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Geological and Geotechnical Analyses for the Modification Decision Analysis (MDA)

CLE ELUM DAM

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

I. INTRODUCTION

This Technical Memorandum (TM) has been prepared as supporting geotechnical documentation for the Cle Elum Dam Modification Decision Analysis (MDA) Memorandum. Herein, the Safety of Dam (SOD) deficiency issues identified in the Safety Evaluation of Existing Dams (SEED) Analysis Report [1[1]] are addressed.

The past performance and current condition of Cle Elum Dam is summarized in this memorandum. Analyses included in this memorandum were performed using previously available data and data from a Becker Penetration Test program completed in November 1998. The analyses were completed to determine if the potential dam safety deficiencies previously defined should be further considered for corrective actions. In addition, the potential effects of a 3-foot increase in the normal high-reservoir pool level are addressed.

A. Description of Structure

Completed in 1933, Cle Elum Dam is located on the Cle Elum River, approximately 8 miles northwest of Cle Elum, Washington. Figure 1 shows the general location of Cle Elum Dam. Cle Elum Reservoir is authorized to provide irrigation water supplies and is also operated to provide flood storage and recreational benefits.

Cle Elum Dam consists of a main dam and a main dike. In addition, the facility includes three small saddle dikes. Figure 2 illustrates the locations of the main dike and saddle dikes, relative to the dam. The main dam and main dike are zoned, compacted earthfill structures. Figure 3 shows the maximum-height section and a profile along the crest of the main dam. The main dam has a structural height of 165 feet and hydraulic height of 124 feet. The crest of the main dam is 35 feet wide and has a length of 750 feet at elevation 2250. A concrete parapet wall, top elevation 2253, was constructed at the upstream edge of the crest. The main dike is approximately 40 feet high with a crest length of 850 feet, crest width of 30 feet, and crest elevation of 2253 feet. The three saddle dikes range in height from 6 to 13 feet and are comprised of homogeneous compacted earthfill. Their crest elevations and widths vary.

The spillway, located on the right abutment, consists of a concrete gate structure, chute, and stilling basin (Figure 4). The floor of the gate structure is at elevation 2223, and the tops of the five gates, in the fully closed position, are at elevation 2240. The spillway has an effective crest length of 185 feet. Flow through the spillway is controlled by five, 37- by 17-foot radial gates.

The outlet works consist of a trash-rack-protected intake structure and transition, a 14-foot-diameter inlet tunnel approximately 746 feet long, a concrete gate control structure with two 5- by 6.5-foot emergency high-pressure slide gates in tandem with two 5- by 6.5-foot regulating high pressure slide gates, and a 14-foot diameter outlet tunnel. The outlet tunnel is approximately 898 feet long and discharges into the spillway stilling basin. Modifications

[1] Numbers in brackets refer to references listed at the end of this report.

of the outlet works, completed in 1980, consisted of removing an original cylinder gate system and replacing it with the four, 5- by 6.5-foot slide gates.

The storage capacity of Cle Elum Reservoir at elevation 2240 (top of the gates) is 709,000 acre-feet. The active conservation storage in the reservoir is 436,900 acre-feet, from elevation 2110 to 2240 feet.

The dam site is located in the Northern Cascades province and is characterized by a moderate level of historical seismicity. No late-Quaternary active faults are known to exist in this portion of Washington. The seismic hazard is controlled by "random" background earthquakes and distant seismic sources which include the Cascadia subduction zone and the south Whidbey Island fault.

B. Scope and Approach

A field investigation program was conducted in 1992 and 1993. During that field investigation, zones of potentially loose foundation materials that could extend beneath the dam embankment were identified. Evaluation of the data from the field investigation indicated that portions of these zones may liquefy in the event of a large earthquake. These zones, characterized by lower shear wave velocities measured during cross hole shear wave (CHSW) tests, consisted of a layer between elevation 2105 and 2120 near the spillway which exhibited a shear wave velocity on the order of 850 feet per second (fps), and a similar layer between elevation 2095 and 2110 near the center of the downstream berm with a shear wave velocity ranging from 600 to 800 fps. In addition, both CHSW tests showed the velocities of the foundation materials near the bottoms of the test holes, between approximate elevations 2040 and 2055 near the spillway, and between approximate elevations 2010 and 2040 near the center of the downstream berm, were approximately 1200 fps. Significant liquefaction of the foundation and/or deformation of the structure could result in failure of the dam and severe damage and loss of life in the communities downstream.

Upon re-evaluating the existing geological/geotechnical data for Cle Elum Dam in 1998, it was concluded that it was not possible to confidently assess the liquefaction potential of the foundation soils using the previously available information, which included nine SPT tests and cross hole shear wave velocity information at two locations. In November 1998, a Becker penetration test program was conducted to collect data on the penetration resistance (and inferred density) of the foundation soils beneath the downstream portion of the dam to evaluate the liquefaction concerns.

Voids along the outlet works conduit were identified near the area where rehabilitation work was performed in 1980. Seepage and piping potential along the outlet works conduit, as well as in other areas of the dam, were identified as requiring evaluation.

The investigations and analyses reported herein include evaluating dam safety issues for Cle Elum Dam under the existing operating conditions and for the possibility of increasing the normal high reservoir pool level by 3 feet. Specific issues that are addressed in this memorandum include:

1. Review of information pertaining to the outlet works and the voids identified along the outlet works conduit.
2. Evaluation of seepage conditions and the potential for piping to exist through the dam and the foundation along the outlet works conduit.
3. Evaluation of filter compatibility between the upstream and downstream embankment zones.
4. Review of the static stability analysis completed in 1987 during the SEED Analysis phase and additional analyses based on data from the 1992-93 and 1998 field investigations.
5. Evaluation of the liquefaction potential using data from the following sources: (1) the SPT test data from the 1992-93 field investigations, (2) shear wave velocity data from the 1993 cross hole seismic testing, and (3) penetration data from the 1998 Becker drilling program.
6. Preliminary dynamic analysis of the dam embankment using earthquake ground motions as given in the report titled "Probabilistic Seismic Hazard Analysis Cle Elúm Dam, Yakima Project, Central Washington."[2].

