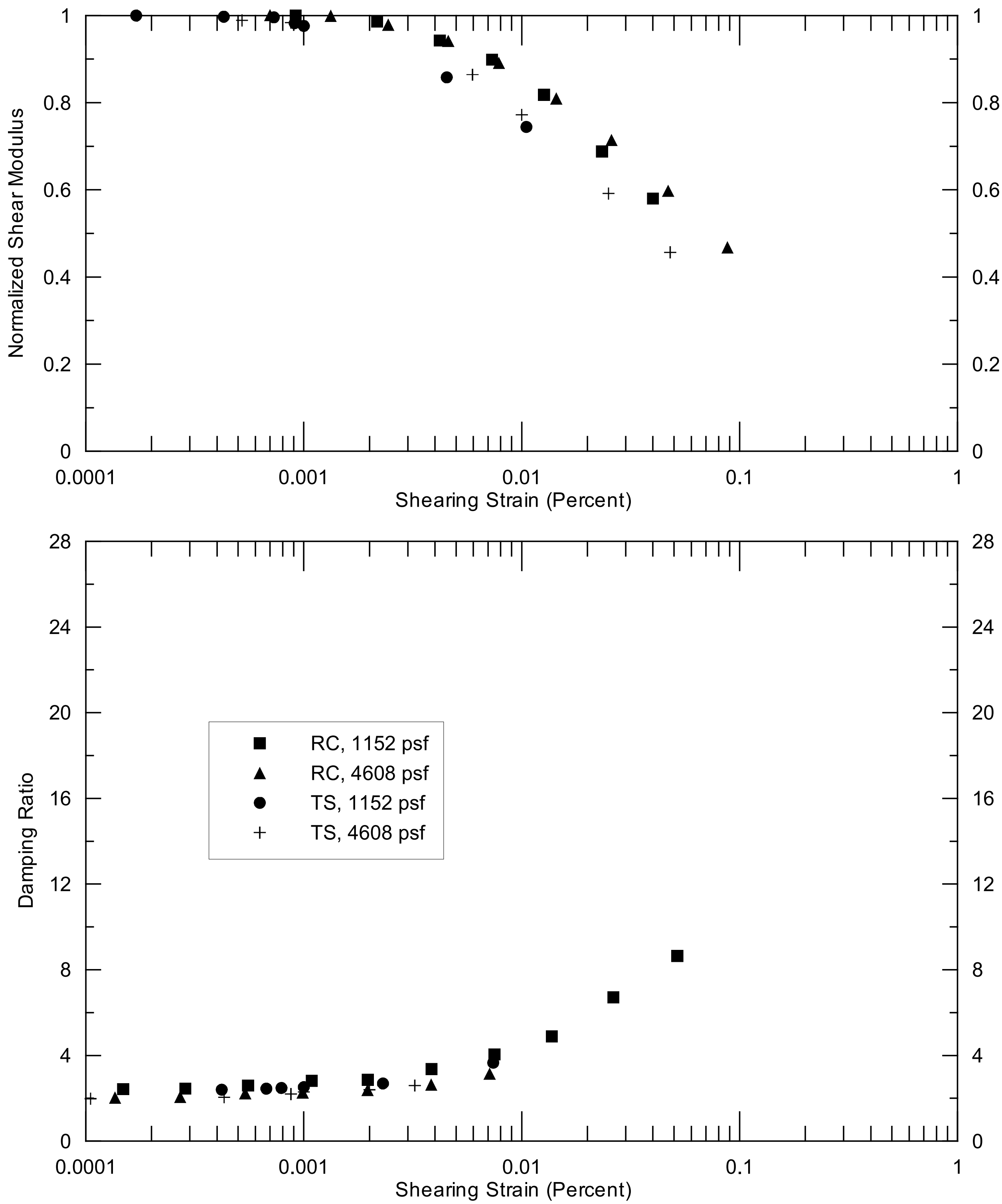


Figure XVII-4. Resonant Column and Torsional Shear Results for Specimen UTA-23-N



DTN: MO0203DHRSSWHB.001

Figure XVII-5. Resonant Column and Torsional Shear Results for Specimen UTA-23-O



DTN: MO0203DHRSSWHB.001

Figure XVII-6. Resonant Column and Torsional Shear Results for Specimen UTA-23-P

