N190-T890071-00-M

GEO RECON INTERNATIONAL

applied geophysics

August 8, 1989
J89-451

Martin McCabe
Dames and Moore
2025 1st Avenue
Suite 500
Seattle, Wn 98121

RE: Compressional and Shear Wave Velocity Measurements
Hanford Works Vitrification Plant, 200 E Area,
Hanford, Washington, For Kaiser Engineers, Inc.

This report presents the results of the Compressional and Shear Wave velocity measurements completed in Borehole VP-8, at the proposed site of the Hanford Works Vitrification Plant located on the western side of the 200 East Area. The field measurements were completed on August 8, 1989.

Boring VP-8 was drilled and cased to a depth of 101 feet. The casing was 4 inch Schedule 40, ABS pipe; the 4 inch casing was grouted in the borehole. The ground elevation at the top of the boring was 708 feet. The casing had a 37 inch (3.08 feet) stickup above the ground surface.

The surface soil material was largely dry, loose silty sand underlain by more compacted silty sands undisturbed by the vehicle traffic during the drilling operations. The top surface layer was generally from 1 to 2 feet in depth depending on location.

The measured compressional and shear wave velocities are presented on Tables 1 and 2 respectively, which show the measured time arrivals, interval velocity computations and the averaged layer velocity calculated from the interval layer velocities. Figure 1 is the time-depth plot of the corrected downhole times, from which the layer depths were measured.

The compressional (P) wave energy was a vertical hammer blow on an aluminum plate, offset 7 feet from the boring. The zero time of the hammer blow was determined from the physical hammer contact on the aluminum plate, by circuit closure to the trigger device in the seismograph. The receiver was a piezo-electric crystal transducer placed in the borehole casing,

which was filled with water. The measurements were made at 5 foot intervals, measured from the top of the casing.

The shear (S) wave energy source was a horizontal hammer blow on the end of a 6x6 inch plank, offset 10 feet from the borehole. This plank was buried approximately 1 foot to avoid the loose surficial soils found on the compressional wave recordings. This shallow layer is the disturbed ground from drilling activity. The plank was placed tangent to a 10 foot circle through the borehole and weighted by placing the front wheels of a vehicle on it. The zero time of the hammer blow was determined by impact to a piezo-electric crystal taped to the hammer. The generated S wave energy was detected by two transducers, separated by 10 feet, placed in the borehole. Each transducer contained 4 horizontal geophones placed on axis of 45 degrees. The measurements were made at 5 foot intervals, measured from the top of the casing.

Two recordings were made for each 5 foot shear wave measurement interval. The two separate recordings were made with reversed (polarized) energy inputs utilizing the two ends of the 6x6 inch plank (blow L(eft) and blow R(ight). The arrival of the shear wave energy was determined by comparing the times and particle motion directions of the energy arrivals from the two recordings. The particle motion of the shear wave energy is polarized, and is dependent on the direction of the energy input. Thus on blow 1, the particle direction of the motion should be reversed from that produced by blow 2. The polarization of the energy, the corresponding wave form and time arrivals recorded, allows the interpreter to separate P wave arrivals, P to S conversions, tube wave arrivals and other energy arrivals (eg. those of other boundary waves) from the generated shear wave arrival.

The compressional and shear wave velocities with the corresponding, calculated Poisson's ratios are shown below:

Depth	P velocity ft/sec	S velocity ft/sec	Poisson's Ratio
0 to 8 feet	2720	519	0.481
8 to 28.5	3834	1057	0.459
28.5 to 50	5331	1471	0.459
50 to 79	6162	1627	0.463
79 to 100.9	6626	1974	0.451

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519	0.481
1057	0.459
1471	0.459
1627	0.463
1974	0.451

LABORATORY TESTING PROGRAM

A laboratory testing program was con
characteristics of soils encountered in
consisted of index property tests such as
Specific tests to determine strength, defo
also conducted and are described below.
included in the boring logs adjacent to th
presented in the summary tables in Plate

Particle size (sieve) analysis tests wer
the soils and to provide a basis for e
deformability, collapse potential and
permeability. Curves describing the pa
Plates B-4 through B-13.

Strength parameters for foundation s
and triaxial compression tests performec
conducted on samples from shallow dep
natural slopes as well as for the analysis
from Elevation 700 to 650 were tested in
estimates for the analysis of foundation s
drained conditions at the natural moistu
reload cycles to better define the true el
are presented on Plates B-16 to B-20.

Compaction characteristics of soil fro
modified Proctor compaction tests in ac
obtained to provide a basis for compact
compacted backfill, and estimates of ea
14 and B-15.

Collapse tests were performed on
recompacted samples of silt and fine sar
standard methods using a consolidomete
in the compaction mold. All samples we
The test results are summarized on Plat

The final section of this appendix in

The formula for Poisson's ratio is:

$$\nu = \frac{(Vp/Vs)^2 - 2}{2((Vp/Vs)^2 - 1)}$$

Where : ν = Poisson's Ratio

Vp = Compressional Wave Velocity

Vs = Shear Wave Velocity

The arrival times were picked initially from the first peak or trough of the energy arrivals. This was done to avoid errors that may be generated by the low amplitude rise time of the particle motion. The time of the first arrival was then determined using the corresponding frequency of the energy wave train to step back to the time of the first energy arrival.

The borehole casing stickup was subtracted from the measured downhole depths to arrive at depths below the ground surface. The arrival times were then converted to downhole times, rather than plotting the arrival time vs the slant distance (a result of the source-borehole offset).

The formula for conversion of the record time to the downhole time is:

DH Time = Record Time x (Cos(Arctan (Offset/detector depth)))

where the DH Time is the vertical travel time down the borehole.

The DH times were then summarized and 5 foot interval velocities computed. The DH times were also plotted on a time-depth plot to determine layer depths, as shown on Figure 1. An average velocity was computed through the interval velocities, generally not utilizing the top velocity.

The recording equipment used in the survey was an ES-1225, a signal enhancement recording seismograph. The measured record lengths may be adjusted from 25, 50, 100, 200, 500 and 1000 milliseconds sweep length with 1024 samples per record length. P wave recordings were done with a 25 millisecond sweep, and the S wave recordings were done with a 100 millisecond sweep. A sweep delay was applied with increasing depth to maintain the energy arrivals in the approximate center of the record.

Copies of the Compressional and Shear wave recordings and QA records (showing sweep calibration, repeatability of switch closures, etc) will be sent under separate cover.

FOR GEO-RECON INTERNATIONAL

John M. Musser Jr.
Principal Geophysicist

Reviewed by:

Clyde Ringstad
Principal Geophysicist

Downhole Compressional and Shear Wave Velocity Measurements
Borehole VP-8, HWVP, 200 East - Hanford, Washington - August, 1989

Compressional Wave Data - Interval Velocity Computations

Depth below Top of Casing	Depth of Data	P Wave Arrival Time	Corrected DH Time	Interval Time	Interval Velocity	Average Velocity
5	1.9	6.350	2.725	2.725	697	Direct Wave
10	6.9	6.500	4.563	1.838	2720	2720
	Velocity Break at 8 feet					
15	11.9	7.250	6.249	1.686	2966	
20	16.9	8.175	7.553	1.304	3835	3834
25	21.9	9.300	8.858	1.306	3829	
30	26.9	10.500	10.162	1.303	3837	
	Velocity Break at 28.5 feet					
35	31.9	11.700	11.428	1.267	3948	
40	36.9	12.600	12.379	0.951	5257	5331
45	41.9	13.500	13.315	0.936	5341	
50	46.9	14.400	14.242	0.927	5395	
	Velocity Break at 50 feet					
55	51.9	15.200	15.064	0.821	6087	
60	56.9	16.000	15.880	0.817	6122	
65	61.9	16.800	16.694	0.813	6148	6162
70	66.9	17.600	17.504	0.811	6166	
75	71.9	18.400	18.313	0.809	6181	
80	76.9	19.200	19.121	0.808	6192	
	Velocity Break at 79 feet					
85	81.9	19.950	19.878	0.757	6609	
90	86.9	20.700	20.633	0.756	6617	
95	91.9	21.450	21.388	0.755	6624	6626
100	96.9	22.200	22.142	0.754	6629	
104	100.9	22.800	22.745	0.603	6633	

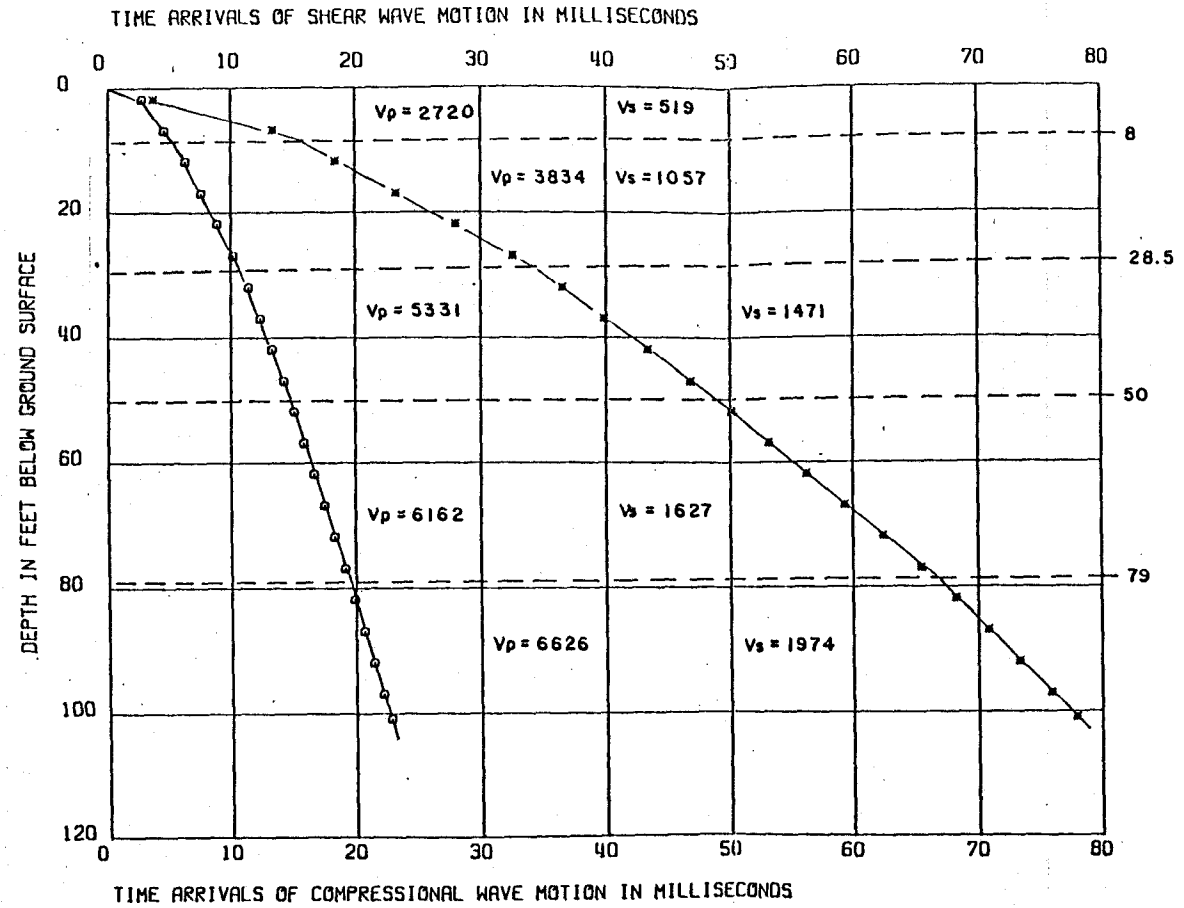
Casing stickup : 3.08 feet (37 Inches) Ground Elevation: 708 feet
Coordinate Location: N 42,130 E 55,960 Plant Datum
Depths in feet - Time in milliseconds - Velocity in ft/sec
Offset at 5 feet depth is 4 feet - remainder at 7 feet.

Downhole Compressional and Shear Wave Velocity Measurements
Borehole VP-8, HWVP, 200 East - Hanford, Washington - August, 1989

Shear Wave Data - Interval Velocity Computations

Depth below Top of Casing	Depth of Data	S Wave Arrival Time	Corrected DH Time	Interval Time	Interval Velocity	Average Velocity
5	1.9	19.50	3.640	3.640	522	519
10	6.9	23.50	13.346	9.706	515	
	Velocity Break at 8 feet					
15	11.9	24.00	18.374	5.028	995	
20	16.9	27.00	23.237	4.863	1028	1057
25	21.9	30.75	27.972	4.735	1056	
30	26.9	34.75	32.572	4.600	1087	
	Velocity Break at 28.5 feet					
35	31.9	38.25	36.499	3.927	1273	
40	36.9	41.25	39.814	3.315	1508	1471
45	41.9	44.50	43.284	3.470	1441	
50	46.9	47.75	46.700	3.416	1464	
	Velocity Break at 50 feet					
55	51.9	51.00	50.079	3.379	1480	
60	56.9	54.00	53.185	3.106	1610	
65	61.9	57.00	56.270	3.086	1620	1627
70	66.9	60.00	59.341	3.070	1629	
75	71.9	63.00	62.399	3.059	1635	
80	76.9	66.00	65.449	3.050	1640	
	Velocity Break at 79 feet					
85	81.9	68.75	68.243	2.794	1789	
90	86.9	71.25	70.783	2.540	1969	
95	91.9	73.75	73.317	2.534	1973	1974
100	96.9	76.25	75.847	2.530	1976	
104	100.9	78.25	77.869	2.021	1979	

Casing stickup : 3.08 feet (37 inches). Ground Elevation: 708 feet
Coordinate Location: N 42,130 E 55,960 Plant Datum



LEGEND

- COMPRESSIONAL WAVE ARRIVAL
- SHEAR WAVE ARRIVAL

BOREHOLE ELEVATION: 708

SCALE:

SCALE AS SHOWN ON GRAPH

DAMES AND MOORE
HWVP - 200 E
HANFORD WASHINGTON

DOWNHOLE GEOPHYSICAL SURVEY

COMPRESSIONAL AND SHEAR WAVE PLOTS

BORING VP-8

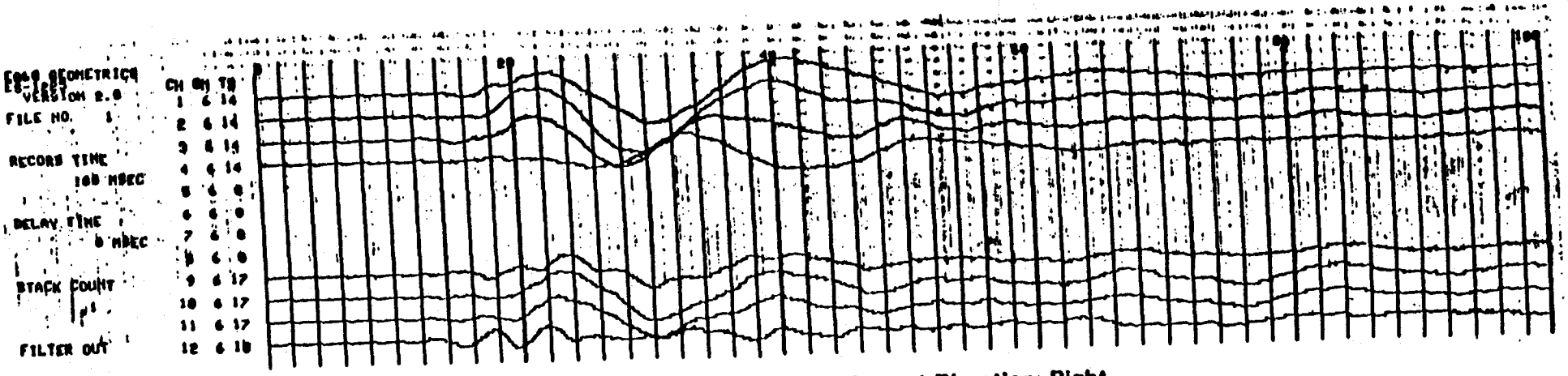
AUGUST 1989 J89-451

GEO-RECON INTERNATIONAL FIG.1

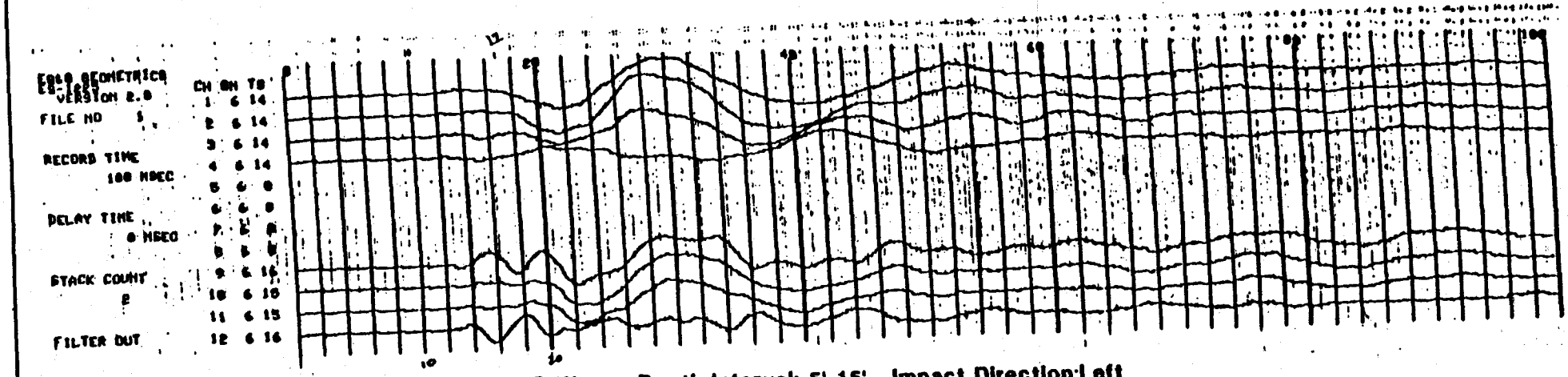
ORIGINAL FIELD DATA

Job No 805-396-016

Downhole Seismic Test Data



S-Wave Depth Interval: 5'-15' Impact Direction: Right



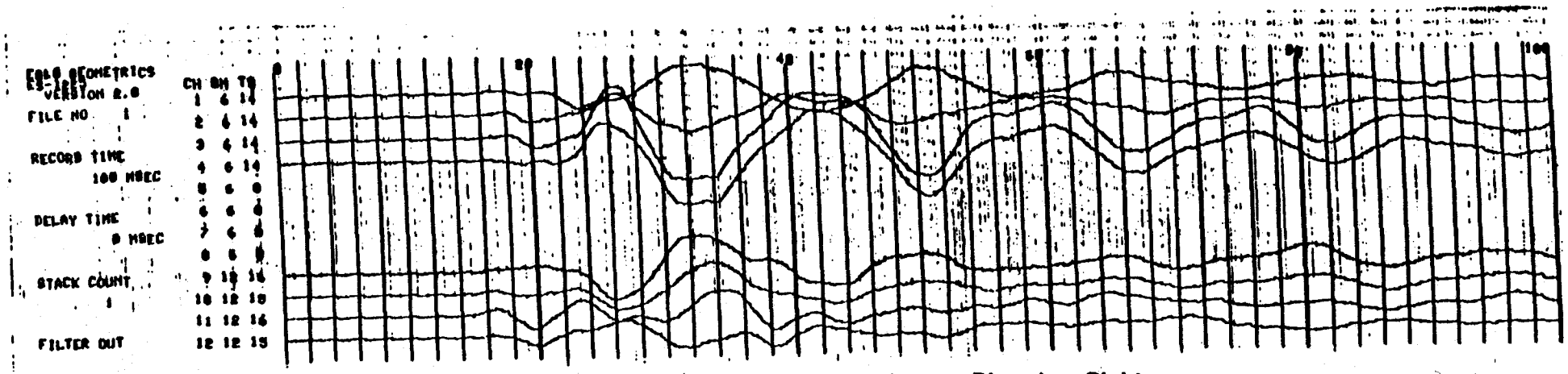
S-Wave Depth Interval: 5'-15' Impact Direction:Left

Hanford Waste
Vitrification Plant
Dames & Moore

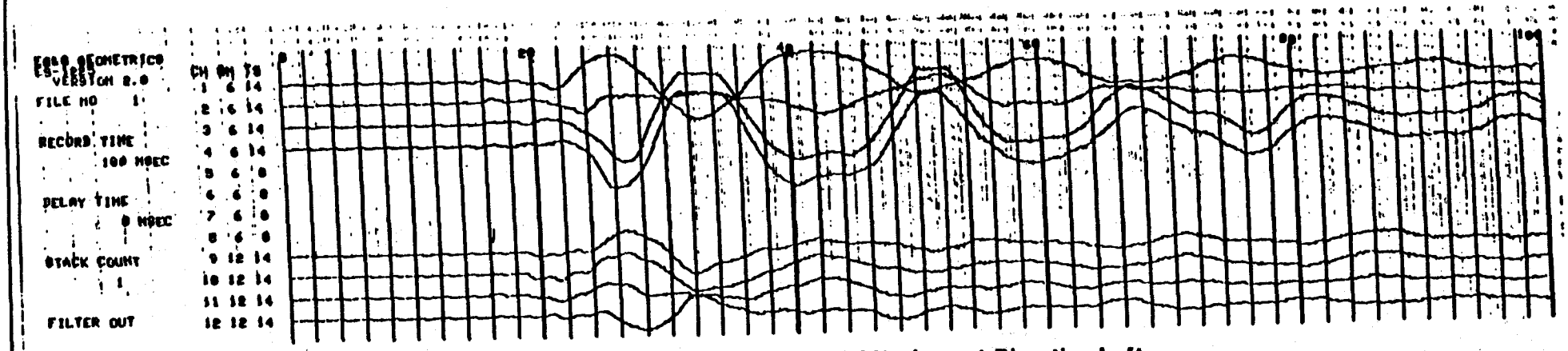
Job N 0805-398-016

122854

Downhole Seismic Test Data



S-Wave Depth Interval: 10'-20' Impact Direction: Right



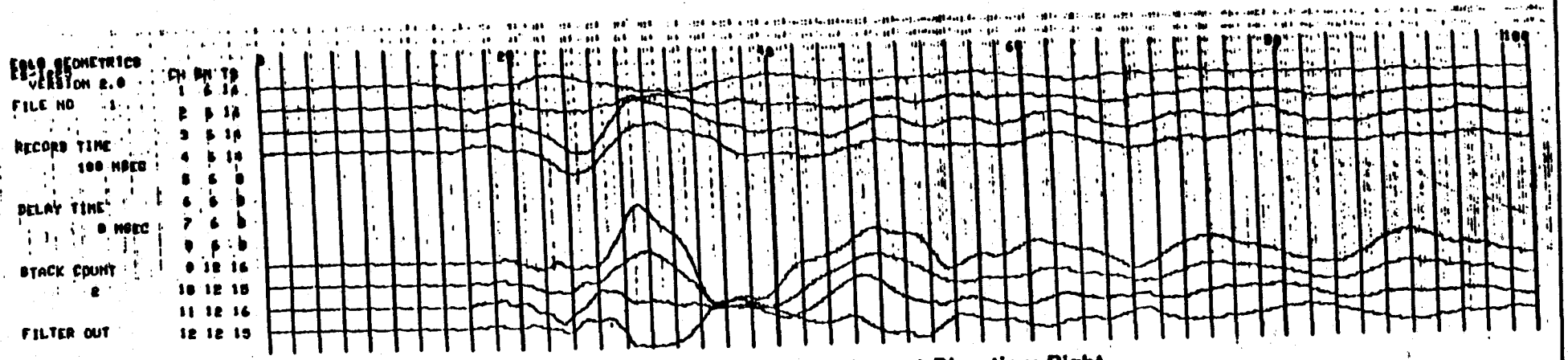
S-Wave Depth Interval: 10'-20' Impact Direction:Left

Hanford Waste Vitrification Plant
Dames & Moore

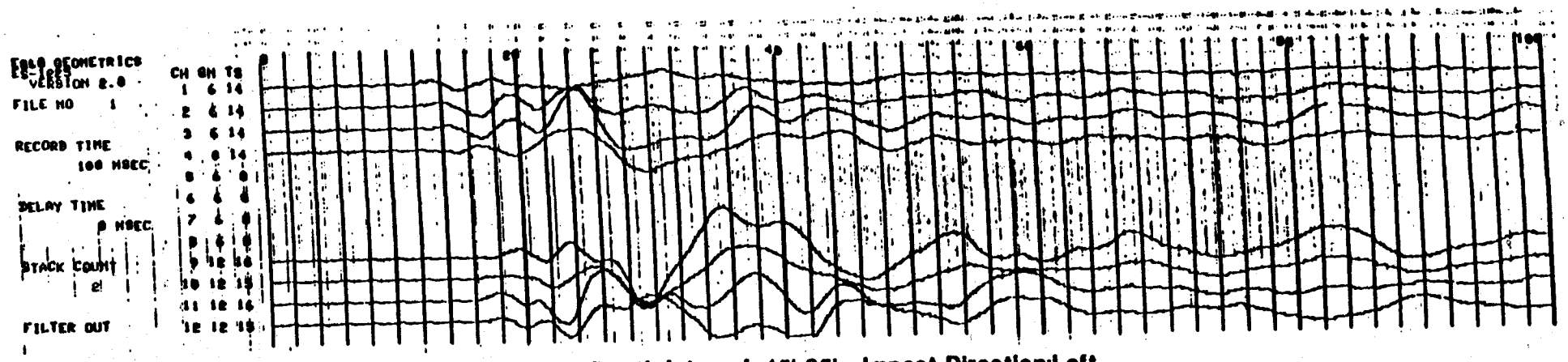
Job No 805-398-016

122954

Downhole Seismic Test Data



S-Wave Depth Interval: 15'-25' Impact Direction: Right



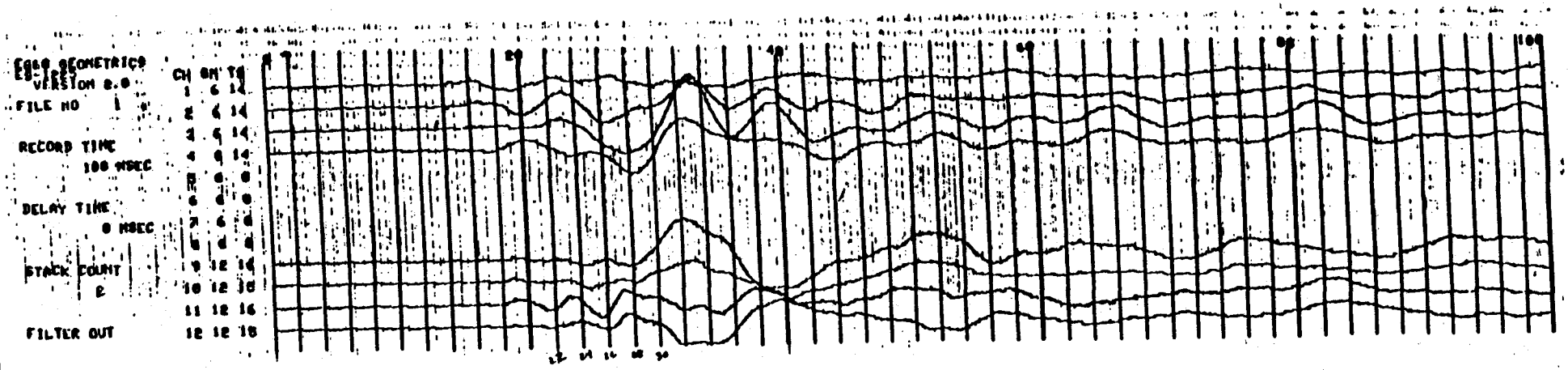
S-Wave Depth Interval: 15'-25' Impact Direction:Left

Hanford Waste Vitrification Plant
Dames & Moore

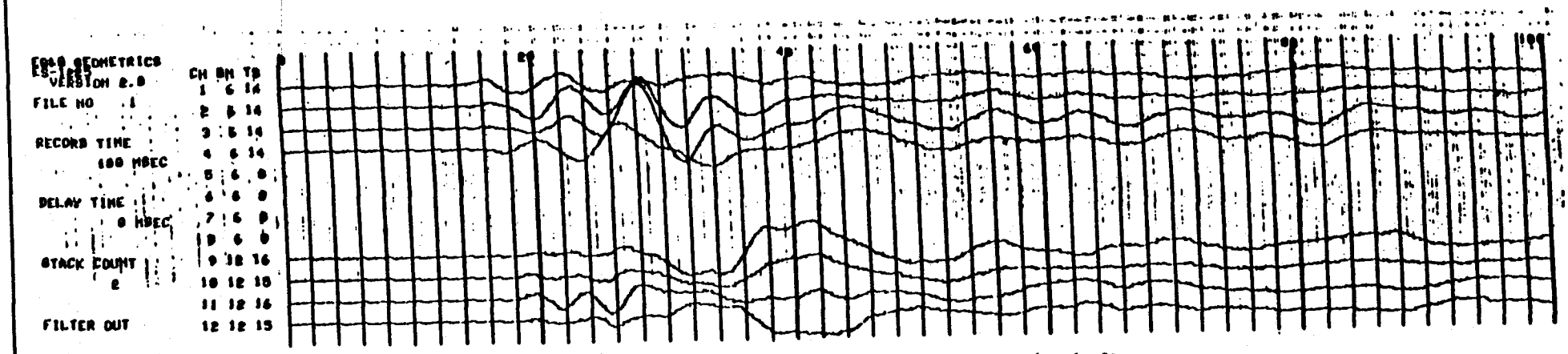
Job No. 10605-398-016

122954

Downhole Seismic Test Data



S-Wave Depth Interval : 20'-30' Impact Direction: Right



S-Wave Depth Interval: 20'-30' Impact Direction:Left

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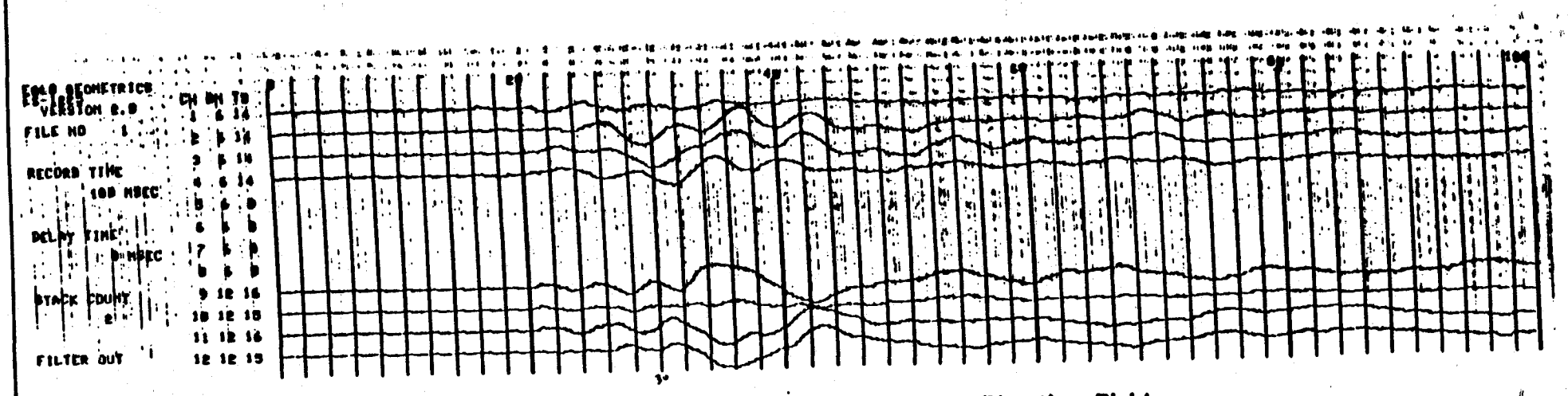
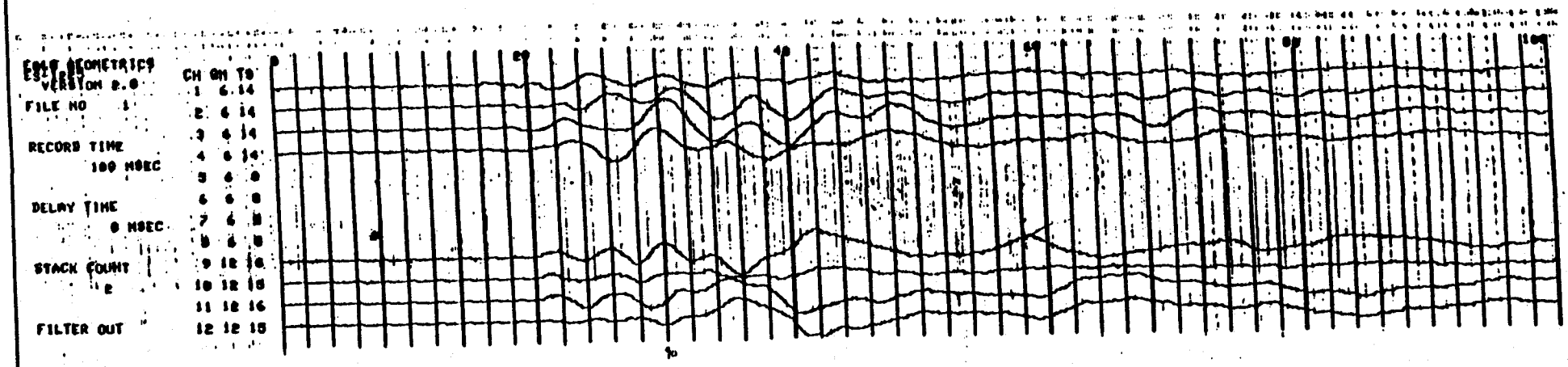
Job No. 805-398-016

122954

Downhole Seismic Test Data



S-Wave Depth Interval: 25'-35' Impact Direction: Right



S-Wave Depth Interval: 25'-35' Impact Direction:Left

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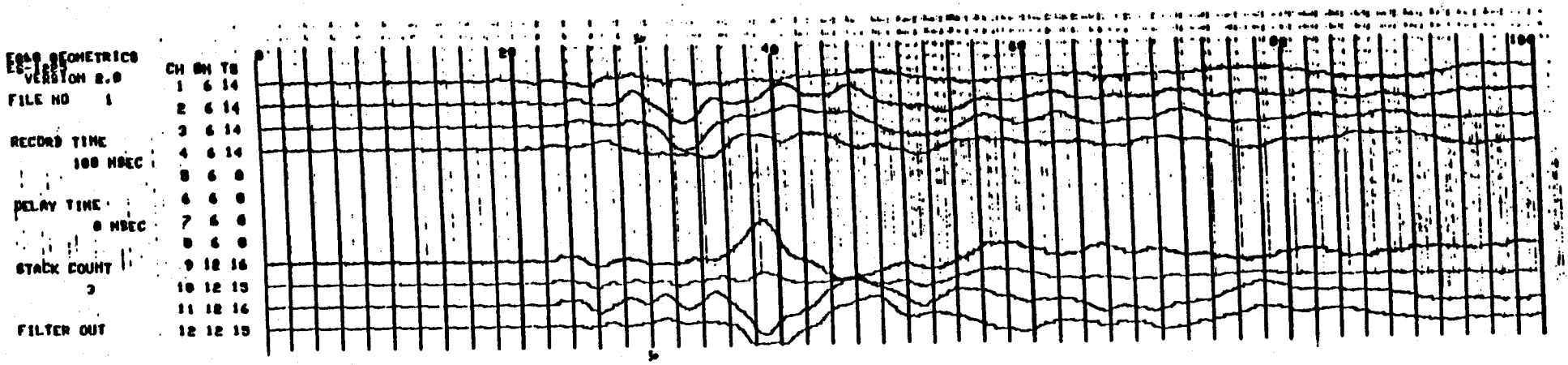
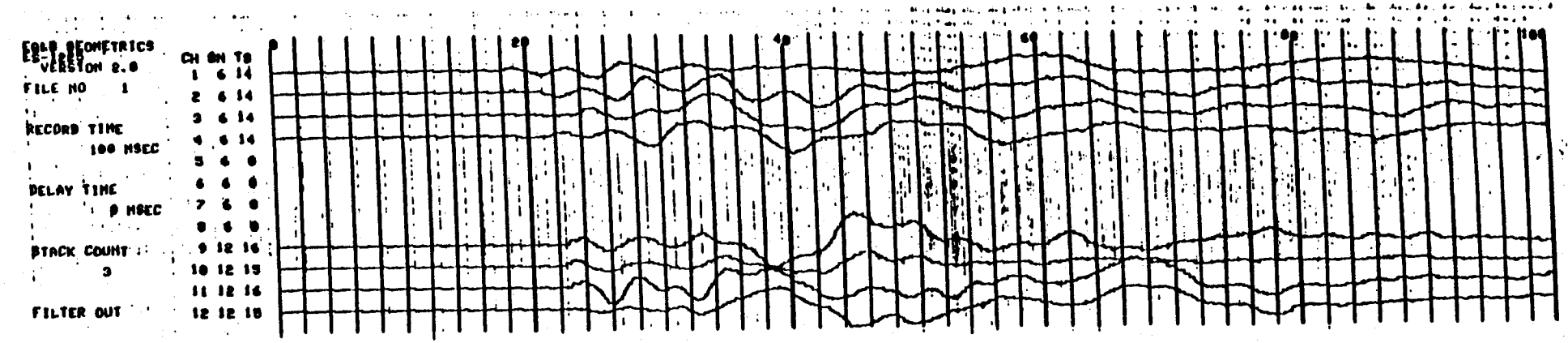
Downhole Seismic Test Data