C. Failure Potential Assessment

The overall safety of dams classification for Cle Elum Dam is fair. There exists no dam safety deficiency under normal loading conditions. The following reasons for this classification, identified within, are:

- A low potential for piping failure of the dam embankment.
- A low to medium likelihood of seepage-related problems in the vicinity of the outlet works.
- A low likelihood for static stability failure under steady-state seepage.
- A low to medium likelihood for static stability failure under rapid drawdown conditions, due to a lower than recommended calculated safety factor for the upstream embankment slope.
- A low potential for liquefaction of the foundation soils, and resulting very small anticipated dynamic deformations of the dam.

The failure potential assessment is not affected by the 3-foot rise in the normal maximum pool elevation.

II. SITE DATA

A. Geology

1. Regional Geology

Cle Elum Dam and Reservoir are located on the eastern flank of the northern Cascade Range that is underlain by a sequence of intrusive and highly deformed metamorphic rocks, probably of Late Jurassic to Cretaceous age [3]. Eocene sedimentary and volcanic rocks outcropping along the reservoir overlie the older rocks unconformably.

The U-shaped valley in which the dam and reservoir are located was formed by successive multiple advances of alpine glaciers during the Pleistocene. Drainage through the valley was essentially blocked by a terminal moraine/outwash deposit during the most recent glacial advance. This natural dam resulted in the formation of a lake that later breached the natural dam, forming the modern outlet of Lake Cle Elum.

The Cascade Range area of Western Washington is characterized by relatively moderate to high levels of historical and recent seismicity, though few active faults are known. Cle Elum Dam is located within the Northern Cascades seismic zone, and adjacent to several other seismic zones, of which the Puget Lowlands was considered to be the most significant [2].

2. Geologic Investigations

Bedrock exposures have not been identified at the base of the Cle Elum River valley in the immediate vicinity of Cle Elum Dam. Explorations conducted at the site have not penetrated through the thick sequence of glacial and alluvial deposits forming the dam foundation. A water well drilled one mile northeast of the dam intercepted the bedrock foundation (Roslyn Formation) at a depth of 173 feet, while another well located about 7 miles from the dam near the town of Cle Elum reached bedrock at a depth of about 650 feet [3]. Field investigations have been conducted at the site in 1977-78, 1981, 1992-92, and 1998, as discussed below. Figure 5 shows the locations of exploration borings, test pits, and Becker penetration tests. Table 1 summarizes the field explorations dating from 1977 to the present. The boring logs from the investigations prior to 1998 are included in Appendix A. Results from the 1998 Becker testing program are presented in Appendix B.

a. Previous Investigations

In 1992/1993, a field investigation was performed following the 1987 SEED investigation to provide information for assessing the liquefaction potential of the Cle Elum Dam foundation. For this investigation, six (6) borings (DH-92-1 through DH-92-6) were drilled and Standard Penetration Tests (SPT) were performed in two of the borings. All SPT tests, nine (9) total, indicated refusal (>50 blows/6 inches) in the coarse-grained foundation materials. Details of standard penetration tests are included in Appendix C. Two cross hole shear wave couplets were performed for determination of the shear wave velocities of the foundation layers. In addition, two piezometers were installed.

Table 1
FIELD EXPLORATION DATA

Hole No.	N/E Coords.	Surface Elev. (feet)	Station	Dam Axis Offset	Hole Depth (feet)	Purpose[4]
BDH98-1	N 270.39[1] E 270.79[1]	2184.94	N/A	[3] d/s	72	BDH
BDH98-1B	N 261.01[1] E 292.24[1]	2183.16	N/A	[3] d/s	69	BDH
BSH98-1	N 265.16[1] E 283.53[1]	2184.14	N/A	[3] d/s	250	Sample hole
BDH98-2	N 154.80[1] E 584.19[1]	2153.72	N/A	[3] d/s	142	BDH
BDH98-3	N 226.05[1] E 148.79[1]	2129.53	N/A	[3] d/s	139	BDH
BDH98-4	N 857.22[1] E 942.33[1]	2177.97	N/A	[3] d/s	207	BDH
DH-92-1	N 4394.8[2] E 5451.4[2]	2178.8	8+43.0	613.9' d/s	161	CHSW
DH-92-2	N 4387.6[2] E 5458.4[2]	2178.3	8+48.6	622.5' d/s	181.9	CHSW/SPT
DH-92-3	N 4416.8[2] E 5426.2[2]	2180.1	8+28.6	583.7' d/s	90	Piezometer
DH-92-4	N 4677.8[2] E 5508.4[2]	2154.7	5+55.1	593.2' d/s	155.6	CHSW
DH-92-5	N 4668.0[2] E 5505.3[2]	2155.9	5+65.3	592.9' d/s	156.6	CHSW/SPT
DH-92-6	N 4795.1[2] E 5186.7[2]	2185.7	5+28.1	251.5' d/s	100	Piezometer
AP-81-1	N 4270[2] E 5883[2]	2129.7	8+48	1063' d/s	5	Hand auger
DH-81-2	N 4253[2] E 5890[2]	2129.8	8+57	1073' d/s	110	Piezometers
CE-1	N 4483[2] E 4859[2]	2251	9+16	19' d/s	77	Abandoned
CE-2	N 4527[2] E 4875[2]	2250.6	8+69.2	23.5' d/s	160	Piezometer
CE-3	N 4492[2] E 4823[2]	2250.6	9+17.4	18.0' d/s	160	Piezometer