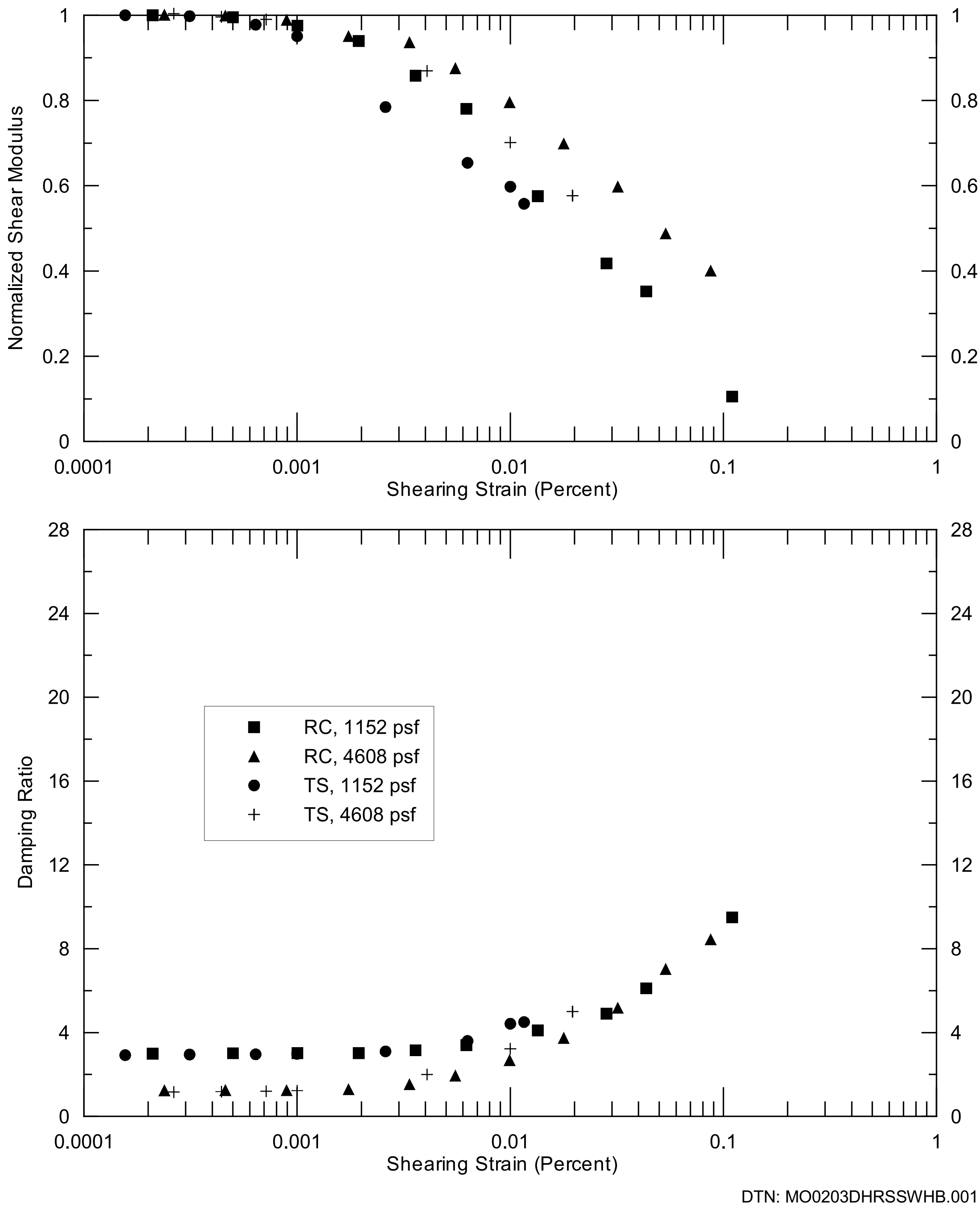


Figure XVII-7. Resonant Column and Torsional Shear Results for Specimen UTA-23-U

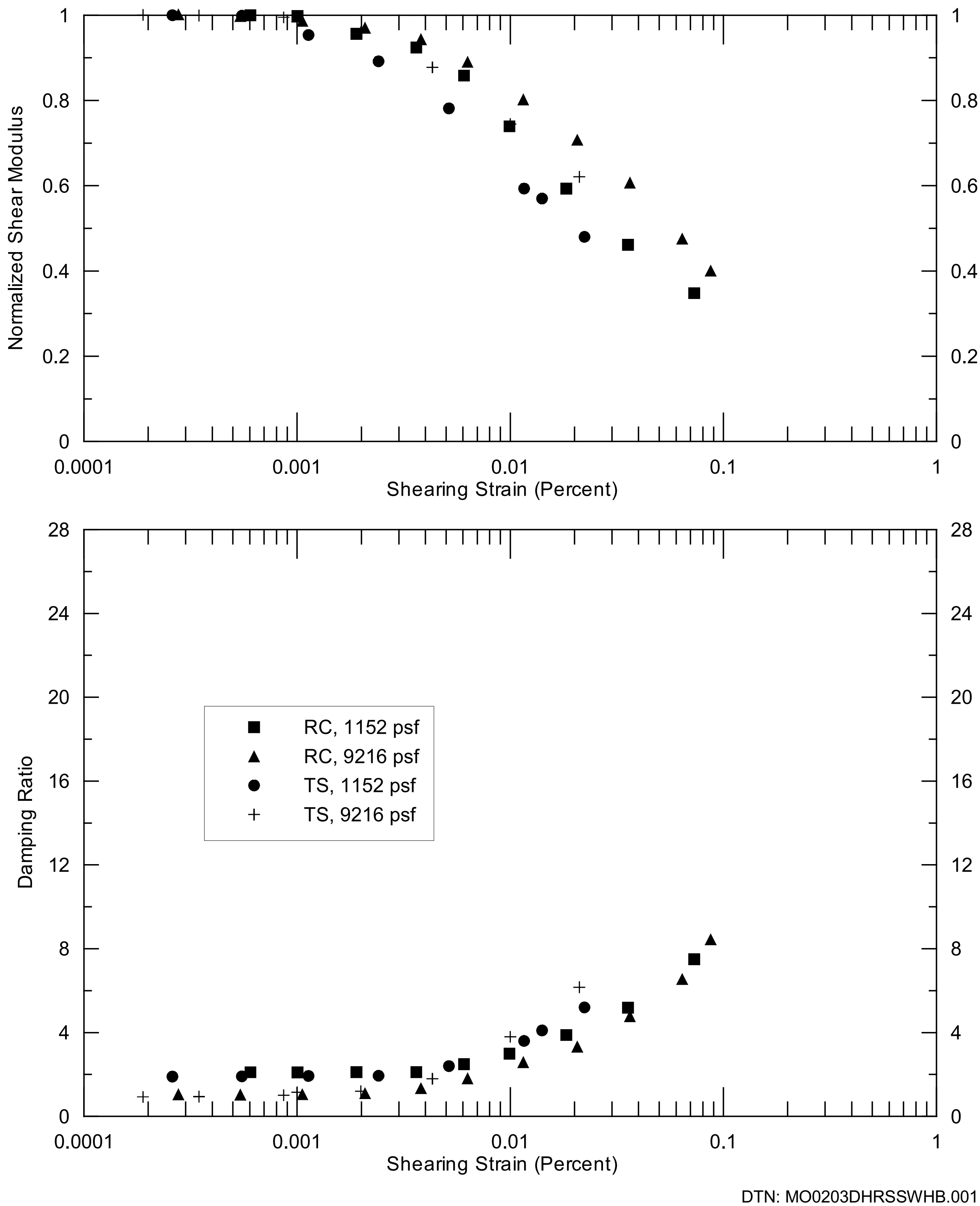


Figure XVII-8. Resonant Column and Torsional Shear Results for Specimen UTA-23-V

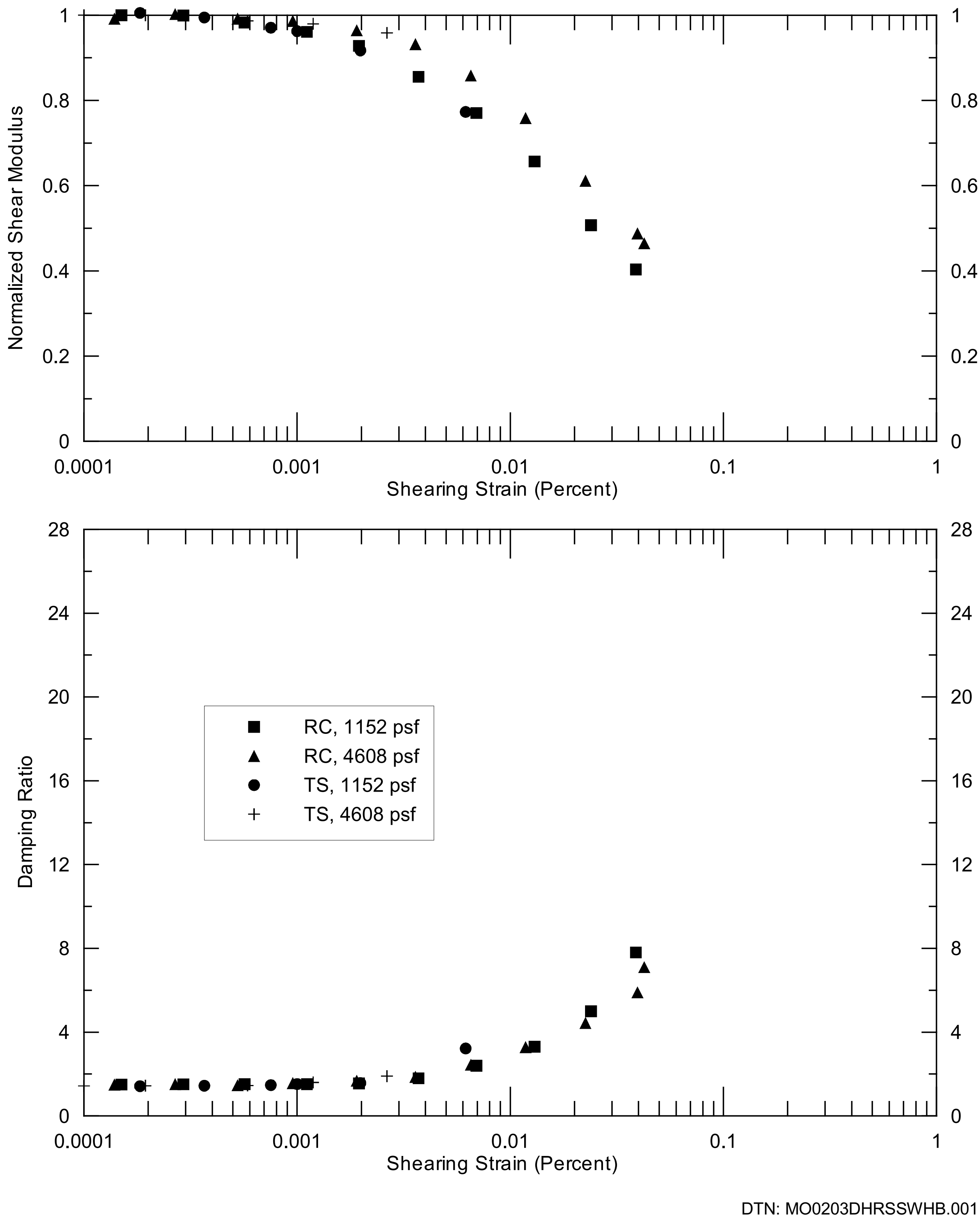


Figure XVII-9. Resonant Column and Torsional Shear Results for Specimen UTA-23-W