S-Wave Depth Interval: 30'-40' Impact Direction: Right



S-Wave Depth Interval: 30'-40' Impact Direction:Left

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Job No. 305-398-016

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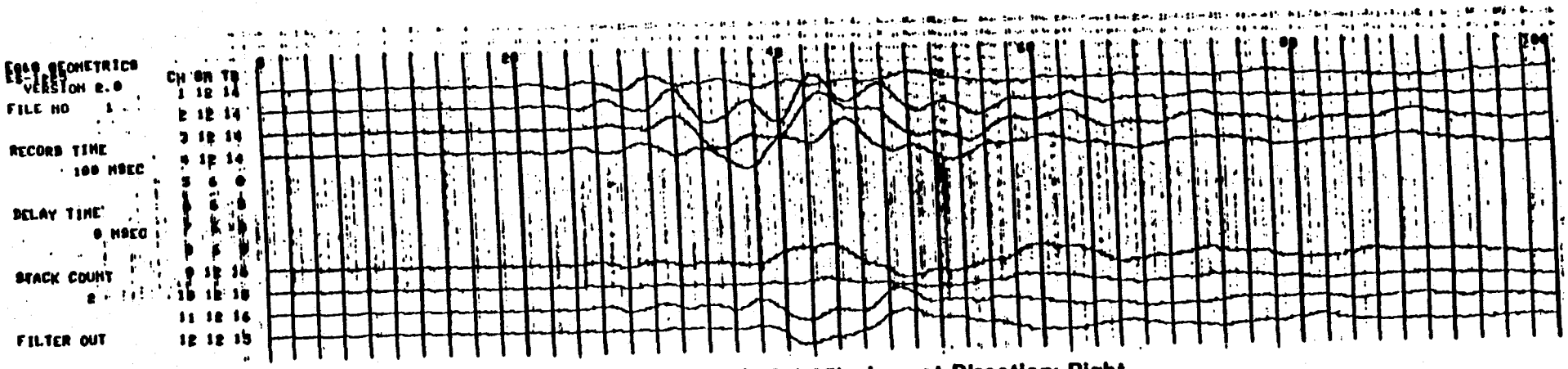
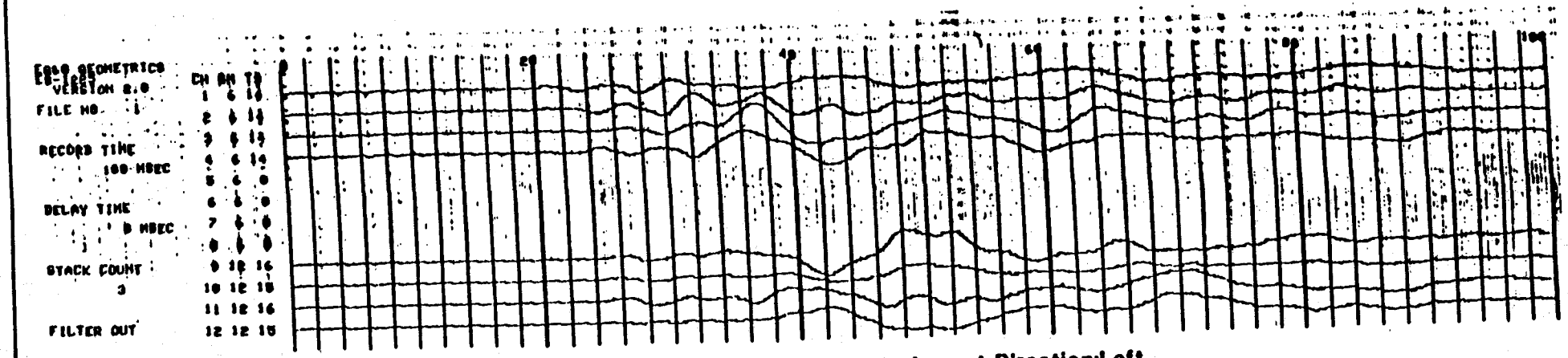
Downhole Seismic Test Data



S-Wave Depth Interval: 35'-45' Impact Direction: Right



S-Wave Depth Interval: 35'-45' Impact Direction:Left

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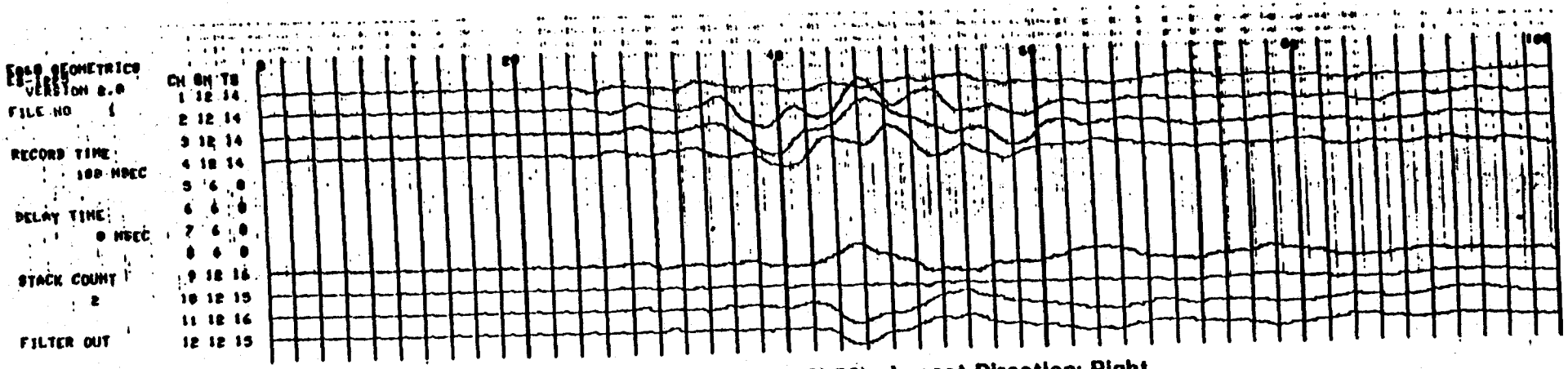
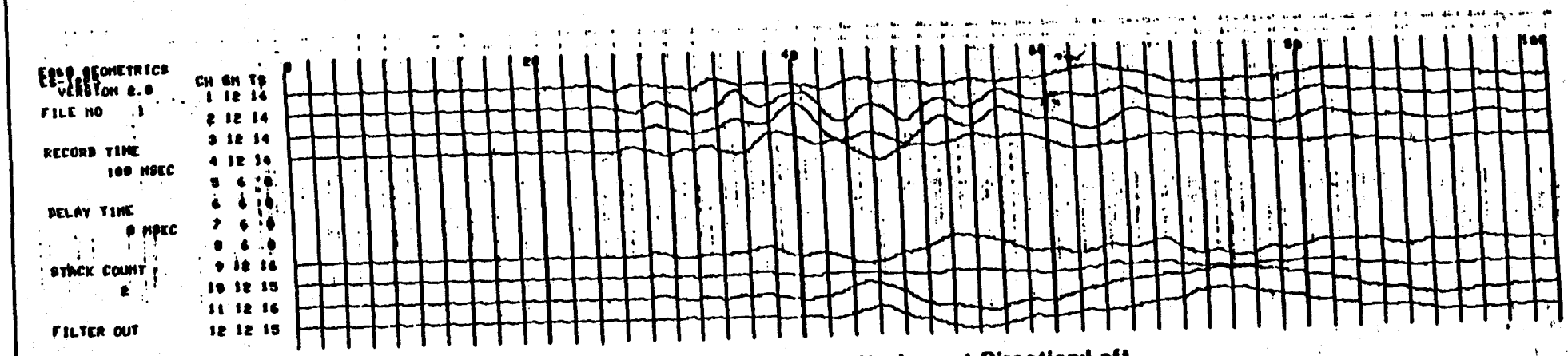
Downhole Seismic Test Data



S-Wave Depth Interval: 40'-50' Impact Direction: Right



S-Wave Depth Interval: 40'-50' Impact Direction:Left

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Job No. 0805-398-016

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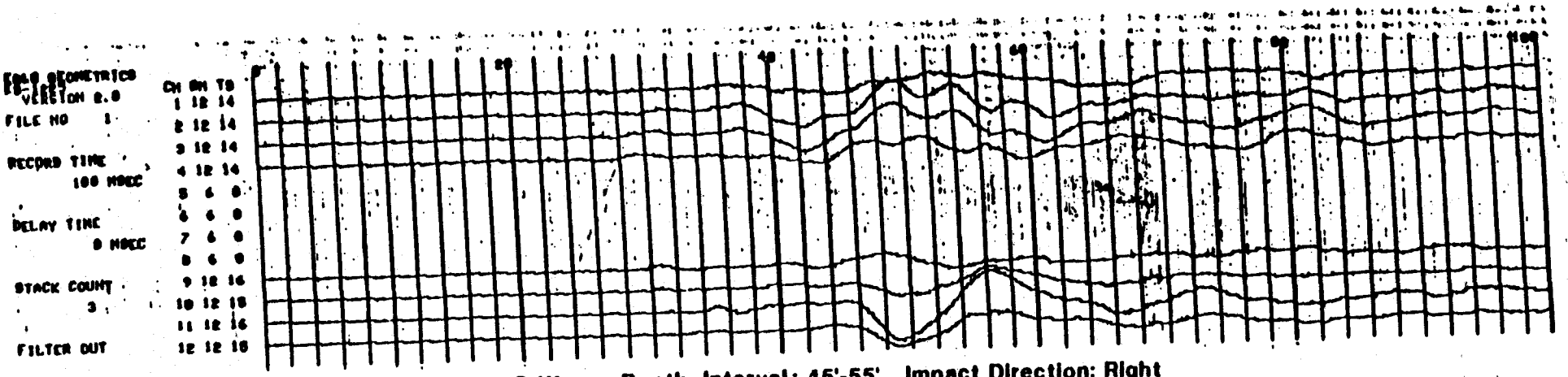
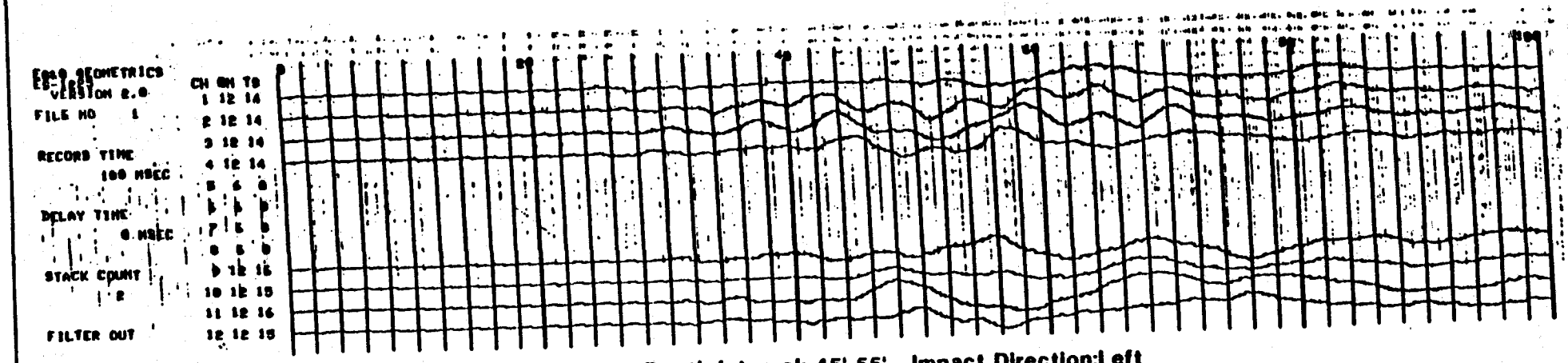
Downhole Seismic Test Data



S-Wave Depth Interval: 45'-55' Impact Direction: Right



S-Wave Depth Interval: 45'-55' Impact Direction:Left

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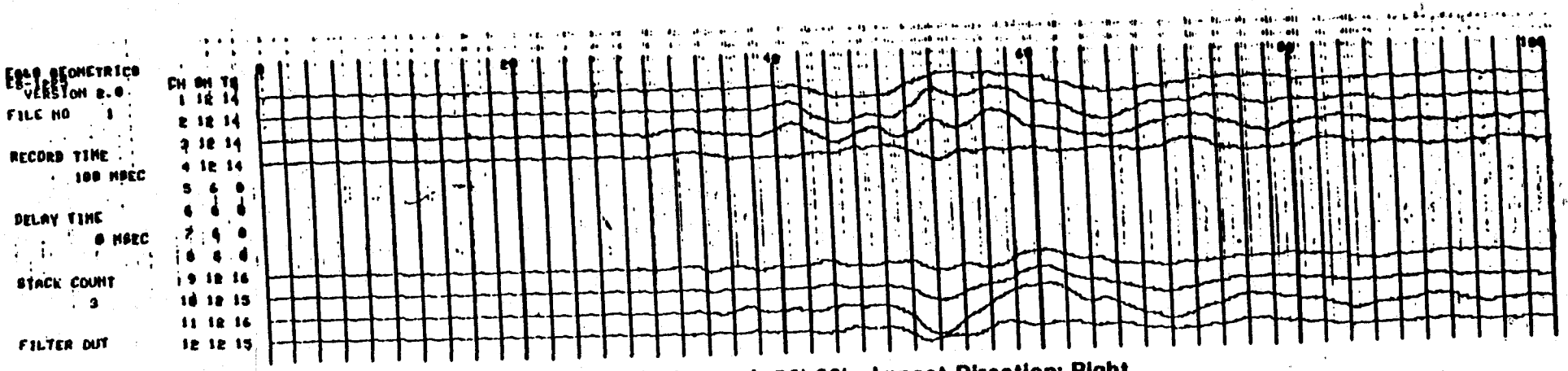
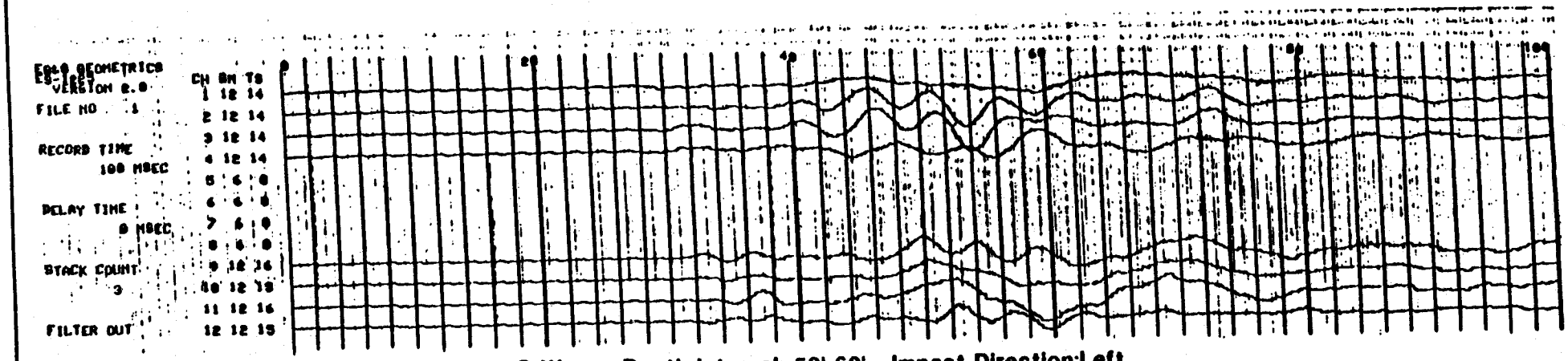


S-Wave Depth Interval 50'-60' Impact Direction: Right



S-Wave Depth Interval: 50'-60' Impact Direction:Left

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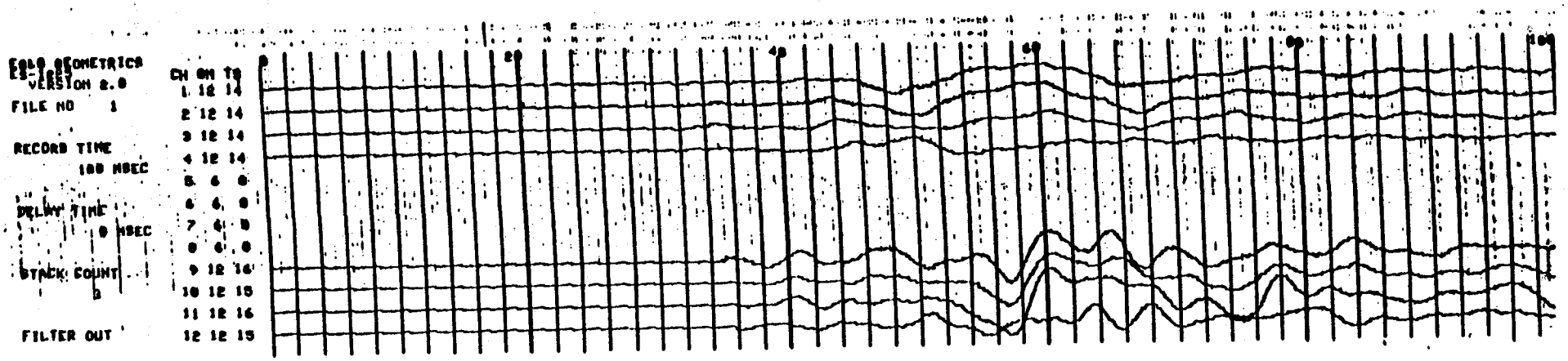
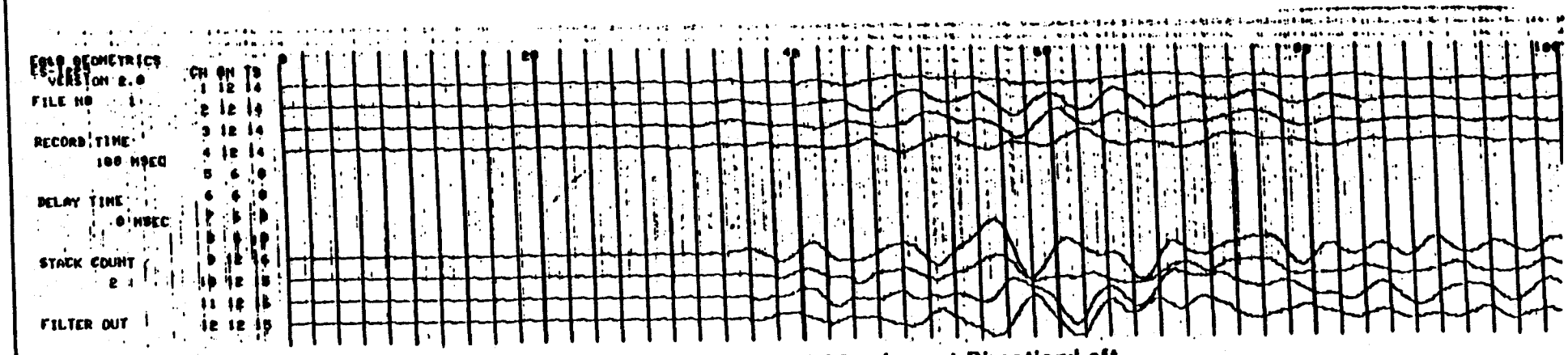
Downhole Seismic Test Data



S-Wave Depth Interval: 55'-65' Impact Direction: Right



S-Wave Depth Interval: 55'-65 Impact Direction:Left

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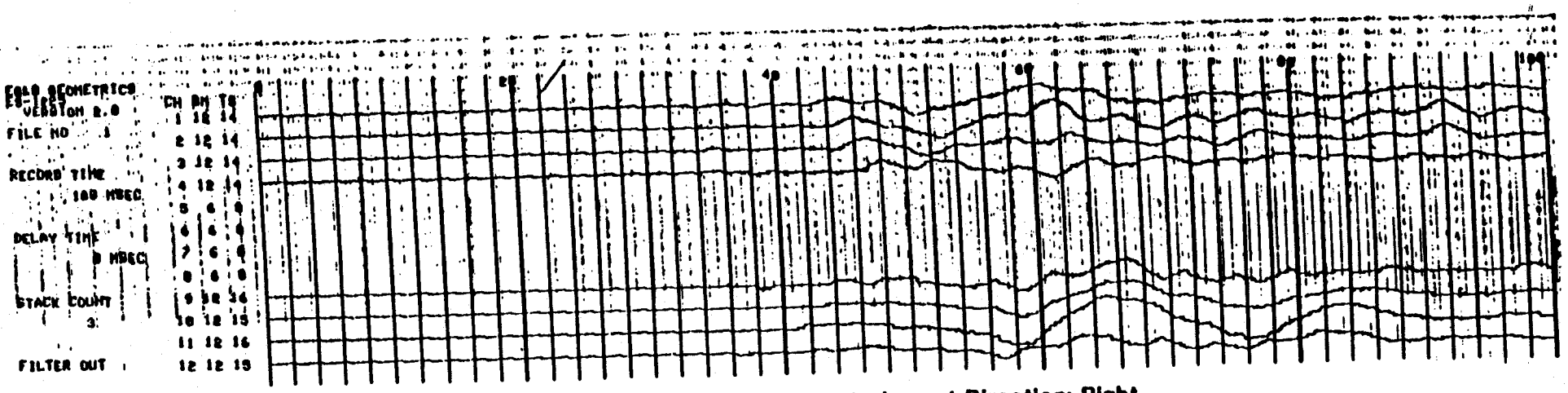
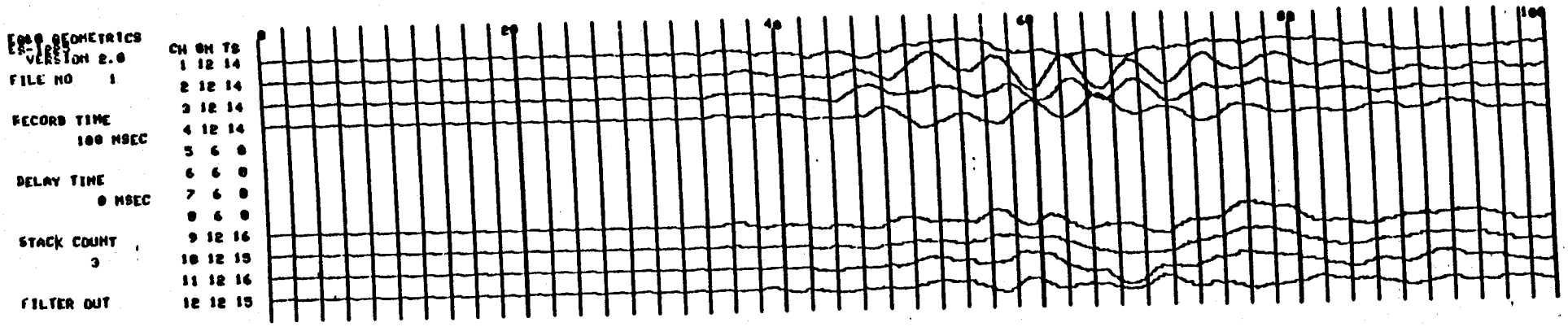
Downhole Seismic Test Data



S-Wave Depth Interval: 60'-70' Impact Direction: Right



S-Wave Depth Interval: 60'-70' Impact Direction:Left

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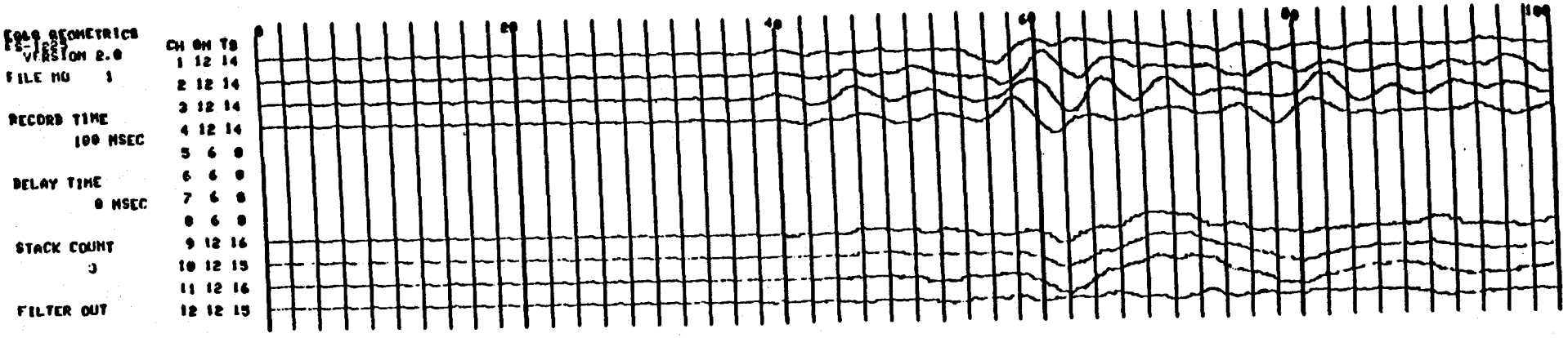
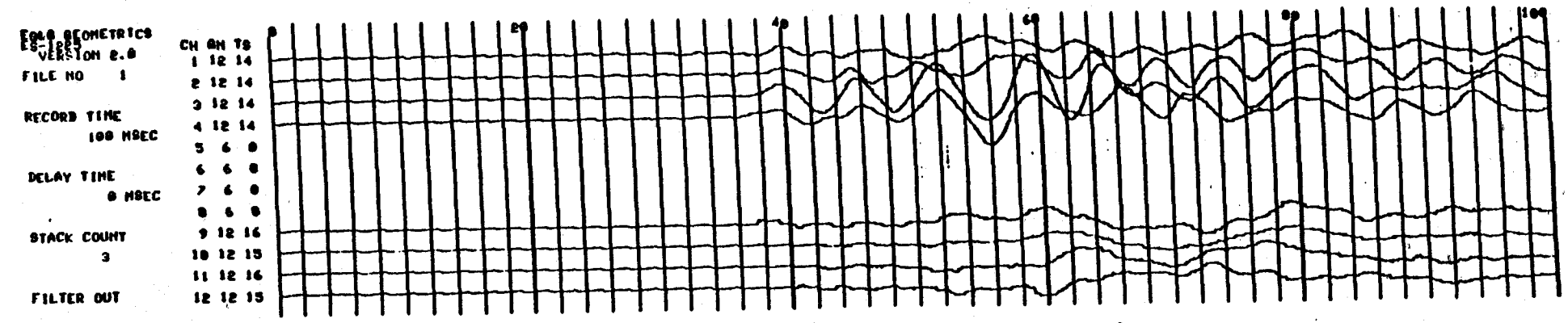
Downhole Seismic Test Data



S-Wave Depth Interval: 65'-75' Impact Direction: Right



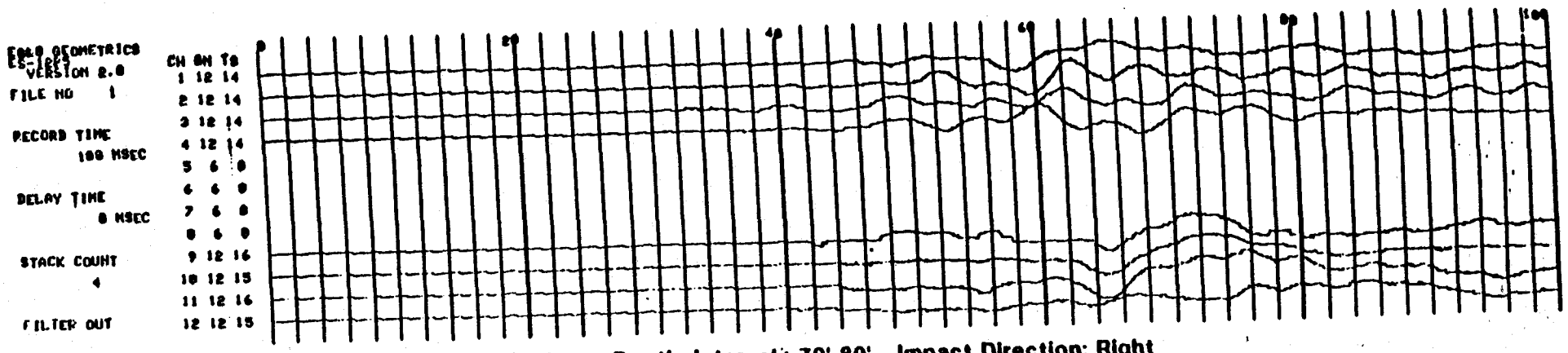
S-Wave Depth Interval: 65'-75' Impact Direction:Left

Hanford Waste
Vitrification Plant
Dames & Moore

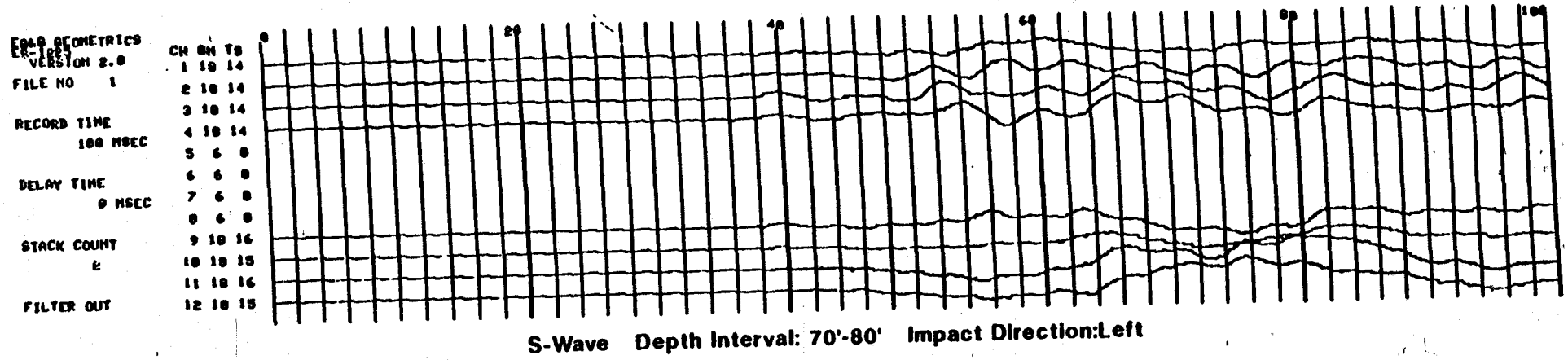
Job No. 0805-398-016

122954

Downhole Seismic Test Data



S-Wave Depth Interval: 70'-80' Impact Direction: Right

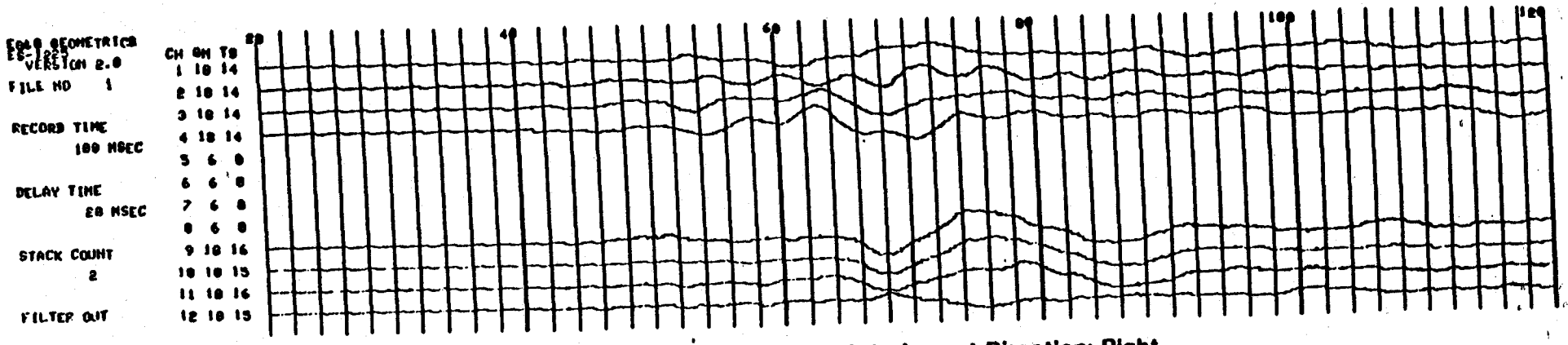


S-Wave Depth Interval: 70'-80' Impact Direction:Left

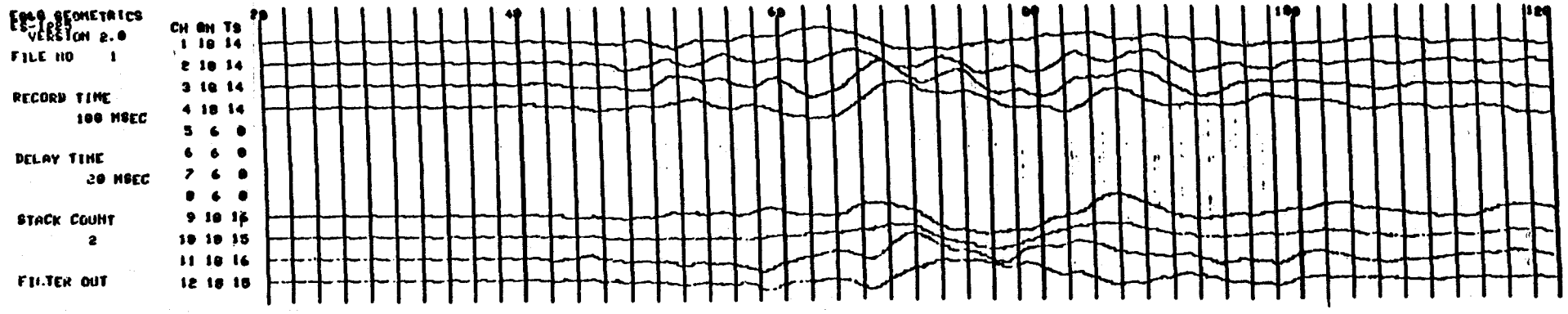
Hanford Waste
Vitrification Plant
Dames & Moore

Job No 805-398-016

Downhole Seismic Test Data



S-Wave Depth Interval: 75'-85' Impact Direction: Right



S-Wave Depth Interval: 75'-85' Impact Direction:Left

Hanford Waste
Vitrification Plant
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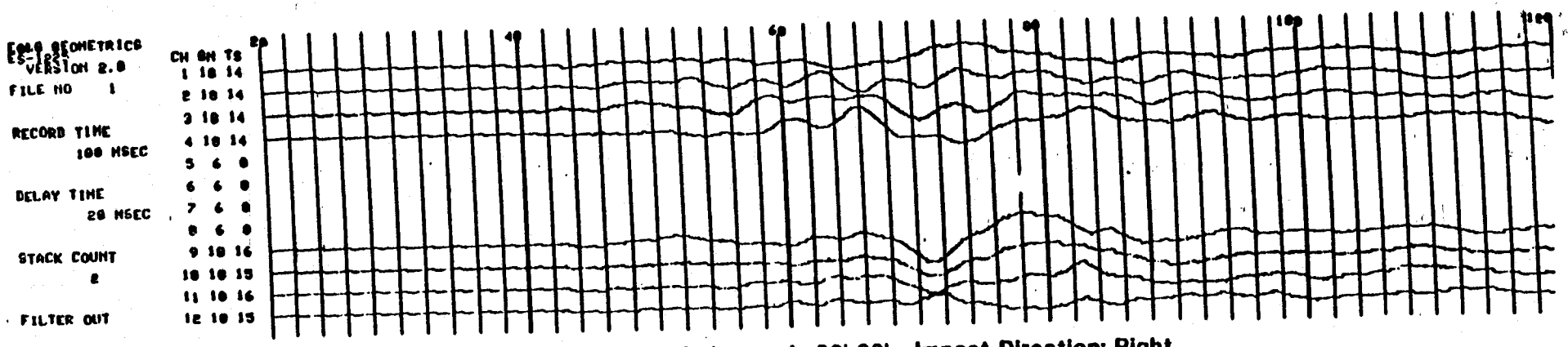
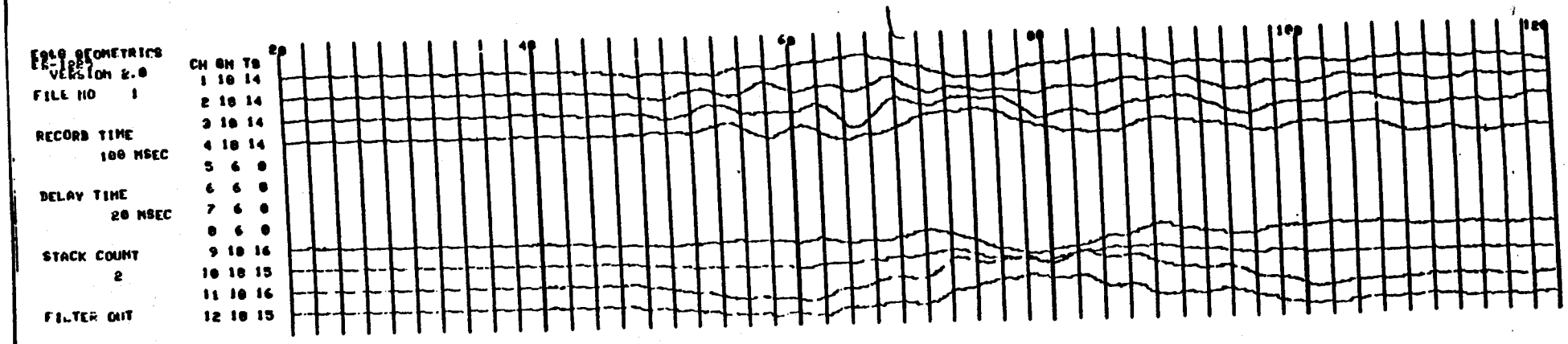
Job No. 0805-398-016