Hole No.	N/E Coords.	Surface Elev. (feet)	Station	Dam Axis Offset	Hole Depth (feet)	Purpose[4]
CE-4	N 4473[2] E 4949[2]	2227.9	9+04.4	109.3' d/s	150	Piezometer
CE-5	N 4567[2] E 4853[2]	2251.2	8+04.0	12.1' d/s	255	Pump Well

NOTES: [1] Nature of coordinate system unknown.
[2] State plane coordinates.
[3] Unknown information.
[4] BDH - Becker drill hole; CHSW-cross hole shear wave; SPT-standard penetration test.
[5] N/A - not available.

During the 1992/1993 cross hole shear wave tests, the majority of the foundation materials indicated shear wave velocities of 1200 feet per second or greater, suggesting low liquefaction potential. Two layers within the foundation were identified as potentially liquefiable, characterized by lower shear wave velocities ($600<V_s<850$ fps or $V_s<1200$ fps). Figures 6A and 6B show the shear wave velocity versus elevation for the two cross hole shear wave couplets.

The quality of the cross hole shear wave velocity measurements has been questioned because of the larger than expected volumes of grout required to backfill the holes drilled and the apparent occurrence of grout permeation between drill holes [4]. The presence of grout was noted while drilling drill hole DH-92-2, located approximately 10 feet downstream of previously completed drill hole DH-92-1; these two drill holes comprise one of the cross hole shear wave velocity couplets. For the other cross hole couplet (DH-92-4 and DH-92-5), it was noted that the grout take in DH-92-5 was considerably greater than expected, considering the casing diameter and hole size. Completion of drill hole DH-92-5 required 5600 lb. of cement, 1400 lb. of bentonite, and 100 lb. of Cal seal. The elevations where grout loss occurred are not documented in the boring logs; though initial grout stabilization occurred in drill hole DH-92-5 at an elevation of 2091 feet. The large amount of grout required to complete the cross hole couplets may be due to the large voids which were caused by drilling disturbance, in addition to the high permeability of the coarse-grained foundation materials allowing permeation of grout through the foundation. The presence of large voids around the cross hole casing, and possibly associated loosening of surrounding soils, may result in the lower shear wave velocities which were measured for certain test intervals, discussed previously. In addition, shrinkage or collapse of the grout could result in voids or loose zones that would produce lower shear wave velocities.

In 1981, one auger hole (AP-81-1) and one drill hole (DH-81-2) were conducted as part of a power plant feasibility study. A dual piezometer was installed in drill hole DH-81-2 at the downstream toe on the right side.

Rehabilitation work for the outlet works took place in 1977 and 1978. During that work, five (5) borings (CE-1 through CE-5) were drilled. Standpipe piezometers were installed in three (3) of the borings.

Initial investigations prior to construction of Cle Elum Dam began as early as 1905. Many of the pre-construction investigations were made during 1914 and included the following [5]:

1. Test pits were excavated and wash-drill borings were drilled in the river section.
2. Borrow pits for the embankment materials were explored.
3. A diamond-drill hole was drilled on the lake side of the proposed outlet tunnel.
4. Sub-storage features were investigated, topographic surveys were conducted, and flow-line surveys were made.
5. Early foundation investigations consisted of a total of 65 test pits, 2 tunnels, 2 trenches, 5 wash borings, 8 diamond drill holes, and laboratory gradation tests on borrow materials.

b. TM Investigations

Re-evaluation of the 1992-93 Standard Penetration Tests (SPT) was conducted in 1998. It was judged that the potential for liquefaction of the foundation materials could not be concluded based on the SPT tests. And, as discussed previously, the liquefaction potential could not be accurately determined by the cross hole shear wave tests. In 1998, recommendations were made to conduct a Becker testing program to clarify the liquefaction concerns.

A series of Becker penetration tests were performed on the downstream side of the dam in November of 1998, to provide data to evaluate the coarse-grained foundation materials, with respect to their potential for liquefaction under earthquake loads. Five (5) Becker drill holes and one (1) Becker sample hole were completed to depths up to 250 feet. The potential for liquefaction of the foundation soils was investigated after lower shear wave velocity zones ($600<V_s<850$ fps) were measured in the foundation materials during the 1992-93 cross hole shear wave tests performed on the site. Those lower velocity zones were not supported by low Becker blow counts during the 1998 Becker drilling program [6]. Complete details of the Becker field investigation are provided in "Geotechnical Investigations at Cle Elum Dam, Becker Drilling Program Results" [6], included in Appendix B.

Laboratory tests were performed on samples of the foundation materials obtained from Becker sample hole BSH98-1. Samples were collected at about five-foot intervals from depths of 60 feet to the bottom of the hole at 250 feet. Results of laboratory gradation tests, hydrometer tests, and Atterberg limits are summarized in Table 2.