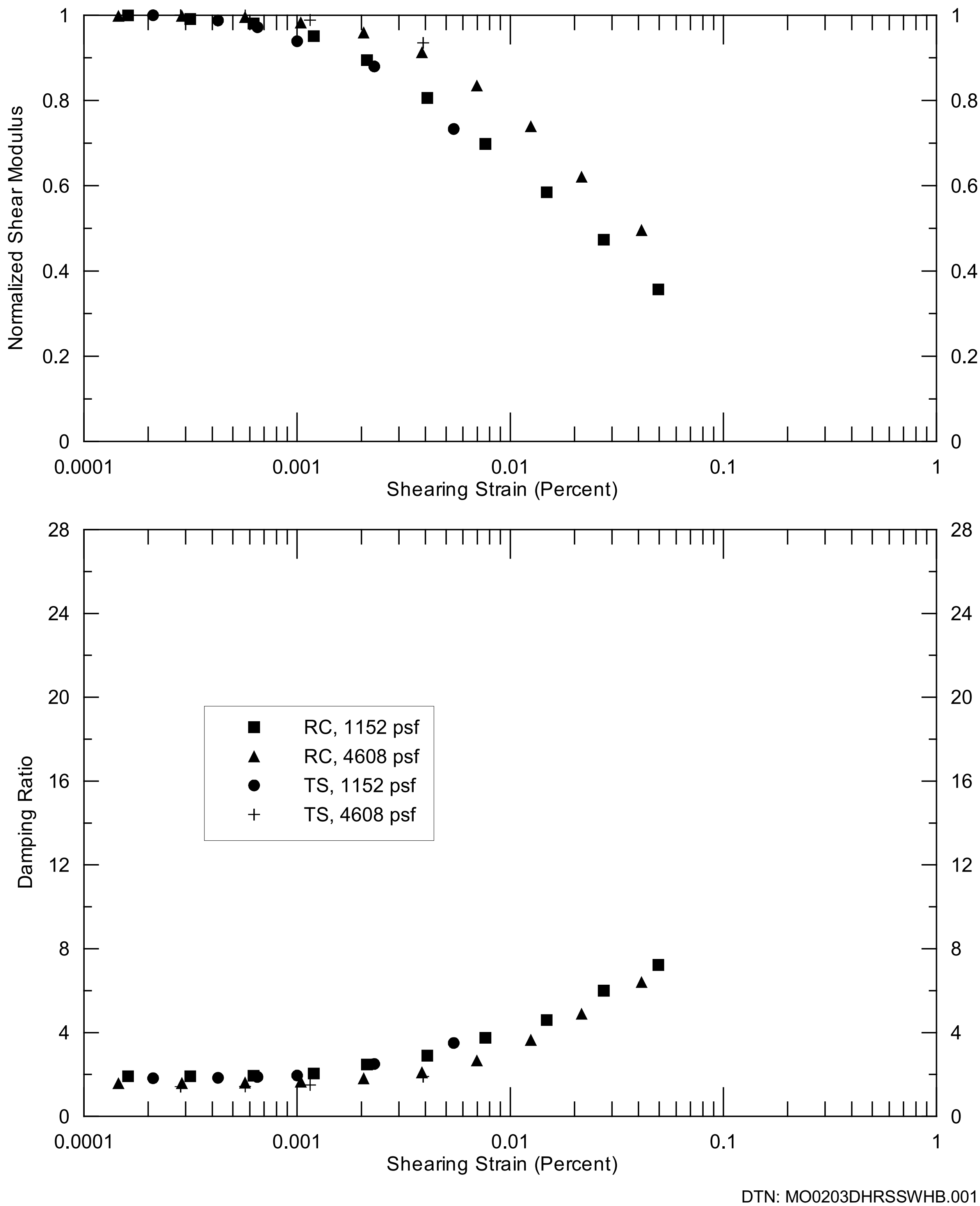


Figure XVII-10. Resonant Column and Torsional Shear Results for Specimen UTA-23-Y

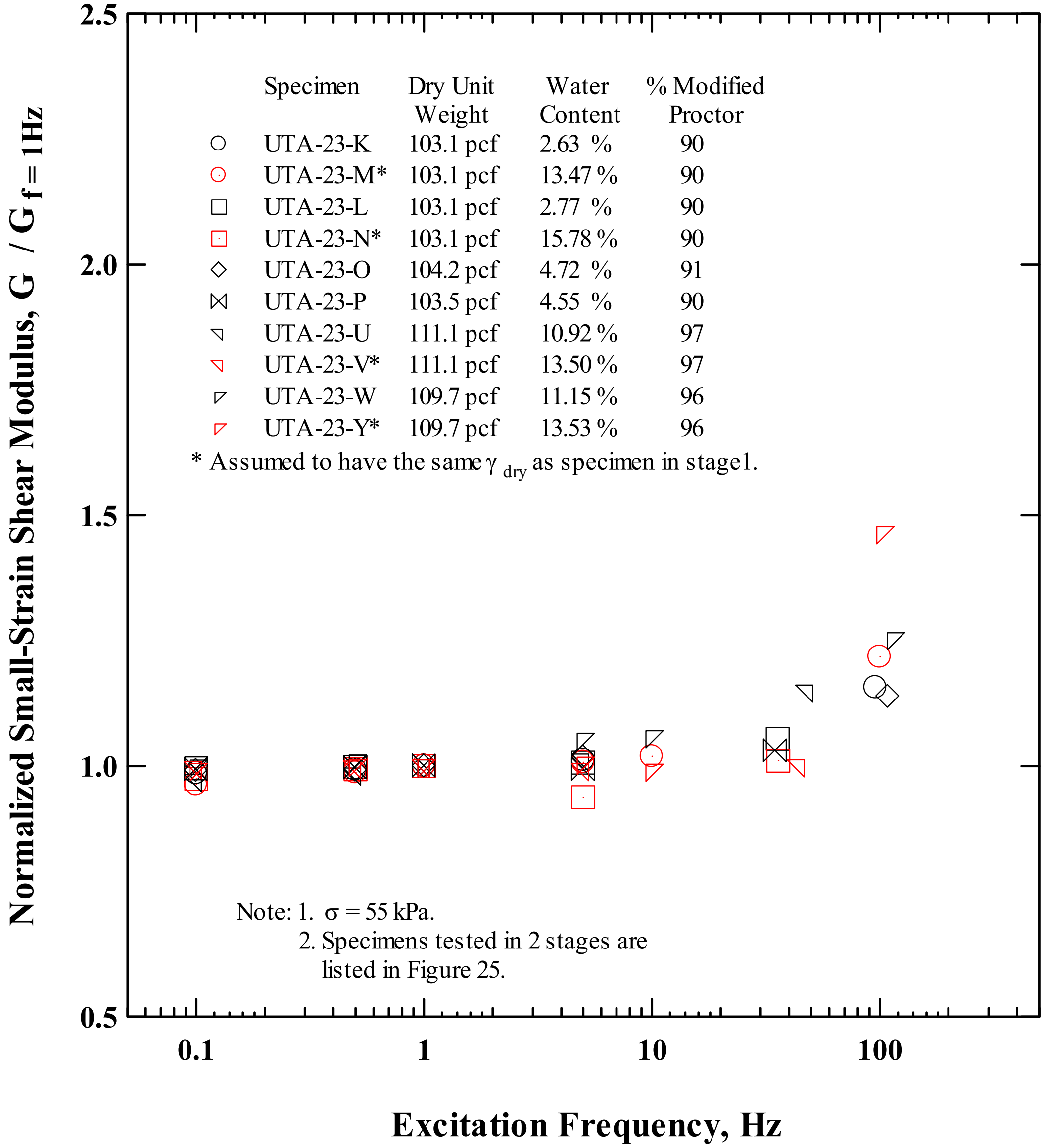


Figure XVII-11. Variation in Small-Strain Shear Modulus with Excitation Frequency of Reconstituted Specimens of the Proposed Engineered Fill.