Downhole Seismic Test Data



S-Wave Depth Interval: 80'-90' Impact Direction: Right



S-Wave Depth Interval: 80'-90' Impact Direction:Left

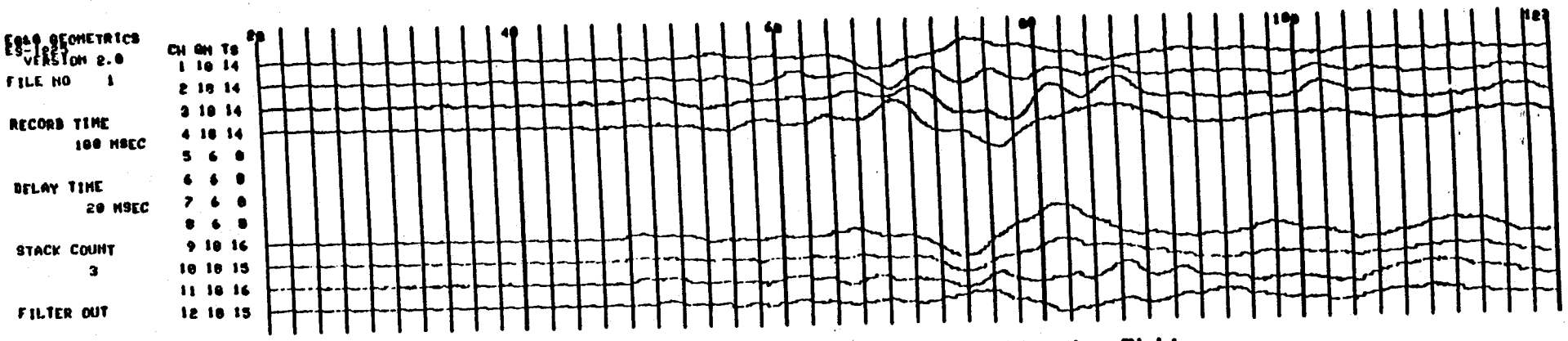
Hanford Waste
Vitrification Plant
Dames & Moore

122954

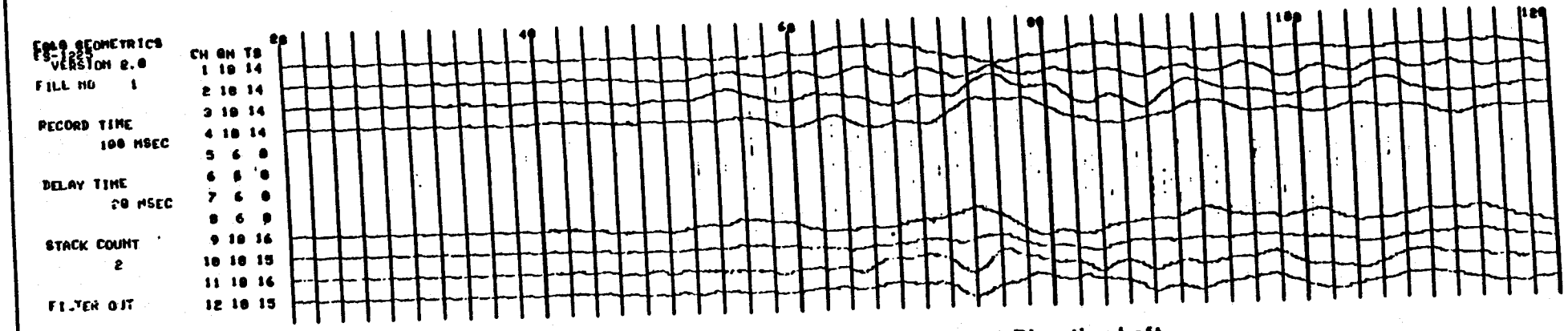
Job No. 805-398-016

122954

Downhole Seismic Test Data



S-Wave Depth Interval: 85'-95' Impact Direction: Right

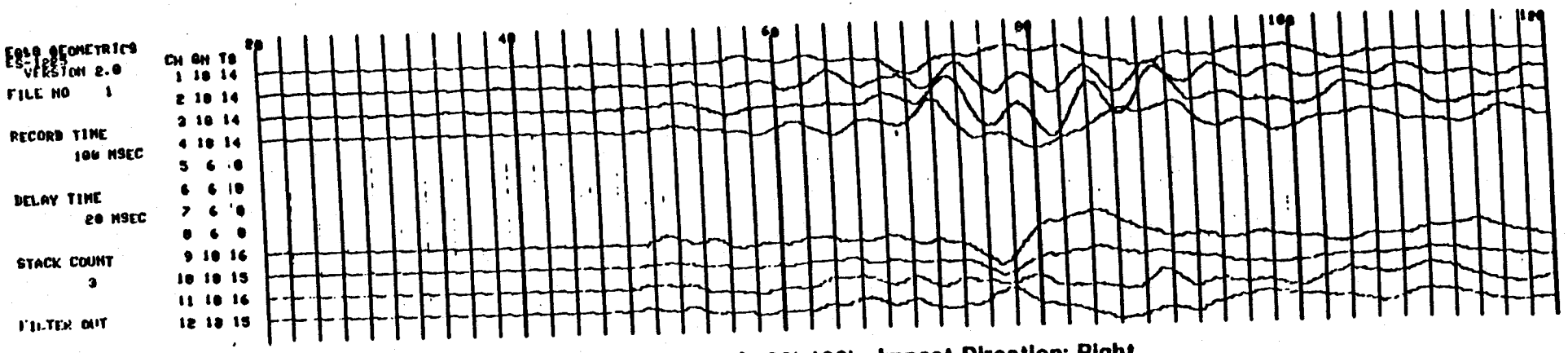


S-Wave Depth Interval: 85'-95' Impact Direction:Left

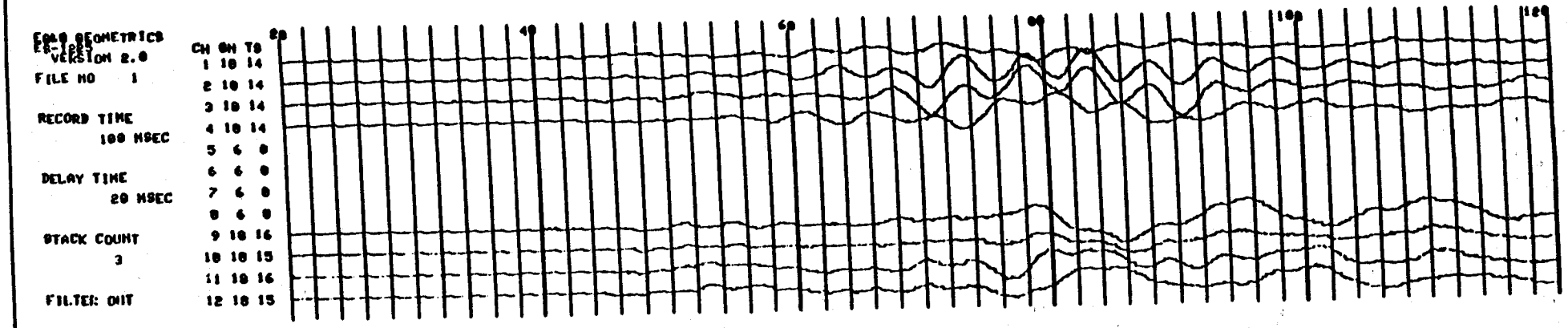
Hanford Waste Vitrification Plant
Dames & Moore

Job No 805-398-016

Downhole Seismic Test Data



S-Wave Depth Interval: 90'-100' Impact Direction: Right



S-Wave Depth Interval: 90'-100' Impact Direction:Left

Hanford Waste Vitrification Plant
Dames & Moore

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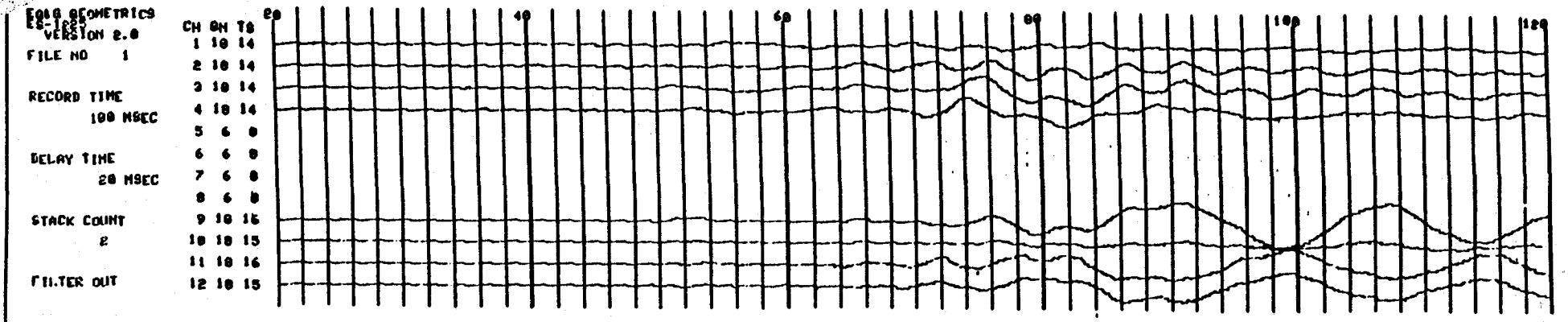
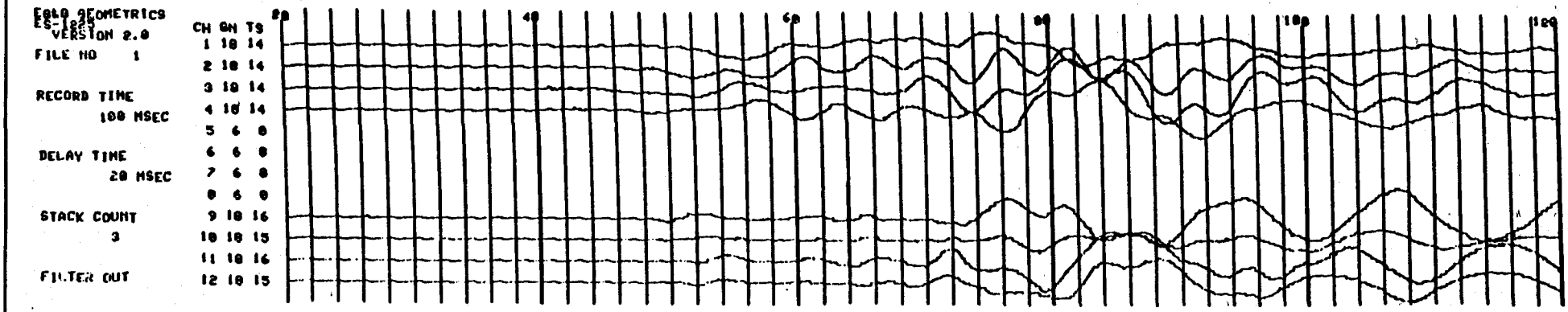
Downhole Seismic Test Data



S-Wave Depth Interval: 94'-104' Impact Direction: Right



S-Wave Depth Interval: 94'-104' Impact Direction:Left

Hanford Waste
Vitrification Plant
Dames & Moore

132954

APPENDIX B

LABORATORY TESTING PROGRAM

A laboratory testing program was conducted to establish pertinent physical and engineering characteristics of soils encountered in the exploration phase of the project. The program consisted of index property tests such as moisture content, density, particle size analysis tests. Specific tests to determine strength, deformability, compaction and collapse characteristics were also conducted and are described below. Moisture content and natural density test results are included in the boring logs adjacent to the appropriate sample location. All other test results are presented in the summary tables in Plates B-1 through B-3.

Particle size (sieve) analysis tests were conducted on samples in order to assist in classifying the soils and to provide a basis for estimating engineering performance such as strength, deformability, collapse potential and erodibility. This data is also useful for estimating permeability. Curves describing the particle size gradation of tested samples are presented in Plates B-4 through B-13.

Strength parameters for foundation soils encountered were obtained using both direct shear and triaxial compression tests performed on slightly disturbed samples. Direct shear tests were conducted on samples from shallow depths to provide data for the analysis of the stability of natural slopes as well as for the analysis of foundation bearing capacity. Samples in the range from Elevation 700 to 650 were tested in triaxial compression primarily to provide deformability estimates for the analysis of foundation settlements. The tests were conducted under consolidated drained conditions at the natural moisture content of the sample, and included several unload-reload cycles to better define the true elastic modulus. Stress versus strain curves for these tests are presented on Plates B-16 to B-20.

Compaction characteristics of soil from Stratum 1 and Stratum 3 were examined by conducting modified Proctor compaction tests in accordance with ASTM D-1557. This information was obtained to provide a basis for compacted fill recommendations, estimates of loads applied by compacted backfill, and estimates of earth pressures. The tests results are plotted on Plates B-14 and B-15.

Collapse tests were performed on one slightly to moderately disturbed sample and 2 recompacted samples of silt and fine sand from Stratum 1. Two of the tests were conducted by standard methods using a consolidometer, and one test on a recompacted sample was conduced in the compaction mold. All samples were loaded to overburden stress levels prior to inundation. The test results are summarized on Plate B-21.

The final section of this appendix includes raw data sheets from selected laboratory tests.

Boring	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	% Passing #200 Sieve	DIRECT SHEAR TEST (1) Normal Stress (psf)	DIRECT SHEAR TEST (1) Peak Shear Stress (psf)	TRIAXIAL COMPRESSION TEST (2) Confining Stress (psf)	TRIAXIAL COMPRESSION TEST (2) Maximum Deviator Stress (psf)	TRIAXIAL COMPRESSION TEST (2) Modulus of Elasticity (ksf)	Other
VP-1	0.5	SM									Compaction (Plate B-14)
VP-2	16-18	SM/SP									"
VP-6	0-3	SM									Collapse (Plate B-21)
VP-8	0.2	SM			40.6						
	25.5	SM/SP	108	2.3	7.9	1000 2000	1110 1745				
	30.5	SM/SP	98	1.8	5.6						
	35.5	SM/SP	107	9	5.8						
	40.5	SM/SP	102	2.8	6.4			2000	8350	1870 (3)	
	45.5	SM/SP	116	5	10.1						
	45.6	ML	102	20.1	72.2						
	50.5	SM/SP	107	1.8	7.1			4000	16850	1200	
	75.5	SM/SP	106	4.1	8.1						

SM : well-graded gravelly sands, little or no fine
SP : poorly graded sands or gravelly sands, little or no fines.

Summary of Laboratory Tests

Hanford Waste Vitrification Plant

DAMES & MOORE

11/15/89
10805-398-016

Plate: B-1

Boring	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	% Passing #200 Sieve	DIRECT SHEAR TEST (1)		TRIAXIAL COMPRESSION TEST (2)			
						Normal Stress (psf)	Peak Shear Stress (psf)	Confining Stress (psf)	Maximum Deviator Stress (psf)	Modulus of Elasticity (ksf)	Other
VP-9	5.5	SM	95	5.2							Collapse (Plate B-21)
VP-10	5 10	SM SM/GM	94	3	18.6 6.2			1000	4350	360	
VP-11	6	SM	101	2.2	23.5			2000	7490	1080 (3)	
VP-14	15.5 30.5	SM/SP SM/SP	115 117	10 10.5		500 1000 2000 1000 2000	610 1220 2290 1160 2280				
VP-17	3.5	SM						1500	7200	430	

Summary of Laboratory Tests

Hanford Waste Vitrification Plant

DAMES & MOORE

Notes: 1) Moisture was added to samples tested in direct shear prior to transfering sample to device, in order to maintain intact condition
2) consolidated drained conditions
3) measured using reload cycle (all others measured as initial tangent modulus)

11/15/89
10805-398-016

Plate: B-2

122954

Boring No.	Sample Depth (ft)	Soil Type	Resistivity (ohm-cm)	Moisture (%)	Sulfides (ppm)	Sulfates (ppm)	Chlorides (ppm)	pH		Redox Potential (mv)
								field	lab	
VP-2	4.5	SM	129 000	3.4	negative	8.2	1.4	8.5	7.9	247.2
VP-3	5.0	SM	55 900	2.6	negative	39.1	66.5	9.3		213.6
VP-9	30.0	SM/SP	132 000	2.3	negative	196	12.1	8.6	8.3	221.8
VP-11	10.0	SM/GM	2.6	2.6	negative	280	44.5	8.3		213.1
VP-14	10.0	SM/GM	748 000	1.4	negative	12.4	9.2	9.2		205.3

Soil Corrosivity Test Results
Hanford Waste Vitrification Plant

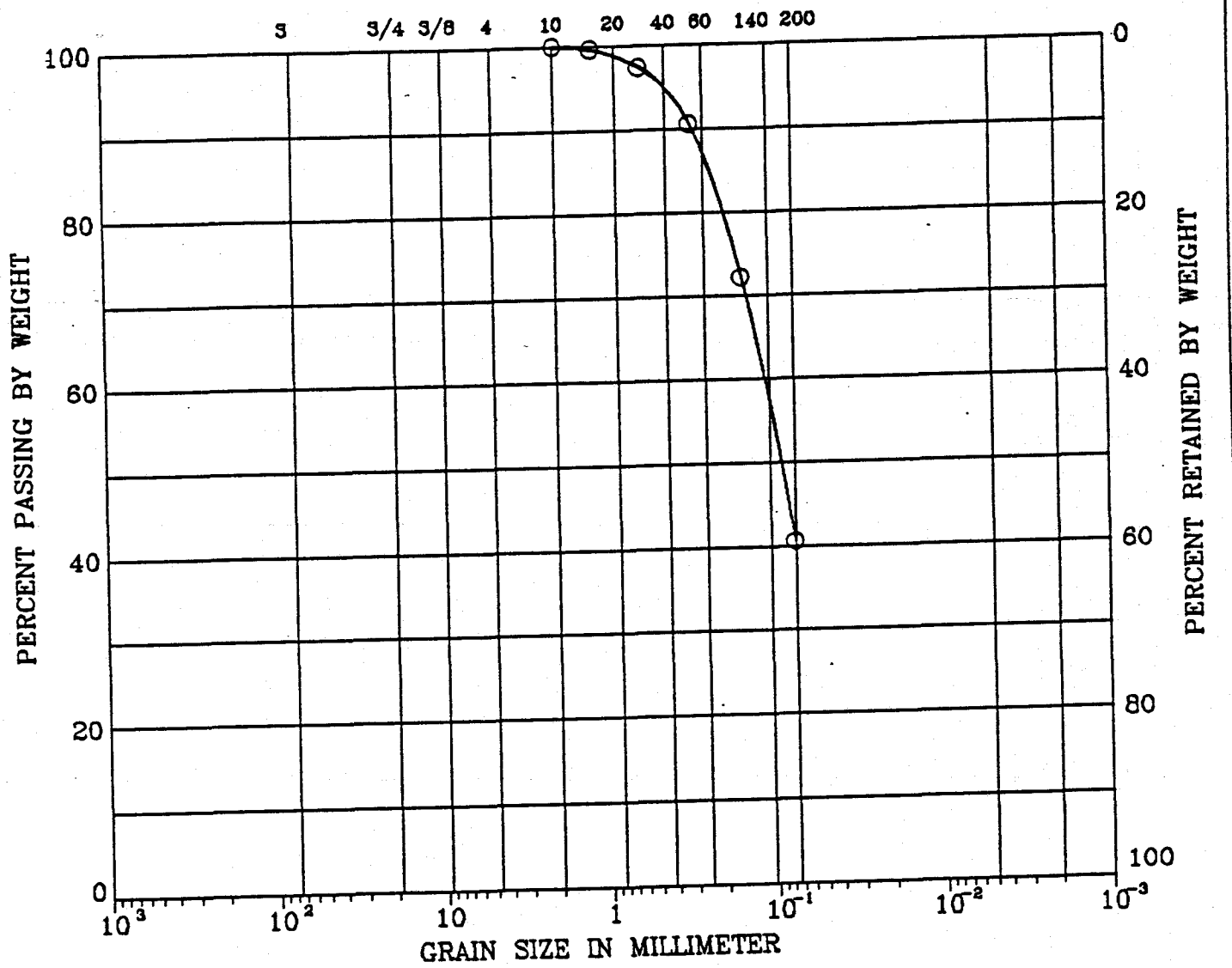
November 15, 1989

Dames & Moore

Plate B-3

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



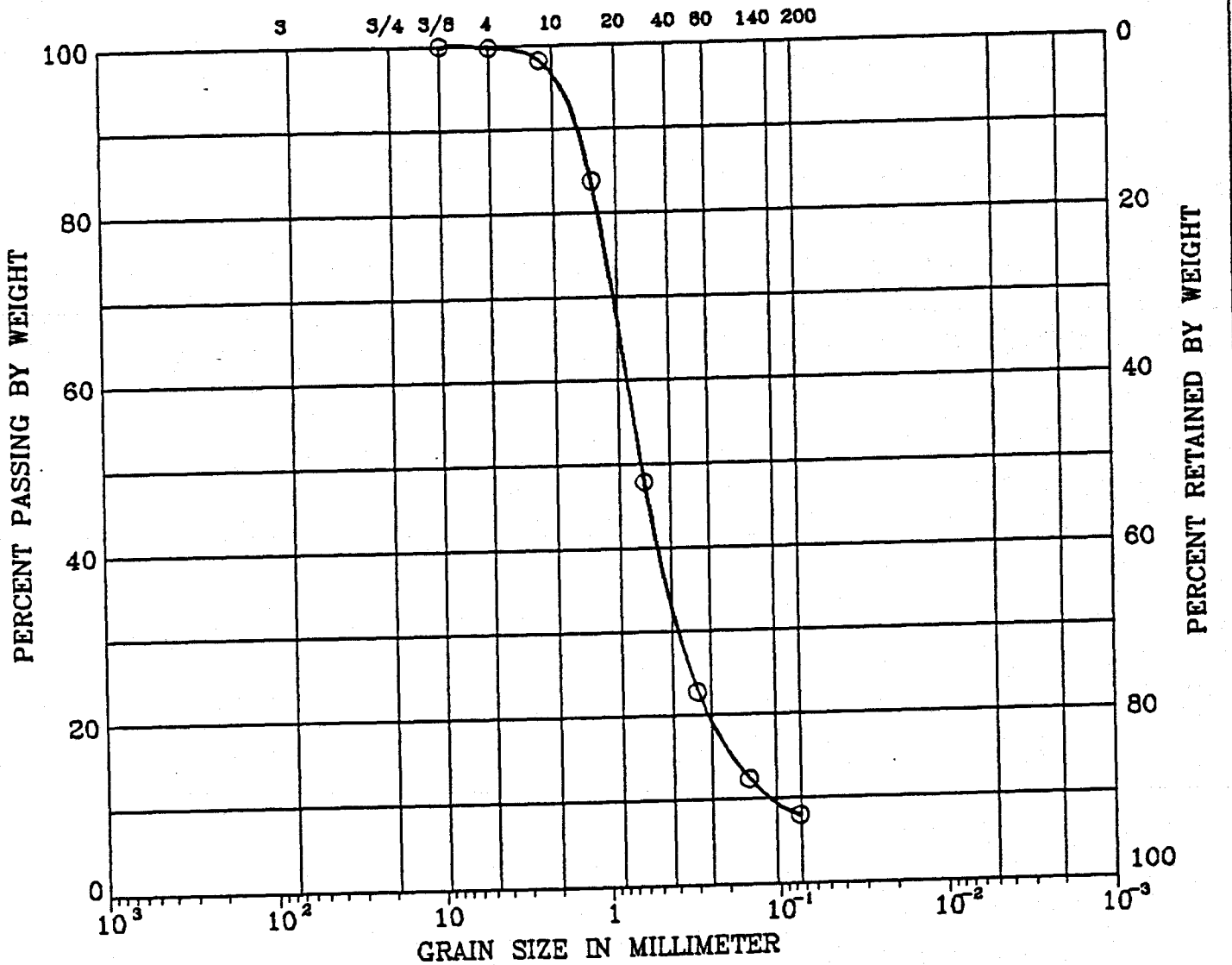
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-8	0.2			SILTY SAND (SM)

Remark :

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B-4

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



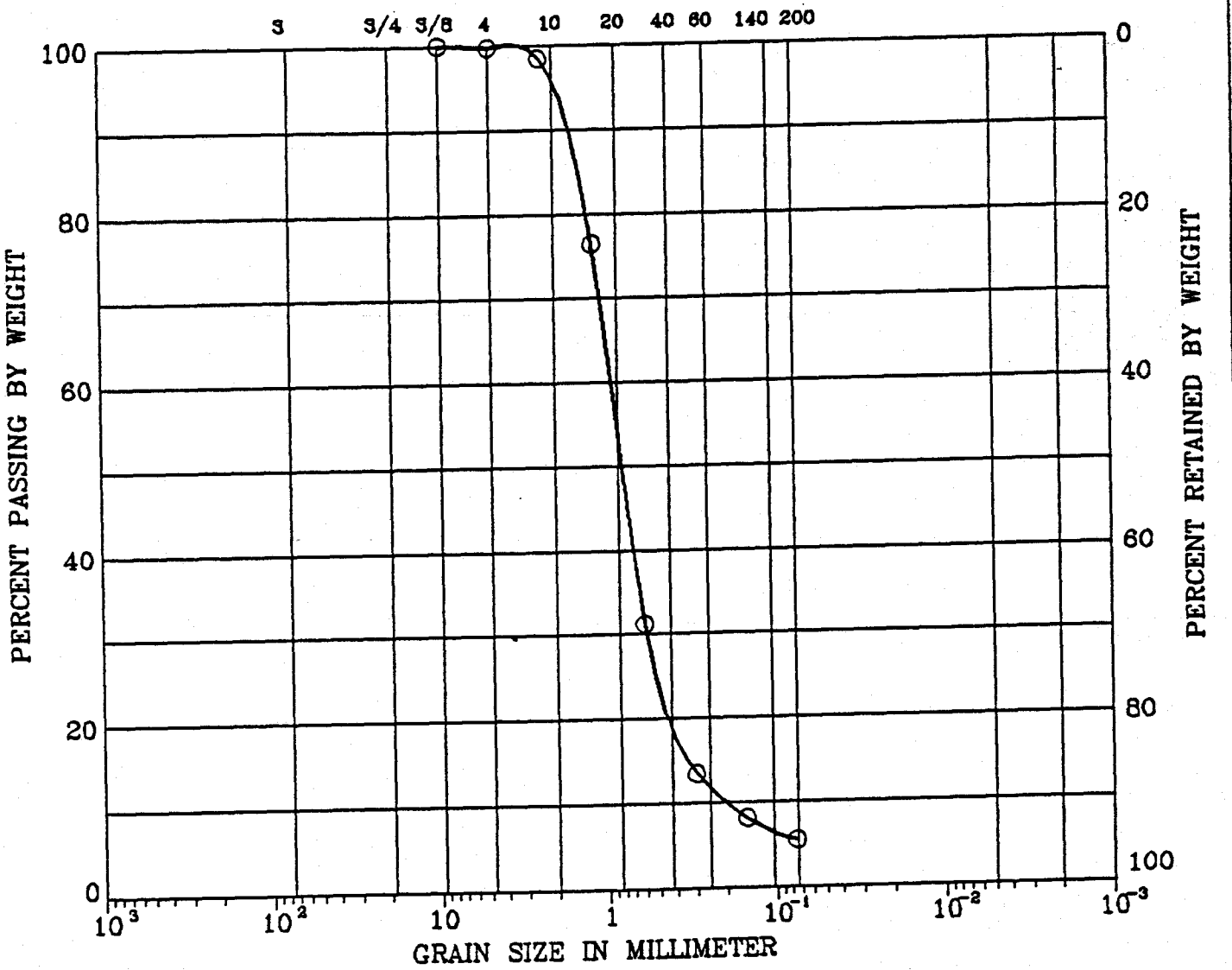
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	VP-8	25.5			SAND (SW)

Remark :

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B- 5

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



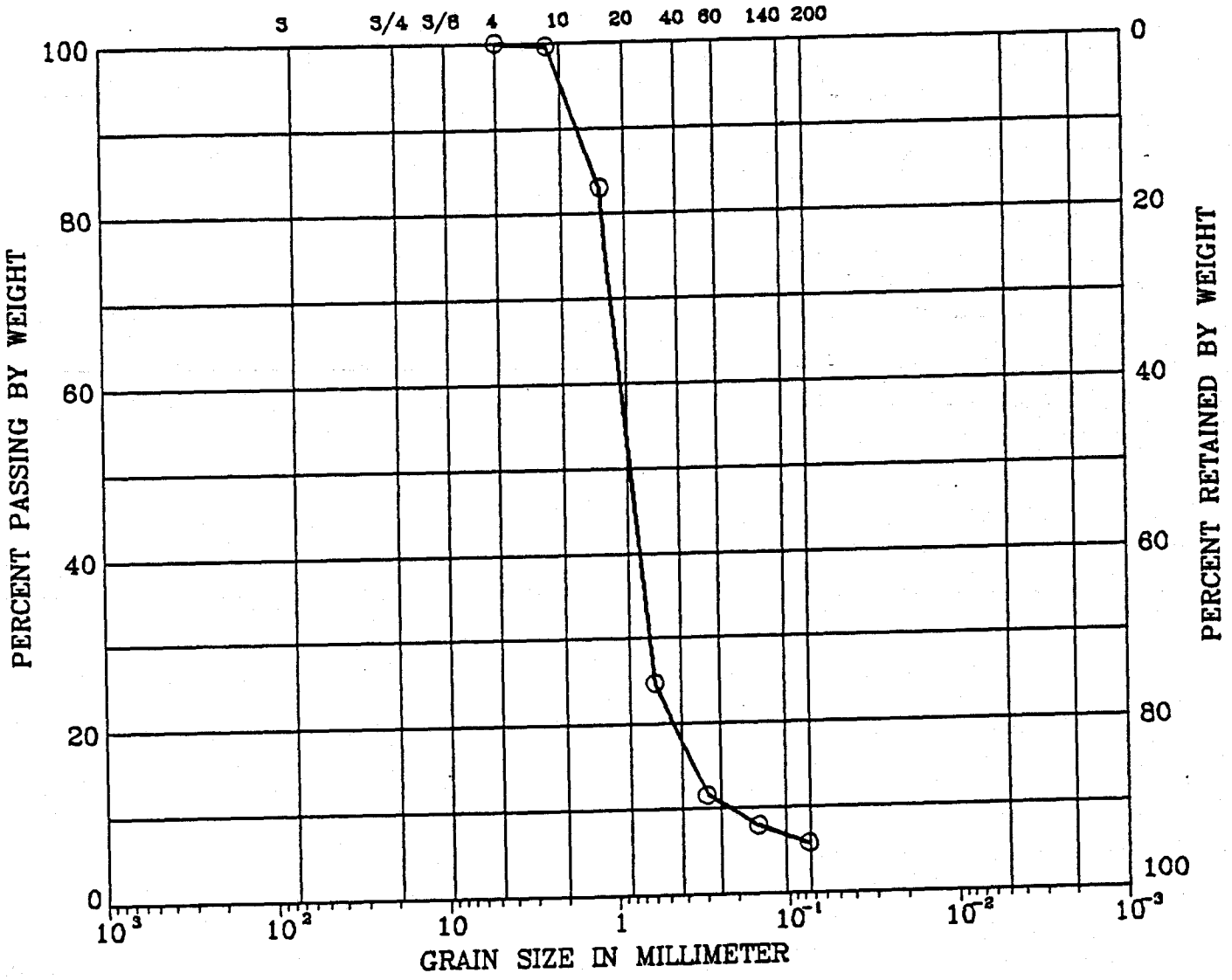
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-8	30.5			SAND (SP)

Remark :

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B-6

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



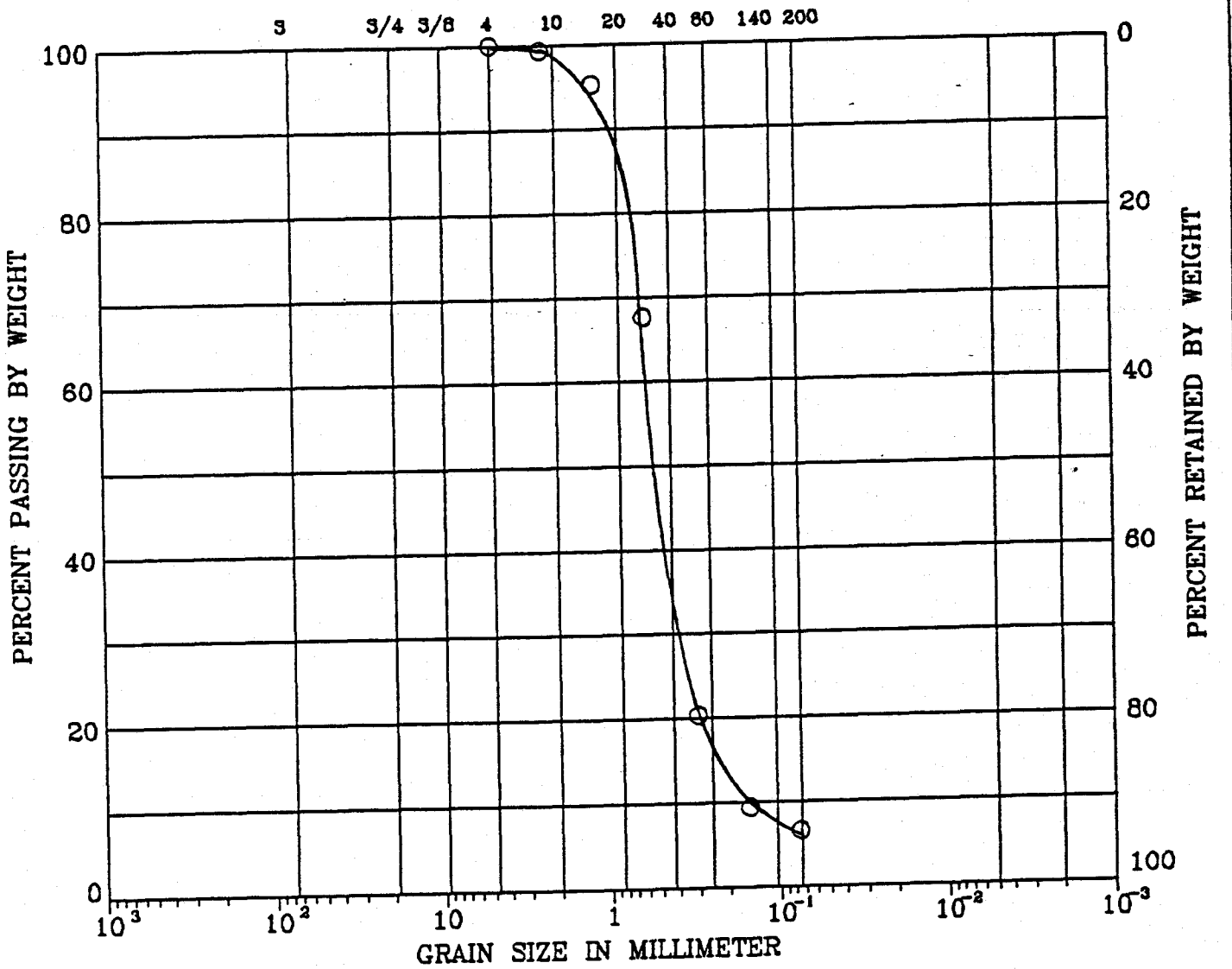
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-8	35.5			SAND (SP)

Remark :

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B- 7

UNIFIED SOIL CLASSIFICATION

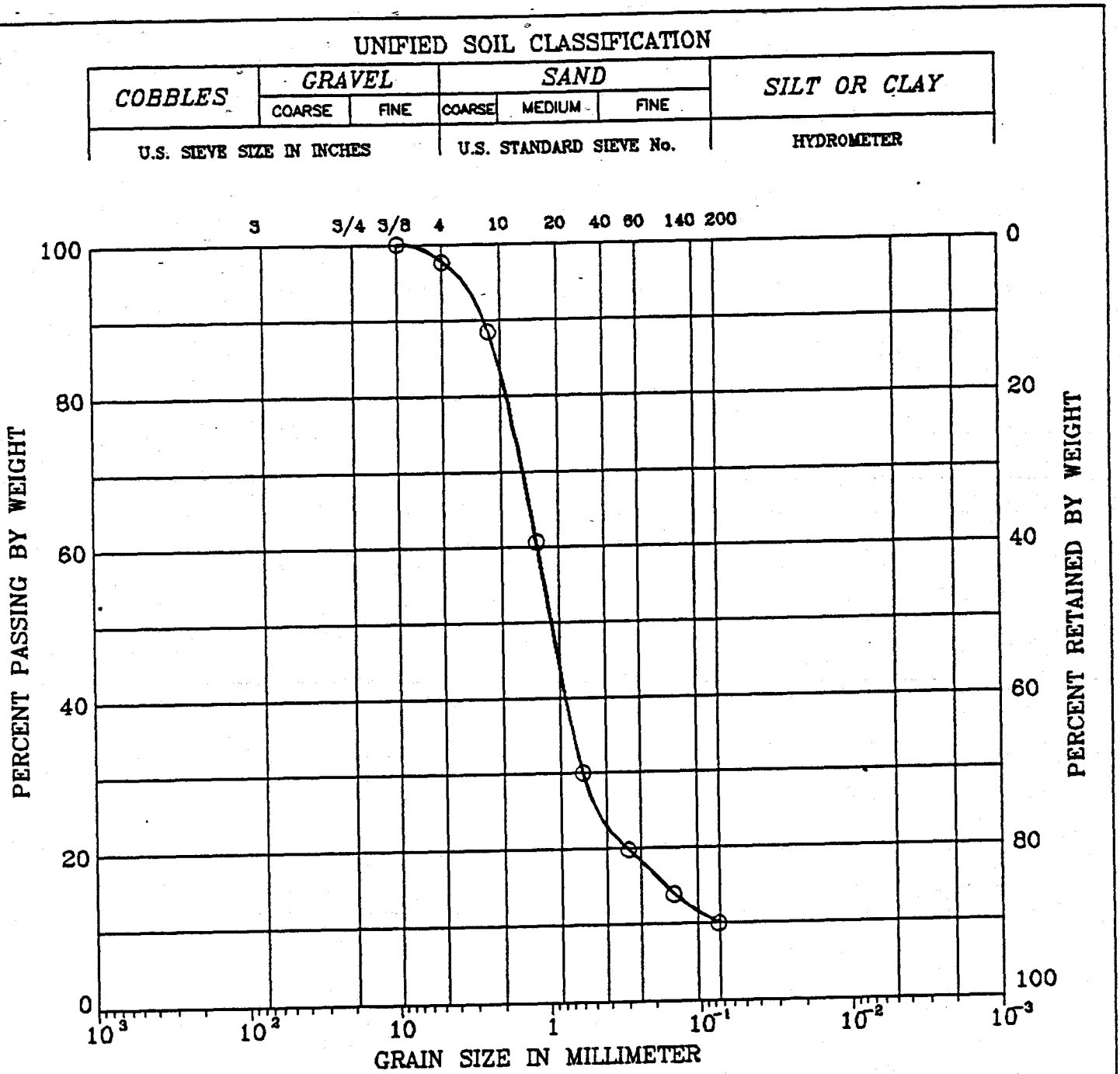
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-8	40.5			SAND (SP)