Table 2
RESULTS OF LABORATORY TESTS FOR BECKER SAMPLE HOLE BSH98-1

Depth (feet)	USCS	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit (w_c%)	Plastic Limit (w_c%)
60-65	GP-GC	58.3	32.9	8.8	21.5	4.1
65-70	GP-GC	65.9	27.2	6.9	21.9	4.7
70-75	GW-GM	66.6	24.4	9.0	21.5	3.7
75-80	GP-GM	73.5	21.5	5.0	21.0	2.8
80-85	GP-GC	65.2	24.5	10.3	23.3	4.7
85-90	GW-GM	67.8	27.1	5.1	21.7	3.7
90-95	GP-GC	77.3	16.7	6.0	22.8	5.3
95-100	GW-GC	52.6	31.8	15.6	23.6	7.0
100-105	GP	51.9	45.4	2.7	N/A	N/A
105-110	GP	62.3	34.8	2.9	N/A	N/A
110-115	GP	51.7	47.6	0.7	N/A	N/A
115-120	GW	68.0	30.8	1.2	N/A	N/A
120-125	SP	40.8	58.5	0.7	N/A	N/A
125-130	GP	58.8	40.4	0.8	N/A	N/A
130-135	GP	57.2	41.6	1.2	N/A	N/A
135-140	GP	53.1	46.2	0.7	N/A	N/A
140-145	SM	0.0	86.3	13.7	N/A	N/A
145-150	SP	8.0	87.6	4.4	N/A	N/A
150-155	SM	0.0	78.4	21.6	N/A	N/A
155-165	SP	44.7	53.5	1.8	N/A	N/A
165-170	GW	68.9	30.0	1.1	N/A	N/A
170-175	SW	19.3	77.5	3.2	N/A	N/A
175-180	SW	38.2	60.8	1.0	N/A	N/A
180-185	SP	31.7	66.0	2.3	N/A	N/A
185-190	SM	3.5	79.9	16.6	N/A	N/A
190-195	SM	0.0	64.8	35.2	N/A	N/A
195-200	SM	0.0	74.9	25.1	N/A	N/A
200-206	SM	0.6	79.1	20.3	N/A	N/A
208.6-210	ML	0.0	26.9	73.1	21.1	NP
210-215	ML	0.0	18.7	81.3	21.2	1.4
215-220	ML	0.0	10.8	89.2	23.6	3.6
220-225	ML	0.0	2.2	97.8	25.5	3.9
225-230	ML	0.0	1.7	98.3	23.8	2.8
230-235	ML	0.0	0.5	99.5	25.8	2.8
235-240	CL-ML	0.0	1.8	98.2	25.6	4.4
240-245	ML	0.0	3.8	96.2	23.5	3.1
245-250	ML	0.0	3.6	96.4	22.9	2.4

NOTES: 1. N/A - not applicable; NP - non-plastic; w_c - water content.

3. Stratigraphy

The stratigraphy of the Cle Elum site is a product of Pleistocene glaciation, specifically the Lakedale glaciation. Cle Elum Dam is located along the crest of the youngest Lakedale moraine complex. The foundation of Cle Elum Dam is principally composed of glacial outwash materials deposited along the margin and downstream of the Domerie ice front [3]. The materials in the outwash range from large boulders to rock flour, though it generally consists of pervious, crudely stratified sand and gravel with interbeds of variously compacted clay and silt [3]. Underlying the outwash materials (at depths greater than 100 feet) are glaciolacustrine sediments comprised of fine sand and silt, and silty clay and lean clay. The thickness of these unconsolidated materials at the site is unknown, because no borings have penetrated into the underlying rock foundation. Maximum depths of investigation into the river valley in the vicinity of Cle Elum Dam have been 250 feet.

Based on the results of modern explorations at the site, it is inferred that the outwash deposits underlie the dam from the crest downstream. Recent investigations at the site have concentrated on the downstream foundation, and, therefore, have not included sampling of the foundation upstream of the crest. From available geologic information and original design and construction reports, it is inferred that the stratification of the upstream foundation is variable. In some locations, it is believed that the upstream section of the embankment is underlain by glacial till deposits, consisting chiefly of gravel, cobbles, and boulders floating in a matrix of silty sand. It is also believed that the foundation at the upstream toe of the dam and extending some distance into the reservoir is composed of glaciolacustrine sediments and ice-contact lakebed sediments.

The glaciolacustrine sediments consist predominantly of fine-grained materials which were deposited within an ancestral glacial lake. The glaciolacustrine deposits near the upstream toe of the dam have not been sampled in modern exploration programs, but, based on samples from two downstream holes and available geologic information, they are believed to consist of silty clay and lean clay, and fine sand and silt.

Similarly, recent drilling programs have not included samples of the ice-contact lakebed sediments. Based on available geologic information, they are believed to consist of deformed lakebed sediments that were gouged from the bottom of the lake by glaciers and plastered up against the morainal till. These deposits are believed to have been derived, at least in a large part, from the glaciolacustrine sediments. Consequently, they are believed to be predominantly silt and clay soils. A field sample collected from a representative outcrop of the ice-contact lakebed sediments in 1995 was tested in the laboratory and found to consist of 66 percent low plasticity fines and 34 percent sand. Based on outcrop observations, the ice-contact lakebed sediments are laminated to stratified and have been intensely deformed, with highly contorted and truncated bedding planes common in the unit. The unit also includes less than 5 percent by weight drop stones and was overconsolidated by glacial ice.

The ice-contact lakebed sediments and the glaciolacustrine deposits are believed to effectively provide a low permeability upstream blanket for the dam, which may explain the low measured piezometric levels in the downstream foundation, as discussed below. According to available records [14,15], the importance of this natural low permeability blanket was recognized early in the original pre-design investigations, and the dam was located to take advantage of these deposits. A concerted effort was made during construction of the dam to prevent damage to or penetration of these deposits, and, reportedly, windows in these deposits were identified during construction and corrected with placement of low permeability material.

Figures 7A, 7B, and 7C show geologic cross sections through the outlet works (A-A'), the maximum-height section (B-B'), and a profile near the downstream toe of the dam (C-C'). The descriptions of the units shown on those figures are given in Appendix C of the risk analysis report [10], which is reproduced in Appendix D of this report.