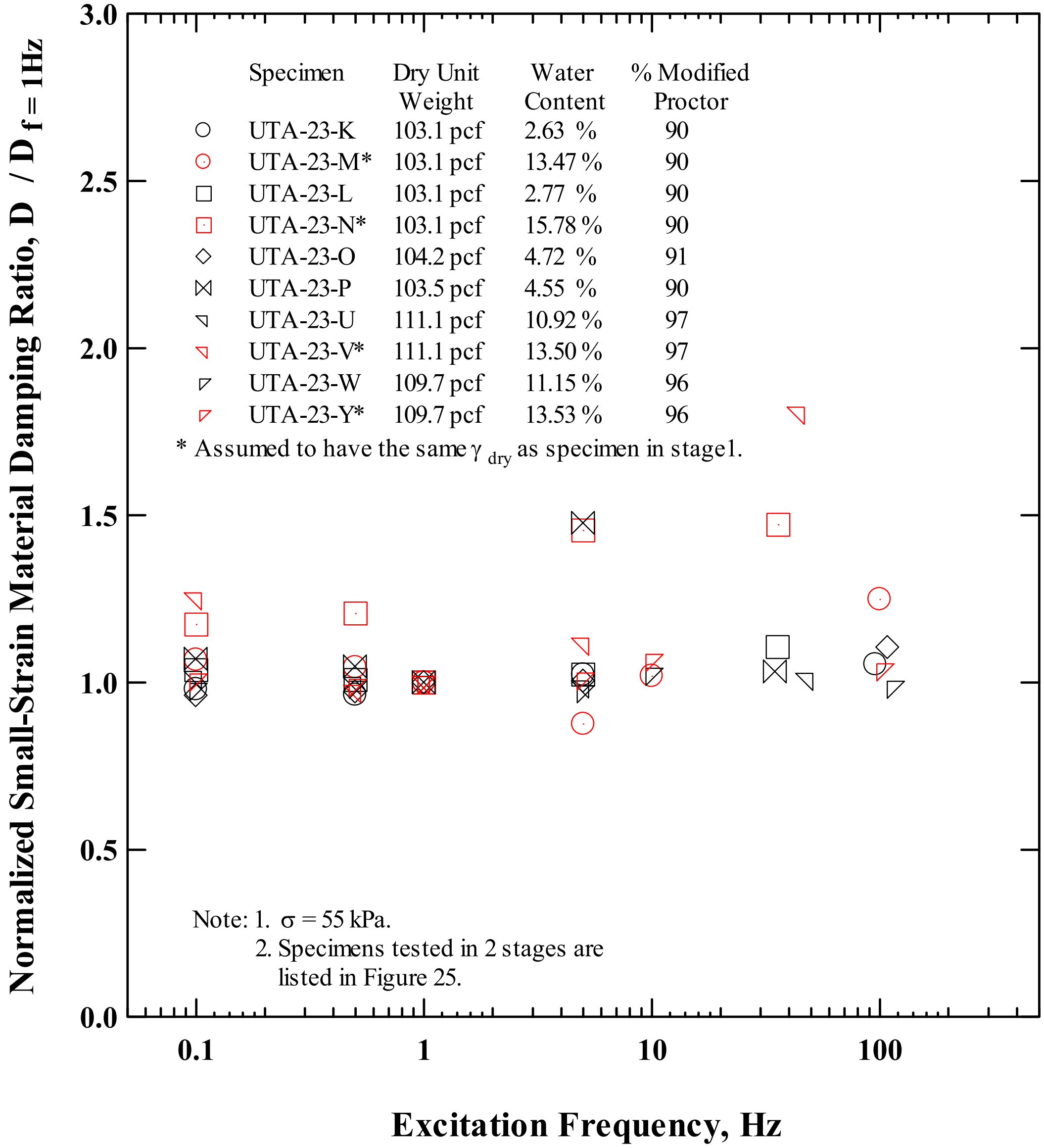


Figure XVII-12. Variation in Normalized Small-Strain Material Damping Ratio with Excitation Frequency of Reconstituted Specimens of the Proposed Engineered Fill.

Table XVII-1a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-K.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio, Dmin, %	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)		
2	288	13.8	800	38	488	2.08	0.60
4	576	27.6	1037	50	555	1.64	0.60
8	1152	55.2	1422	68	657	1.64	0.60
16	2304	110.5	2841	136	925	1.42	0.59
32	4608	220.9	3689	177	1053	1.23	0.58

Table XVII-1b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-K; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
1.44E-04	1505	1.00	1.32E-04	1.44
2.78E-04	1500	1.00	2.57E-04	1.26
5.36E-04	1495	1.00	4.92E-04	1.42
9.10E-04	1486	0.99	8.00E-04	1.48
1.95E-03	1425	0.95	1.77E-03	1.62
3.47E-03	1395	0.93	3.12E-03	1.79
6.23E-03	1365	0.91	5.41E-03	2.36
1.11E-02	1248	0.83	9.28E-03	3.03
2.07E-02	1031	0.69	1.62E-02	4.29
4.10E-02	778	0.52	2.93E-02	6.10

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-1c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-K; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.14E-04	1350	1.00	1.17	1.14E-04	1339	1.00	1.18
2.27E-04	1342	1.00	1.18	2.27E-04	1332	0.99	1.19
4.54E-04	1332	0.99	1.18	4.54E-04	1321	0.99	1.19
7.01E-04	1310	0.97	1.19	7.01E-04	1300	0.97	1.20
8.04E-04	1308	0.97	1.22	8.04E-04	1290	0.97	1.24
1.00E-03	1300	0.96	1.35	1.00E-03	1290	0.96	1.36
2.00E-03	1280	0.95	1.65	2.00E-03	1270	0.95	1.67
4.72E-03	1200	0.89	2.40	4.73E-03	1180	0.89	2.42
6.90E-03	1150	0.85	2.90	7.00E-03	1100	0.82	2.91
8.77E-03	1100	0.81	3.50	8.80E-03	1050	0.78	3.52
1.20E-02	1000	0.74	3.90	1.20E-02	970	0.72	3.95

DTN: MO0203DHRSSWHB.001

Table XVII-1d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-K; Effective Confining Pressure, σ_o' =32psi (4.6 ksf = 221 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
6.36E-05	3805	1.00	5.84E-05	1.21
1.25E-04	3805	1.00	1.16E-04	1.21
2.44E-04	3795	1.00	2.28E-04	1.21
4.91E-04	3785	0.99	4.56E-04	1.22
9.65E-04	3785	0.99	8.95E-04	1.24
1.73E-03	3760	0.99	1.60E-03	1.29
3.40E-03	3686	0.97	3.12E-03	1.44
6.12E-03	3564	0.94	5.53E-03	1.70
1.07E-02	3373	0.89	9.34E-03	2.21
1.84E-02	3052	0.80	1.55E-02	2.95
3.21E-02	2621	0.69	2.55E-02	3.97

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-1e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-K; Effective Confining Pressure, σ_o' = 32psi (4.6 ksf = 221 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.95E-04	3090	1.00	1.12	1.95E-04	3080	1.00	1.13
3.80E-04	3080	1.00	1.14	3.89E-04	3070	1.00	1.15
7.35E-04	3060	0.99	1.15	7.35E-04	3060	0.99	1.16
9.80E-04	3045	0.99	1.16	9.80E-04	3040	0.99	1.17
2.00E-03	2988	0.97	1.17	2.01E-03	2980	0.97	1.18
3.30E-03	2910	0.94	1.47	3.33E-03	2900	0.94	1.44

DTN: MO0203DHRSSWHB.001

Table XVII-2a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-L.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %	
2	288	13.8	764	37	471	3.01	0.52
4	576	27.6	967	46	531	2.40	0.52
8	1152	55.2	1374	66	646	2.40	0.52
16	2304	110.5	2484	119	863	1.46	0.50
32	4608	220.9	3370	162	1004	1.42	0.50

Table XVII-2b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-L; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
1.00E-03	1500	1.00	9.27E-04	1.24
2.57E-03	1460	0.97	2.36E-03	1.39
5.22E-03	1425	0.95	4.20E-03	1.60
8.75E-03	1327	0.89	7.17E-03	2.10
1.42E-02	1242	0.83	1.17E-02	2.65
2.73E-02	1020	0.68	2.26E-02	3.70
5.35E-02	910	0.61	4.45E-02	6.00
9.16E-02	719	0.48	5.98E-02	8.11
1.86E-01	526	0.35	1.04E-01	12.12

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-2c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-L; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
9.36E-04	1430	1.00	1.12	9.36E-04	1420	1.00	1.14
1.00E-03	1420	1.00	1.13	1.00E-03	1415	1.00	1.15
4.50E-03	1323	0.93	1.80	4.50E-03	1316	0.93	1.82
7.10E-03	1261	0.88	2.10	7.10E-03	1257	0.89	2.15
9.10E-03	1170	0.82	2.60	9.10E-03	1156	0.82	2.62
1.00E-02	1163	0.82	2.80	1.00E-02	1150	0.81	2.90
1.50E-02	1040	0.73	3.50	1.52E-02	1030	0.73	3.60

DTN: MO0203DHRSSWHB.001

Table XVII-2d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-L; Effective Confining Pressure, σ_o' =32psi (4.6 ksf = 221 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
6.36E-05	3805	1.00	5.84E-05	1.20
1.25E-04	3805	1.00	1.16E-04	1.20
2.44E-04	3795	1.00	2.28E-04	1.20
4.91E-04	3785	0.99	4.56E-04	1.22
9.65E-04	3785	0.99	8.95E-04	1.24
1.73E-03	3760	0.99	1.60E-03	1.29
3.40E-03	3686	0.97	3.12E-03	1.44
6.12E-03	3564	0.94	5.53E-03	1.70
1.07E-02	3373	0.89	9.34E-03	2.21
1.84E-02	3052	0.80	1.55E-02	2.95
3.21E-02	2621	0.69	2.55E-02	3.97

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-2e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-L; Effective Confining Pressure, σ_o' = 32psi (4.6 ksf = 221 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.57E-04	3393	1.00	1.20	3.57E-04	3390	1.00	1.21
7.17E-04	3361	1.00	1.21	7.17E-04	3350	0.99	1.22
9.00E-04	3350	0.99	1.22	9.00E-04	3340	0.99	1.23
1.00E-03	3334	0.99	1.23	1.00E-03	3320	0.99	1.24
1.80E-03	3290	0.97	1.42	1.83E-03	3280	0.97	1.45
5.88E-03	3070	0.91	1.90	5.89E-03	3060	0.91	1.91
1.00E-02	2812	0.83	2.50	1.00E-02	2812	0.83	2.52

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Table XVII-3a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-M.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %	
2	288	13.8	884	42	493	2.33	0.52
4	576	27.6	1123	54	555	2.33	0.52
8	1152	55.2	1662	80	676	1.81	0.52
16	2304	110.5	2967	142	903	1.81	0.50
32	4608	220.9	4016	193	1050	1.50	0.50