Remark :

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B-8



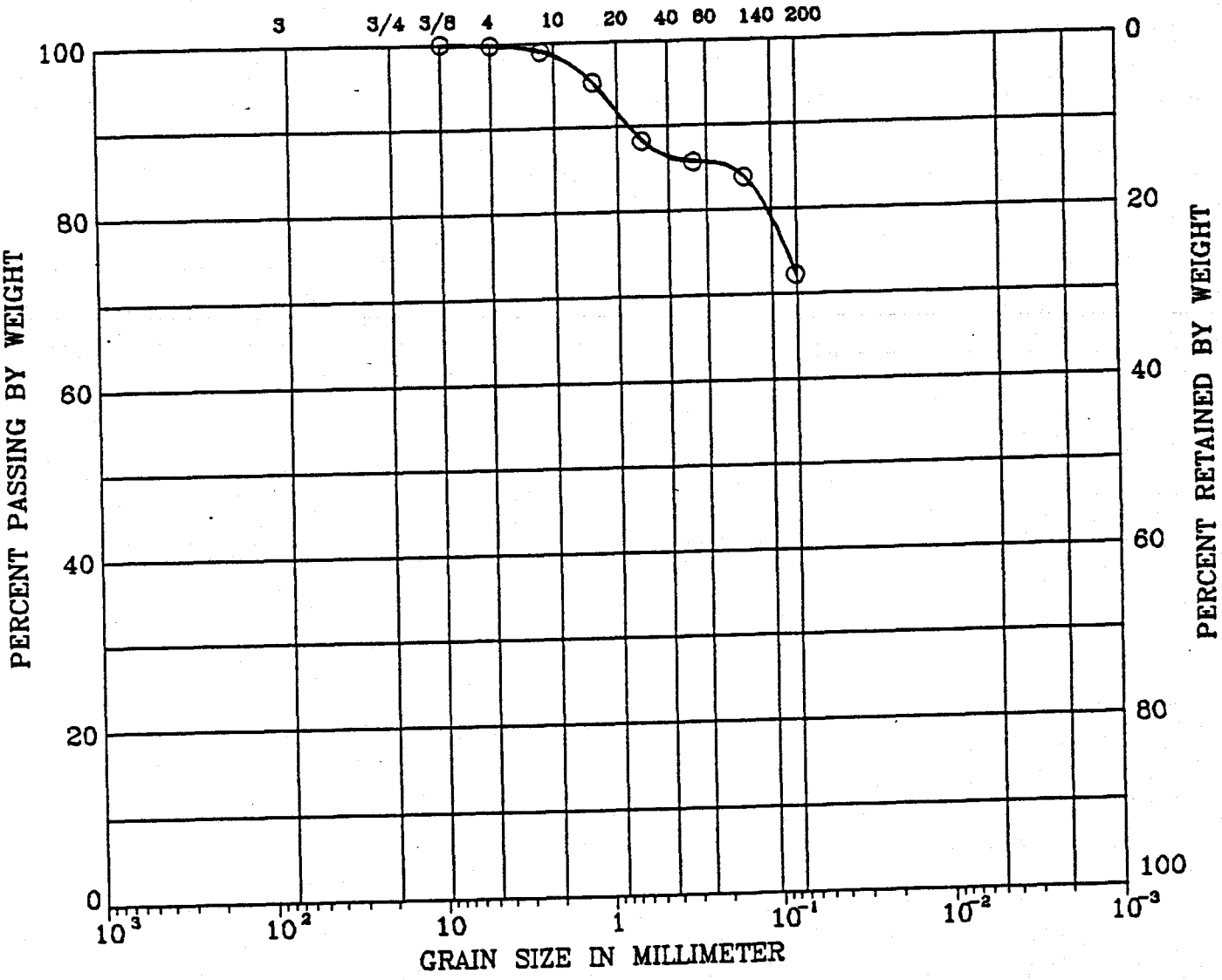
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-8	45.5			SAND (SM)

Remark : Test result of top 2 rings of sample No.10

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B- 9

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



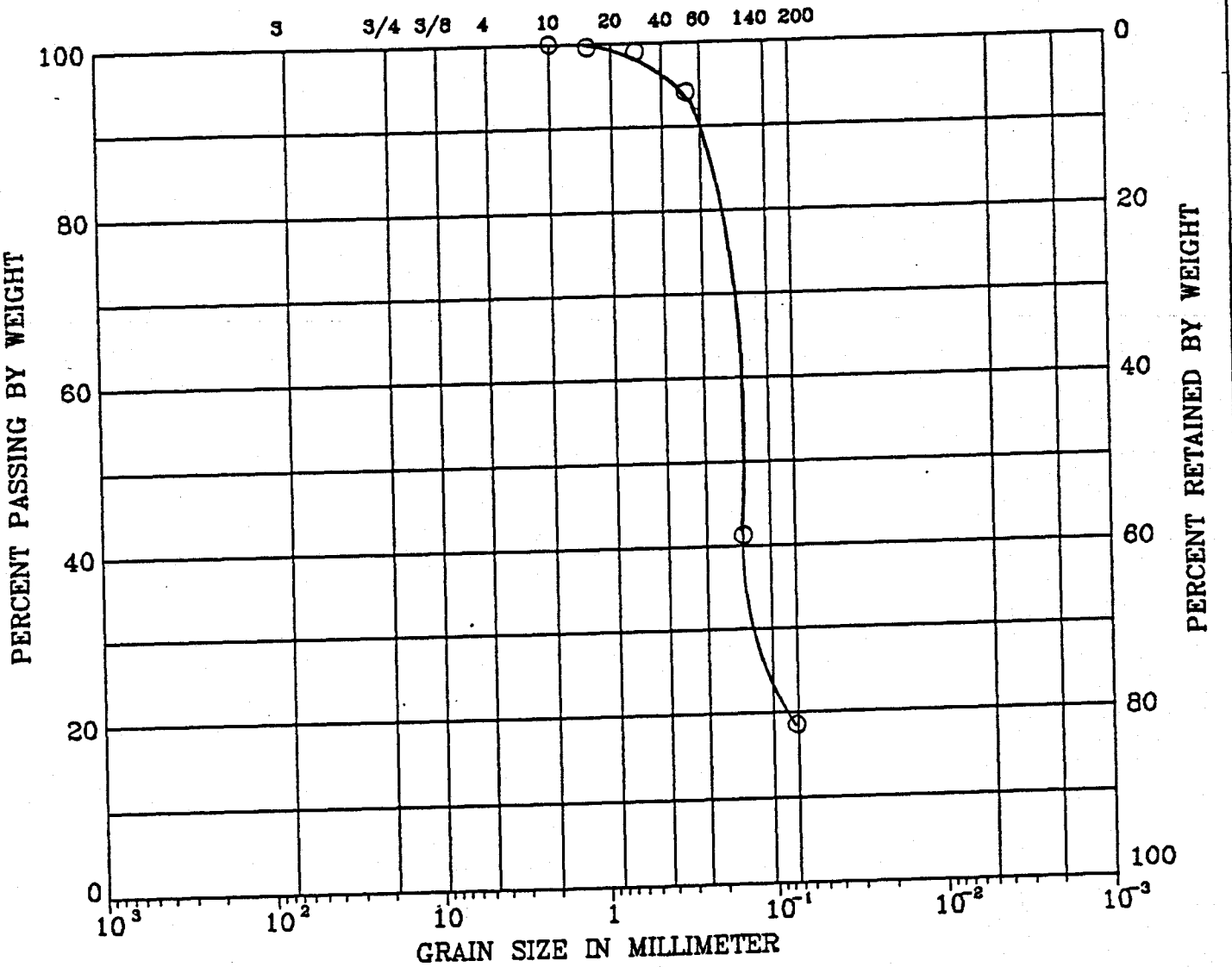
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-8	45.5			SILT WITH SOME SAND (ML)

Remark : Test result of bottom 2 rings of sample No.10

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B-10

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



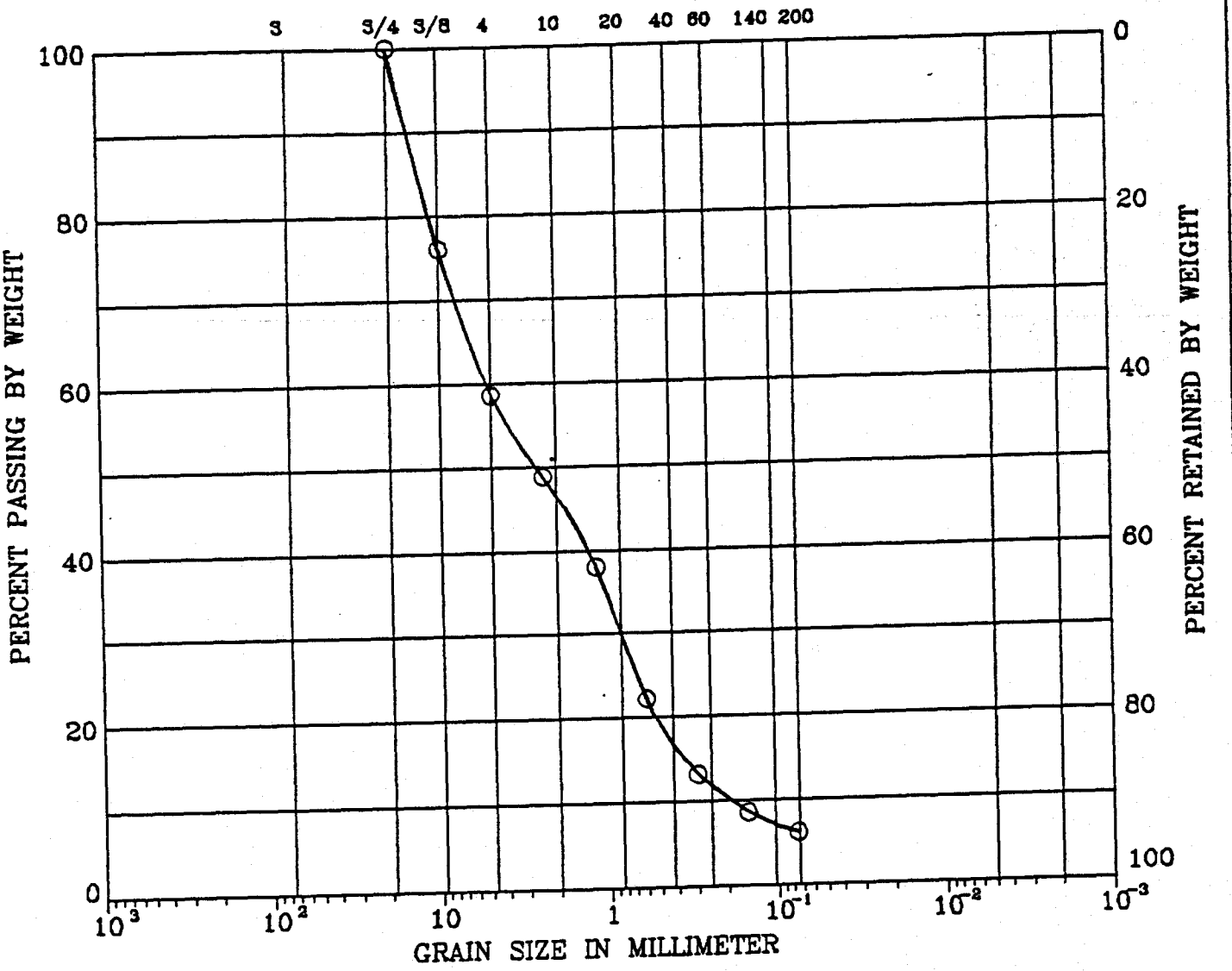
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-10	5			SILTY SAND (SM)

Remark :

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B- 11

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



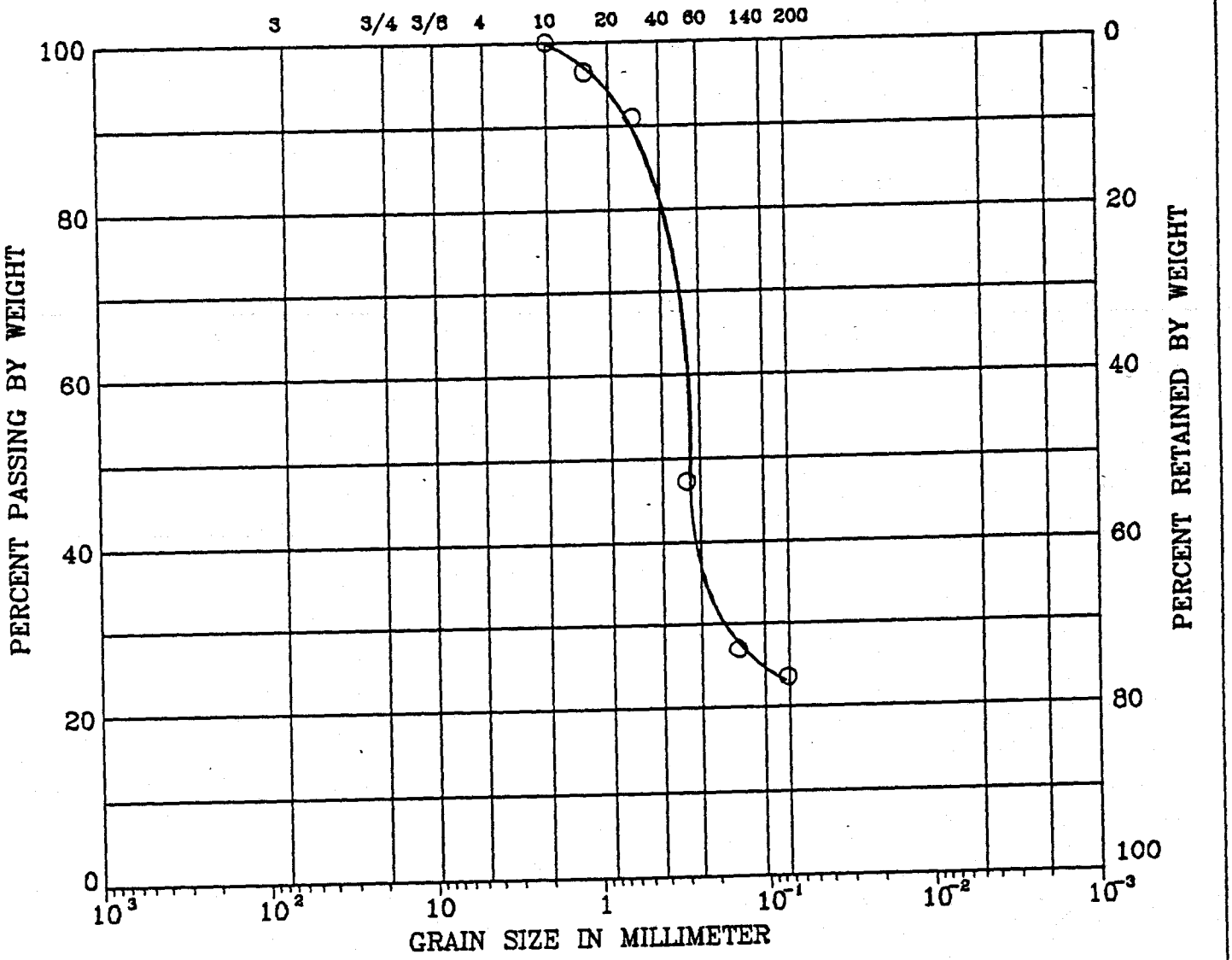
SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-10	10			GRAVELLY SAND (SM/GM)

Remark : Test result only on portion finer than 3/4"

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B-12

UNIFIED SOIL CLASSIFICATION

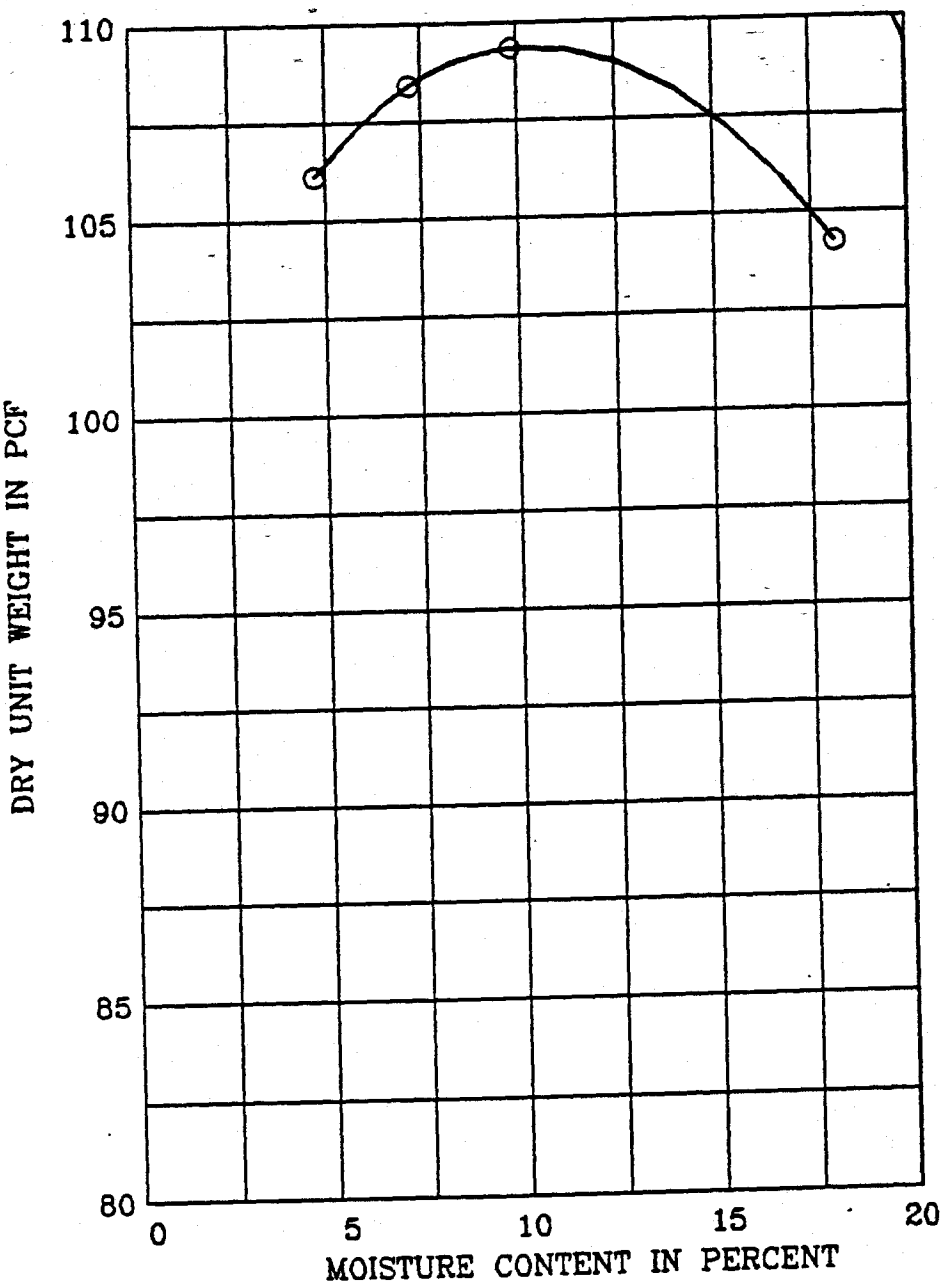
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN INCHES			U.S. STANDARD SIEVE No.			HYDROMETER



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
O	VP-11	6			SILTY SAND (SM)

Remark :

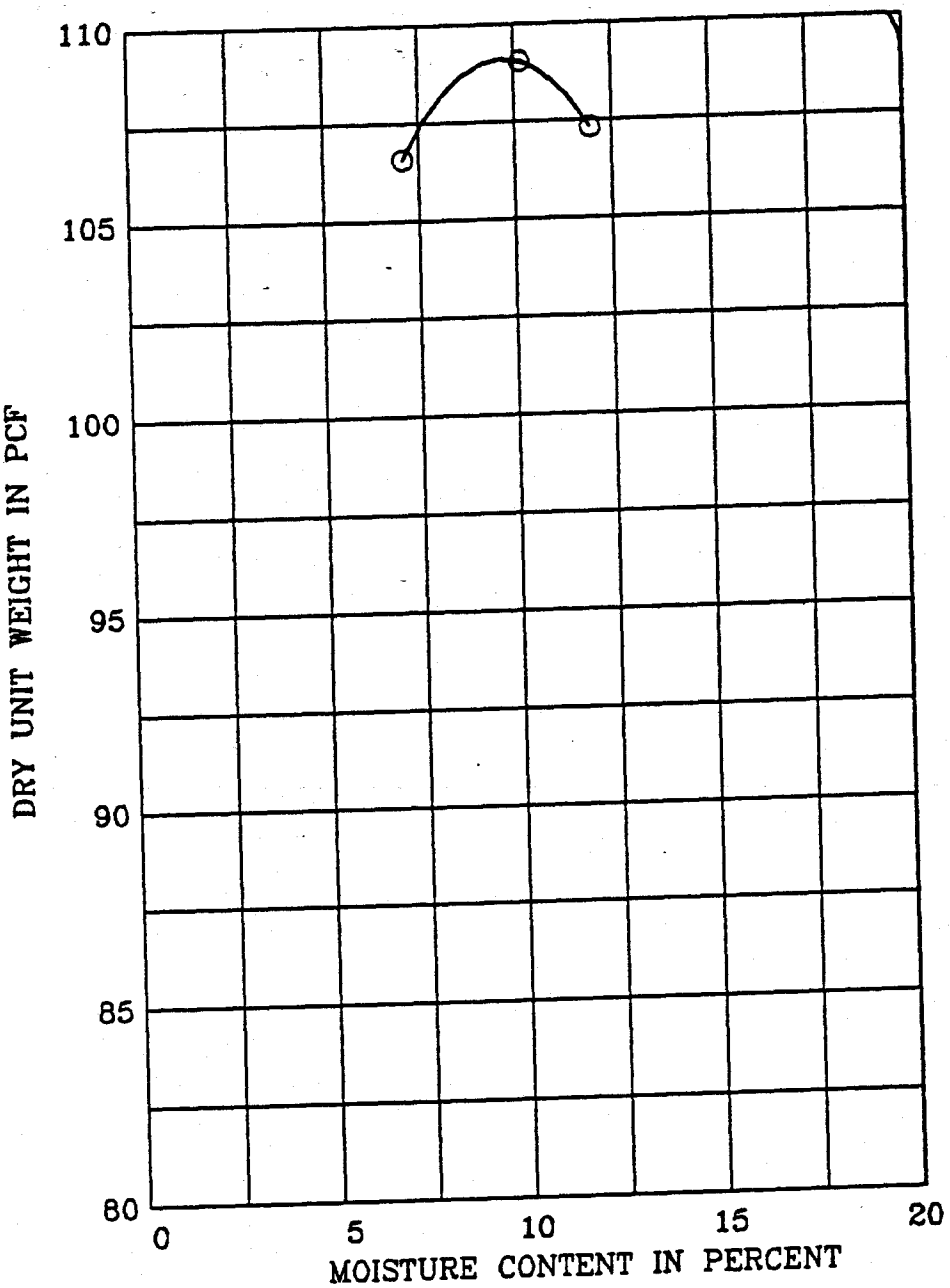
10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	GRAIN SIZE DISTRIBUTION Plate No.B- 13



SYMBOL	SAMPLE LOCATION	DEPTH (ft)	DESCRIPTION	TEST METHOD	OPTIMUM MOISTURE (%)	MAXIMUM DRY DENSITY (pcf)
O	VP-1	0-5	SM	Modified	9.9	109.3

Remark :

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	COMPACTION TEST Plate No.B- 14



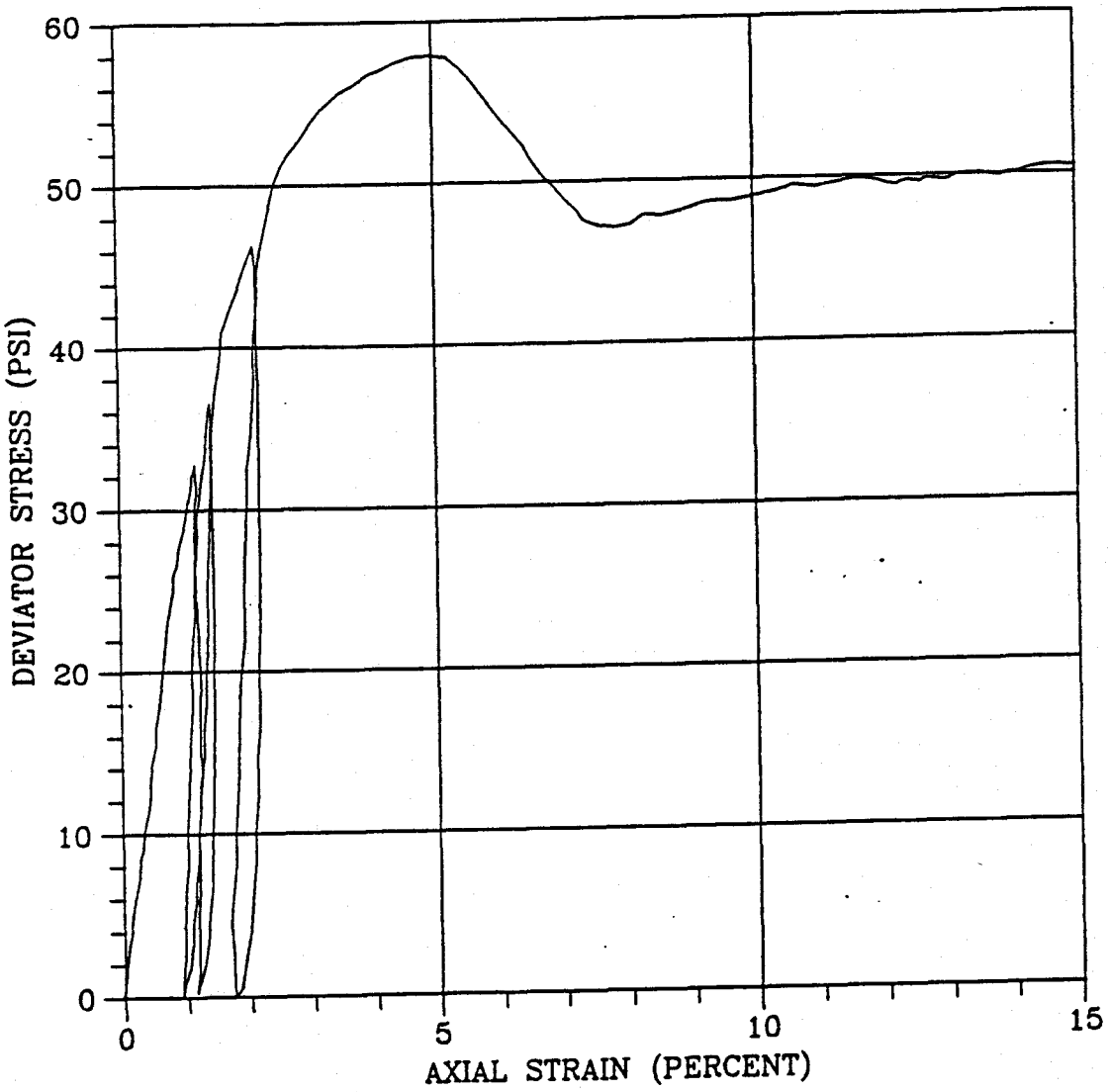
SYMBOL	SAMPLE LOCATION	DEPTH (ft)	DESCRIPTION	TEST METHOD	OPTIMUM MOISTURE (%)	MAXIMUM DRY DENSITY (pcf)
O	VP-2	16-18	SM	Modified	9.7	109.1

Remark :

10805-398-016	Hanford Waste Vitrification Plant
Dames & Moore November 15, 1989	COMPACTION TEST Plate No.B- 15

CONSOLIDATED–DRAINED TRIAXIAL TEST DATA

CLIENT: KAISER ENGINEERS HANFORD



Boring No. VP-8	Depth(ft) 40.5	Sample No. 9	Initial Hight (in.) 6		
SUMMARY OF SAMPLE DATA:					
Moisture Content (%)	2.8				
Wet Density (pcf)	105				
Dry Density (pcf)	102				
SUMMARY OF TEST DATA:					
Confining Pressure (psf)	2000	(13.9 PSI)			
Peak Deviator Stress (psf)	8350	(58 PSI)			
Elastic Modulus (ksf)	1870	(Reload)			
DESCRIPTION:	Fine to Medium Sand, Trace of Silt (Stratum 3)				

November 15, 1989

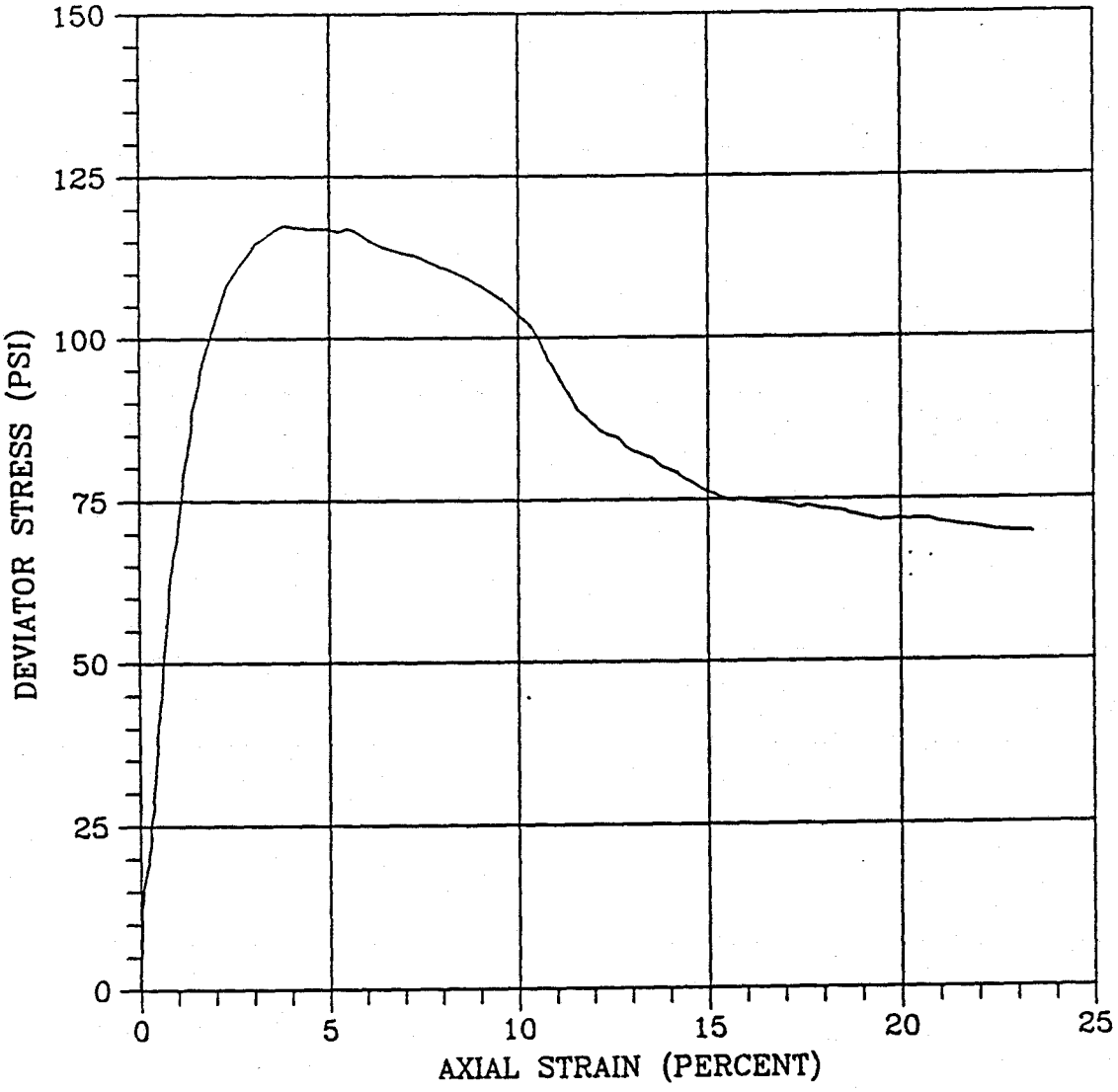
DAMES & MOORE

Job No. 10805-398-016

Plate No. B-16

CONSOLIDATED-DRAINED TRIAXIAL TEST DATA

CLIENT: KAISER ENGINEERS HANFORD



Boring No.	VP-8	Depth(ft)	50.5	Sample No. 11	Initial Hight (in.) 6

SUMMARY OF SAMPLE DATA:		
Moisture Content (%)	1.8	
Wet Density (pcf)	109	
Dry Density (pcf)	107	
SUMMARY OF TEST DATA:		
Confining Pressure (psf)	4000	(27.8 PSI)
Peak Deviator Stress (psf)	16850	(117 PSI)
Elastic Modulus (ksf)	1200	(8.3 KSI)
DESCRIPTION:	Fine to Medium Sand, Trace of Silt (Stratum 3)	

November 15, 1989

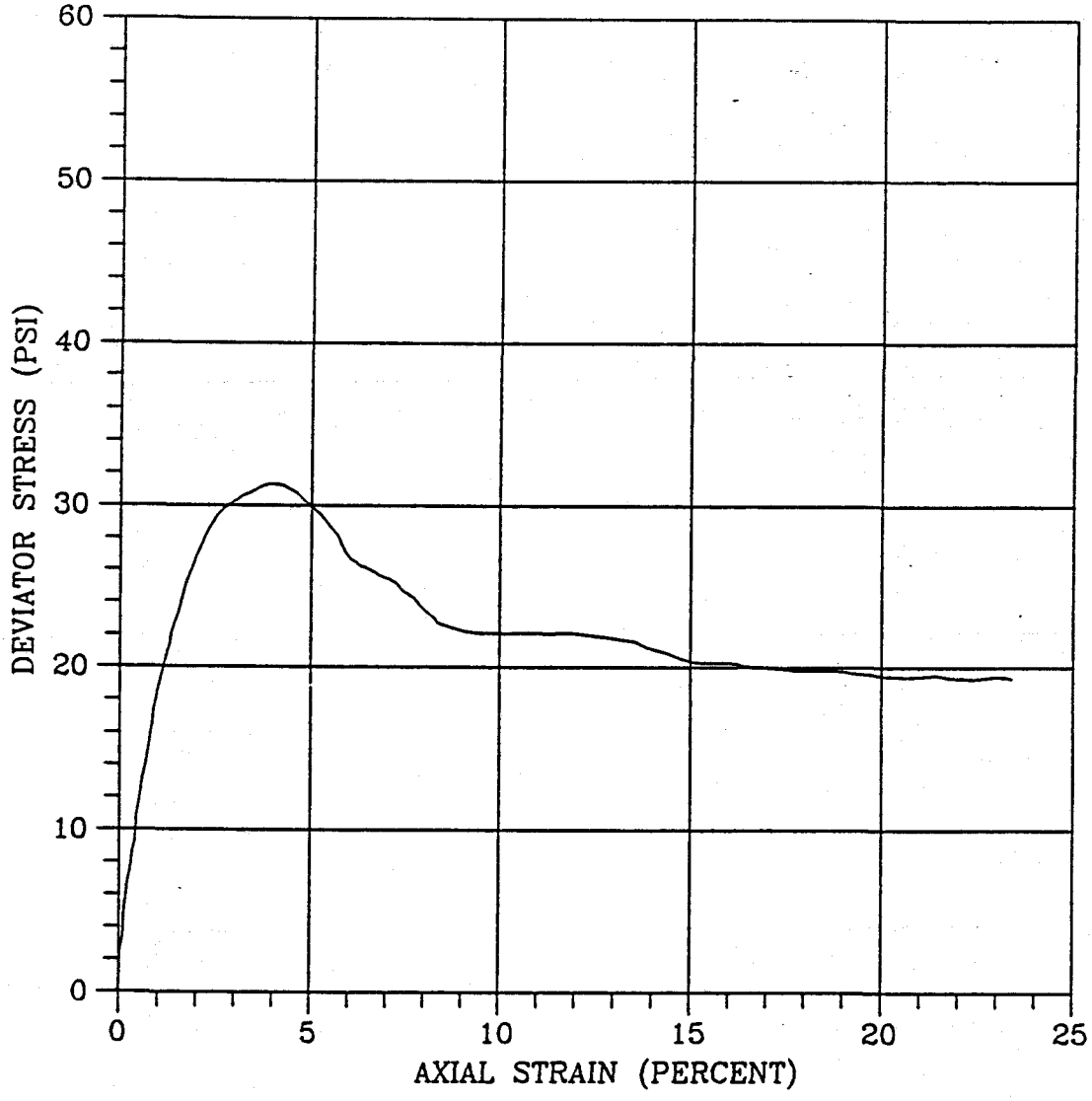
DAMES & MOORE

Job No. 10805-398-016

Plate No. B-17

CONSOLIDATED-DRAINED TRIAXIAL TEST DATA

CLIENT: KAISER ENGINEERS HANFORD



Boring No. VP-10	Depth(ft) 5	Sample No. 2	Initial Hight (in.) 6
SUMMARY OF SAMPLE DATA:			
Moisture Content (%)	3		
Wet Density (pcf)	97		
Dry Density (pcf)	94		
SUMMARY OF TEST DATA:			
Confining Pressure (psf)	1000	(6.9 PSI)	
Peak Deviator Stress (psf)	4350	(30.2 PSI)	
Elastic Modulus (ksf)	360	(2.5 KSI)	
DESCRIPTION:	Silt and Fine Sand (Stratum 1)		