4. Groundwater

The records of piezometer monitoring over the past 20 years were reviewed to assess seasonal fluctuations, seepage rates, and observed trends. Eight (8) piezometers/observation wells were installed at the dam. Observation wells SP-77-2, SP-77-3, SP-78-4, and SP-78-5 were installed near the outlet works in 1977 and 1978. In 1981, a dual piezometer was installed at the downstream toe of the dam (SP-81-2UP and SP-81-2LO). During the 1992-93 field investigation, two additional piezometers (PT-92-3 and PT-92-6) were installed on the downstream slope of the dam.

The details of the piezometer and well installations varied from piezometer to piezometer and well to well. Table 3 summarizes the details of the installations as understood from the available information. The bottoms of all of the piezometers/observation wells are in the glacial foundation materials.

The majority of the piezometers/observation wells have been monitored fairly regularly since 1980. The maximum and minimum recorded values each year for each individual piezometer or observation well, along with the corresponding maximum and minimum reservoir elevations for each year are included in Appendix E. Table E-1 summarizes the total change in reservoir and piezometer or observation well elevations recorded during each year, for the readings provided.

During the period of available piezometer records, the annual fluctuation in the reservoir water surface level has varied from 50 to 125 feet, and in years when the reservoir has filled to the Normal Water Surface (NWS), elevation 2240, it has stayed at that elevation only for a very short duration. Although the reservoir elevations exhibited a large variation each year, the piezometer levels typically varied by much smaller amounts. The recorded annual change in elevation from minimum to maximum for the piezometers ranged from approximately 1 to 17 feet and was typically about 5 feet. The minimum

Table 3
PIEZOMETER AND OBSERVATION WELL DETAILS

Piezometer/ Observation Well	Depth (ft)	Type	Screened Interval	Backfill/Interval
SP-77-2	160 ft.	Observation well: 1$^1/_2$-in. PVC pipe	(1)	Medium fine sand[2] Cuttings[2]
SP-77-3	160 ft.	Observation well: 1$^1/_2$-in. PVC pipe	(1)	Medium fine sand[2] Cuttings[2]
SP-78-4	150 ft.	Observation well: 1$^1/_2$-in. PVC pipe	145-150 ft.	Pea Gravel 1-150 ft. Cement 0-1 ft.
SP-78-5	230 ft.	Pump well: 14-in. casing	175 - 205 ft. 220 - 230 ft.	$^3/_4$-in. Min. Gravel 230-255 ft.
SP-81-2	110 ft.	Dual-piezometer: 1$^1/_4$-in. PVC	LO: 75-110 ft. UP: 15-65 ft.	(1)
PT-92-3	89 ft.	(1)	80-89 ft.	Silica sand 80-90.4 ft. Bentonite seal 74.5-80 ft. Random sand/gravel 20.3-74.5 ft. Cement bentonite 0-20.3 ft.
PT-92-6	96 ft.	(1)	90-96 ft.	Silica sand 90-100 ft. Bentonite seal 87-90 ft. Random sand/gravel 68-87 ft. Bentonite seal 62-68 ft. Random sand/gravel 20-62 ft. Cement bentonite 0-20 ft.

NOTES: [1] Limited information.
[2] Interval unknown.

recorded piezometer elevations nearly coincided with the bottom elevation of the outlet works tunnel (el. 2106 feet), while the maximum recorded piezometer elevations correspond to elevations approximately at the mid-height of the tunnel (el. 2115 feet). The variation in piezometer water levels was relatively constant from piezometer to piezometer and did not appear to vary significantly from location to location. The gradient from the gate chamber to the downstream toe, as determined from piezometer readings, is quite flat, at approximately 0.0015, and the piezometric levels are relatively low. Currently, there are no piezometers located upstream of the gate chamber or the dam crest; therefore, no direct data are available on the gradients in the upstream section of the dam embankment or the upstream foundation [10].

5. Hydraulic Conductivity

No laboratory or field permeability data were found in the available documentation for Cle Elum Dam. It is believed that the outwash deposits have a relatively high permeability because of their coarse-grained nature (gravels and sands), while the glaciolacustrine and ice-contact lakebed deposits have relatively low permeabilities because of their fine-grained nature (predominantly clays and silts). The glacial till deposits are believed to have permeabilities intermediate between the limits of the materials described in the previous sentence.

6. Seepage

There has been expressed concern at the Cle Elum site regarding seepage and piping potential, specifically along the outlet works tunnel. However, no surface expression of seepage has ever been observed at the main dam, the main dike, and the saddle dikes [1]. The only mode for monitoring seepage in place at Cle Elum Dam is piezometers, observation wells, and visual monitoring. Instrumentation records dating from 1939 show that Cle Elum's reservoir level is at or below elevation 2210 fifty percent of the time, and at or below elevation 2200 approximately thirty-six percent of the time, staying at or near the Normal Water Surface (elevation 2240) for a very short duration [10]. Therefore, given the operational history and structural composition of the dam, there is little probability that Cle Elum exhibits a high enough phreatic surface to pose as a seepage-related threat. In addition, the low measured downstream gradient of approximately 0.0015 may not have sufficient energy to cause a seepage-related problem.

B. Seismotectonics

A probabilistic seismic hazard analysis was performed in December 1998 [2]. Results of that study are summarized in Table 4.

For typical return periods of 10,000, and 50,000 years, the estimated mean peak horizontal accelerations at the ground surface are 0.28g and 0.42g, respectively [2]. The peak acceleration hazard at the site is dominated by the Northern Cascades source zone, which the dam is located in, and the intraplate source for return periods greater than 300 years. The Cascadia subduction zone is the primary long-period ground motion contributor for periods greater than 10,000 years.