Table XVII-3b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-M; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
1.10E-04	1657	1.00	9.98E-05	1.66
2.09E-04	1647	1.00	1.88E-04	1.66
4.11E-04	1642	0.99	3.68E-04	1.67
8.05E-04	1632	0.99	7.19E-04	1.67
1.53E-03	1581	0.96	1.36E-03	1.92
2.68E-03	1517	0.92	2.31E-03	2.44
4.95E-03	1410	0.85	4.16E-03	2.94
9.45E-03	1249	0.76	7.57E-03	3.83
1.75E-02	1057	0.64	1.31E-02	5.19
3.34E-02	810	0.49	2.37E-02	6.26
6.55E-02	578	0.35	4.47E-02	7.13

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-3c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-M; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
9.39E-05	1600	1.00	1.52	9.40E-05	1584	1.00	1.54
3.80E-04	1560	0.99	1.54	3.80E-04	1550	0.99	1.55
8.45E-04	1540	0.96	1.62	8.45E-04	1520	0.96	1.64
1.01E-03	1520	0.95	1.70	1.01E-03	1510	0.95	1.73
2.00E-03	1380	0.86	2.10	2.03E-03	1340	0.85	2.12
4.47E-03	1156	0.73	3.36	4.53E-03	1148	0.73	3.40
9.70E-03	966	0.61	5.55	9.90E-03	957	0.61	5.59

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Table XVII-3d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-M; Effective Confining Pressure, σ_o' =32psi (4.6 ksf = 221 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
3.92E-05	4234	1.00	3.78E-05	1.85
7.52E-05	4234	1.00	6.72E-05	1.88
1.48E-04	4234	1.00	1.31E-04	1.87
2.96E-04	4210	0.99	2.64E-04	1.87
5.87E-04	4210	0.99	5.20E-04	1.98
1.08E-03	4177	0.99	9.59E-04	2.00
2.10E-03	4072	0.96	1.84E-03	2.14
4.08E-03	3920	0.93	3.53E-03	2.43
7.54E-03	3618	0.85	6.30E-03	3.04
1.40E-02	3148	0.74	1.11E-02	4.05
2.47E-02	2627	0.62	1.85E-02	5.17

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-3e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-M; Effective Confining Pressure, σ_o' = 32psi (4.6 ksf = 221 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.22E-05	3620	1.01	1.72	4.25E-05	3609	1.00	1.73
1.68E-04	3580	0.99	1.73	1.68E-04	3577	1.00	1.74
6.41E-04	3530	0.98	1.74	6.41E-04	3520	0.98	1.75
1.00E-03	3515	0.98	1.75	1.00E-03	3491	0.97	1.76
1.98E-03	3409	0.95	1.84	1.99E-03	3390	0.94	1.87

DTN: MO0203DHRSSWHB.001

Table XVII-4a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-N.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio, Dmin, %	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)		
2	288	13.8	685	33	429	3.25	0.52
4	576	27.6	988	47	515	3.15	0.52
8	1152	55.2	1440	69	622	2.65	0.52
16	2304	110.5	2301	110	787	2.30	0.49
32	4608	220.9	3631	174	988	1.95	0.49

Table XVII-4b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-N; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
6.68E-04	1563	1.00	6.00E-04	2.00
1.18E-03	1504	0.98	1.04E-03	2.05
2.22E-03	1436	0.94	1.91E-03	2.40
4.38E-03	1341	0.87	3.74E-03	2.80
7.45E-03	1214	0.79	5.90E-03	4.06
1.25E-02	1028	0.67	9.52E-03	5.10
2.42E-02	791	0.52	1.62E-02	6.80
4.54E-02	698	0.46	2.83E-02	8.00
1.25E-01	451	0.29	7.59E-02	9.85

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-4c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-N; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
8.14E-05	1530	1.00	1.62	8.20E-05	1520	1.01	1.64
3.99E-04	1517	1.00	1.63	4.00E-04	1501	0.99	1.65
7.29E-04	1487	0.98	1.66	7.29E-04	1471	0.97	1.68
9.00E-04	1483	0.97	1.67	9.08E-04	1470	0.97	1.69
1.00E-03	1479	0.97	1.68	1.00E-03	1474	0.98	1.70
5.21E-03	1156	0.76	3.36	4.53E-03	1148	0.76	3.40
1.00E-02	922	0.61	6.10	1.00E-02	905	0.60	6.15
2.93E-02	650	0.43	9.15	3.03E-02	630	0.42	9.19
9.96E-02	386	0.25	11.17	1.00E-01	380	0.25	11.23

DTN: MO0203DHRSSWHB.001

Table XVII-4d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-N; Effective Confining Pressure, σ_o' =32psi (4.6 ksf = 221 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
7.01E-04	3824	1.00	6.56E-04	1.60
1.33E-03	3817	1.00	1.20E-03	1.66
2.44E-03	3739	0.98	2.22E-03	1.75
4.60E-03	3593	0.94	4.11E-03	1.87
7.86E-03	3405	0.89	6.82E-03	2.39
1.44E-02	3088	0.81	1.22E-02	2.82
2.58E-02	2726	0.71	2.01E-02	4.43
4.70E-02	2282	0.60	3.36E-02	6.12
8.79E-02	1786	0.47	5.90E-02	7.46
1.66E-01	1314	0.34	1.83E-01	9.65

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-4e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-N; Effective Confining Pressure, σ_o' = 32psi (4.6 ksf = 221 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.57E-04	3810	1.00	1.50	1.60E-04	3805	1.00	1.51
4.68E-04	3808	1.00	1.51	4.68E-04	3803	1.00	1.52
7.86E-04	3805	1.00	1.52	7.87E-04	3800	1.00	1.53
1.00E-03	3800	1.00	1.53	1.00E-03	3798	1.00	1.54
3.35E-03	3750	0.98	1.63	3.58E-03	3700	0.97	1.65
7.50E-03	3500	0.92	2.40	7.60E-03	3480	0.91	2.50
1.10E-02	3200	0.84	3.00	1.12E-02	3100	0.81	3.10
3.11E-02	2700	0.71	5.20	3.13E-02	2690	0.71	5.25

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Table XVII-5a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-O.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %	
2	288	13.8	985	47	539	2.81	0.51
4	576	27.6	1274	61	637	2.51	0.51
8	1152	55.2	1698	81	707	2.70	0.51
16	2304	110.5	2570	123	870	2.25	0.50
32	4608	220.9	3827	183	1059	2.18	0.50

Table XVII-5b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-O; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
1.48E-04	1912	1.00	1.23E-04	2.43
2.86E-04	1923	1.00	2.47E-04	2.46
5.55E-04	1902	0.99	4.84E-04	2.60
1.09E-03	1894	0.99	9.21E-04	2.82
1.97E-03	1822	0.95	1.66E-03	2.86
3.85E-03	1685	0.88	3.17E-03	3.36
7.49E-03	1556	0.81	5.94E-03	4.05
1.37E-02	1432	0.75	1.04E-02	4.88
2.64E-02	1142	0.60	1.83E-02	6.71
5.17E-02	791	0.41	3.31E-02	8.64

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-5c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-O; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.44E-05	1729	1.00	2.30	4.53E-05	1712	1.00	2.31
4.20E-04	1666	0.98	2.40	4.29E-04	1665	0.99	2.45
6.73E-04	1661	0.98	2.45	6.73E-04	1653	0.98	2.46
7.90E-04	1660	0.98	2.48	8.00E-04	1650	0.98	2.49
1.00E-03	1650	0.95	2.52	1.00E-03	1648	0.96	2.53
2.31E-03	1550	0.90	2.69	2.33E-03	1540	0.90	2.70
7.40E-03	1279	0.75	3.66	7.50E-03	1269	0.75	3.69

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Table XVII-5d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-O; Effective Confining Pressure, σ_o' =32psi (4.6 ksf = 221 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average$^+$ Shearing Strain, %	Material Damping Ratio^x, D, %
3.60E-05	4149	1.00	3.19E-05	1.98
6.87E-05	4155	1.00	6.09E-05	2.00
1.36E-04	4165	1.00	1.20E-04	2.02
2.71E-04	4165	1.00	2.39E-04	2.06
5.39E-04	4180	1.00	4.71E-04	2.23
9.87E-04	4126	0.99	8.62E-04	2.26
1.96E-03	4045	0.99	1.70E-03	2.38
3.84E-03	3938	0.97	3.29E-03	2.64
7.12E-03	3684	0.94	5.92E-03	3.15

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-5e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-O; Effective Confining Pressure, σ_o' = 32psi (4.6 ksf = 221 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.05E-04	3520	1.00	1.98	1.05E-04	3506	1.00	1.99
4.31E-04	3472	0.99	2.05	4.32E-04	3455	0.99	2.06
8.72E-04	3435	0.98	2.20	8.72E-04	3420	0.98	2.21
1.00E-03	3420	0.98	2.30	1.00E-03	3418	0.98	2.32
2.00E-03	3400	0.97	2.40	2.00E-03	3380	0.96	2.41
3.23E-03	3380	0.96	2.60	3.00E-03	3370	0.96	2.61