November 15, 1989

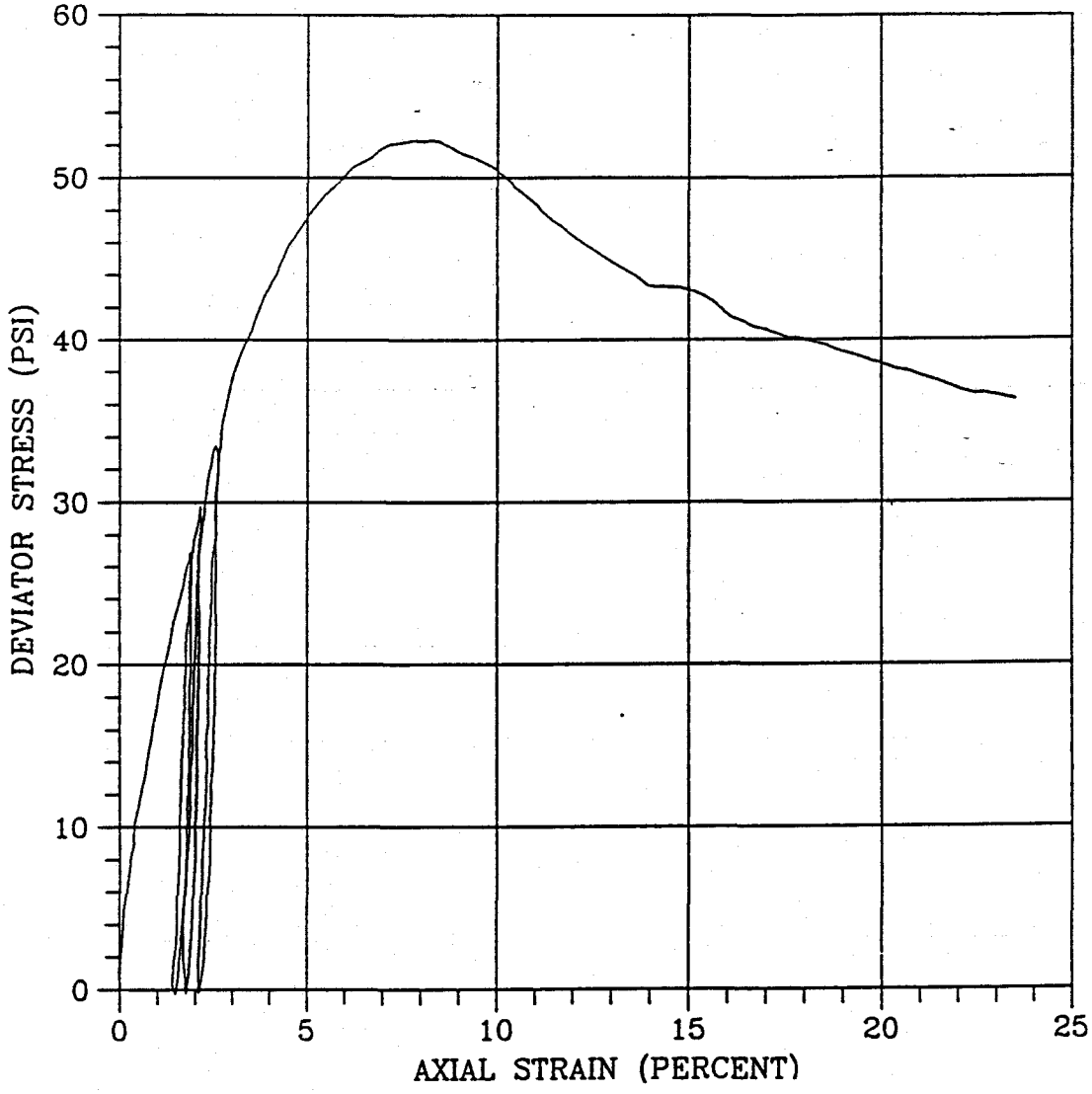
DAMES & MOORE

Job No. 10805-398-016

Plate No. B-18

CONSOLIDATED–DRAINED TRIAXIAL TEST DATA

CLIENT: KAISER ENGINEERS HANFORD



Boring No.	VP-11	Depth(ft)	6	Sample No. 2	Initial Hight (in.) 6

SUMMARY OF SAMPLE DATA:

Moisture Content (%)	2.2
Wet Density (pcf)	103
Dry Density (pcf)	101

SUMMARY OF TEST DATA:

Confining Pressure (psf)	2000	(13.9 PSI)
Peak Deviator Stress (psf)	7490	(52 PSI)
Elastic Modulus (ksf)	1080	(Reload)

DESCRIPTION: Silt and Fine Sand (Stratum 1)

November 15, 1989

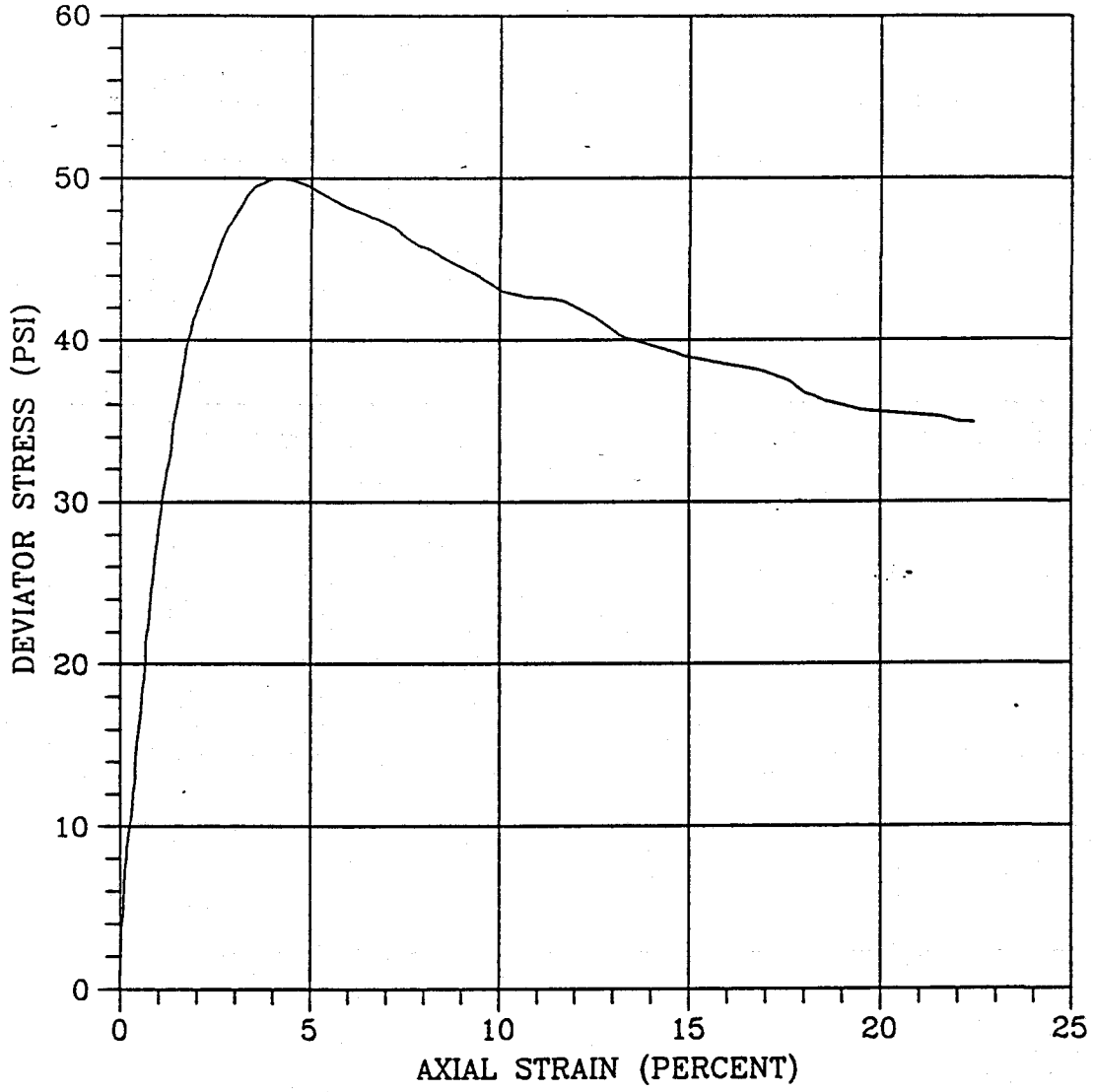
DAMES & MOORE

Job No. 10805-398-016

Plate No. B-19

CONSOLIDATED–DRAINED TRIAXIAL TEST DATA

CLIENT: KAISER ENGINEERS HANFORD



Boring No.	VP-17	Depth(ft)	3.5	Sample No.	2	Initial Hight (in.)	6

SUMMARY OF SAMPLE DATA:

Moisture Content (%)	2.5
Wet Density (pcf)	106
Dry Density (pcf)	103

SUMMARY OF TEST DATA:

Confining Pressure (psf)	1500	(10.4 PSI)
Peak Deviator Stress (psf)	7200	(50 PSI)
Elastic Modulus (ksf)	430	(3 KSI)

DESCRIPTION: Silt and Fine Sand (Stratum 1)

November 15, 1989

DAMES & MOORE

Job No. 10805-398-016

Plate No. B-20

Boring	Sample Depth (feet)	Initial Diameter (inches)	Initial Height (inches)	Initial Dry Density (pcf)	Initial Moisture Content (%)	% Collapse	Remarks
VP-9	5.5	2.0	1.0	95	5.2	2.58	natural conditions
VP-6	0-3	2.0	1.0	101	10.0	0.26	Recompacted in consolidometer
	0-3	4.0	3.5	103	10.0	0.32	Recompacted in compaction mold

COLLAPSE TEST RESULTS
Hanford Waste Vitrification Plant

Dames & Moore

11/15/89
10805-398-016

Plate: B-21

ORIGINAL LAB DATA

Collapse Test (Consolidometer)

CONSOLIDATION TEST DATA — Collapse Test — Natural Conditions — 2/18/89 – 8/21/89 by JWS

Client:	Kaiser Engr.
Job No:	10805-392
Location:	Hanford
Boring No:	VP-9
Sample No:	2
Depth (ft):	5.5'
Soil Type:	SM
Load Sequence:	Normal load 6' × 110 pcf = 600 psf

Note: Use 1 D&M Ring for test	INITIAL	FINAL
Wet Wt. of Soil + Tare (g)	165.3	187.68
Dry Wt. of Soil + Tare (g)	159.4	159.4
Weight of Tare (g)	45.3	45.3
Length (in)	1	0.93
Diameter (in)*	2.42	
Specific Gravity (est)	—	
Wet Density (pcf)	100.0	127.6
Dry Density (pcf)	95.1	102.2
Moisture Content (%)	5.2	24.8

*D&M Sample = 2.416 in

Time/Comment	Load (psf)	Reading (×0.0001")
8/18 16:10	0	
16:10		1923
16:15	600	
16:20		1525
16:30		1511
16:45		1500
17:15		1498
18:21		1497
8/19 9:05		1496 → 0.0427
9:15	Start Saturation	
9:15		1330
9:16		1320
10:05		1302
8/21 8:10		1249
9:10		1249 → 0.0674

Time/Comment	Load (psf)	Reading

$$\% \text{ Collapse} = \frac{0.0674 - 0.0427}{1.0 - 0.0427} \times 100\% = 2.58\%$$

Dames & Moore

Collapse Test (compaction mold)

CONSOLIDATION TEST DATA Collapse Test Recompacted 10/23—10/31/89 by JWS

Client:	Kaiser Engr
Job No:	10805-398
Location:	Hanford
Boring No:	VP-6
Sample No:	
Depth (ft):	0-3'
Soil Type:	SM
Load Sequence:	Normal load 6' x 100 pcf = 600 PSF

Note: Use 1 D&M Ring for test

	INITIAL	FINAL
Wet Wt. of Soil + Tare (g)	3.795# = 1720.5(g)	
Dry Wt. of Soil + Tare (g)	3.45# = 1564.9(g)	
Weight of Water (g)	0.345# = 156.5(g)	
Length (in)	4.58"	
Diameter (in)*	4"	
Specific Gravity (est)	—	
Wet Density (pcf)	113.9	
Dry Density (pcf)	103.6	
Moisture Content (%)	10%	

*D&M Sample = 2.416 in

Time/Comment		Load (psf)	Reading
Time	load	Reading left	Reading right
	(psf)	(0.001")	(0.001")
10/23 14:00 PM	0	950	950
10/23 14:00	600	876	887
14:10		881	866
10/24 9:45		877	854
AM 10:45		877.0	854.0
10:45	Start Saturation		
11:05		869	849
[illegible]		862	849
10/25 12:12PM		862	848
4:13		862	848
10/26 8:25		[illegible]	847.3
4:30		[illegible]	847
10/27 11:45		859.5	847
10/30 15:30	PM	857.1	845.1
10/31 9:00	AM	857.1	845.1

Time/Comment	Load (psf)	Reading
= 950.0		
= 865.5 → 0.0845		
= 851.1 → 0.0989		

$$\% \text{ collapse} = \frac{0.0989 - 0.0845}{4.58 - 0.0845} = 0.32\%$$

Dames & Moore

Collapse Test (consolidometer)

CONSOLIDATION TEST DATA Collapse Test — Recompacted — 10/23/89 — 10/31/89 — by JWS

Client:	Kaiser Engr
Job No:	10805-398
Location:	Hanford
Boring No:	VP-6
Sample No:	
Depth (ft):	0-3'
Soil Type:	SM
Load Sequence:	Normal load 6 x 100 psf = 600 psf
	Tested by JWS

Note: Use 1 D&M Ring for test	Designed INITIAL	Actual Initial ~~FINAL~~
Wet Wt. of Soil + Tare (g)	154.36	226.4
Dry Wt. of Soil + Tare (g)	141.96	198.38
Weight of Tare (g)	17.66	76.88
Length (in)	1	1
Diameter (in)*	2.42	2.42
Specific Gravity (est)	—	—
Wet Density (pcf)	113.9	124.6
Dry Density (pcf)	103.6	101.3
Moisture Content (%)	10%	10%

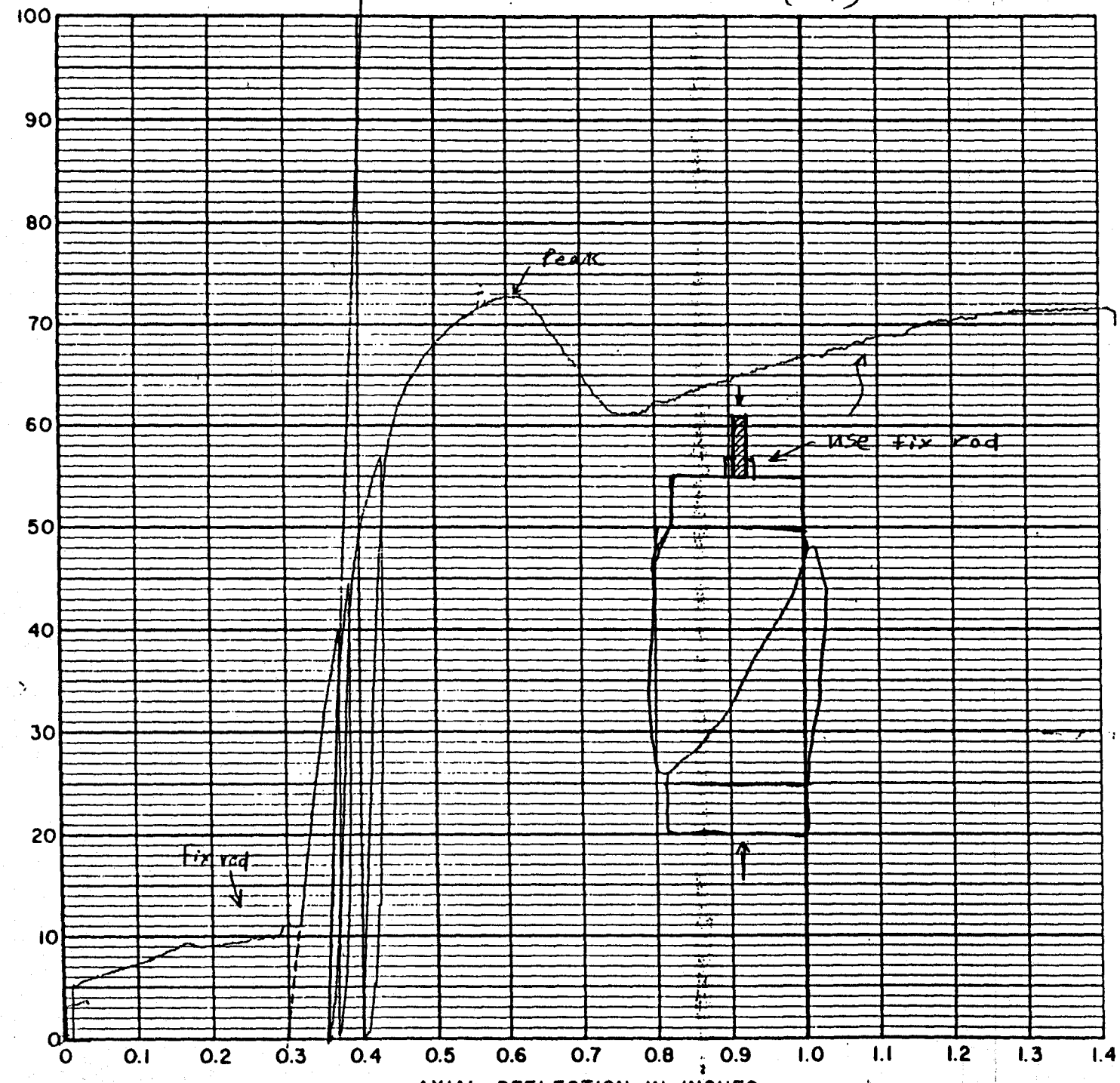
*D&M Sample = 2.416 in

Time/Comment	Load (psf)	0.0001" Reading
10/23/89 15:00 PM	0	3100
15:00 PM	600	
		2995
10/24 09:45 AM		2970
10:45 AM		2969 → 0.0131
10:45 AM	Start Saturation	
11:10 AM		2952
3:46 PM		2949
10/25 12:12		2947
4:14		2947
10/26 8:25		2946.5
4:30		2946.5
10/27 11:45		2946
10/30 15:30 PM		2944
10/31 9:00 AM		2943 → 0.0157

Time/Comment	Load (psf)	Reading

$$\% \text{ collapse} = \frac{0.0157 - 0.0131}{1.0 - 0.0131} \times 100\% = 0.26\%$$

TEST DATA SHEET



Weight soil & dish no.		1029.3
Dry weight soil & dish		869.4
Net loss of moisture		21
Weight of dish only	#3	134.0
Net weight of dry soil		735.4
Moisture, % of dry weight		2.8%
Wt. solids + moisture	W_o	756.4 gr
W_o ÷ 454	W_o'	— lb
Weight solids	W_s	— gr
Wet density $W_o' \div V_o'$		105.0 pc
Dry density		102.0 pc
Net diameter	D_o	2.42 in.
Area ($0.785\ D_o^2$)	A_o	4.6 sq
Height	H_o	6 in.
Volume ($A_o H_o$) ÷ 1728	V_o'	cu
Volume ($A_o H_o$) x 16.4	V_o	cc
Specific gravity of solids	G_s	
Volume of solids $W_s \div G_s$	V_s	cc
$(V_o - V_s) \div V_s$	e_i	
Initial burette reading		cc
Burette reading under pressure		cc
$(V_p - V_s) \div V_s$	e_p	

Deflecting Speed 0.02 in (Hr / Min)

Lateral Pressure 2000 / 13.89 PSF / PSI

Saturated ☐ Field Moisture ☒ cp

Set-up TWS Tested TWS (GA Office)

Soil Type SM Fine to med. Sand, trace of silt (Stratum 3)

Location Hanford

Owner Kaiser Engr

Depth 40.5 Sample # 9

Job # 10805-398 Boring # VP-8

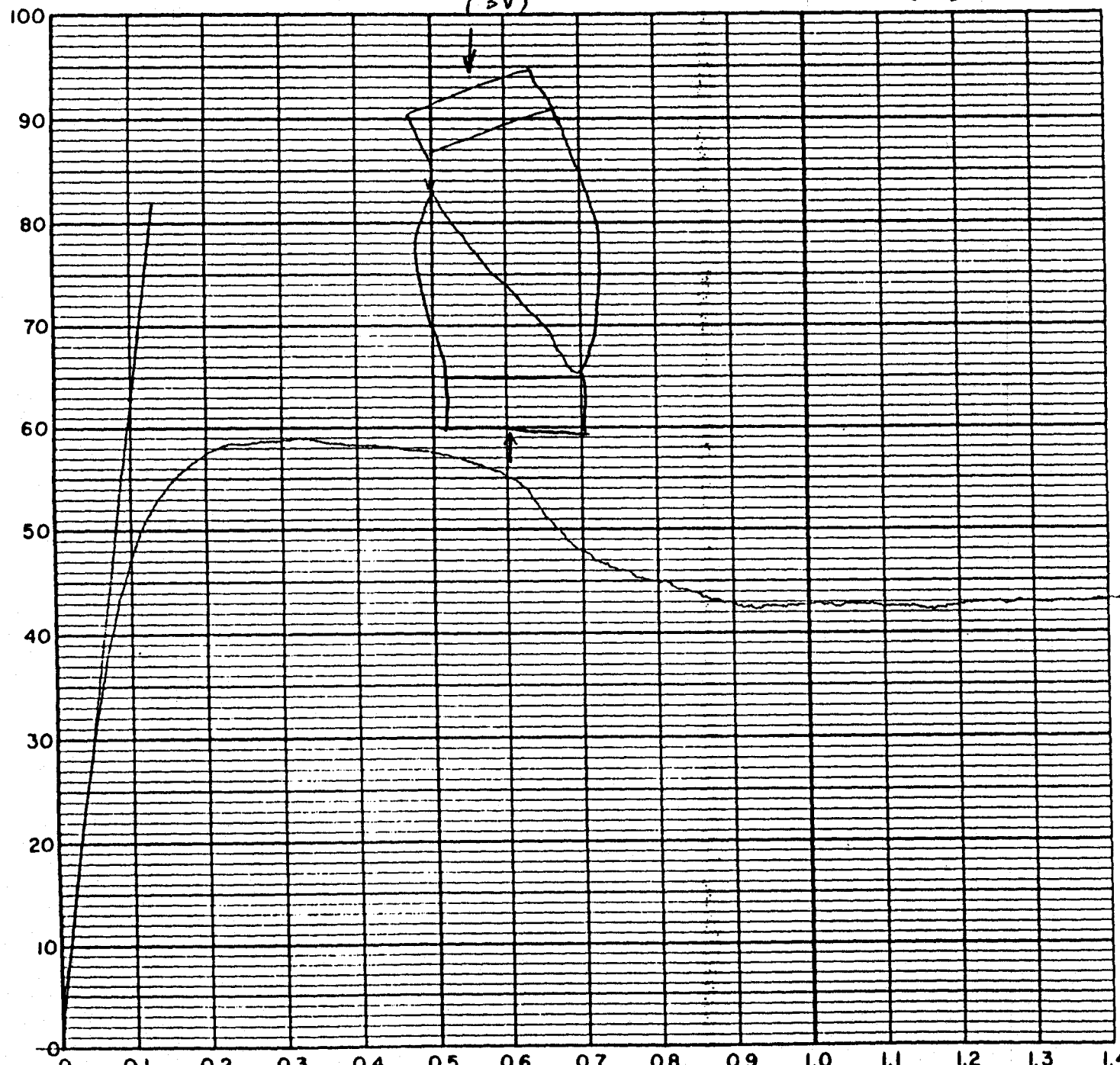
FORM NO. 857.46

APPLIED EARTH SCIENCES

TEST DATA SHEET

30,000 load cell (5V)

▼ % OF AXIAL LOAD RANGE: 30,000 (5V) LBS./SQ. FT.



Weight soil & dish no.		1054-8(6
Dry weight soil & dish		952.9
Net loss of moisture		13.8
Weight of dish only	#003	184.8Y
Net weight of dry soil		768.1
Moisture, % of dry weight		1.8%
Wt. solids + moisture	W_o	781.9 gms
$W_o \div 454$	W'_o	— lbs
Weight solids	W_s	— gms
Wet density $W'_o \div V'_o$		108.6 pcf
Dry density		106.7 pcf
Net diameter	D_o	2.42 in.
Area $(0.785\ D_o^2)$	A_o	4.6 sq.
Height	H_o	6 in.
Volume $(A_o H_o) \div 1728$	V'_o	cu.
Volume $(A_o H_o) \times 16.4$	V_o	cc
Specific gravity of solids	G_s	
Volume of solids $W_s \div G_s$	V_s	cc
$(V_o - V_s) \div V_s$	e_i	
Initial burette reading		cc
Burette reading under pressure		cc
$(V_p - V_s) \div V_s$	e_p	

Deflecting Speed 0.02 in. Hr / Min

Lateral Pressure 4000 PSF / 27.8 PSI

Saturated ☐ Field Moisture ☒ CD

Set-up JWS Tested JWS (☒ Office)

Soil Type SM - Fine to Med. Sand, trace of silt (Stratum

Location Hanford

Owner Kaiser Engr

Depth 50.5' Sample # 11

Job # 10805-398 Boring # VP-8

FORM NO. 857.46

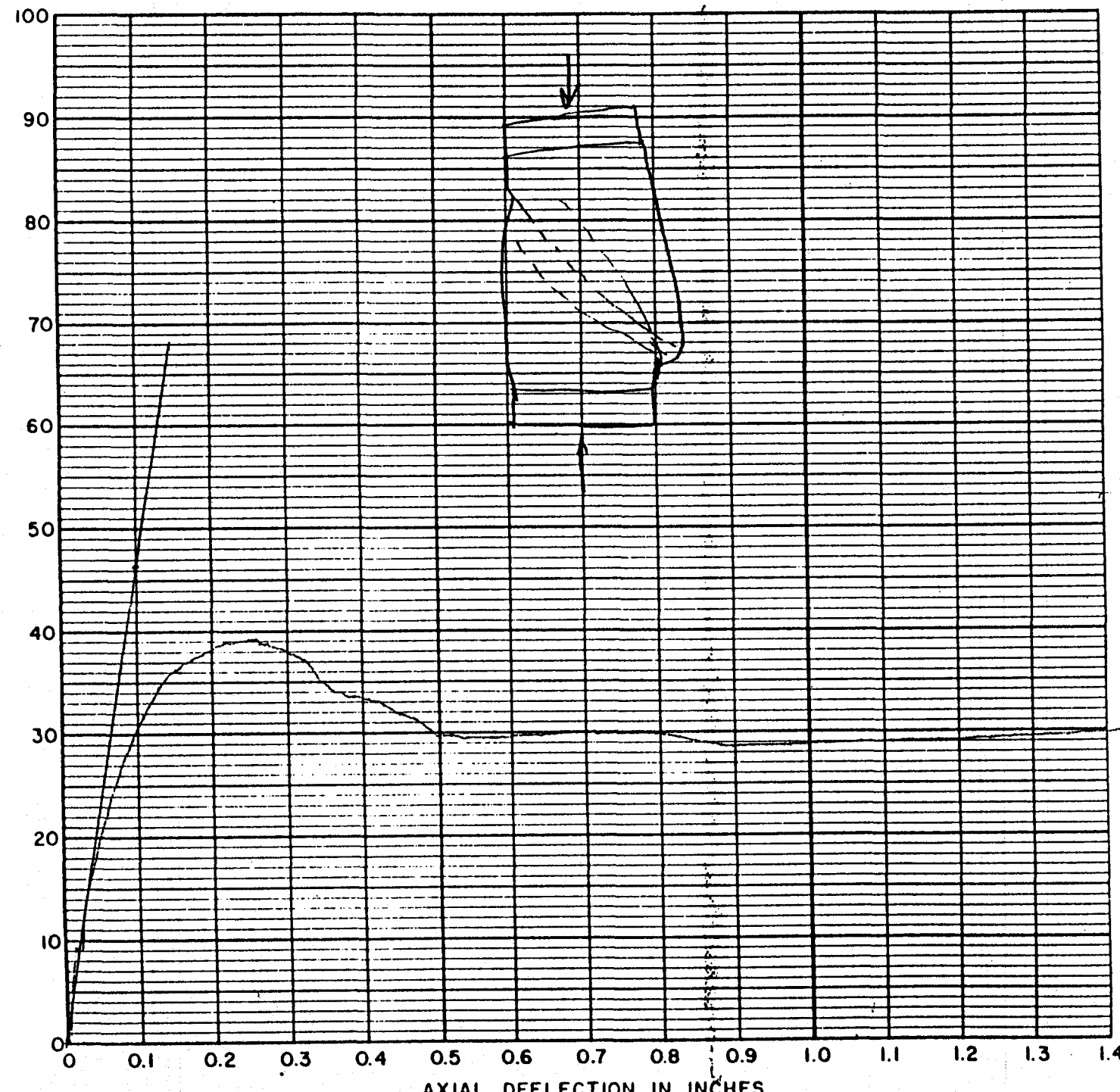
(3)

APPLIED EARTH SCIENCES

TEST DATA SHEET

30,000 load cell
2 V

% OF AXIAL LOAD RANGE: 12,000 LBS./SQ. FT.



Weight soil & dish no.	972.1	
Dry weight soil & dish	863.5	
Net loss of moisture	20.54	
Weight of dish only #1003	184.84	
Net weight of dry soil	678.7	
Moisture, % of dry weight	3%	
Wt. solids + moisture	W_o 699.2	gms
$W_o \div 454$	W'_o –	lbs
Weight solids	W_s –	gms
Wet density $W'_o \div V'_o$	97.1	pcf
Dry density	94.2	pcf
Net diameter	D_o 2.42	in.
Area ($0.785\ D_o^2$)	A_o 4.6	sq.
Height	H_o 6	in.
Volume ($A_o H_o$) ÷ 1728	V'_o	cu.
Volume ($A_o H_o$) x 16.4	V_o	cc
Specific gravity of solids	G_s	
Volume of solids $W_s \div G_s$	V_s	cc
$(V_o - V_s) \div V_s$	e_i	
Initial burette reading		cc
Burette reading under pressure		cc
$(V_p - V_s) \div V_s$	e_p	

Deflecting Speed 0.02 in. / (Hr) (Min)

Lateral Pressure 1000 / 6.9 (PSF) (PSI)

Saturated ☐ Field Moisture ☒ C D

Set-up JWS Tested JWS (SEA Office)

Soil Type SM - Silt and Fine Sand (Stratum 1)

Location Hanford, WA

Owner Kaiser Engr.

Depth 5' Sample # 2

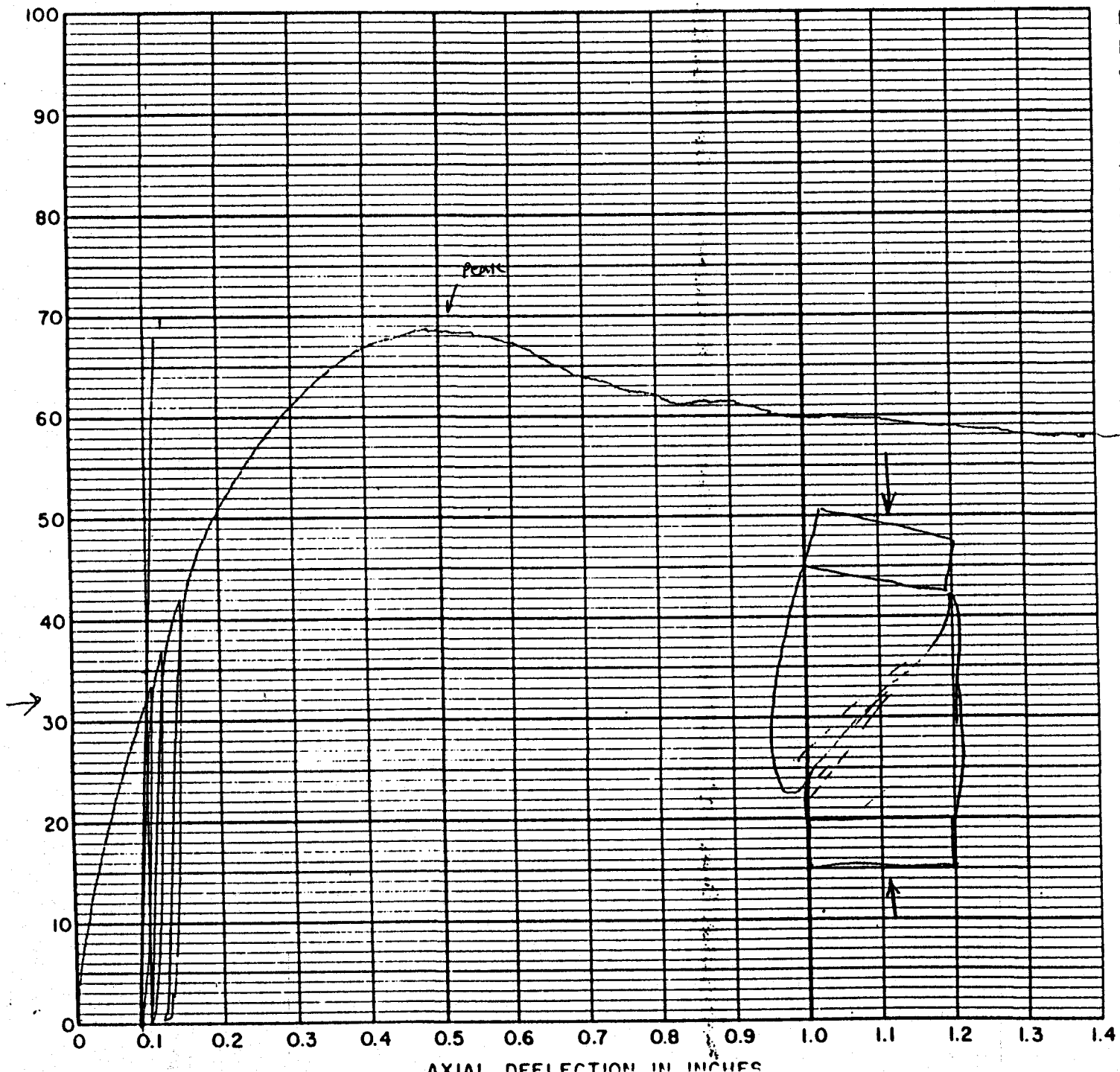
Job # 10805-378 Boring # VP-10

FORM NO. 857.46

DAMES & MOORE
APPLIED EARTH SCIENCES

TRIAXIAL COMPRESSION TEST DATA SHEET

30,000 load cell (2V)



Weight soil & dish no.	1014.8 (6	
Dry weight soil & dish	859.9	
Net loss of moisture	16.0	
Weight of dish only # 3	134.0	
Net weight of dry soil	725.0	
Moisture, % of dry weight	2.2%	
Wt. solids + moisture	W_o 741.9	gms
$W_o \div 454$	W_o' –	lbs
Weight solids	W_s –	gms
Wet density $W_o' \div V_o'$	103.0	pcf
Dry density	100.8	pcf
Net diameter	D_o 2.42	in.
Area ($0.785\ D_o^2$)	A_o 4.6	sq.
Height	H_o 6	in.
Volume ($A_o H_o$) ÷ 1728	V_o'	cu.
Volume ($A_o H_o$) x 16.4	V_o	cc
Specific gravity of solids	G_s	
Volume of solids $W_s \div G_s$	V_s	cc
$(V_o - V_s) \div V_s$	e_1	
Initial burette reading		cc
Burette reading under pressure		cc
$(V_p - V_s) \div V_s$	e_p	

Deflecting Speed 0.02 in/(Hr) Min

Lateral Pressure 2000 PSF / 13.89 PSI

Saturated ☐ Field Moisture ☒

Set-up JWS Tested JWS (SEA Office)

Soil Type SM - Silt and Fine Sand (Stratum 1)

Location Hanford, WA

Owner Kaiser Eggr.