Table 4
MAXIMUM CREDIBLE EARTHQUAKES
FOR CLE ELUM DAM

Source	MCE[1]	Epicentral Distance (km)	Focal Depth (km)	Peak Ground Motion (g)
Cascadia Subduction				
intraslab	$7\,^1/_2$ (M_W)	115	40 to 70	0.3-0.4
interface	$8\,^1/_4$ (M_W)	135	N/A	0.25-0.5
Mount Rainier Zone	$6\,^1/_2$ (M_S)	65	N/A	0.3-0.4

Source	MCE[1]	Epicentral Distance (km)	Focal Depth (km)	Peak Ground Motion (g)
Northern Cascades Zone				
shallow	6 1/2 (M_L)	19	5 to 10	0.3-0.4
deeper	7 1/2 (M_S)	65	40 to 60	N/A
Middle Cascades	6 3/4 to 6 1/4 (M_W)	N/A	N/A	0.3-0.4
Puget Lowlands	7 to 7 1/2 (M_W)	55	N/A	0.3-0.4
Columbia Plateau	6 3/4 to 7 1/4 (M_W)	N/A	N/A	0.3-0.4
Goat Rocks Zone	5 3/4 to 6 1/4 (M_W)	N/A	N/A	0.3-0.4
Williamette Trough	6 3/4 to 7 1/4 (M_W)	N/A	N/A	0.3-0.4
St. Helens Zone	6 1/2 to 7 (M_W)	N/A	N/A	0.3-0.4
Subduction Zone Intraplate	7 to 7 1/2 (M_W)	N/A	N/A	0.3-0.4
South Whidbey Island Fault	7 to 7 1/2 (M_W)	55	N/A	0.3-0.4
Seattle Fault	7 to 7 1/2 (M_W)	76	N/A	0.3-0.4
Ahtanum Ridge Fault	6 1/2 to 7 (M_W)	85	N/A	0.3-0.4
Toppenish Ridge Fault	7 to 7 1/2 (M_W)	111	N/A	0.3-0.4
Doty Fault	6 3/4 to 7 1/4 (M_W)	125	N/A	0.3-0.4
Olympia Fault	7 to 7 1/2 (M_W)	111	N/A	0.3-0.4

NOTES: [1] M_S - surface wave magnitude; M_W - moment magnitude; M_L - shallow focus local magnitude.
[2] N/A - not available.

Ground surface motions developed by the Oakland office of URS Greiner Woodward Clyde include the following:

- A 10,000-year, short-period, magnitude 7 earthquake, at 7.5 miles (12 km) from the dam.
- A 10,000-year, long-period, magnitude 9 earthquake, at 140 miles (225 km) from the dam.
- A 50,000-year, short-period, magnitude 7 earthquake, at 9.3 miles (15 km) from the dam.
- A 50,000-year, long-period, magnitude 9 earthquake, at 140 miles (225 km) from the dam.

The acceleration-time history plots for these earthquakes are included in Appendix F. The magnitude 7 earthquakes exhibit durations of strong shaking on the order of 10 seconds. The magnitude 9 earthquakes exhibit strong shaking for a much longer duration (up to 3 minutes). The total durations of ground motion for the magnitude 7 earthquakes were approximately 40 seconds, while the total durations of ground motion for the magnitude 9 earthquakes were approximately 160 seconds. For a 10,000-year return period, the peak accelerations were 0.28g and 0.20g for the magnitude 7 and magnitude 9 earthquakes, respectively. The peak accelerations for the 50,000-year magnitude 7 and magnitude 9 earthquakes were 0.40g and 0.25g, respectively.

C. Design Data

1. Dam

No information in the records reviewed indicate that any type of stability or stress analysis was performed for the design of Cle Elum Dam. Other than gradation tests on selected borrow pit materials and logging of test pits, no pre-construction testing was performed. An in-depth dynamic evaluation of the dam has not been previously performed.

According to specifications drawings [5], the dam consists of two primary zones: (1) a relatively impervious upstream Zone 1, consisting of earthfill (sprinkled and rolled in 8" layers) and (2) a free-draining downstream Zone 2, comprised of gravel and cobbles. The slopes of the upstream and downstream faces are both 3:1 (H:V). An upstream berm with a slope of 20:1 is comprised of the same material as the upstream zone 1. A waste berm with a slope of 11.3:1 was constructed downstream of the dam, consisting of remnant construction materials.

The dam has 10 feet of freeboard (between the top-of-spillway-gate elevation 2240 and crest elevation 2250). The freeboard is 13 feet if considering the top of the parapet wall (elevation 2253). A 30" layer of riprap underlain by a 12" layer of gravel was placed on the upstream face of the dam.

2. Foundation

Foundation preparation beneath Cle Elum Dam consisted of stripping the upper soil zone and constructing an upstream cutoff trench. No foundation grouting was performed [1]. Excavation of material to be wasted (Station 10+00 to 51+00) was performed by a Monighan walking dragline with a 70-foot boom and 3 $^1/_2$ yd^3 bucket [5]. Excavation of the upper part of the channel (Station 0+24 to Station 10+00) was completed using the Monighan and some Bucyrus-Erie 43B shovels. Excavation of the river channel at the Cle Elum site consisted of excavating 143,000 yd^3, which was to be wasted, and 272,000 yd^3 to be used for construction of the dam [5].

D. Construction Data

Review of the report titled "Final Report on Design and Construction of Cle Elum Dam and Reservoir" [5] indicates that construction methods and quality appear to have been relatively good, considering the time of construction of the dam. Records of placement and compaction of the fill are limited; however, the apparent overall minimal settlement attests to the quality of construction.