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Table XVII-6a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-P.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %	
2	288	13.8	580	28	415	3.99	0.52
4	576	27.6	964	46	550	3.17	0.52
8	1152	55.2	1563	75	670	3.14	0.50
16	2304	110.5	1836	88	800	2.33	0.50
32	4608	220.9	3604	173	1028	1.95	0.48

Table XVII-6b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-P; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average[+] Shearing Strain, %	Material Damping Ratio[x], D, %
9.17E-04	1379	1.00	8.10E-04	1.50
2.17E-03	1360	0.99	1.98E-03	1.52
4.21E-03	1300	0.94	3.80E-03	1.80
7.31E-03	1225	0.90	6.33E-03	2.42
1.27E-02	1116	0.82	1.08E-02	3.00
2.33E-02	938	0.69	1.96E-02	4.00
4.00E-02	800	0.58	3.81E-02	6.00

[+] Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

[x] Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-6c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-P; Effective Confining Pressure, σ_o' = 8psi (1.2 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.70E-04	1347	1.00	1.42	1.70E-04	1340	1.00	1.44
4.29E-04	1340	1.00	1.43	4.29E-04	1335	1.00	1.45
7.29E-04	1338	1.00	1.45	7.29E-04	1321	0.99	1.46
9.08E-04	1320	0.98	1.48	9.08E-04	1319	0.98	1.49
1.00E-03	1315	0.98	1.52	1.00E-03	1311	0.98	1.53
4.53E-03	1156	0.86	2.30	4.53E-03	1148	0.86	2.31
1.05E-02	1000	0.74	3.00	1.05E-02	995	0.74	3.20

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Table XVII-6d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-P; Effective Confining Pressure, σ_o' =32psi (4.6 ksf = 221 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
7.01E-04	3864	1.00	6.21E-04	1.50
1.33E-03	3860	1.00	1.20E-03	1.52
2.44E-03	3779	0.98	2.22E-03	1.65
4.60E-03	3636	0.94	4.11E-03	1.87
7.86E-03	3442	0.89	6.82E-03	2.30
1.44E-02	3125	0.81	1.22E-02	3.50
2.58E-02	2759	0.71	2.01E-02	4.43
4.70E-02	2308	0.60	3.36E-02	6.12
8.79E-02	1806	0.47	5.90E-02	8.00
1.66E-01	1330	0.34	9.81E-02	10.45

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-6e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-P; Effective Confining Pressure, σ_o' = 32psi (4.6 ksf = 221 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.72E-04	3522	1.00	1.42	1.72E-04	3500	1.00	1.43
5.21E-04	3444	0.99	1.43	5.21E-04	3420	0.99	1.44
8.72E-04	3427	0.98	1.45	8.72E-04	3411	0.99	1.47
1.00E-03	3403	0.98	1.47	1.00E-03	3400	0.98	1.48
5.94E-03	3011	0.86	2.30	5.96E-03	2990	0.86	2.35
1.00E-02	2690	0.77	3.20	1.00E-02	2678	0.77	3.30
2.50E-02	2060	0.59	5.70	2.50E-02	2050	0.59	5.73
4.80E-02	1590	0.46	7.30	4.80E-02	1575	0.45	7.32

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Table XVII-7a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-U.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %	
2	288	13.8	1400	67	605	3.97	0.42
4	576	27.6	1767	85	687	3.55	0.41
8	1152	55.2	2709	130	841	3.28	0.41
16	2304	110.5	4431	212	1074	2.64	0.41
32	4608	220.9	5079	244	1149	1.63	0.40
64	9216	441.8	7598	364	1403	1.31	0.40

Table XVII-7b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-U; Effective Confining Pressure, σ_o' = 8 psi (1.15 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
2.10E-04	2110	1.00	2.00E-04	3.00
5.00E-04	2100	1.00	4.87E-04	3.01
1.00E-03	2059	0.98	8.40E-04	3.02
1.94E-03	1983	0.94	1.46E-03	3.02
3.59E-03	1811	0.86	2.99E-03	3.15
6.22E-03	1647	0.78	4.89E-03	3.40
1.35E-02	1214	0.58	1.04E-02	4.10
2.83E-02	881	0.42	2.18E-02	4.90
4.34E-02	743	0.35	3.10E-02	6.11
1.10E-01	271	0.11	7.61E-02	9.50

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-7c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-U; Effective Confining Pressure, σ_o' = 8 psi (1.15 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.56E-04	1912	1.00	2.92	1.56E-04	1908	1.00	2.93
3.13E-04	1899	1.00	2.95	3.14E-04	1881	1.00	2.96
6.39E-04	1841	0.98	2.96	6.40E-04	1883	0.98	2.97
1.00E-03	1762	0.95	2.98	1.00E-03	1760	0.95	3.04
2.60E-03	1500	0.78	3.10	2.62E-03	1497	0.78	3.20
6.30E-03	1250	0.65	3.60	6.10E-03	1240	0.65	3.65
1.00E-02	737	0.60	4.42	1.00E-02	728	0.60	4.43
1.16E-02	620	0.56	4.50	1.18E-02	610	0.56	4.51

DTN: MO0203DHRSSWHB.001

Table XVII-7d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-U; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average⁺ Shearing Strain, %	Material Damping Ratio^x, D, %
2.38E-04	5497	1.00	2.21E-04	1.24
4.61E-04	5485	1.00	4.27E-04	1.26
8.93E-04	5430	0.99	8.37E-04	1.25
1.74E-03	5223	0.95	1.61E-03	1.30
3.37E-03	5143	0.94	3.07E-03	1.53
5.52E-03	4809	0.88	4.91E-03	1.94
9.93E-03	4372	0.80	8.47E-03	2.68
1.78E-02	3839	0.70	1.43E-02	3.74
3.20E-02	3284	0.60	2.39E-02	5.18
5.36E-02	2679	0.49	3.67E-02	7.04
8.71E-02	2201	0.40	5.61E-02	8.45

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-7e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-U; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.64E-04	5234	1.00	1.16	2.64E-04	5230	1.00	1.17
4.41E-04	5195	1.00	1.18	4.41E-04	5194	1.00	1.19
7.16E-04	5163	0.99	1.20	7.16E-04	5143	0.99	1.22
1.00E-03	5090	0.98	1.23	1.00E-03	5083	0.98	1.24
4.07E-03	4534	0.87	2.00	4.07E-03	4514	0.87	2.10
1.00E-02	3658	0.70	3.23	1.00E-02	3649	0.70	3.25
1.96E-02	3007	0.58	5.00	1.96E-02	3004	0.58	5.20

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Table XVII-8a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-V.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio,	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	Dmin, %	
2	288	13.8	681	33	417	3.83	0.42
4	576	27.6	1067	51	523	3.43	0.41
8	1152	55.2	1493	72	618	2.71	0.41
16	2304	110.5	2618	126	818	1.92	0.41
32	4608	220.9	4199	201	1036	1.43	0.41
64	9216	441.8	6421	308	1281	1.24	0.42

Table XVII-8b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-V; Effective Confining Pressure, σ_o' = 8 psi (1.15 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
1.01E-03	1608	1.00	8.95E-04	2.10
6.03E-04	1610	1.00	5.96E-04	2.11
1.90E-03	1540	0.96	1.76E-03	2.11
3.63E-03	1488	0.92	3.19E-03	2.12
6.06E-03	1382	0.86	5.22E-03	2.49
9.91E-03	1190	0.74	7.04E-03	3.00
1.83E-02	955	0.59	1.46E-02	3.89
3.57E-02	743	0.46	2.67E-02	5.19
7.28E-02	560	0.35	5.59E-02	7.50

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-8c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-V; Effective Confining Pressure, σ_o' = 8 psi (1.15 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.60E-04	1682	1.00	1.90	2.60E-04	1680	1.00	1.92
5.50E-04	1680	1.00	1.91	5.50E-04	1660	0.99	1.93
1.13E-03	1603	0.95	1.93	1.13E-03	1597	0.96	1.94
2.41E-03	1498	0.89	1.94	2.43E-03	1494	0.90	1.95
5.15E-03	1310	0.78	2.40	5.16E-03	1300	0.78	2.50
1.16E-02	990	0.59	3.60	1.18E-02	960	0.58	3.50
1.41E-02	950	0.57	4.10	1.42E-02	944	0.57	4.40
2.23E-02	797	0.48	5.20	2.25E-02	793	0.48	5.20