Depth 6' Sample # 2

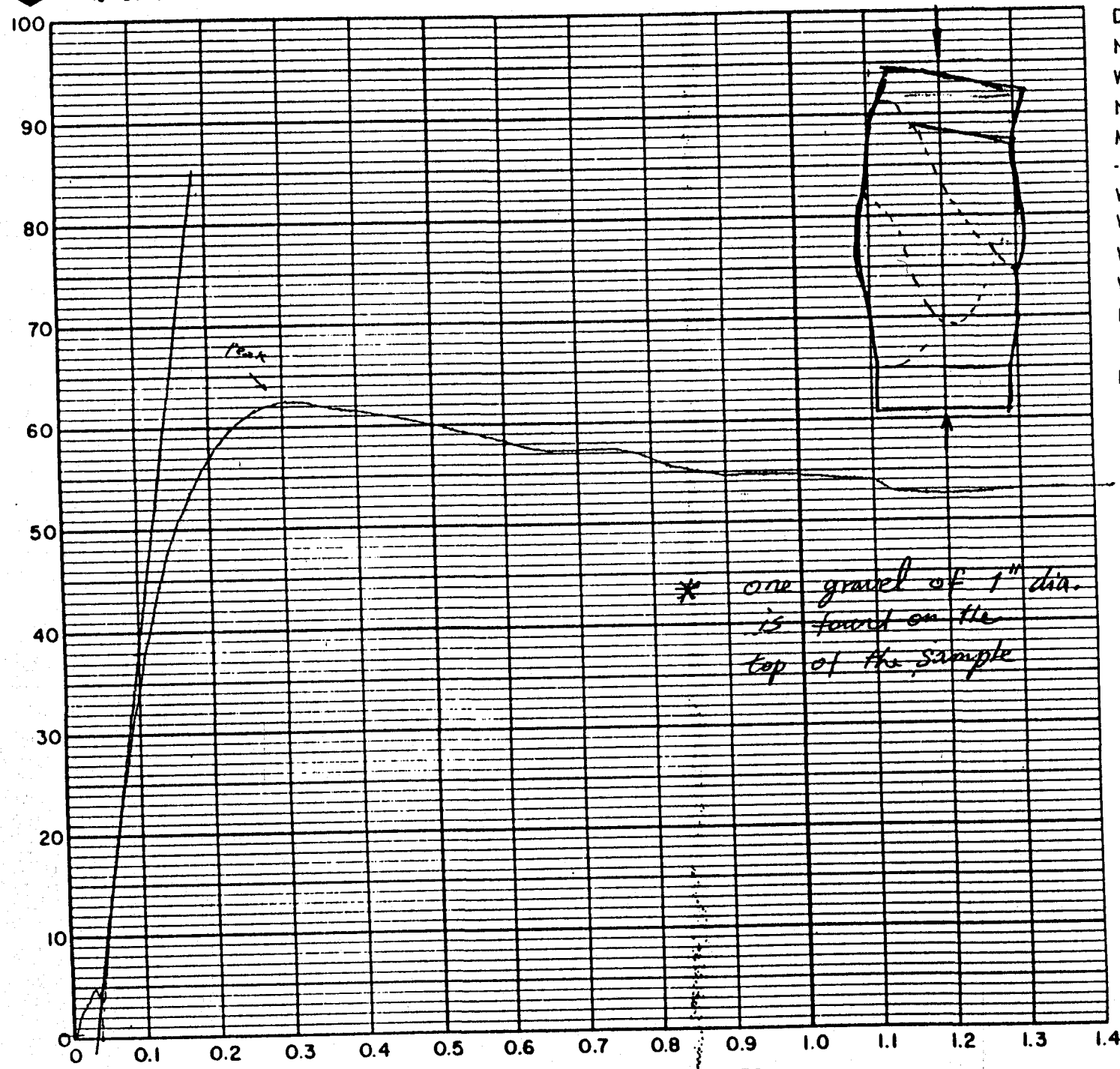
Job # 10805-398 Boring # VP-11

APPLIED EARTH SCIENCES

TEST DATA SHEET

30 ton load cell
2V.

% OF AXIAL LOAD RANGE: 12,000 LBS./SQ. FT.



Weight soil & dish no.	1034.5 16
Dry weight soil & dish	877.1
Net loss of moisture	18.6
Weight of dish only	#31 134.1
Net weight of dry soil	743.0
Moisture, % of dry weight	2.5%
Wt. solids + moisture	W_o 761.6 g
$W_o \div 454$	W'_o — lb
Weight solids	W_s — g
Wet density $W'_o \div V'_o$	105.8 p
Dry density	103.2 p
Net diameter	D_o 2.42 in
Area $(0.785\ D_o^2)$	A_o 4.6 s
Height	H_o 6 in
Volume $(A_o H_o) \div 1728$	V'_o c
Volume $(A_o H_o) \times 16.4$	V_o c
Specific gravity of solids	G_s
Volume of solids $W_s \div G_s$	V_s c
$(V_o - V_s) \div V_s$	e_i
Initial burette reading	c
Burette reading under pressure	c
$(V_p - V_s) \div V_s$	e_p

Deflecting Speed 0.02 in/Hr (Min)

Lateral Pressure 1500 10.4 (PSF) (PSI)

Saturated ☐ Field Moisture ☒

Set-up JWS Tested JWS (SEA Office)

Soil Type SM/ML - Silt and Fine Sand (Stratum 1)

Location Hanford

Owner Kaiser Engr.

Depth 3.5 Sample # 2

Job # 10805-398 Boring # VP-17

FORM NO. 857.46

BATCH START

STAPLE
OR
DIVIDER

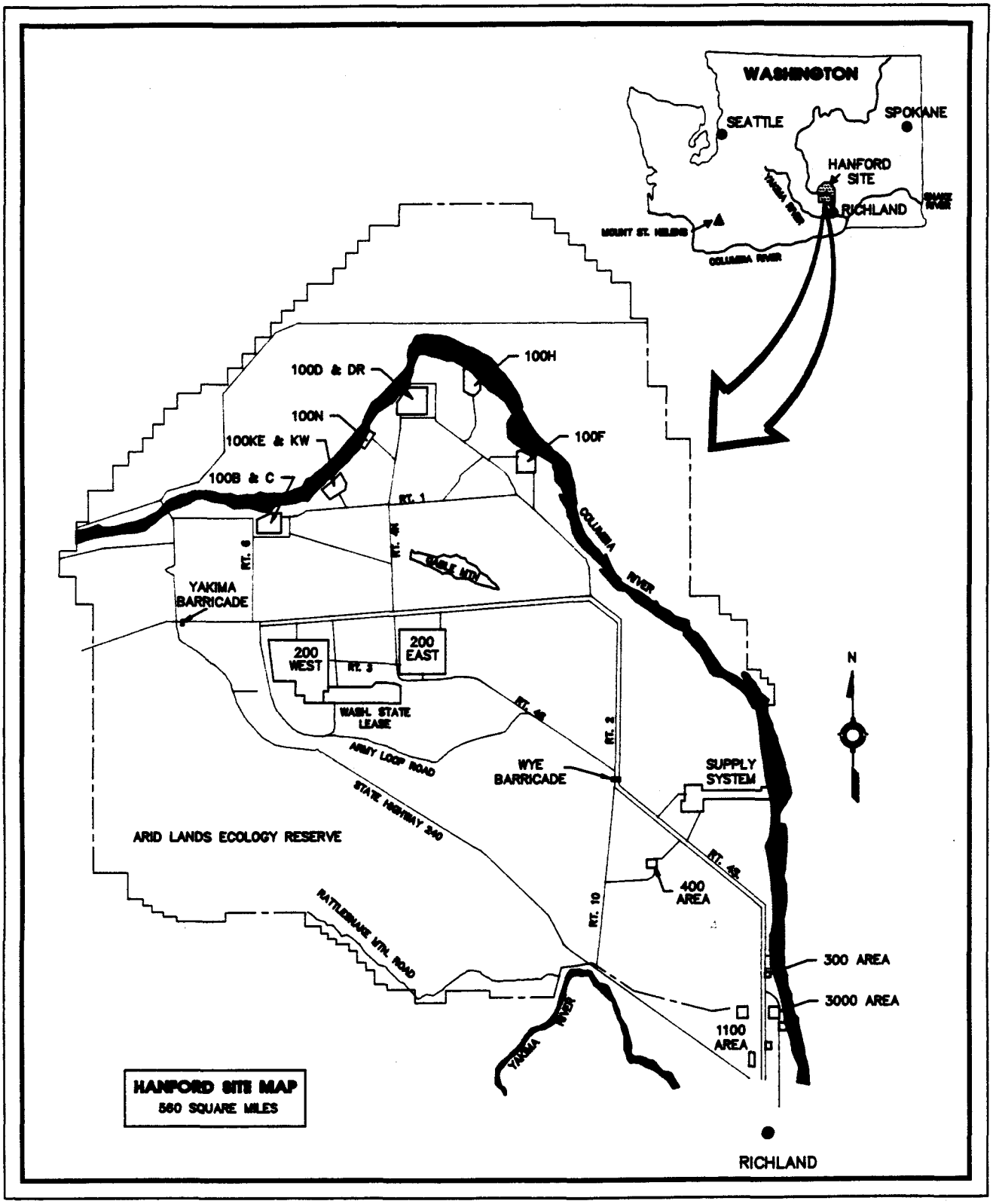
2.0 GENERAL SITE INFORMATION

The Hanford Site is owned by the United States Government and administered by the Department of Energy (DOE). It occupies a mostly flat, semiarid site of about 560 mi^2 in southeastern Washington (Figure 2-1).

The Tri-Cities Metropolitan Statistical Area (MSA) is centered along the Columbia River downstream south and southeast of the Hanford Site. It represents the major population concentration in the area with a population of about 139,600 people.

Other areas surrounding the Hanford Site are predominantly agricultural and sparsely populated.

The Hanford Site is an isolated, controlled access area that has been used for production and test reactor operations and related activities since 1943. Current major operations on the site include nuclear fuel processing and waste management activities, the Fast Flux Test Facility (FFTF), alternate energy research and development (R&D), environmental technology development, and site cleanup.



CADFILE: HIP\WASH

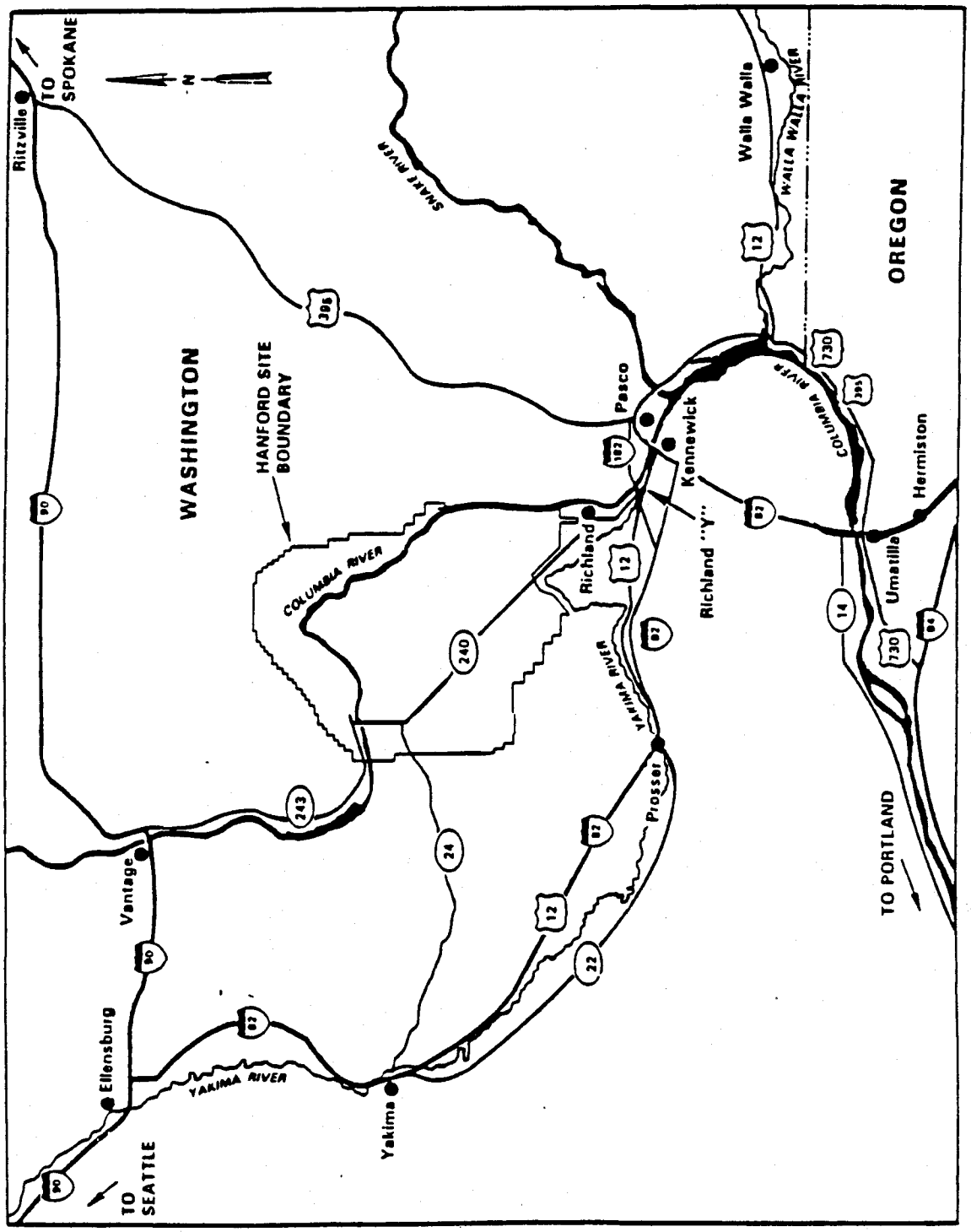
2.4 PUBLIC TRANSPORTATION

An excellent transportation network within and surrounding the Tri-Cities area facilitates travel and the marketing of goods and commodities. Commercial air transportation is available at the Tri-Cities Airport, which offers direct service to major regional cities with connections to cities nationwide via several airlines. Barge lines are used to transport bulk commodities along the Columbia and Snake rivers. A network of freight rail transportation is provided by the Burlington Northern, Washington Central, and Union Pacific railroads. Interstate highways and state routes connect the region to major metropolitan areas throughout the Pacific Northwest.

2.4.1 Road Networks

Interstate highways provide ready access to the Tri-Cities area. Interstates 84 and 90 run east/west and are located to the north and south of the Tri-Cities, respectively (Figure 2-7). These two highways are connected to the Tri-Cities by Interstate 82. These three highways provide the major links to Seattle and Spokane, Washington; Boise, Idaho; and Portland, Oregon.

Figure 2-7. Local and Regional Highway Network Linking the Tri-Cities with Major Interstate Highways.



Four important United States and state routes provide access to the major interstate highways (see Figure 2-7). The U.S. Highway 12 comes from the Puget Sound area and continues through to the Midwest via Walla Walla, Washington and Lewiston, Idaho. The U.S. Highway 395 begins north of Spokane at the Canadian border and extends to southern California. State Route 14 connects with U.S. Highway 395 to provide intrastate traffic between the Tri-Cities and Vancouver, Washington. State Route 240 provides access to Interstate 90 at Vantage. Interstate 5 connects Seattle and Portland, and runs the entire length of the West Coast (Figure 2-8).

Interstate 90 extends from Seattle through the Midwest to Chicago, Cleveland, Buffalo, and Boston.

Major highways in the Tri-Cities area carry between 30,000 and 50,000 vehicles per day. Highway capacities are generally adequate to meet highway transportation needs.

The Hanford Site is served by roadways that are owned and maintained by the DOE.

2.4.2 Airlines and Airports

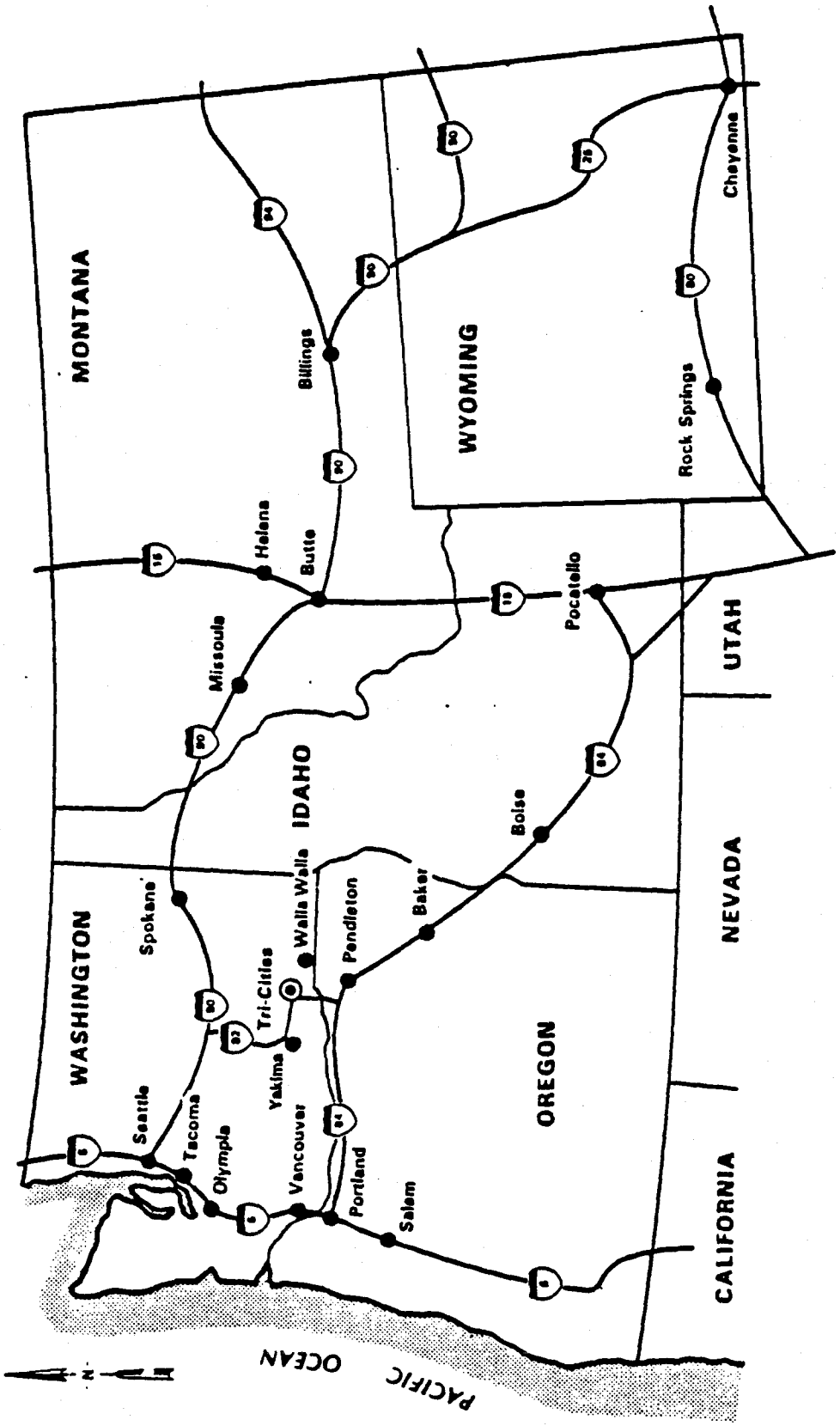
The Tri-Cities is served by four public airports, seven private airports, and six heliports. The public airports are the Tri-Cities Airport in Pasco, Vista Field in Kennewick, Richland Airport in Richland, and the Prosser Airport in Prosser. The Tri-Cities Airport is classified as an air carrier airport, Richland as a commuter service airport, and Vista Field and Prosser as general aviation airports.

The Tri-Cities Airport is the major air carrier airport in the area. A regional air facility, it serves portions of seven counties in Washington and Oregon. It is one of four air carrier airports in Washington State; the other three are Seattle-Tacoma International Airport, Spokane International Airport, and the Yakima Air Terminal.

Total annual commercial passenger boardings at the Tri-Cities airport by year since 1985 are as follows:

- 1985--142,911
- 1986--189,994
- 1987--180,934
- 1988--160,121
- 1989--158,598.

Figure 2-8. Major Pacific Northwest Interstate Highways Providing Access to the Tri-Cities.



Projected commercial passenger boardings for 1990, as of January 1990, are in a range of 160,000 to 170,000. Current air carriers include Delta, United Express, and Horizon Air.

A new 58,000 ft^2 terminal building, completed in 1986, provides state-of-the-art air traffic control, ticketing, baggage handling, and related services for Tri-Cities airline customers. Convenient features of the airport include adjacent parking facilities operated by the Port of Pasco, numerous automobile rental agencies, and passenger transport services to all Tri-Cities points by the Ben Franklin Transit Authority.

2.4.3 Railroads

The Tri-Cities is served by the Burlington Northern, Washington Central, and Union Pacific Railroads, making the area one of the few between the Cascade Range and the Rocky Mountains to be linked by these systems. Passenger services are provided by Amtrak. In addition, a short line, operated by the DOE, runs in the Richland/Hanford Site area.

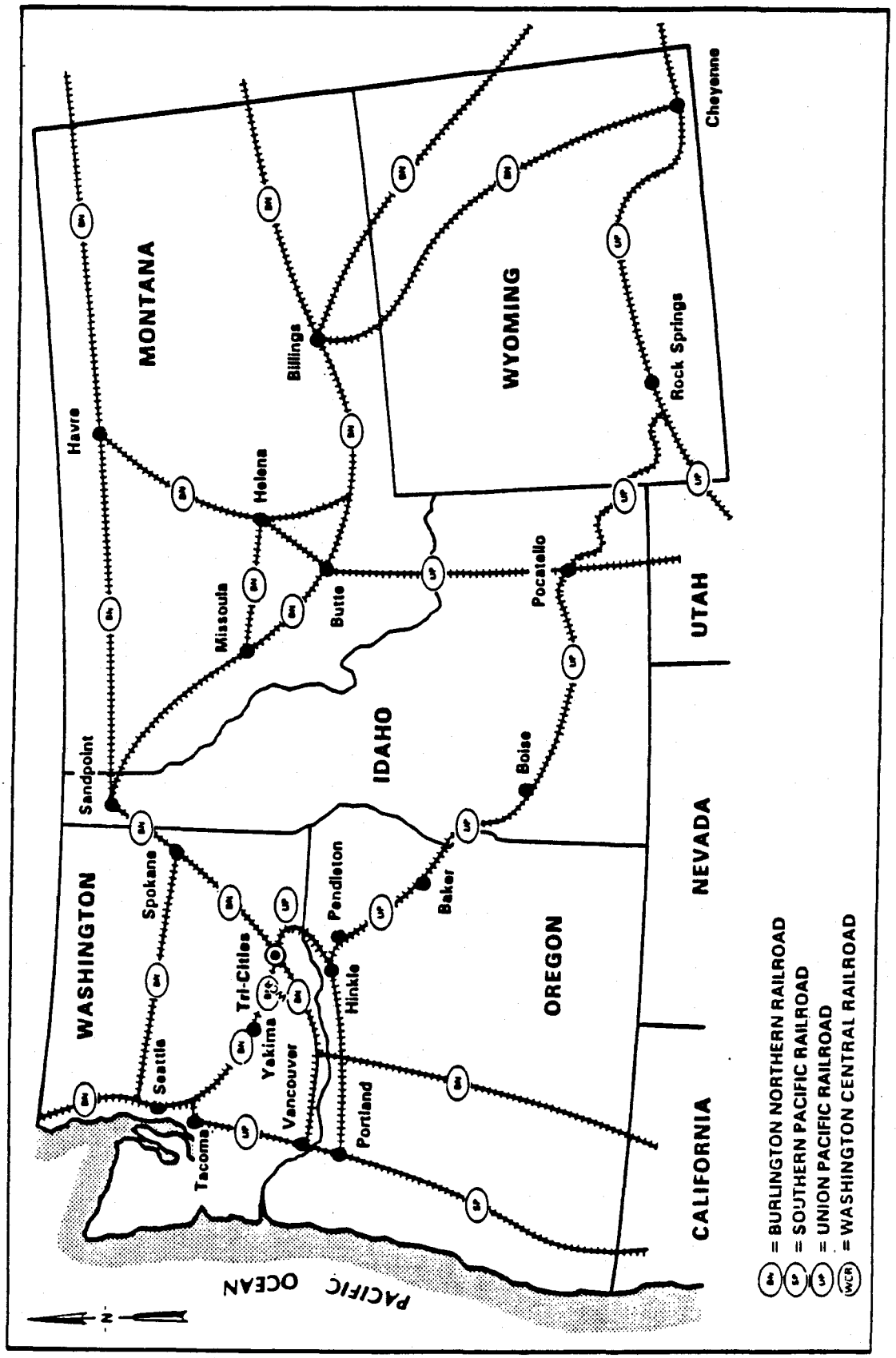
Agricultural products, fuel, and fertilizer, plus construction materials and equipment, are the principal commodities shipped by rail. Manufactured fertilizer products, grain, and frozen food make up the greatest share of outgoing commodities. Large quantities of other food products also leave the Tri-Cities by rail. The inbound freight includes fertilizer, raw material, chemical, fuel, farm equipment, and construction supplies and equipment.

The Tri-Cities is the hub of the Burlington Northern lines in the Pacific Northwest, which extends 232 mi southwest to Portland, 145 mi northeast to Spokane, and 251 mi northwest to Seattle (Figure 2-9). Washington Central Railroad recently acquired the Burlington Northern line between the Tri-Cities and Yakima. A computerized classification yard is located in Pasco. Trains move into the yard and are broken up and blocked to move east, west, north, or south.

The Union Pacific connects the Pacific Northwest and the cities of San Francisco and Los Angeles on the West coast to the Great Lakes region and the Gulf of Mexico to the east and southeast, respectively. All service to the Pacific Northwest over the Union Pacific system goes through the modern, computerized regional classification yard at Hinkle, Oregon, approximately 50 mi south of the Tri-Cities. The Tri-Cities is serviced by the Yakima branch line, which connects directly to the regional classification yard at Hinkle.

The DOE controls the rail access into the Hanford Site; their tracks tie into the Union Pacific tracks southeast of the Richland "Y" area near U.S. Highway 12. The Washington Central Railroad Company and Union Pacific have trackage rights over the DOE trackage between the Richland "Y" area and the DOE 1100 Area in north Richland. The DOE tracks serving the Hanford Site are parallel to the Route 240 bypass.

Figure 2-9. Major Pacific Northwest Rail Lines Providing Access to the Tri-Cities.



2.4.4 Waterways

The Columbia-Snake River System is one of the most modern internodal transportation networks in the world. This commercial waterway extends 465 mi from the Pacific Ocean to Lewiston, Idaho. The system includes eight dams and lock complexes that allow the numerous barge lines serving the river system to transport commodities. The Panamax vessels, which transport the commodities, are operated by 35 steamship lines that call at several ports along the 40-ft channel in the lower Columbia River. The lower Columbia River ports offer the shortest route to the Orient, which is approximately 4,217 nautical miles from the mouth of the river to Japan.

Numerous docking facilities in the Tri-Cities are available for commercial use or for serving specific industries. These facilities are only 325 mi inland from the Pacific Ocean and offer an average barge movement time of 36 h to the deepwater ports in the lower Columbia River.

Several barge companies currently offer service to the Tri-Cities area with specialized barges that handle a wide variety of cargo. These barge companies have Interstate Commerce Commission authority to the Tri-Cities area and provide service up the Snake River to ports as far inland as Clarkston, Washington, and Lewiston, Idaho.

2.4.5 Public Transit

The Ben Franklin Transit Authority serves the Tri-Cities MSA in Benton and Franklin Counties. It operates buses on 15 routes spanning 300 mi. Service includes regular and express bus service, van pools, dial-a-ride for the elderly and disabled, park-and-ride lots, and computerized ride matching.

2.5 UTILITIES

Electricity is the only regional utility service supplied to the Hanford Site. Utilities located onsite are described in Section 3.4.1.

Table 2-5 summarizes the energy consumption and costs for all the areas of the Hanford Site from 1985 to 1988.

Table 2-5. Energy Consumption and Costs for Buildings and Facilities on the Hanford Site from 1985 to 1988.

Energy source (unit)	Year	Consumption	Total cost (x $1,000)	Actual unit cost ($)
Electricity (MWh)	1985	542,253	11,847.9	21.85
	1986	539,527	11,753.6	21.78
	1987	510,109	10,876.3	21.32
	1988	497,337	11,486.7	23.09
Fuel oil (1,000 gal)	1985	8,039	5,739.5	713.96
	1986	6,967	3,954.6	567.62
	1987	2,847	1,075.9	377.94
	1988	3,028	1,295.6	427.93
Natural gas (1,000 ft^3)	1985	14,984	98.8	6.59
	1986	23,409	136.4	5.83
	1987	18,223	87.9	4.82
	1988	16,400	114.5	6.98
Liquified petroleum gas (1,000 gal)	1985	17.4	12.6	724.14
	1986	17.2	12.1	703.49
	1987	14.4	9.8	680.55
	1988	874.6	400.4	457.78
Coal (short tons)	1985	114,079	5,797.29	50.82
	1986	133,755	7,843.45	58.64
	1987	101,339	6,066.52	59.86
	1988	101,210	6,085.62	60.12

2.5.1 Electricity

Except for a minor amount of total Site needs provided by the City of Richland to the 700, 1100, and 3000 Areas, electricity for the Hanford Site is supplied by the BPA. Currently, the Northwest generates a surplus of power, but unofficial projections now estimate that the surplus will be fully utilized within the next 10 yr or less depending on the strength of the economy, usage growth, and export to other regions.

The DOE's contract with the BPA gives the Hanford Site a Priority Firm supply rating. This rating ensures that in the event of regional power shortages, the Hanford Site, along with other Priority Firm customers, would be the last level of BPA service to be shut off.

3.5 PHYSICAL CHARACTERISTICS

This section describes the natural factors and associated constraints of the Hanford Site. The following topics are covered: geomorphology and slopes, stratigraphy, soils, geology/structures, hydrology, ~~wetlands, wildlife, vegetation, ecological areas, endangered species~~, meteorology, and climatology.

3.5.1 Physiography and Geomorphology

The Hanford Site is located within the Columbia Intermontane Physiographic Province, which is bounded on the east by the Rocky Mountains and on the west by the Cascade Range. The Site lies in the Pasco Basin, a major topographic and structural basin within the province. The Saddle Mountains form the northern boundary of the Site and Rattlesnake Mountain and the Rattlesnake Hills form the southern boundary. Umtanum Ridge with its eastern extensions, Gable Mountain and Gable Butte, divide the Site into northern and southern parts.

Elevations at the Site range from 345 ft near the Columbia River in the SE corner of the Site to 3,586 ft above mean sea level (MSL) on Rattlesnake Mountain along the southwestern border of the site. The immediate Hanford Site (between Highway 240 and the Columbia River) comprises about 310 mi^2 of terrain, 180 mi^2 of which have slopes that are less than two percent. In the south central part of the Site, where the main waste management operations are located, elevations range from 620 to 800 ft above MSL.

The highest elevations on the Hanford Site occur on basalt ridges. The intervening valleys are depositional basins. The basalt ridges resulted from tectonic forces, which folded and faulted basalt flows of the Columbia River Basalt Group. The depositional basins have been accumulating sediments since the Miocene Era (17 million yr ago).

The geomorphology of the south central Hanford Site is the product of two primary geomorphic processes: Pleistocene cataclysmic flooding, and Holocene eolian activity. The cataclysmic flooding, which ended 13,000 yr ago, created the Cold Creek bar, the prominent bench on which the 200 Areas are located. The last floods covered the 200 Areas with a blanket of coarse-grained deposits. Since the end of the Pleistocene, winds have deposited a thin veneer of eolian sand in places. Alluvium deposits occur south of the 200 Areas in the Cold Creek-Dry Creek alluvial plain.

3.5.2 Stratigraphy

There are three principal geologic units beneath the Hanford Site: the Columbia River Basalt Group with interbedded sediments of the Ellensburg Formation, the Ringold Formation, and the Hanford formation (Figure 3-14). The Columbia River Basalt Group, which is over 11,000 ft thick, was emplaced between 6 and 17 million yr ago. These basalt flows are interbedded with and overlain by Miocene-Pliocene epiclastic and volcaniclastic sediments of the Ellensburg Formation.

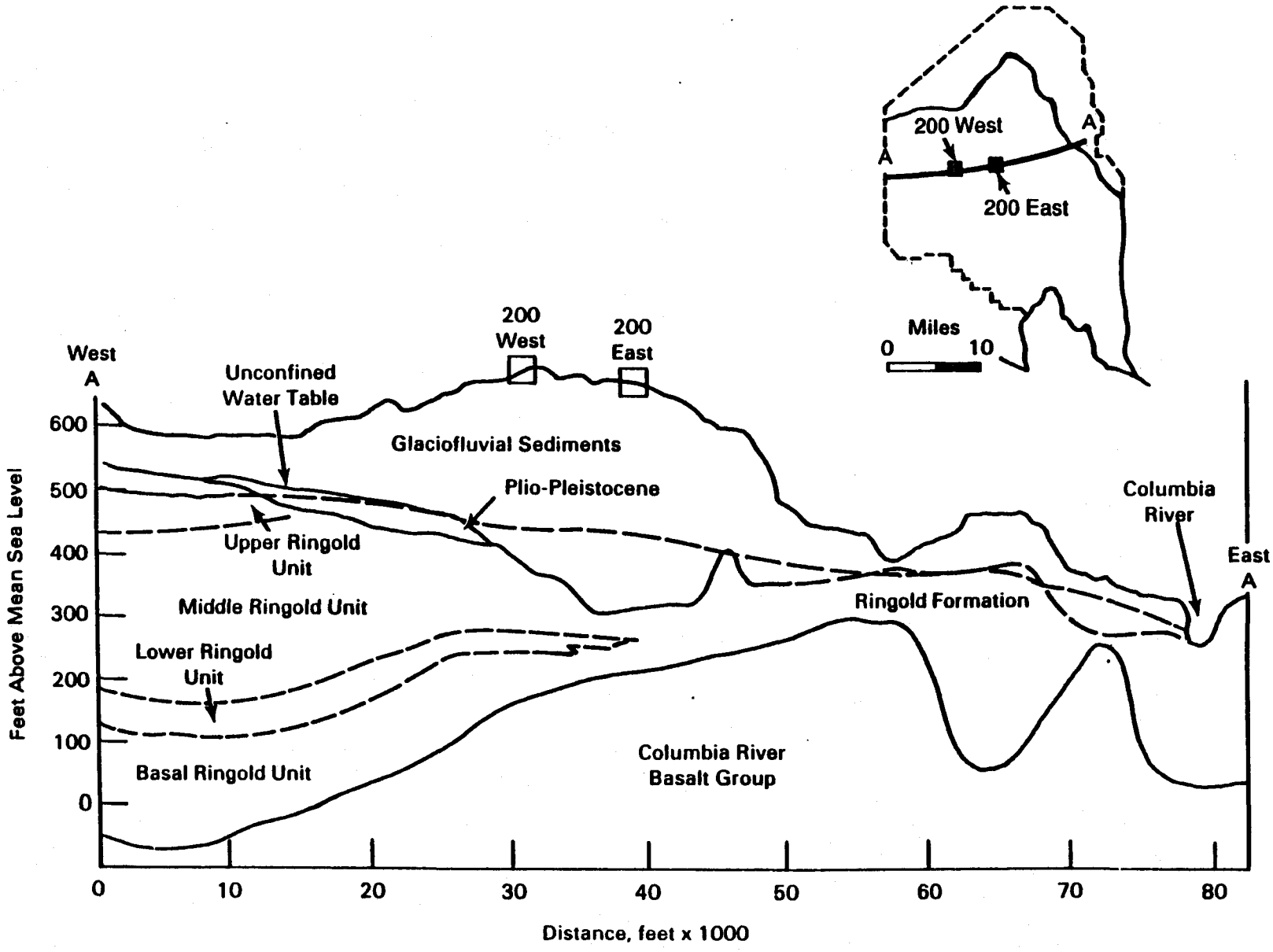


Figure 3-14. Geologic Cross-Section of the Hanford Site.

The sediments of the Hanford formation over lie the Miocene-Pliocene Ringold Formation, a Plio-Pleistocene sedimentary deposit, and the Columbia River Basalt Group. The Hanford formation was deposited by catastrophic floods when glacial dams in western Montana and northern Idaho were breached and large volumes of glacial melt water spilled abruptly across eastern and central Washington. The last major depositional sequence from such flooding has been dated at about 13,000 yr ago. The Hanford formation consists of the fine-grained toucher beds, which are slack water deposits, and the Pasco Gravels.

3.5.3 Soils

Fifteen different soil types have been identified on the Hanford Site (no data are available for the area across the Columbia River):

- Ritzville silt loam
- Rupert sand
- Hezel sand
- Koehler sand
- Burbank loamy sand
- Ephrata sandy loam
- Lickskillet silt loam
- Ephrata stony loam
- Kiona silt loam
- Warden silt loam
- Scootney stony silt loam
- Pasco silt loam
- Esquatzel silt loam
- Riverwash
- Dunesand.

At the lower elevations on the Site (mainly the central, eastern, and southeastern portions), the predominant soil type is Burbank loamy sand. Although some Burbank loamy sand is found in the northern portion of the Site, the major type located there is Ephrata sandy loam.

At the higher elevations (the ALE and Rattlesnake Mountain), there are nine different soil types scattered throughout the area. The predominant soil is Warden silt loam, with Ritzville silt loam and Hezel sand secondary.

The remaining six types are present in smaller amounts, but again are scattered widely throughout the area.

A large amount of Dunesand (several square miles) is located just to the north of the Supply System-leased land with several smaller areas west of the Wye Barricade between there and State Route 240. These are the only locations on the Hanford Site where Dunesand appears.

3.5.4 Geology/Structures

The Hanford Site is in the geologic region known as the Columbia Plateau. The Columbia Plateau is a broad plain made up of basalt flows of the Columbia River Basalt Group, and intercalated and overlying sedimentary rocks. The Hanford Site lies within the eastern part of the Yakima Fold Belt, a series of anticlinal ridges and synclinal valleys in the western part of the Columbia Plateau. The Yakima Fold Belt developed as the basalt flows were faulted and folded during the past 17 million yr by forces generated by plate tectonic activity in the Pacific Northwest.