E. Performance History

1. Reservoir Operating History

In general, the dam and appurtenant structures appear to be operated in accordance with criteria dictated by the SOP (Standard Operating Procedures). Routine maintenance operations at the dam and appurtenant structures appear to be generally adequate.

As reservoir measurements indicate, the change in reservoir level from minimum to maximum fluctuated a total of 50 to 125 feet in any given year. This corresponds to fluctuations of the reservoir level between elevation 2115 and 2240.

2. Instrumentation

Instrumentation at Cle Elum Dam consists of eight (8) piezometers and observation wells located on the downstream slope and crest of the embankment. These piezometers and wells were located in drill holes DH-92-3, DH-92-6, CE-2, CE-3, CE-4, CE-5, and DH-81-2 drilled during either the 1992-93 field investigation, the 1977-78 outlet works rehabilitation, or in 1981. Observation wells SP-77-2, SP-77-3, and SP-78-4 installed in drill holes CE-2, CE-3, and CE-4, respectively, were monitored during 1980, and again from 1994 to the present. Well SP-78-5, installed in drill hole CE-5, was only monitored during 1980, because it was installed for the primary purpose of performing a pump test. Piezometers PT-92-3 and PT-92-6, installed in drill holes DH-92-3 and DH-92-6, respectively, have been monitored regularly since their installation in 1992. The bottoms of all piezometers/observation wells are in the glacial foundation materials. The piezometer installed in drill hole DH-81-2 at the downstream toe is a dual piezometer (SP-81-2UP and SP-81-2LO) which has been monitored consistently from 1981 to the present. The purpose of these piezometers is to monitor the piezometric levels in the foundation. No piezometers are installed within the compacted earthfill zone and the actual phreatic line within that zone is unknown.

Embankment measurement points are monitored on a 6-year cycle, with the next reading scheduled for the year 2000 [12]. One of the measurement points was reported to be damaged [1]. No significant settlement or horizontal deflections of the embankment have been reported [1].

3. Geological/Geotechnical

For the most part, Cle Elum Dam has been performing well. However, the SEED analysis report concluded that open voids were located within the foundation soils near the lower portion of the outlet gate structure, located near the right abutment [1]. Subsequent review of available information indicates that voids are actually located in the upper portion of the outlet works tunnel [4]. These voids may have been created during the original construction of the outlet works tunnel, as the construction history reported considerable caving and the presence of flowing sands and running gravels during tunneling [5]. No surface expression of seepage through the embankments, abutments, or foundation has ever been observed or reported at Cle Elum Dam [1].

III. ANALYSES

A. Scope of Analyses

For the most part, Cle Elum Dam has been performing well. However, the SEED analysis report concluded that open voids were located within the foundation soils near the lower portion of the outlet gate structure, located near the right abutment [1]. Subsequent review of available information indicates that voids are actually located in the upper portion of the outlet works tunnel [4]. These voids may have been created during the original construction of the outlet works tunnel, as the construction history reported considerable caving and the presence of flowing sands and running gravels during tunneling [5]. No surface expression of seepage through the embankments, abutments, or foundation has ever been observed or reported at Cle Elum Dam [1].

B. Seepage and Piping Potential

According to the 1987 SEED analysis report, the potential for piping failure of Cle Elum Dam was considered low, as there has been no evidence of seepage through the foundation or the embankment [1]. The dam was constructed with very flat upstream (3H:1V and 20H:1V) and downstream (3H:1V and 11.3H:1V) slopes and a cutoff trench to reduce under-seepage. The flat slopes were included in the original design to provide a percolation distance equal to 10 times the available percolation head [1].

1. Seepage and Piping Through the Embankment

According to the SEED analysis report, the downstream compacted pervious fill provides an adequate filter for the upstream compacted impervious fill [1]. That conclusion was re-evaluated by Reclamation in 1992 and again in the analyses completed for this TM. Reclamation's 1992 calculations and those completed for this TM are both included in Appendix G. For this TM, filter compatibility was initially evaluated based on the guidelines in Reclamation's Design Standards No. 13, Chapter 5 [16] for the following four cases:

1. Average impervious fill gradation compared with average pervious fill gradation.
2. Average impervious fill gradation compared with coarsest pervious fill gradation.
3. Finest impervious fill gradation compared with average pervious fill gradation.
4. Finest impervious fill gradation compared with coarsest pervious fill gradation.

Gradations for the pervious and impervious fill were taken from Reclamation's 1933 report titled "Analysis of Materials for Cle Elum Dam" [11]. For all four comparisons, the impervious fill gradations were corrected for material coarser than the No. 4 sieve size, in accordance with the recommendations included in Reclamation's Design Standards No. 13, Chapter 5 [16].

Key characteristics of the gradations of the impervious fill and the pervious fill are the following:

Impervious fill - average gradation - corrected	% fines = 34% (Category 3) D_{85B} = 1.1 mm D_{15B} = 0.017 mm
Impervious fill - minimum gradation - corrected	% fines = 48% (Category 2) D_{85B} = 0.6 mm D_{15B} = 0.009 mm
Pervious fill - average gradation	D_{15F} = 1.1 mm Maximum size = 6 inches
Pervious fill - coarsest gradation	D_{15F} = 4 mm Maximum size = 8 inches

The filter criteria comparisons are summarized in Table 5.