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Table XVII-8d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-V; Effective Confining Pressure, σ_o' = 64 psi (9.2 ksf = 442 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average⁺ Shearing Strain, %	Material Damping Ratio^x, D, %
5.41E-04	4334	1.00	5.08E-04	1.04
2.77E-04	4350	1.00	2.67E-04	1.05
1.06E-03	4286	0.99	9.82E-04	1.06
2.08E-03	4214	0.97	1.95E-03	1.10
3.81E-03	4097	0.94	3.51E-03	1.34
6.30E-03	3866	0.89	5.64E-03	1.82
1.15E-02	3483	0.80	9.85E-03	2.59
2.06E-02	3072	0.71	1.70E-02	3.33
3.64E-02	2637	0.61	2.78E-02	4.78
6.41E-02	2066	0.48	4.49E-02	6.55
1.03E-01	1819	0.42	6.50E-02	8.83

$^+$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-8e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-V; Effective Confining Pressure, σ_o' = 64 psi (9.2 ksf = 442 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.89E-04	4100	1.00	0.93	1.89E-04	4100	1.00	0.94
3.46E-04	4100	1.00	0.94	3.45E-04	4090	1.00	0.95
8.64E-04	4080	1.00	1.01	8.64E-04	4080	1.00	1.02
1.00E-03	4030	0.98	1.15	1.00E-03	4020	0.98	1.14
1.99E-03	3910	0.96	1.20	2.00E-03	3900	0.96	1.21
4.31E-03	3510	0.88	1.80	4.33E-03	3500	0.88	1.82
1.00E-02	2870	0.74	3.80	1.00E-02	2800	0.73	3.84
2.11E-02	2280	0.62	6.16	2.12E-02	2200	0.60	6.20

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Table XVII-9a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-W.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio, Dmin, %	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)		
2	288	13.8	1180	57	558	2.21	0.43
4	576	27.6	1561	75	642	1.86	0.43
8	1152	55.2	2265	109	773	1.76	0.43
16	2304	110.5	3558	171	968	1.58	0.43
32	4608	220.9	5240	251	1174	1.53	0.43
64	9216	441.8	7774	373	1428	1.54	0.42

Table XVII-9b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-W; Effective Confining Pressure, σ_o' = 8 psi (1.15 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
1.50E-04	2442	1.00	1.38E-04	1.50
2.92E-04	2440	1.00	2.68E-04	1.51
1.11E-03	2346	0.96	1.01E-03	1.52
1.95E-03	2265	0.93	1.77E-03	1.55
3.71E-03	2088	0.86	3.36E-03	1.80
6.93E-03	1881	0.77	6.25E-03	2.40
5.66E-04	2400	0.98	5.13E-04	1.52
1.30E-02	1603	0.66	1.01E-02	3.30
2.39E-02	1238	0.51	1.69E-02	5.00
3.88E-02	985	0.40	2.57E-02	7.80

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-9c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-W; Effective Confining Pressure, σ_o' = 8 psi (1.15 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.83E-04	1970	1.01	1.42	1.83E-04	1970	1.01	1.43
3.67E-04	1950	0.99	1.44	3.67E-04	1950	0.99	1.45
7.53E-04	1910	0.97	1.47	7.53E-04	1900	0.97	1.48
1.00E-03	1890	0.96	1.52	1.00E-03	1880	0.96	1.54
1.98E-03	1800	0.92	1.57	1.99E-03	1790	0.91	1.58
6.18E-03	1520	0.77	3.22	6.20E-03	1500	0.77	3.12

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Table XVII-9d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-W; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratio^x, D, %
2.68E-04	5816	1.00	2.44E-04	1.52
1.39E-04	5752	0.99	1.27E-04	1.49
5.26E-04	5751	0.99	4.81E-04	1.46
9.53E-04	5721	0.99	8.67E-04	1.57
1.90E-03	5593	0.96	1.72E-03	1.67
3.58E-03	5404	0.93	3.20E-03	1.87
6.52E-03	4977	0.86	5.64E-03	2.44
1.18E-02	4398	0.76	9.74E-03	3.28
2.25E-02	3545	0.61	1.75E-02	4.44
3.95E-02	2829	0.49	3.01E-02	5.90
4.25E-02	2696	0.46	3.80E-02	7.10

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-9e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-W; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.00E-04	3750	1.00	1.43	1.01E-04	3740	1.00	1.44
1.94E-04	3750	1.00	1.44	1.95E-04	3760	1.00	1.45
5.85E-04	3700	0.99	1.45	5.87E-04	3700	0.99	1.46
1.19E-03	3680	0.98	1.60	1.20E-03	3670	0.98	1.61
2.64E-03	3600	0.96	1.90	2.65E-03	3580	0.95	1.91

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Table XVII-10a. Variation in Low-Amplitude Shear-Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio and Void Ratio with Effective Isotropic Confining Pressure from RC Tests of Specimen UTA-23-Y.

Effective Isotropic Confining Pressure, σ_o'			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear-Wave Velocity, Vs	Low-Amplitude Material Damping Ratio, Dmin, %	Void Ratio, e
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)		
2	288	14	856	41	471	2.76	0.44
4	576	27.6	1332	64	587	2.23	0.44
8	1152	55.2	2055	99	729	1.88	0.43
16	2304	110.5	3263	156	918	1.66	0.43
32	4608	220.9	5000	240	1136	1.58	0.43
64	9216	441.8	7613	365	1401	1.51	0.43

Table XVII-10b. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-Y; Effective Confining Pressure, σ_o' = 8 psi (1.15 ksf = 55 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average^{+} Shearing Strain, %	Material Damping Ratio^{x}, D, %
8.45E-05	1999	1.00	7.54E-05	1.90
1.61E-04	1997	1.00	1.43E-04	1.92
3.15E-04	1980	0.99	2.81E-04	1.92
6.24E-04	1960	0.98	5.55E-04	1.94
1.20E-03	1900	0.95	1.06E-03	2.04
2.13E-03	1788	0.89	1.83E-03	2.48
4.08E-03	1610	0.81	3.37E-03	2.90
7.65E-03	1395	0.70	5.97E-03	3.75
1.48E-02	1168	0.58	1.09E-02	4.60
2.75E-02	946	0.47	1.94E-02	6.00
4.95E-02	712	0.36	3.36E-02	7.22

$^{+}$ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

^{x} Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-10c. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-Y; Effective Confining Pressure, σ_o' = 8 psi (1.15 ksf = 55 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.11E-04	1705	1.00	1.82	2.11E-04	1704	1.00	1.83
4.25E-04	1684	0.99	1.84	4.25E-04	1683	0.99	1.84
6.52E-04	1657	0.97	1.88	6.52E-04	1652	0.97	1.89
1.00E-03	1601	0.94	1.95	1.00E-03	1600	0.94	1.96
2.30E-03	1500	0.88	2.50	2.30E-03	1490	0.87	2.52
5.43E-03	1250	0.73	3.50	5.45E-03	1239	0.73	3.54

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Table XVII-10d. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-23-Y; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Average+ Shearing Strain, %	Material Damping Ratiox, D, %
3.78E-05	5080	1.00	3.54E-05	1.55
7.25E-05	5060	1.00	6.59E-05	1.56
1.45E-04	5060	1.00	1.32E-04	1.58
2.88E-04	5060	1.00	2.61E-04	1.59
5.69E-04	5050	1.00	5.16E-04	1.62
1.04E-03	4980	0.98	9.39E-04	1.66
2.05E-03	4860	0.96	1.84E-03	1.82
3.85E-03	4630	0.91	3.39E-03	2.10
6.97E-03	4230	0.84	5.95E-03	2.67
1.25E-02	3750	0.74	1.01E-02	3.65
2.16E-02	3150	0.62	1.64E-02	4.90
4.13E-02	2510	0.50	2.91E-02	6.41

+ Average Shearing Strain from the First Three Cycles of the Free Vibration Decay Curve

x Average Damping Ratio from the First Three Cycles of the Free Vibration Decay Curve

Table XVII-10e. Variation in Shear Modulus, Normalized Shear Modulus and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-23-Y; Effective Confining Pressure, σ_o' = 32 psi (4.6 ksf = 220 kPa)

First Cycle				Tenth Cycle			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.84E-04	4544	1.00	1.42	2.84E-04	4540	1.00	1.43
5.70E-04	4540	1.00	1.43	5.70E-04	4539	1.00	1.45
1.15E-03	4490	0.99	1.50	1.16E-03	4480	0.99	1.51
3.90E-03	4250	0.94	1.90	3.91E-03	4240	0.93	1.91

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ATTACHMENT XVIII

GLOSSARY

GLOSSARY

This glossary presents definitions for selected geologic and geotechnical terms as used in this Scientific Analysis Report. Alternative definitions may be used in other disciplines or in other contexts.