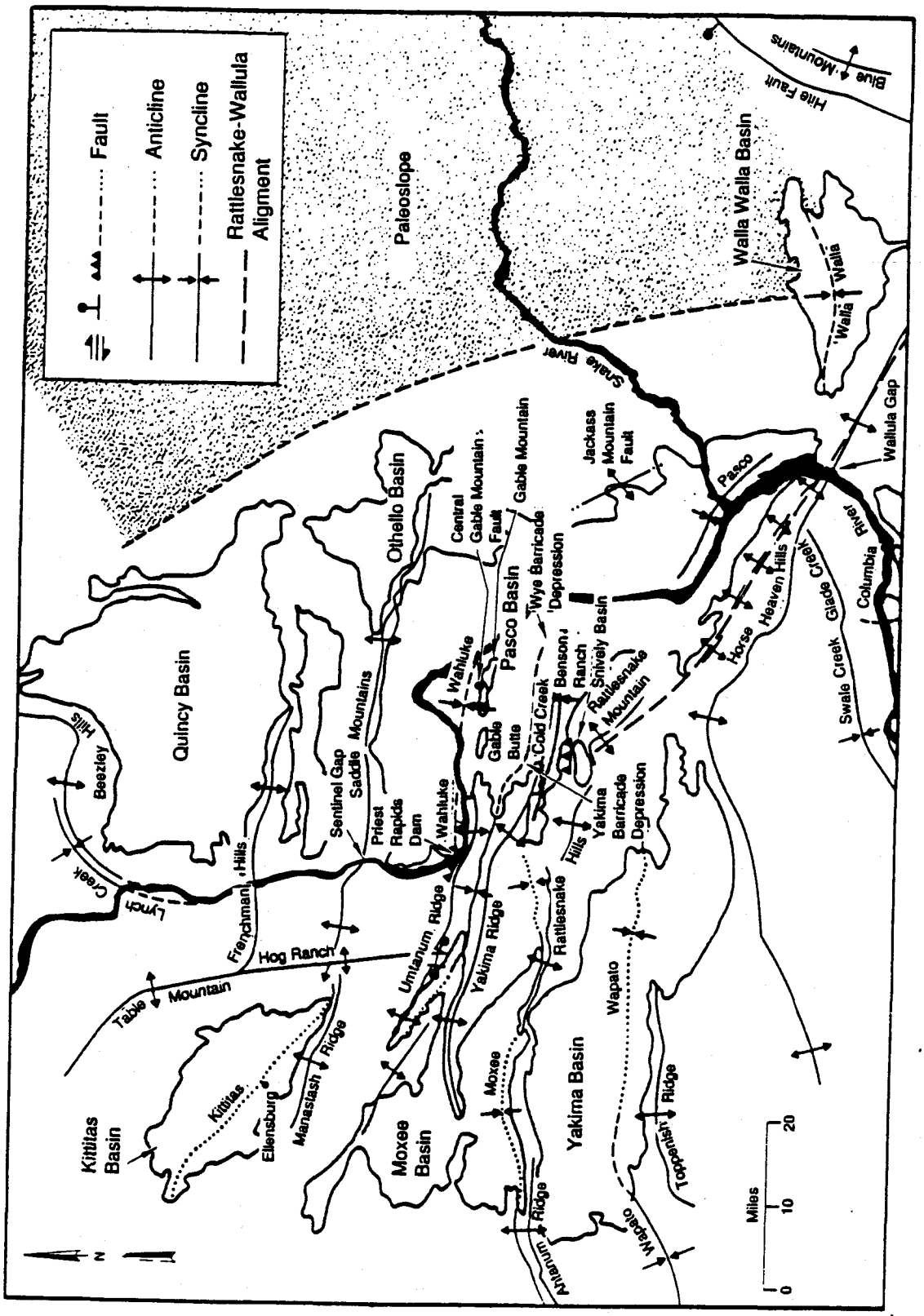
Geologic activities currently at the Hanford Site are directed toward supporting waste management and hazardous waste cleanup activities. These activities include geologic and hydrologic characterization of the Hanford Site, and seismic monitoring activities.

3.5.4.1 Geologic History. The geologic development of the Hanford Site is closely linked to the geologic history of the Pacific Northwest. The present geologic features of the Site are the product of Plate Tectonic activity off the west coast of North America. The pre-Cenozoic history of the Pacific Northwest is dominated by the accretion of lithospheric plates to the North American continent. The Cenozoic history is dominated by mountain building and igneous activity. THe Hanford Site lies in an area of past volcanic activity.

The geologic history of the Hanford Site is directly tied to the volcanic eruptions of the Columbia River Basalt Group and the deformational processes that occurred simultaneously with and after the eruptions. The Columbia River basalt is one of the world's youngest and smallest continental flood-basalt provinces. Beginning about 17 million yr ago, large volumes of basaltic lava were extruded from fissures along the eastern border of Washington, Oregon and western Idaho. The basalts flowed westward down a preexisting paleoslope, some spreading as far west as the Pacific Ocean. The Columbia River Basalt Group eventually covered 164,000 km^2 and have a total volume of 175,000 km^3. The last basalt flow occurred 6 million yr ago at the end of the Miocene.

Simultaneously with the eruptions, the area was undergoing north-south directed compression which resulted in folding and faulting of the basalt flows. The present ridges that bound the Site are anticlinal ridges and the valleys are synclinal structures. These anticlinal structures and synclinal valleys continued to grow after basaltic volcanism ceased on the Columbia Plateau. The present relief developed in the 10 million yr since the last basalt was erupted. Present tectonic activity is very low as indicated by the absence of active faults and the very low microseismic activity. A generalized geologic structure map is shown in Figure 3-15..

Figure 3-15. Generalized Geologic Structure Map of the Central Columbia Plateau.



Since the end of the Columbia River Basalt Group volcanic eruptions, the area received sediments of the Pliocene Ringold Formation and the Pleistocene Hanford formation. Ringold sediments were derived from the ancestral Columbia River and were deposited in the synclinal valleys. Overlying the Ringold sediments are glacial-fluvial sediments deposited by catastrophic flood waters of glacial-lake Missoula. The last flood occurred over 13,000 yr ago but prior to that the area was inundated many times by these floods. The 200 Areas plateau is a flood bar formed by these floods.

3.5.4.2 Structural Geology of the Hanford Site. The principal geologic structures at the Hanford Site are folds that formed the anticlinal ridges and the synclinal valleys.* As the folds developed, the basalt flows shattered and fractured forming faults. Figure 3-16 is a structure map of the Hanford Site and adjacent area showing the location of the principal fold and faults. The principal fault zones are confined to the north flanks of the anticlinal ridges and are frontal faults that developed as the anticlines grew. The greatest amount of tectonic jointing and faulting occurs along the axes of the anticlinal ridges in the hinge zones and in the more steeply dipping beds. Very little faulting occurs in the synclinal valleys. Fault in the synclines are typically small faults occurring in conjugate pairs and usually limited to individual basalt flows or strata. There is no evidence of major through-going faults in the synclinal areas.

Detailed investigations at the Hanford Site over the past 20 yr have shown that there are no active faults on the Site. In general, faults in the Hanford Site show no evidence for movement younger than 13,000 yr before present and most have not moved in the last 50,000 yr or more. The Rattlesnake Mountain fault is the largest fault on the Site and is assumed capable.** This fault is part of the Rattlesnake-Wallula deformed zone that extends from Rattlesnake Mountain to Wallula Gap on the Columbia River. Five faults on Gable Mountain are also considered capable but the Nuclear Regulatory Commission (NRC) and the U.S. Geological Survey consider these faults to have low seismic potential. A conservative approach was taken during reactor construction at the Hanford Site in the past. Those faults for which evidence was inconclusive, as to capability, were considered capable. This conservative approach is currently used on the Site.

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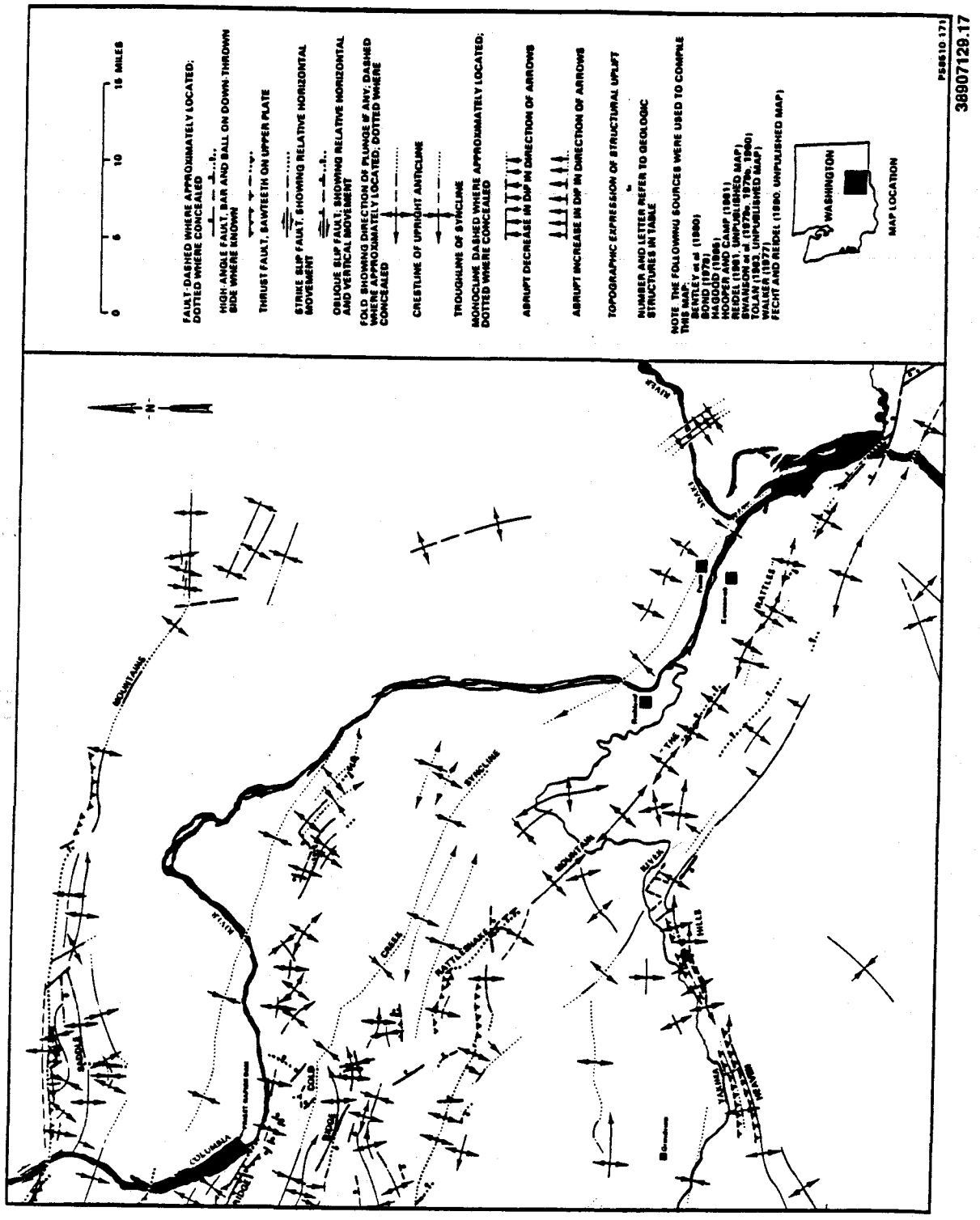
*Anticlines are folds in which layered strata are folded downward and away from the axes (convex downward). Synclines are folds which are convex upward.

**Appendix A of 10 CFR 100 defines a capable fault as having exhibited one or more of the following characteristics:

- Movement at or near the ground surface at least once within the past 35,000 yr or movement of a recurring nature within the last 500,000 yr
- Macro-seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault
- A structural relationship to a capable fault according to one of the two characteristics above such that movement on one could be reasonably expected to be accompanied by movement on the other.

Figure 3-16. Structure Map of the Hanford Site and Surrounding Area.



3.5.4.3 Earthquake Potential. Before 1969, the instrumental detection of earthquakes in eastern Washington State, northeastern Oregon, and northern Idaho was limited to a few events that were sufficiently large to have been recorded by the sparse network of stations that existed. This restricted the instrumental record to events that were generally larger than Richter magnitude 4. Since the installation of additional networks in 1969 by the U.S. Geological Survey, the University of Washington and the BWIP, the instrumental record has become far more complete and accurate.

There have been a few seismic events in eastern Washington that warrant discussion because of their possible significance to the Hanford Site.

On December 4, 1872, a major earthquake occurred in the vicinity of north-central Washington State. Because of the sparse population and lack of recording instruments at that time, the location and size of this earthquake are uncertain. A Washington Public Power Supply System study concluded that the earthquake occurred within the Northern Cascades tectonic province in a broad meizoseismal zone extending northward from the vicinity of Lake Chelan to southern British Columbia. The NRC concluded that the boundary between the North Cascades tectonic province and the Columbia Plateau is about 140 km (88 mi) north of the Hanford Site at its closest approach (NRC 1982).

On March 5, 1893, an earthquake occurred near Umatilla, Oregon, which is about 70 km (44 mi) south of the Hanford Site. Early estimates suggested that this earthquake had a maximum MM intensity of VII, but this was subsequently reduced to MM intensity VI (WPPSS 1981, p. 123).

An earthquake occurred in the vicinity of the Saddle Mountains and Frenchman Hills on November 1, 1918, which was followed by several, smaller events over subsequent weeks. The original report of this event (BSSA 1918; WPPSS 1981, p. 2.5-120) estimated a Rossi-Forel epicentral intensity of IV, which is equivalent to an MM intensity IV to V (Richter 1958, Appendix III). Recently, the instrumental location and magnitude of this event have been estimated from the lone seismogram recorded at Spokane or station SPO (WPPSS 1981, pp. 2.5J-36 to -37). A surface-wave magnitude of 4.4 was estimated on the basis of the recorded waveform and an empirical moment-magnitude relationship (WPPSS 1981, p. 2.5J-36).

The largest earthquake known to have occurred within the Columbia Plateau was the July 16, 1936, Milton-Freewater, Oregon, earthquake. This earthquake was felt over much of eastern Washington State and northeastern Oregon and was accompanied by a number of foreshocks and aftershocks (Rasmussen 1967, p. 468; WCC 1980, p. 28). The maximum epicentral intensity was estimated to be MM VII, and the surface-wave magnitude was originally estimated to be 5-3/4 (Gutenberg and Richter 1965, p. 164). An evaluation of Gutenberg's original seismographic data suggested that the Richter magnitude could be as high as 6.1 (WCC 1980, p. 12). A reevaluation using station corrections (WCC 1982) yielded a surface wave magnitude of 5.7 to 5.8 (NRC 1982, G-17).

The location of the 1936 earthquake and, therefore, its association with a known geologic structure are uncertain. A summary of the various locations of the event is given in WCC (1980). Most recently, WCC (1980) estimated a location at 46° 12.3′ N, 118° 14.0′ W from a reexamination of the instrumental data.

On December 20, 1973, a coda magnitude 4.4 earthquake occurred near the same location as the November 1, 1918 event. This was a shallow earthquake, near the base of the basalt and was followed by numerous aftershocks and swarm type activity over the next few months (Malone et al. 1975; BSSA Vol. 65, No. 4, pp. 855-864).

A code-length magnitude 4.1 earthquake occurred near College Place, Washington, on April 8, 1979. This was a shallow event with a focal depth of between 3 and 6 km (1.9 to 3.7 mi).

The historic record of events with epicentral intensities of MM IV or greater (Figure 3-17) and the seismographic record of events of magnitude 3 or greater (Figure 3-18) are remarkably similar, and indicate that the major seismicity of the Columbia Plateau is broadly scattered. The instrumental seismic record, which commenced in 1969, reveals that areas of concentrated seismicity occur near Lake Chelan and in the central Columbia Plateau.

Most of the currently observed seismicity of the central Columbia Plateau is concentrated between the Saddle Mountains and Frenchman Hills, and between the Saddle Mountains and the Gable Mountain-Gable Butte area. The regional detection threshold has varied over time as the seismographic coverage has evolved (WPPSS 1981, Table 2.5J-1) but for events of magnitude 2 or greater, concentrations have persisted (WPPSS 1981, p. 2.5J-14).

The densest groups of epicenters are swarms. An earthquake swarm may be defined as a cluster of events of comparable magnitude that first wax and then wane in number with no one outstanding event; the main criterion here is that no "outstanding" (large) event occurs. An outstanding event is considered a mainshock, and any earthquakes that precede or follow it are considered foreshock or aftershock activity. However, because of the low seismicity rates and generally small magnitudes of events that have been observed in the central plateau region (roughly 90% have magnitudes of 2 or less), the distinction between swarm and nonswarm activity is not always clear.

Based on the seismic record, Columbia Plateau seismicity segregates by depth into three zones: 0-4 km, 4-8 km, and deeper than 8 km (WPPSS 1981, Figure 2.5J-11 to -14). On the order of 90% of the seismicity occurs at depths less than 8 km, and most of this shallow seismicity (70-80%) occurs in the uppermost 4 km (2.5 mi) (WPPSS 1981, pp. 2.5J-15 to -17). No seismicity has been observed below the local Moho depth of 30 km. These shallow, intermediate, and deep zones coincide approximately with zones of basalt, sub-basalt sediment, and crystalline basement.

In the subsequent discussions, the seismicity of the shallow and intermediate zones are discussed together.

Figure 3-17. Historical Seismicity of the Columbia Plateau and Surrounding Areas, Pre-1969.

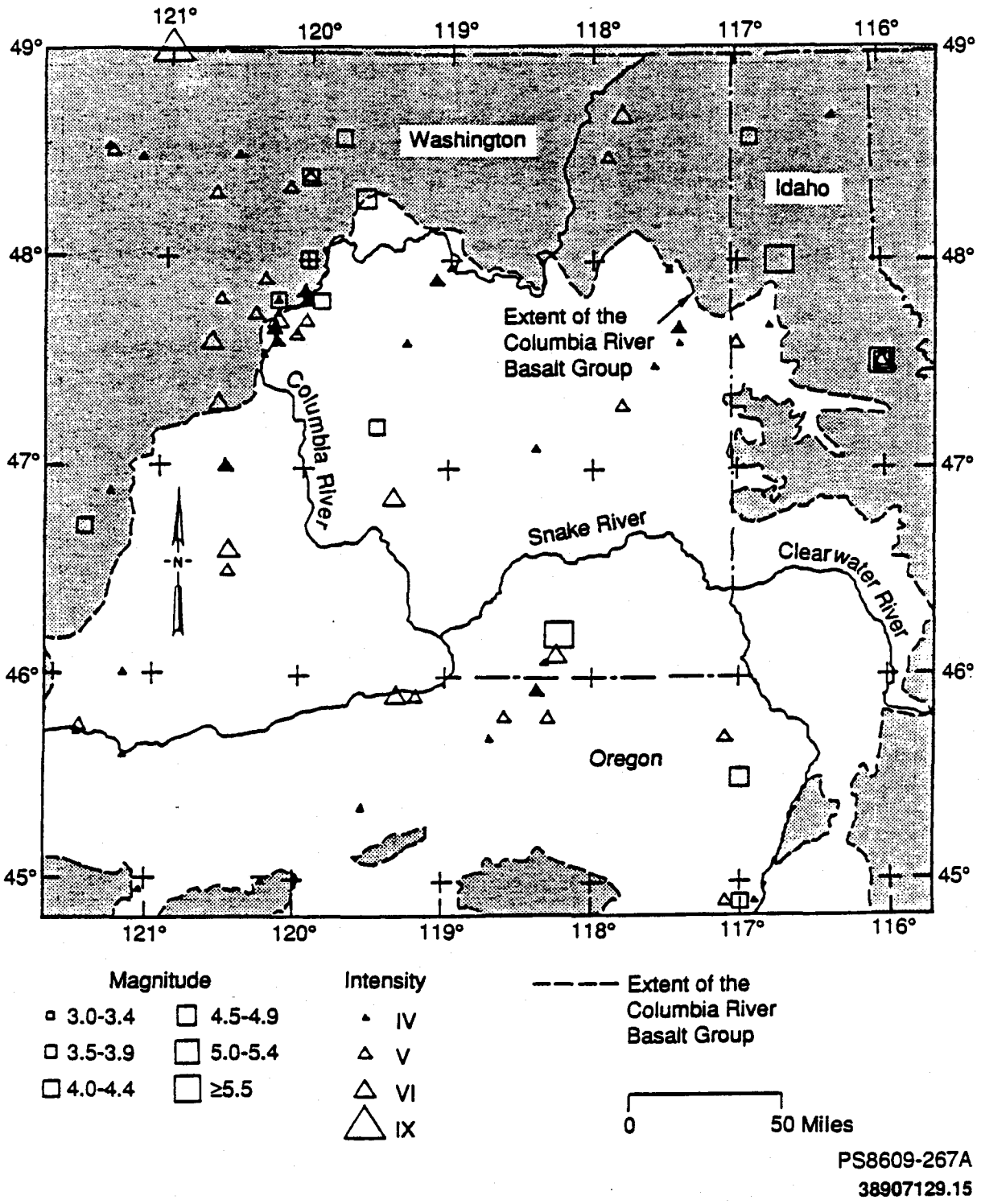
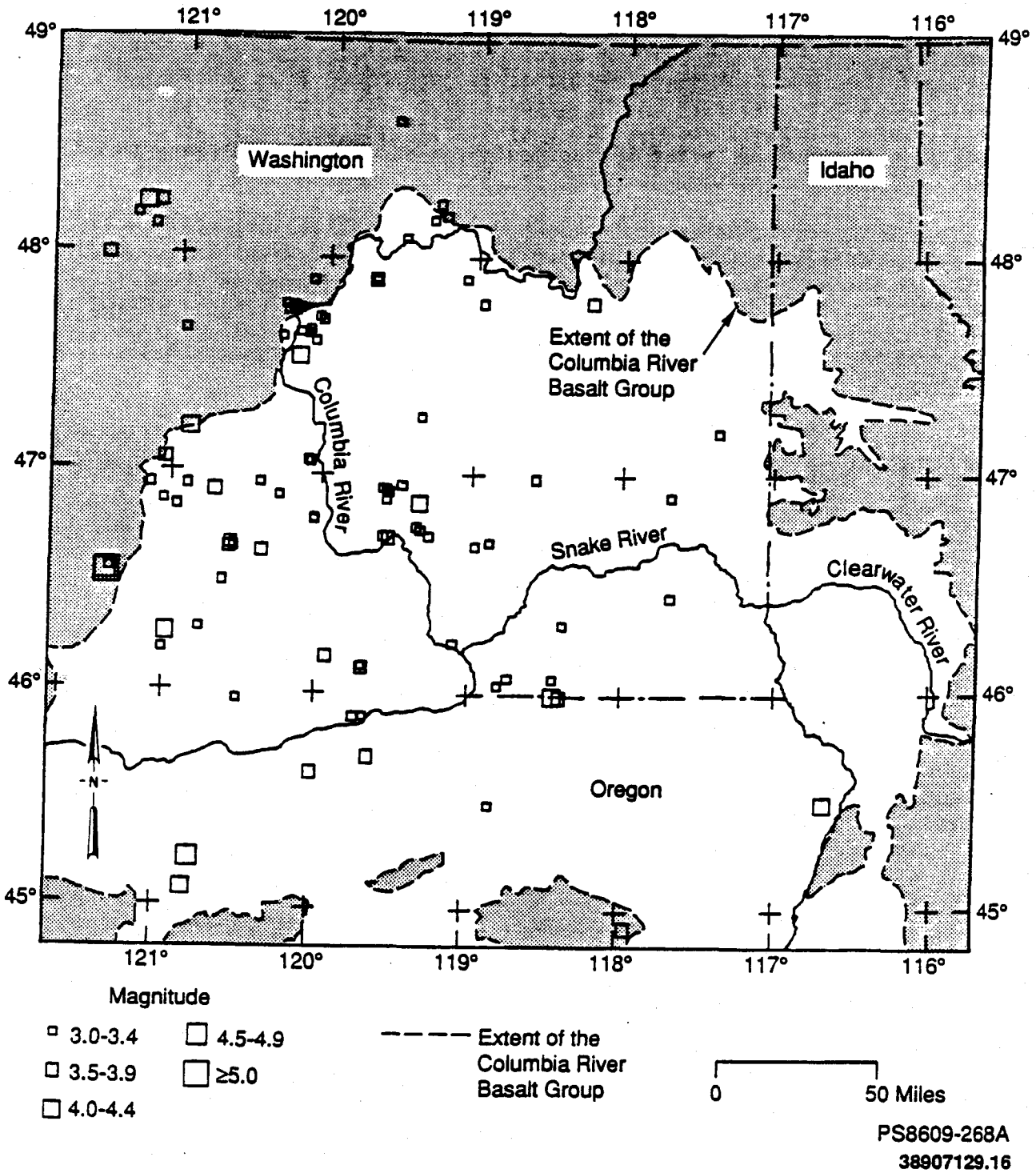


Figure 3-18. Recent Seismographic Seismicity of the Columbia Plateau and Surrounding Areas Since 1969.



Most central Columbia Plateau earthquakes are located at depths less than 8 km (5 mi) and occur north and northeast of the Columbia River. The shallowest seismicity is predominantly swarm activity.

Using well-located events, UWGP (1979) outlined 13 swarm areas in the Columbia Plateau. The boundaries of the areas, which were subjective to some degree, have a typical dimension on the order of 10 km (6.2 mi) on a side. They did not analyze the distribution of swarm depths or the vertical extent of individual swarms, but they classified the swarms as shallow seismicity, which were defined as having focal depths of less than approximately 6 km (3.7 mi) (UWGP 1979, p. 24).

A Washington Public Power Supply System study established 28 additional swarm areas (21 in the central plateau region), and modified the boundaries of four of the UWGP's areas; however, the typical dimension of these swarms remained on the order of 10 km (6.2 mi) on a side. Individual swarms were found to cluster within areas on the order of 25 km^2 (9.65 mi^2) (WPPSS 1981, p. 2.5J-26) and have depths on the order of 0-6 km. The depth precision is 2 to 4 km (1.3 to 2.5 mi).

Since 1969 when the collection of local Columbia Plateau seismographic data began, most swarm events have been observed to have coda-length magnitudes of about 1.5 or less. The largest swarm event has been the 4.4 coda-length magnitude 1973 Royal Slope shock, which in some ways exhibited mainshock characteristics. As stated previously, only about 10% of the seismicity at depths less than 8 km (5 mi) exceed (coda-length) magnitude 2.0.

Below about 8 km (5 mi) depth, the seismicity in the central Columbia Plateau displays characteristics that are quite distinct from shallower seismicity. Deeper seismicity is generally diffusely distributed throughout the Columbia Plateau. Clusters of events occur at the eastern end of the Saddle Mountains where the Scootney Reservoir and Connell swarm areas extend to 10 and 12 km (6.2 and 7.5 mi), respectively, at a single area between the Frenchman Hills and the Saddle Mountains near Corfu, and south of the Horse Heaven Hills near Prosser.

Delineation of patterns suggestive of faulting surfaces is hampered in the central Columbia Plateau by the combination of low seismicity, location precision, and small swarm dimensions and magnitudes. In general, the pattern and distribution of earthquakes deeper than about 8 km (5 mi) do not exhibit an obvious relationship to known folds or faults having surface expression. Also, this seismicity generally does not coincide with areas of intense shallow swarm activity, but rather, it occurs in a diffuse pattern.

Estimates for the earthquake potential of structures and zones in the central Columbia Plateau have been developed during the licensing of nuclear powerplants at the Hanford Site. The NRC (1982, pp. 2-22 to 2-30), in its review of the operating license application for the WNP-2 at the Hanford Site, concluded that four earthquake sources should be considered for the purpose of seismic design: the Rattlesnake-Wallula alignment, Gable Mountain, a floating earthquake in the tectonic province, and a swarm area.

For the Rattlesnake-Wallula alignment, the NRC assumed strike-slip motion with minor amounts of oblique slip and a seismogenic length of 120 km (74.5 mi). Using the relationship developed by Slemmons between fault length and surface-wave magnitude (NRC 1982, Appendix H) yields a surface-wave magnitude of 6.5.

Of the five Gable Mountain faults, the NRC assumed that the Central Fault, which has the largest rupture area, is capable of generating the largest event (NRC 1982, pp. 2-27 to 2-29). The NRC staff extended the reverse-oblique slip data of Wyss (1979, pp. 336-340) on fault area versus maximum magnitude to the lower values appropriate to the Gable Mountain faults and estimated a maximum surface-wave magnitude of 5.0, ± 0.5.

The floating earthquake for the tectonic province was developed from the largest event felt or recorded on the Columbia Plateau, which occurred in 1936 near Milton-Freewater, Oregon, and had a surface-wave magnitude of 5.75 (Gutenberg and Richter 1965, p. 164; NRC 1982, p. 2-25). Because of uncertainty in the association of this event with a specific structure, the NRC stance was that a similar event could occur in the immediate vicinity of the WNP-2 site.

The magnitude and location characteristics of the hypothetical swarm were based on the observed seismicity. The largest Columbia Plateau swarm event thus far observed (1973 Royal Slope earthquakes) had a coda-length magnitude of 4.4 (Malone et al. 1975). The NRC has interpreted this event (NRC 1982, pp. 2-26 to 2-27) as a Richter magnitude 4.0 to reflect the relative overestimation by the coda-length scale. On the basis of studies that suggest that swarms preferentially occur in areas of irrigation (WPPSS 1981, pp. 2.5J-39 to 2.5J-49), the NRC adopted the distance to the nearest areas of irrigation [3 km (1.9 mi)] as the minimum distance of the maximum swarm event to the WNP-2 site.

The maximum magnitudes for the potentially seismogenic structures identified above were estimated from empirical fault dimension-magnitude relationships. This approach was adopted because no significant seismicity is located on the structures. However, the applicability of relationships in these cases is questionable (NRC 1982, Appendix H) because they were developed for larger events and fault surfaces than those of the Columbia Plateau, and furthermore, they were developed for plate boundaries rather than plate interiors.

Below are brief descriptions for estimating recurrence intervals of earthquakes from seismogenic sources that might effect the Hanford Site.

Reliable recurrence calculations are available for events of coda-length magnitude less than 4.5 in the Pasco Basin. Extrapolation of these calculations to magnitudes greater than 4.5 for the Columbia Plateau may not be valid because the data suggest that earthquake processes may be different at higher magnitudes (Rothe 1978, Chapter VII).

Past determinations of recurrence intervals in eastern Washington State vary depending on the investigator, the areas studied, and method of analysis. Some recurrence intervals for events in the Pasco Basin, Columbia Plateau, and specific structures are found in WPPSS (1981, pp. 49-52 and Fig. 2.5-16, 2.5-17, 2.5-18, and 2.5-29) and NRC (1982, pp. 20-32).

Instrumentally recorded seismicity alone was not sufficient to provide recurrence estimates for individual structures. The Washington Public Power Supply System based their recurrence intervals for earthquakes on specific structures on stratigraphic data as well as instrumental data. The earthquake recurrence characteristics they determined for specific structures are as follows (WPPSS 1981, Appendix 2.5K, pp. 2.5K-49 to 2.5K-53):

- On the central fault of Gable Mountain--10,000 yr for a magnitude 5.0 ± 0.5
- In the Finley Quarry area--at least several tens of thousands of years, and possible longer for a surface rupture
- For surface rupture on the Wallula Fault Zone--in excess of 10,000 yr, and may be much longer
- For surface rupture on the Toppenish Ridge--on the order of thousands to a few tens of thousands of years
- For surface rupture on Ahtanum Ridge--on the order of at least tens of thousands of years.

3.5.5 Hydrology

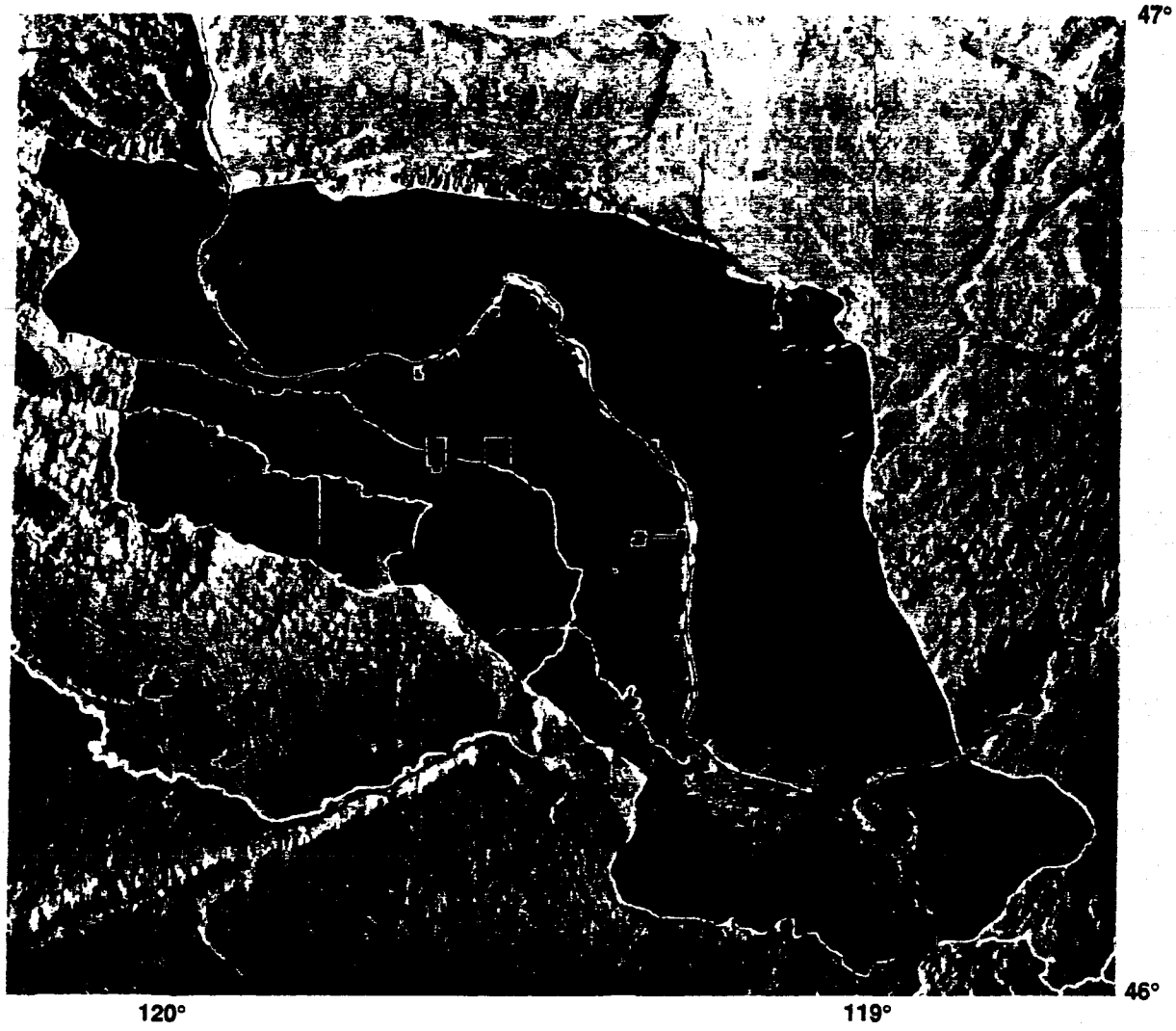
The primary surface-water features associated with the Hanford Site are the Columbia and Yakima rivers. Several surface ponds and ditches are present, which are generally associated with fuel and waste processing activities.

Flow from approximately two-thirds of the Hanford Site drains directly into the Columbia River; runoff is extremely low, if not zero. The section of the Columbia River along the Hanford Site reach, which extends from the headwaters of Lake Wallula to the Priest Rapids Dam, is the last free flowing stretch of the Columbia River. Flow along this reach is controlled by the Priest Rapids Dam. Several drains and intakes are also present along this reach. Most notably, these include irrigation outfalls from the Columbia Basin Irrigation Project and Hanford Site intakes for the onsite water export system.

Cold Creek and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system along the southern boundary of the Hanford Site. Approximately one-third of the Hanford Site is drained by the Yakima River system. Figure 3-19 shows the drainage areas for Cold Creek and Dry Creek.

The Yakima River, bordering the southern portion of the Hanford Site, has a low annual flow compared with the Columbia River. The average discharge of the Yakima River, measured at Kiona, Washington is about 7,000 ft^3/s.

Figure 3-19. Drainage Areas for Cold Creek and Dry Creek on the Hanford Site.



West Lake, a 10 acre pond less than 3 ft deep, is the only natural pond within the Hanford Site. Its presence is probably due to a combination of factors, such as its location within a topographic depression (which places it closer to the water table) and vertical groundwater leakage from shallow confined aquifers (caused by erosional windows in the basalt flows).

3.5.5.1 Flood Potential. Flooding of the Columbia River could significantly impact the Hanford Site facilities and operations. Major floods on the Columbia River are characteristically the result of rapid melting of the winter snowpack over a wide area, augmented by above-normal precipitation. The maximum historical flood on record occurred June 7, 1894. The peak discharge at the Hanford Site was 740,000 ft^3/s. The largest recent flood took place in 1948, with an observed peak discharge of 690,000 ft^3/s at the Hanford Site. The probability of flooding at the magnitude of the 1894 and 1948 floods has been greatly lowered as a result of upstream regulation at Priest Rapids Dam. Actual river flows currently range between 36,000 and 160,000 ft^3/s, whereas unregulated flows (before Priest Rapids Dam construction) ranged between 70,000 and 380,000 ft^3/s.

The 1894 flood inundated areas less than 400 ft MSL. A flood of this magnitude would inundate the 100-F Area and sections of Richland. The major four-lane highway on the Hanford Site would be flooded near the old Hanford townsite, cutting off a direct route to Richland. However, access from the west via Route 240 would still be possible. Today's regulated maximum flow, 160,000 ft^3/s, has no effect on any facilities on the Hanford Site. The probable maximum flood* (PMF) for the Columbia River below Priest Rapids Dam is calculated as 1.4 million ft^3/s. This magnitude of flooding would inundate the 100-F Area, part of the 100-B and C Area, part of the 100-H Area and large areas within the city of Richland. The 200 and 300 Areas, as well as the central portion of the Hanford Site, would remain unaffected (Figure 3-20).

Flooding of the Yakima River would have only a minor impact on the Hanford Site. Yakima River floods occur as a result of the same hydrometeorologic events that induced the Columbia River flood flows. In addition to spring snowmelt and warm rains, ice and debris jams contribute to flooding on the Yakima River. Since 1862, there have been 16 major floods on the Yakima River. The most severe ones occurred in November 1906, December 1933, and May 1948. The peak discharge magnitude of these floods measured at Kiona, Washington were 66,000, 67,000, and 37,000 ft^3/s, respectively. The recurrence interval for the 1933 and 1948 floods are estimated at 170 and 33 yr, respectively. The most recent flood occurred in December 1977 with a peak discharge of 29,000 ft^3/s and a recurrence interval of 14 yr.

The only major source of local or surface flooding on the Hanford Site is the Cold Creek watershed. This is divided into the upper and lower Cold Creek. At its headwaters along the Yakima Ridge, the elevation is it is above 4,000 ft above MSL; at the point where it drains into the Yakima River, about 420 ft above MSL. The Cold Creek floodplain is located in the

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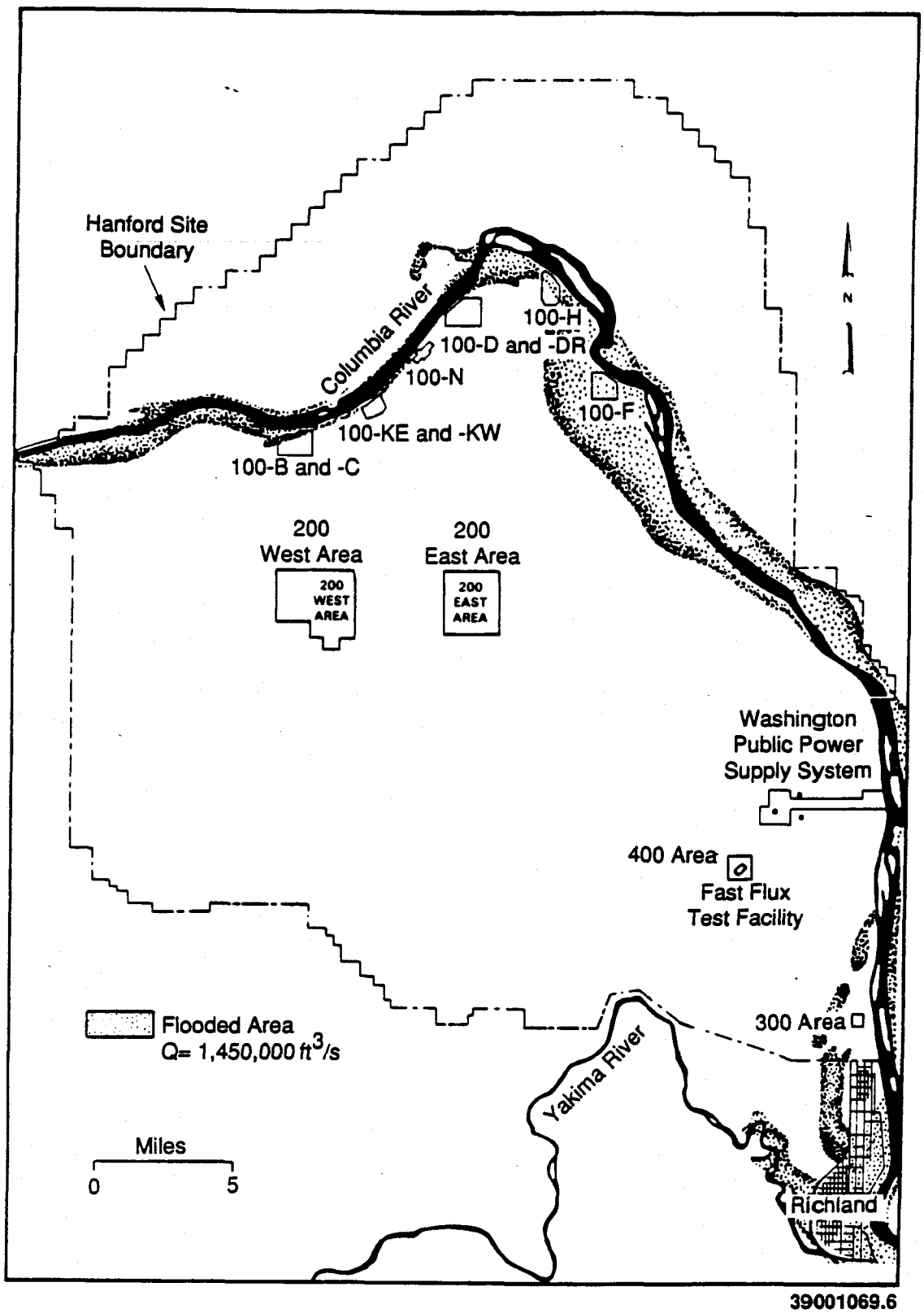
*A probable maximum flood is a concept where evaluation of flood conditions is determined from upper limits of precipitation falling on a drainage area, moisture conditions, snowmelt, and tributary conditions that result in maximum runoff.

Figure 3-20. Probable Maximum Flood (1,450,000 ft^3/s).



lower Cold Creek southeast of the 200 Areas. A PMF for the Cold Creek and Dry Creek streams would result in little damage other than localized scouring and deposition within the Site boundaries.

Table 3-7 shows some historical events and estimates of peak discharge rates at Hanford.

Table 3-7. Estimated Peak Discharge Rates for Floods on the Columbia River Below Priest Rapids Dam.

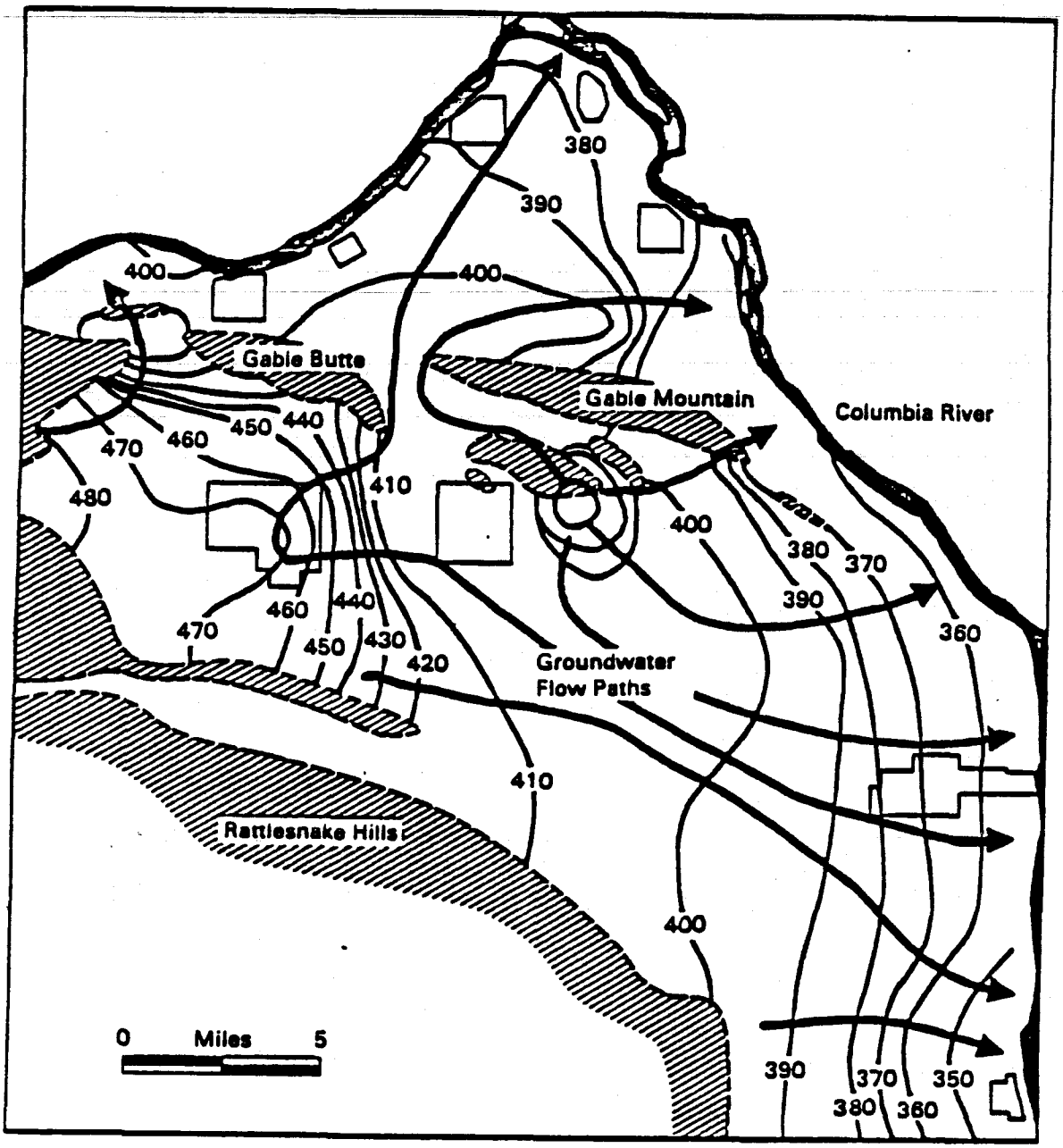
Event	Peak discharge rates at Hanford (ft^3/s)
Dam-regulated probable maximum flood	1,400,000
Seismic damage to Grand Coulee Dam (50% breach)	8,000,000
500-yr flood	840,000
Greatest flood on record (1894-estimated)	740,000
Second highest flood on record (1948)	690,000
100-yr flood	700,000

The water table has been mapped using water level data from the numerous wells. Figure 3-21 shows the water table map with the contour lines linking points of equal hydraulic potential. If the hydraulic conductivity of the aquifer is assumed to be uniform in all directions at a given location, the groundwater flow will be perpendicular to the contour lines and toward lower hydraulic potential (water table elevation). In Figure 3-21, the groundwater flow is predominantly north and east toward the Columbia River, which is mainly a discharge boundary for the confined aquifer. The average discharge rate from the aquifer into the river has been calculated at about 99 ft^3/s; however, the rate and direction of flow within several miles of the river can be affected by the seasonal river-level fluctuations.

The boundary between the confined and unconfined aquifers is at the top of the Columbia River basalt group. A number of confined aquifers lie beneath the Hanford Site. They are composed primarily of permeable sediments primarily between basalt flows.

3.5.5.2 Groundwater. Both confined and unconfined aquifers are present beneath the Hanford Site. The confined aquifers are aquifers bounded by upper and lower confining boundaries. These occur within the Columbia River basalts at the Hanford Site. In general, the unconfined aquifers occur in the Ringold Formation and the Hanford formation, as well as some more recent alluvial sediments in areas adjacent to the Columbia River. The water table

Figure 3-21. Water Table Elevations (1986).



is the top of the unconfined aquifer. This relatively shallow aquifer has been impacted more than the uppermost confined aquifer by wastewater disposal at the Hanford Site.

Recharge to the unconfined system comes from several sources. Natural recharge from precipitation and runoff occurs principally to the west from the Cold Creek and Dry Creek areas. The Yakima River recharges the unconfined aquifer as it flows along the southwest boundary of the Hanford Site. The Columbia River recharges the unconfined aquifer during its high stages when river water is transferred to bank storage. The unconfined system receives little, if any, recharge from precipitation within the perimeters of the Hanford Site.

Artificial recharge occurs predominantly from liquid-waste disposal operations in, or adjacent to, the 200 West and 200 East Areas. It has been estimated that recharge to the groundwater from the Separations Area (which includes B Pond as well as the various cribs and trenches in the 200 West and 200 East Areas) adds ten times as great an annual volume of water to the unconfined aquifer as is contributed by natural inflow to the area from precipitation and irrigation waters to the west. The discharge of water has created groundwater mounds near each of the major wastewater disposal facilities in the Separations Area, and the 100 and 300 Areas (Figure 3-21). These mounds alter the general flow pattern in the aquifer, from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east.

Groundwater levels have changed continuously over the years because of variations in the volume of wastewater discharged. Consequently, the movement of the groundwater and its associated constituents has also changed with time. Although groundwater mounding occurs in the 100 and 300 Areas, the volume of liquid discharged to the ground is less. The mounding is also affected by the proximity of these areas to the Columbia River, where river stages may play a part. Therefore, groundwater mounding in these areas may not be as significant as in the Separations Area. The effect on the quality of the groundwater that enters the Columbia River from the 100 and 300 Areas may be more pronounced because of the short travel times involved, compared with the longer travel times required to move possible contaminants from the 200 Areas.

3.5.12 Meteorology

Climatological data are available from the Hanford Meteorology Station (HMS), which is located between the 200 Areas. The HMS consists of a 410-ft steel tower with booms spaced at 50-ft intervals. At each interval, except at the 150- and 350-ft intervals, there is a temperature sensor. A wind sensor is located at several of these intervals except at the 150-, 250-, and 350-ft intervals. Data have been collected at the HMS since 1945. Temperature and precipitation data from nearby locations are available for 1912 through 1943. Data from the HMS are assumed to be representative of the general climatic conditions for the region.

The Cascade Mountains greatly affect the climate of the Hanford Site, although they are not visible from the HMS. Because the Hanford Site is in the rain shadow of these mountains, precipitation averages only 6.25 in. annually. Extremes in precipitation have been as follows: a record storm of October 1-2, 1957, in which rainfall totaled 1.88 in. in 12 h, or 30% of the annual average. At the other extreme, there have been 81 consecutive days without measurable rain (June 22 to September 10, 1967). The months of September through December account for 40% of the total annual precipitation. Normal rainfall for this period of time is 2.50 in.

About 38% of all precipitation during the months of December through February is in the form of snow. The record greatest depth of snow on the ground was 24.5 in., which occurred in February 1916. However, since that date, the greatest depth has been 15.6 in., which occurred in December 1985. Annual snowfall is 13.7 in.

Temperatures at the Hanford Site are colder in winter and warmer in summer than would be the case without the Cascade Mountains. Other mountain ranges to the north and east shield the area from many of the arctic surges, and in half of all winters, temperatures remain above 0 °F. Although winter minimum temperatures have varied from -27 to +22 °F, summer maxima have varied only from 100 to 115 °F. However, there is considerable variation in the frequency of such maximum temperatures. Although temperatures reach 90 °F or above an average of 55 days/yr, minimum temperatures of 70 °F or above occur only an average of 8 days/yr.

3.5.12.1 Wind. Wind data are collected routinely at the HMS. In addition to the surface wind data (7-ft), wind data are collected at the 50-, 100-, 200-, 300-, and 400-ft intervals of the 410-ft tower at the HMS. Telemetry stations distributed on and around the Hanford Site provide supplementary surface (30-ft) wind data for defining wind patterns. These data are essential to Hanford Site emergency response programs in the event of a release of radioactive material to the atmosphere (Figure 3-25).

Prevailing wind directions are from the northwest in all months (Figure 3-26). Southwesterly winds are of secondary importance. Wind direction summaries indicate that winds from the northwest quadrant occur most often during the winter (December, January, February) and summer (June, July, and August). During the spring and fall, the frequency of southwesterly winds increases with a corresponding decrease in northwesterly flow. Winds blowing from other directions (e.g., northeast) display minimal variation from month to month.

Monthly average wind speeds are lowest during the winter months, averaging 6 to 7 mi/h, and highest during the summer, averaging 9 to 10 mi/h. Wind speeds that are well above average are usually associated with southwesterly winds. In the summer, high-speed winds from the southwest are responsible for most of the dust storms experienced in the region.

3.5.12.2 Temperature. From 1951 through 1980, the average monthly temperatures ranged from a low of 30.1 °F in January to a high of 76.6 °F in July. During the winter, the highest monthly average temperature at the HMS was 44.5 °F in February 1958, and the record low was 14.0 °F, which occurred during January 1979. During the summer, the record, maximum, monthly average temperature was 82.2 °F in July 1985, and the record lowest was 63.0 °F in June 1953. Table 3-8 shows the annual high/low/average temperatures by month.

Figure 3-27 is a graph of daily extremes of maximum and minimum temperatures and the daily normal temperatures. The longest departures from normal for both the maximum and minimum occur during the winter months.

3.5.12.3 Probability and Intensities of Severe Storms and Tornadoes. This subsection discusses the probability and intensity of severe storms and tornadoes on the Hanford Site. In general, the Site does not experience a large number of severe storms or tornadoes.

Figure 3-25. Wind Roses for the Hanford Telemetry Network, 1979 Through 1982. (The points of each rose represent the directions from which the wind comes. The lengths of the points represent the percentage of time the wind blows from that direction.)

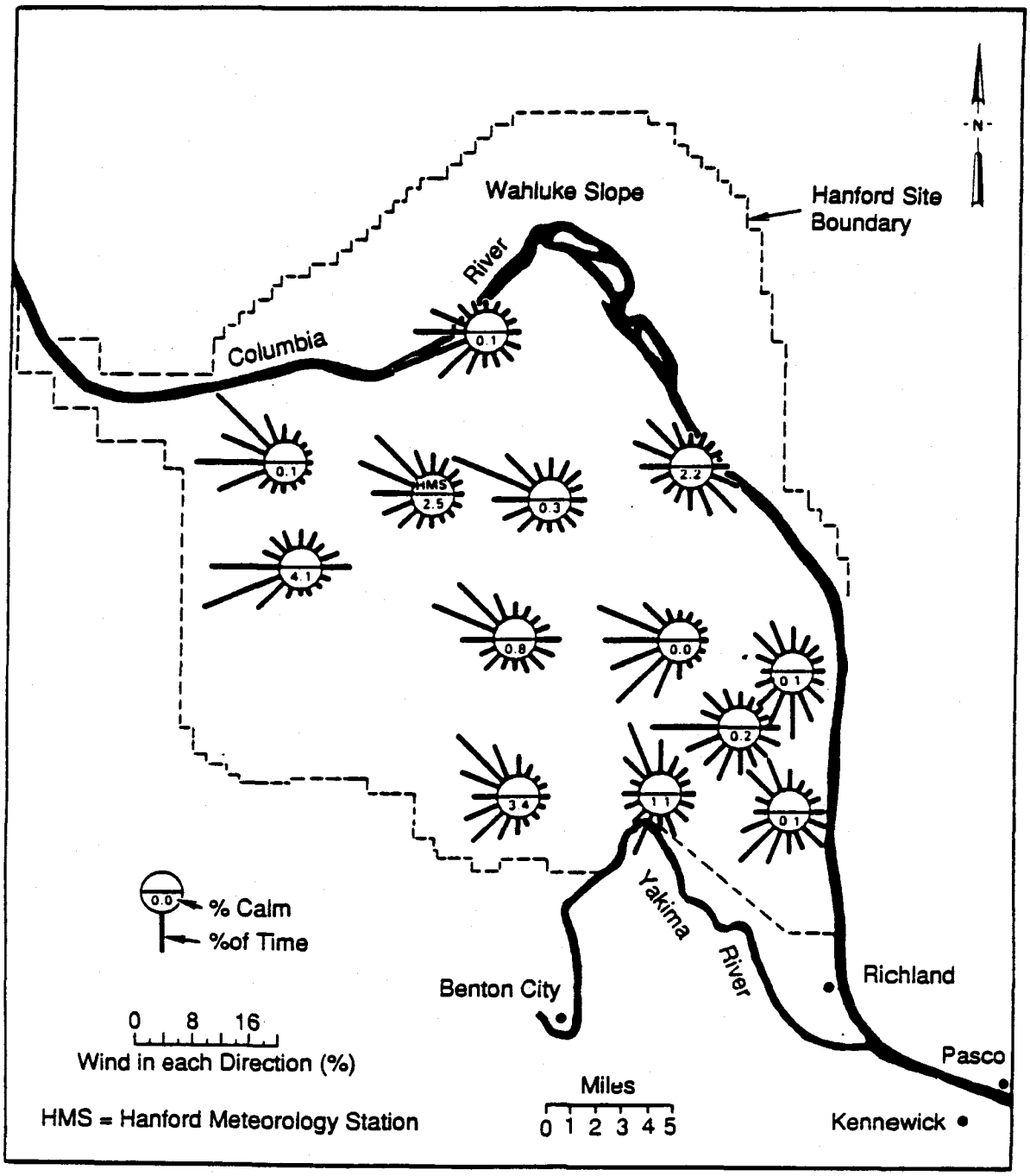


Figure 3-26. Monthly Wind Roses for the Hanford Meteorology Station Based on (50-foot) Wind Data, 1955 Through 1980. (The points of the rose represent the directions from which the wind blows. The length of the point represents the percent of time the wind blows from that direction.)

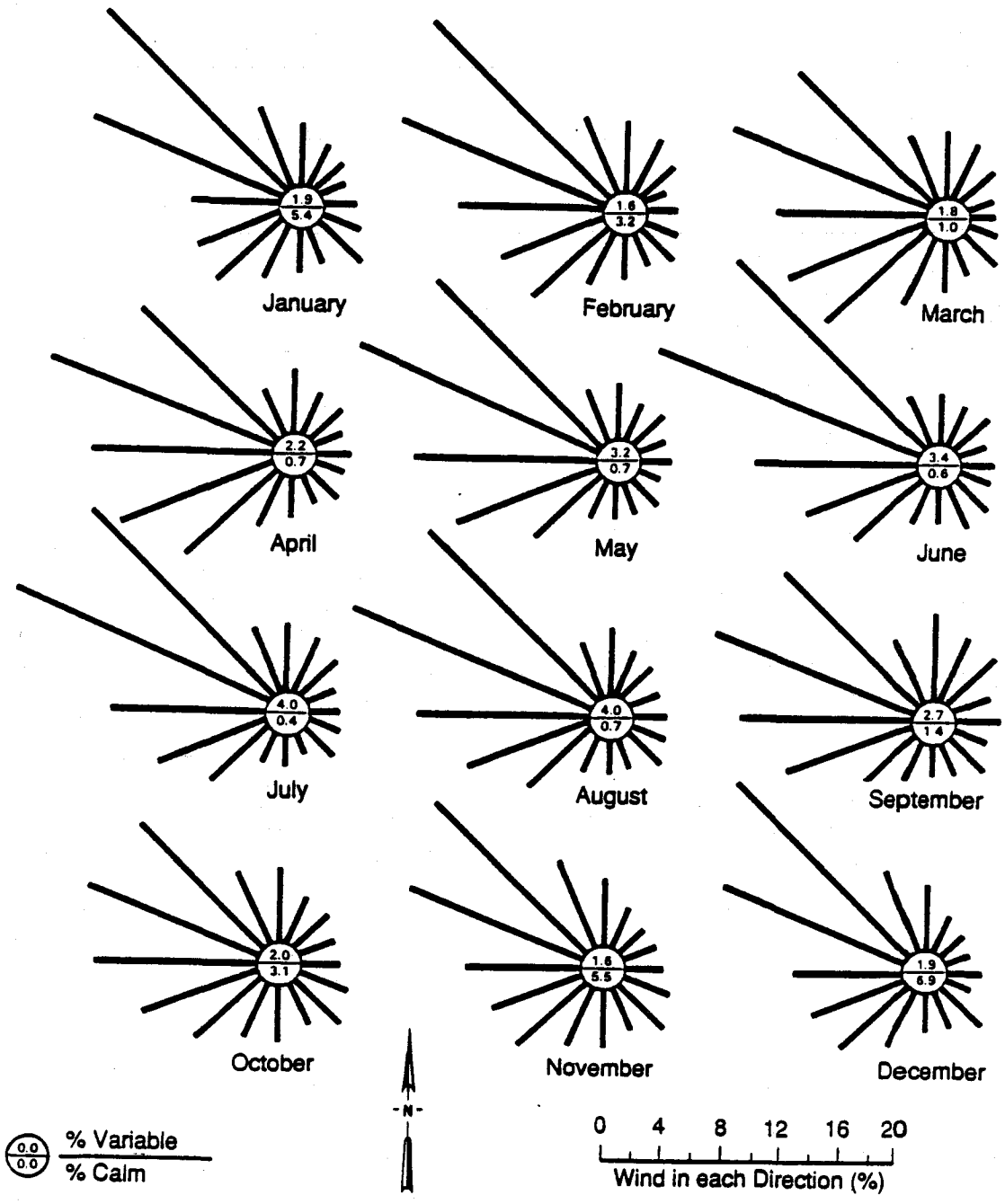


Table 3-8. Annual High/Low/Average Temperature (1951 to 1980).

Temperature (°F)	Month												Annual
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
High	37.4	46.8	56.0	65.5	75.2	83.5	92.1	89.7	80.6	65.8	48.1	39.9	65.0
Low	22.9	28.8	32.8	39.2	47.4	55.1	61.1	59.5	51.7	40.5	31.0	26.2	41.4
Average	30.1	37.8	44.4	52.3	61.3	69.3	76.6	74.6	66.2	53.1	39.5	33.1	53.2

3.5.12.3.1 Severe Storms. The Hanford Site experiences numerous thunderstorms due to its geographic location, but very few are classified as "severe." The National Weather Service criteria for classifying a thunderstorm as severe requires hail with a diameter of greater than 3/4 in., or wind gusts of greater than 58 mi/h. Applying this same definition at the Hanford Site, there have been only eight severe storms recorded from 1945 to 1986 (Table 3-9), and all met the definition based on the wind-gust criteria. Of the total number of thunderstorm events observed at the HMS (430), only 2% have been severe storms.

Thunderstorms have been observed at the station in every month except November and January. Although severe ones are rare, lightning strikes have occasionally ignited grass fires that have burned thousands of acres of Hanford Site land, resulting in considerable wind erosion.

3.5.12.3.2 Tornadoes. Tornadoes are infrequent and generally small in the Pacific Northwest. The HMS climatological summary and the National Severe Storms Forecast Center data base list 22 separate tornado occurrences within a 100-mi radius of the Hanford Site from 1916 through September 1982; two additional tornadoes have been reported since September 1982. Table 3-10 lists the 22 tornadoes by data and location. The two additional tornadoes both occurred on April 23, 1983, 3 mi south of Connell, Washington and 8 mi south of Connell, approximately 20 mi from the Hanford Site boundary.

The probability for an occurrence in any year at any one point within the 100-mi radius is 0.000006824 or one tornado each 146,000 yr. The best estimates of the maximum tangential wind speed expected from a tornado similar to those that have occurred within the 100-mi radius over the last 70 yr is 145 mi/h. Facilities at the Hanford Site are designed with tornado probabilities incorporated. The Hanford Plant Standards Design Criteria (SDC 4.1) uses a maximum horizontal wind velocity of 165 mi/h for reactor facilities and 120 mi/h for nonreactor facilities.

3.5.12.4 Prolonged Rainy or Dry Seasons. The Hanford Site is in a semiarid region; however, there have been some abnormally rainy and dry seasons. These seasons are detailed below.

3.5.12.4.1 Notable Wet Periods. There are five periods of abnormally high precipitation listed in Table 3-15. The years of record are from 1946 through 1980. From a precipitation standpoint, 1973 was an unusual year.

Figure 3-27. Normal, Extreme, and Daily Temperatures at the Hanford Site.

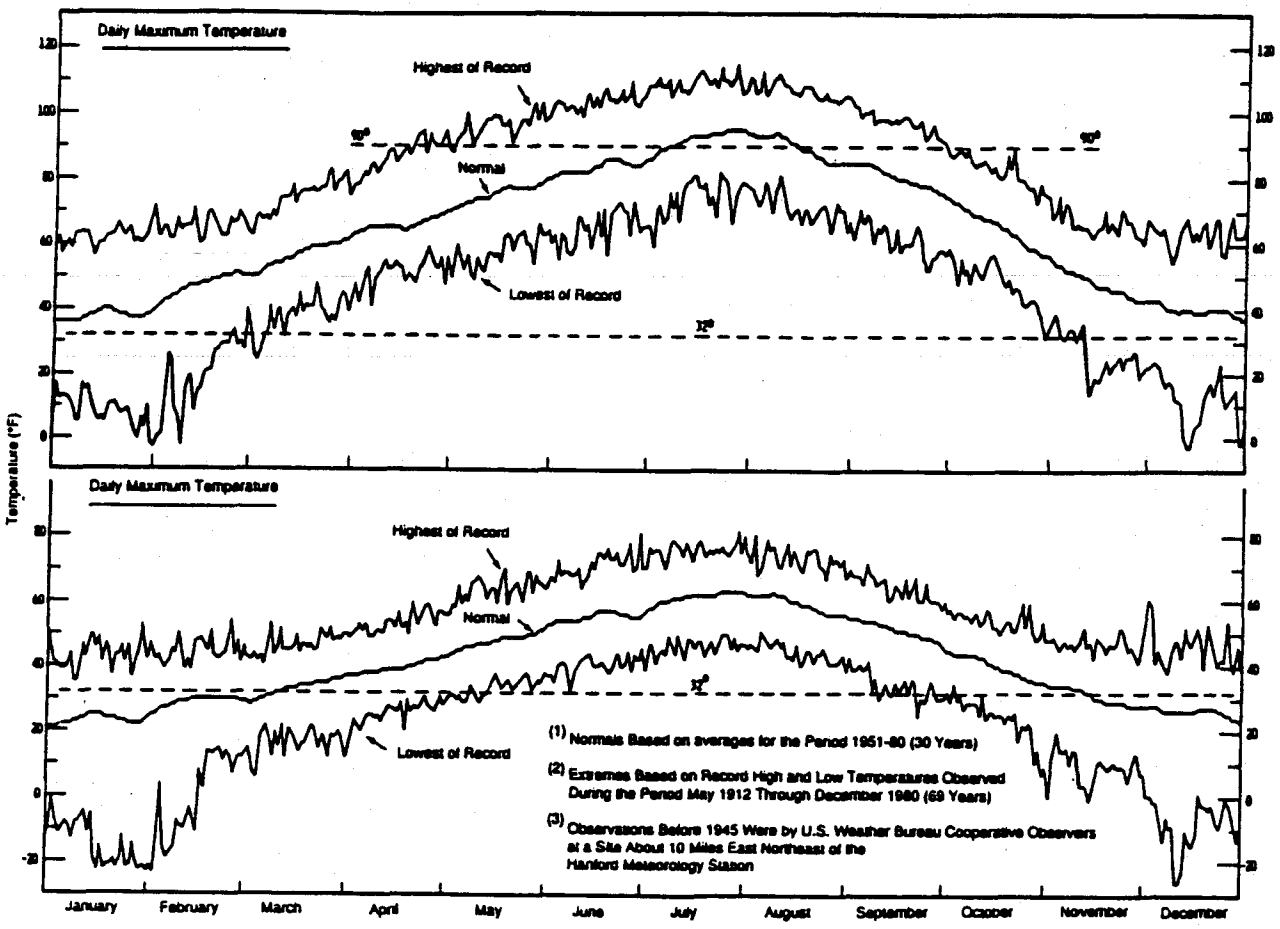


Table 3-9. Severe Thunderstorm Occurrences at the Hanford Site (1945 through 1986).

Date	Time		Peak gusts (mi/h)			Remarks
	Begin	End	50 ft	200 ft	400 ft	
05-26-48	a	a	71	82	80	Accompanied by dust storm (visibility less than 5/8 mi). Cold front passage at 2035 PST; hail.
06-09-48	a	a	61	82	84	Accompanied by dust storm (visibility less than 5/8 mi). Cold front passage at 1935 PST.
06-16-48						Tornado observed near east end of Rattlesnake Mountain, 10 mi south of the HMS.
06-05-57	1650	1925	72	89	93	Visibility reduced to zero in blowing dust. Cold front passage at 1725 PST.
08-15-61	1950	2015	66	73	76	Several grass fires observed in vicinity of HMS. Cold front passage at 1850 PST.
04-05-72	1545	a	73	86	75	Visibility reduced to 3/4 mi in blowing dust.
07-09-79	2137	2205	69	72	78	Accompanied by dust storm (visibility 1/4 mi). Cold front passage at 2030 PST.
06-05-81			62	67	72	Downburst occurred at 1634 PST. Cumulonimbus clouds in vicinity; no thunder audible.

[a]Unknown.
HMS = Hanford Meteorology Station.
PST = Pacific Standard Time.

Table 3-10. Tornado Occurrences Within 100-Mile Radius of the Hanford Meteorology Station.[a]

No.	Date	Location
1	06-26-16	Southeast of Walla Walla, Washington
2	05-15-25	Condon, Oregon
3	09-02-36	Walla Walla, Washington
4	05-20-48	Yakima, Washington
5	05-29-48	Yakima, Washington
6	06-11-48	Ephrata, Washington
7	06-16-48	10 mi south southeast of Hanford Meteorology Station
8	05-10-56	10 mi southeast of Kennewick, Washington
9	04-12-57	Ione, Oregon
10	04-30-57	Yakima, Washington
11	05-06-57	Harrington, Washington
12	04-24-58	20 mi northwest of Walla Walla, Washington
13	06-26-58	Wallula Junction, Washington
14	03-14-66	Little Goose Dam, Washington
15	08-30-71	Near Colfax, Washington
16	04-05-72	40 to 80 mi west of Geiger Field, Spokane, Washington
17	07-01-78	Southeast of Hatton, Washington
18	08-15-78	Almira, Washington
19	05-01-79	Near Davenport, Washington
20	07-01-79	10 mi south of Moses Lake, Washington
21	05-12-80	2 mi east of Ritzville, Washington
22	09-13-82	12 mi west of Walla Walla, Washington

[a]Recorded or referenced in official National Weather Service documents.

Total precipitation for the year was 8.27 in., which was 132% of normal (6.25 in.). March 30 through September 18, 1973, was dry, while October 31 through December 7, 1973 was a notable wet period (Table 3-11). During the months of October, November, and December 1973, 6.38 in. were recorded, which was 289% of normal (2.21 in.) for those months.

3.5.12.4.2 Notable Dry Periods. There have been many dry periods at the Hanford Site. January and December are the only months that have always received measurable precipitation (1912 through 1980). There have been a total of 75 mo in the period of record (1912 through 1980) without measurable precipitation; July and August account for 43 of the 75 total.

Table 3-11. Notable Wet Periods.

Period	Number of days Precipitation, Trace,[a] or More			Total (in.)	
	Total	Greatest consecutive	With measurable precipitation (in.)	Water equivalent	Snow-fall
Oct 7 to Nov 4, 1947	23 of 29	10	17	2.21	0
Jan 3 to 28, 1950	21 of 26	10	15	1.80	23.4
Nov 11 to Dec 19, 1950	33 of 39	12	15	1.37	3.7
Nov 16 to Dec 22, 1955	31 of 37	15	24	3.19	22.7
Oct 31 to Dec 7, 1973	32 of 38	14	20	3.45	8.1

[a]Trace = <0.005 in.

Table 3-12 shows some long periods with small amounts of precipitation.

Table 3-12. Notable Dry Periods.

Period	Number of days	Total precipitation (in.)
May 29 to Nov 1, 1917	157	0.16
April 1 to Aug 26, 1927	148	0.14
Feb 24 to Aug 13, 1968	172	0.32
Mar 30 to Sept 18, 1973	173	0.29
Aug 26 to Dec 31, 1976	128	0.15

The driest year of record (from 1912 through 1980) was 1976. Total precipitation for that year was 2.99 in., which was only 48% of normal (6.25 in.). During the period September through December 1976, the total precipitation was 0.15 in., which is 6% of normal (2.52 in.) for those months.

3.5.12.4.3 Averages and Extremes. Table 3-13 compares the precipitation records of Richland and the HMS. Richland is on the Columbia River about 25 mi southeast of the HMS and approximately 375 ft lower in elevation than the HMS. From 1946 through 1980, the average annual precipitation was higher in Richland than at the HMS, with December and February being significantly higher. Because of the elevation difference, the HMS received a higher annual snowfall (13.7 in. seasonal average compared with 11.2 in. for Richland).

Table 3-13. Monthly and Annual Averages and Extremes of Precipitation for Hanford Meteorology Station Versus Richland, July 1946 through December 1980.

	Averages (in.)		Extremes (in.) HMS				Richland			
Month	HMS	Richland	Greatest	Year	Least	Year	Greatest	Year	Least	Year
Jan	0.96	1.00	2.47	1970	0.08	1977	3.02	1970	0.10	1947
Feb	0.57	0.70	2.10	1961	Trace	1967	1.58	1980	Trace	1967
Mar	0.42	0.51	1.86	1957	0.02	1968	1.98	1957	0.04	1964
Apr	0.41	0.42	1.22	1969	Trace	1977*	1.16	1969	Trace	1977*
May	0.53	0.57	2.03	1972	0.02	1947	2.07	1945	0.01	1966
June	0.56	0.53	2.92	1950	Trace	1979	2.64	1948	Trace	1949
July	0.18	0.17	0.81	1966	Trace	1980*	0.93	1948	0	1967*
Aug	0.29	0.30	1.36	1977	0	1955	1.82	1977	0	1974*
Sept	0.31	0.29	1.34	1947	Trace	1976*	1.12	1959	0	1975*
Oct	0.56	0.55	2.72	1957	Trace	1978*	2.41	1947	Trace	1978
Nov	0.81	0.88	2.64	1973	Trace	1976	2.78	1973	0.07	1946
Dec	0.90	1.04	2.34	1964	0.11	1976*	2.83	1973	0.13	1946
Annual	6.50	6.96	11.45	1950	2.99	1976	11.35	1948	3.12	1967

HMS = Hanford Meteorology Station.
Trace = <0.005 in.
*Also in earlier years.

During the 1955 and 1956 season, Richland received a seasonal record of 41.6 in., compared with 38.5 in. for the HMS. The maximum depth of snow in Richland was 14.0 in. (January 10, 1980) compared with 15.6 in. (December 2, 1985) at the HMS. Richland's record 24-h snowfall of 12.5 in. on January 8 to 9, 1980, exceeded the HMS record of 8.8 in. on November 21 to 22, 1985. During the 35 yr of record, less than half of the extremes at the HMS and Richland occurred in the same years.