BEDDED TUFF	A rock unit composed of volcanic ejecta that was deposited in layers and that exhibits distinct planes of weakness (bedding planes) parallel to layering; deposited either by water or by compositional sorting by air fall.
BULK DENSITY	Synonym of density.
COEFFICIENT OF VARIATION	A statistical parameter providing a means for comparing the relative dispersion of more than one kind of data, computed as the standard deviation of a set of measurements divided by the mean value, expressed either as a decimal or percentage.
COMPRESSION-WAVE VELOCITY	Velocity of the compression (P) wave from a seismic energy source.
COUNT	In statistical analysis, the number of measurements in a data set.
DAMPING	The reduction in the amplitude of vibration of a body or system due to the dissipation of energy internally or by radiation.
DAMPING, MATERIAL	Damping that results from viscous, hysteric or other mechanisms except radiation.
DAMPING, RADIATION	Damping that results from spreading over a greater volume of material. Synonym: geometric damping.
DAMPING RATIO	For a system with viscous damping, the ratio of the actual damping coefficient to the critical damping coefficient.
DENSITY (OF SOIL OR ROCK), ρ (IN UNITS OF MASS PER LENGTH CUBED, E.G., POUND-MASS/FT^3 OR KG/M^3)	The total mass (solids plus liquid plus gas) per total volume.
DENSITY, DRY (OF SOIL OR ROCK), ρ_D (IN UNITS OF MASS PER LENGTH CUBED, E.G., POUND-MASS/FT^3 OR KG/M^3)	The mass of solid particles per the total volume of soil or rock.

DENSITY, SATURATED (OF SOIL OR ROCK), ρ_{SAT} (IN UNITS OF MASS PER LENGTH CUBED, E.G., POUND-MASS/FT^3 OR KG/M^3)	The total mass per total volume of completely saturated soil or rock.
DENSITY OF SOLID PARTICLES, ρ_S (IN UNIT OF MASS PER LENGTH CUBED, E.G., POUND-MASS/FT^3 OR KG/M^3	The mass of solid particles divided by the volume of solid particles.
DRY DENSITY	See density, dry.
DRY UNIT WEIGHT	See unit weight, dry.
ENGINEERED FILL	An artificial fill (i.e., a fill constructed by man) that meets several criteria, typically including: (1) the fill is designed to meet established criteria (e.g., bearing capacity, settlement) for a particular purpose (building, embankment, etc.); (2) criteria are established on drawings and in a written specification for the material placed in the fill; (3) the fill is placed in accordance with drawings and written specifications; (4) the fill placement operations are observed by a geotechnical engineer (usually a geotechnical technician working under the geotechnical engineer's supervision); (5) the material being placed in the fill is sufficiently tested to establish its geotechnical characteristics; (6) the degree of compaction of the fill is verified by either (a) in-situ density tests and compaction tests if relative compaction or relative density is specified, or (b) documenting adherence to a method specification, depending on which acceptance criteria is stipulated in the construction contract documents; (7) all fill material and all compacted fill that do not meet the contract requirements is either removed and replaced or reworked in an appropriate manner; (8) the geotechnical engineer prepares detailed written daily reports stating the geotechnical engineer's observations for the day, which are distributed on a daily basis; and (9) the geotechnical engineer writes and files a report at the conclusion of earthwork construction summarizing the geotechnical engineer's observations and testing made during construction and providing his opinion that the fill was or was not constructed in accordance with the specifications and is suited or not for its intended use.

EOLIAN	Borne, deposited, produced or eroded by wind
FINES CONTENT	The percent of a materials' particles, on a dry weight basis, that pass through a U.S. Standard No. 200 sieve.
GRABEN	A block bounded by faults that has been downthrown relative to the adjacent rock.
HOMOCLINAL	Pertaining to a group of beds having the same dip.
HORST	A block bounded by faults that has been uplifted relative to the adjacent rock.
KIP	a unit of force (weight) equal to one thousand pounds-force (1000 lbf).
LITHOPHYSAE	Hollow, bubble-like structures composed of concentric shells formed by the concentration of gasses during cooling of portions of a volcanic flow deposit.
LITHOPHYSAL	Containing lithophysae.
LOW-AMPLITUDE MATERIAL DAMPING RATIO	See material damping ratio, low-amplitude.
LOW-AMPLITUDE SHEAR MODULUS	See shear modulus, low-amplitude.
LOW-AMPLITUDE SHEAR-WAVE VELOCITY	See shear-wave velocity, low-amplitude.
MATERIAL DAMPING RATIO	The ratio of the energy dissipated to the energy input during one cycle of loading, computed on the basis of the area contained within the hysteresis loop, and the equivalent secant modulus. Symbol: D.
MATERIAL DAMPING RATIO, LOW-AMPLITUDE	The ratio of the energy dissipated to energy input during one cycle of loading at low strain values (< 0.001%). Symbol: D_{min}.
MOIST DENSITY	Synonym of density.
NON-ENGINEERED FILL	An artificial (man-made) fill that does not meet the definition of engineered fill.
NONWELDED TUFF	A volcanic rock consisting of fragments that were deposited with insufficient heat to have become fused.

PERCENT CORE RECOVERY	In a given cored interval, the ratio of the length of core recovered to the length of the interval, expressed as a percentage.
POISSON'S RATIO	In Hooke's Law for isotropic materials, for a material subjected to a stress in some direction, the ratio of the strain in the transverse direction to the strain in the direction of stress application.
POROSITY	The ratio, usually expressed as a percentage, of the volume of voids of a given soil or rock mass to the total volume of the soil or rock mass.
PUMICE	A type of volcanic ejecta consisting of air voids in a matrix of glassy lava, usually with the composition of rhyolite.
RELATIVE COMPACTION	The ratio, expressed as a percentage, of the dry unit weight of a soil mass to the reference maximum dry unit weight of the material as determined by a test, such as ASTM D1557-91 (1998), Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3)).
RELATIVE DENSITY	The ratio of (1) the difference between the void ratio of a cohesionless soil in the loosest state and its actual void ratio, to (2) the difference between the void ratios in the loosest and in the densest states.
ROCK QUALITY DESIGNATION (ABBREVIATED RQD)	The ratio, expressed as a percentage, of the sum of the length of recovered of core pieces that have a length at least 100 mm to the total length of the core run.
SATURATED DENSITY	See density, saturated.
SEPARATION	Refers to the apparent relative displacement of a tabular body or surface across a fault. It is the distance between displaced parts measured in any specified direction. It is distinguished from slip, which refers to the actual relative displacement of the two walls of a fault. To classify a fault in terms of slip, it is necessary to know the direction and sense of translation. If the direction and sense of displacement is not known, then a fault can be classified in terms of separation.

SHEAR MODULUS	The stiffness factor for a material under shear stress, expressed by the relationship of the applied shear force to the change in position produced by this force, calculated as the product of the total mass density (total unit weight divided by gravity) and the square of the shear wave velocity. Symbol: G.
SHEAR MODULUS, LOW-AMPLITUDE	Shear modulus determined as the ratio of the shearing stress divided by the shearing strain at low strain values (< 0.001%). Symbol: G_{max}. Synonym: small-strain shear modulus.
SHEAR-WAVE VELOCITY	Velocity of the shear (S) wave from a seismic energy source.
SHEAR-WAVE VELOCITY, LOW-AMPLITUDE	the velocity of a seismic body wave propagating with a shearing motion that oscillates particles at right angles to the direction of propagation measured at low strain values (< 0.001%). Synonym: small-strain shear-wave velocity.
SMALL-STRAIN MATERIAL DAMPING RATIO	Synonym of low-amplitude material damping ratio.
SMALL-STRAIN SHEAR MODULUS	Synonym of low-amplitude shear modulus.
SMALL-STRAIN SHEAR-WAVE VELOCITY	Synonym of low-amplitude shear-wave velocity.
TOTAL DENSITY	Synonym of density.
TUBE WAVE	A pressure pulse that propagates nearly unattenuated down the fluid in a borehole at a velocity close to that of the shear wave in the surrounding material.
UNIT WEIGHT, γ (IN UNITS OF POUND-FORCE/FT^3 OR kN/M^3	The total weight (solids plus liquid plus gas) per total volume. This parameter is also commonly referred to as “moist unit weight,” “wet unit weight,” or “total unit weight.”
UNIT WEIGHT, DRY, γ (IN UNITS OF POUND-FORCE/FT^3 OR kN/M^3	The total weight of solid particles per total volume.
VITRIC TUFF	An indurated deposit of volcanic ash composed mainly glassy fragments blown out during a volcanic eruption.

WATER CONTENT	The ratio of the mass of water contained in the pore spaces of soil or rock material, to the solid mass of particles in that material, expressed as a percentage (ASTM D 653-97, Standard Terminology Relating to Soil, Rock, and Contained Fluids). Also referred to as gravimetric water content. Note that adsorded water is not considered part of the water in the pore spaces but as water bound to the solid particles.
WELDED TUFF	A rock consisting of volcanic fragments that has been indurated by the heat retained by particles and the enveloping gases.
WHB AREA	The area delimited by the blue heptagon on Figure 1 (in Section 5), within which the Department of Energy has directed the M&O to assume, for the purposes of this report, the potential WHB will be located.

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