Table 5
FILTER COMPATIBILITY EVALUATION – BASED ON RECLAMATION'S DESIGN STANDARDS NO. 13, CHAPTER 5 [16]

Case	Design Standards No.13		
	Actual D_{15F} (mm)	**Maximum D_{15F} (mm)**	**Meet Criteria?**
Average Impervious/ Average Pervious	1.1	1.6	Yes
Average Impervious/ Coarsest Pervious	4.0	1.6	No
Finest Impervious/ Average Pervious	1.1	0.7	No
Finest Impervious/ Coarsest Pervious	4.0	0.7	No

From the results in Table 5, the following observations can be made from the evaluation of filter compatibility according to the guidelines of Design Standards No. 13, Chapter 5 [16]:

1. The average impervious fill meets filter requirements with respect to the average pervious fill. This means that filter compatibility would be met at all locations where impervious fill of average or coarser gradation was in contact with pervious fill of average or finer gradation.

2. The finest impervious fill does not meet filter requirements with respect to the average pervious fill, but this combination misses compliance with filter compatibility criteria by a relatively small margin. In fact, in reviewing the original technical paper [19] that presented the filter compatibility recommendations included in Design Standards No. 13, Chapter 5 [16], it is found that the recommended $(D_{15F})_{max}$ of 0.7 mm for this case is based on test results that indicated $(D_{15F})_{max}$ varying from 0.7 to 1.7 mm. The actual D_{15F} for this case is 1.1 mm, which is in the middle of this measured range. The near compliance of the combination of finest impervious fill and average pervious fill suggests that filter compatibility would likely be met at all locations where the impervious fill is in contact with pervious fill of average or finer gradation, except for those cases where the very finest impervious fill is in contact with pervious fill very near to the average gradation.

3. The coarsest pervious fill does not meet filter criteria for either the average impervious fill or the finest impervious fill.

Overall, these observations lead to the conclusion that filter compatibility, according to Design Standards No. 13, Chapter 5 [16], is probably met at most locations where the impervious fill and pervious fill are in contact. However, filter compatibility according to those guidelines is likely not met at some locations – specifically, at some locations of the finest impervious fill and at most locations with the coarsest pervious fill.

The filter compatibility evaluations according to Design Standards No. 13, Chapter 5 [16], as summarized in the calculations in Appendix G, also indicated:

1. The pervious fill substantially exceeds recommended permeability requirements relative to the impervious fill. This is a favorable condition relative to piping, because it means that the pervious fill will act as a drain for the impervious fill, which should result in a lower phreatic level at the contact between the two zones. This means that there should be less area where water would flow and piping could occur across this contact if the gradations were not compatible.

2. The gradation and the maximum size (greater than 3 inches) of the pervious fill suggest that it may have been susceptible to segregation during placement. This is an unfavorable condition relative to piping, because it suggests that there may be some locations in the pervious fill where the gradations are coarser than indicated

by the available data, and that would provide less piping protection at those locations.

For this TM, filter compatibility was also evaluated according to guidelines recently published by Foster and Fell [18], and the calculations from that evaluation are also included in Appendix G. Foster and Fell [18] note that the filter criteria included in Design Standards No. 13, Chapter 5 [16] are based on the results of "no erosion" filter tests and are intended to represent reasonably conservative boundaries for conditions under which essentially no erosion occurs at the boundary between the two materials. They express the opinion that these filter criteria are reasonable and prudent for design of new facilities, but they also suggest that it is appropriate to consider other criteria when evaluating the risk of piping for existing structures. Specifically, Foster and Fell [18] suggest consideration of a "continuous erosion" boundary that consists of the gradation of a filter that defines the boundary (for a particular base soil) between: (1) the occurrence of some erosion followed by stable conditions, and (2) essentially continuous erosion without abatement. They recommend criteria for estimation of "no erosion" and "continuous erosion" boundaries for the evaluation of existing dams. Their recommendations were developed from: (1) a review of laboratory tests by others, including those that provided the basis of the criteria in Design Standards No. 13, Chapter 5 [16], (2) the results of additional laboratory tests that they completed, and (3) a review of field case histories. The Foster and Fell [18] recommendations for the "no erosion" boundaries are generally similar to the criteria in Design Standards No. 13, Chapter 5, but there are some small differences. The conditions at Cle Elum Dam were evaluated based on the Foster and Fell [18] criteria and the results are summarized in Table 6. The same four cases considered for the criteria in Design Standards No. 13, Chapter 5 [16] were considered for application of the Foster and Fell [18] recommendations.

Table 6
FILTER COMPATIBILITY EVALUATION – BASED ON FOSTER AND FELL [18]

Case	Actual D_{15F} (mm)	No Erosion $(D_{15F})_{NE}$ (mm)	Continuous Erosion $(D_{15F})_{CE}$ mm	Conclusion
Average Impervious/ Average Pervious	1.1	1.42	6 to 9.5	$D_{15F}<(D_{15F})_{NE}<(D_{15F})_{CE}$
Average Impervious/ Coarsest Pervious	4.0	1.42	6 to 9.5	$(D_{15F})_{NE}<D_{15F}<(D_{15F})_{CE}$

Case	Actual D_{15F} (mm)	No Erosion $(D_{15F})_{NE}$ (mm)	Continuous Erosion $(D_{15F})_{CE}$ mm	Conclusion
Finest Impervious/ Average Pervious	1.1	0.7	6 to 8	$(D_{15F})_{NE}<D_{15F}<(D_{15F})_{CE}$
Finest Impervious/ Coarsest Pervious	4.0	0.7	6 to 8	$(D_{15F})_{NE}<D_{15F}<(D_{15F})_{CE}$

A review of Table 6 indicates:

1. The results for the "no erosion" boundary are the same as those for the evaluation relative to the criteria in Design Standards No. 13, Chapter 5 [16].
2. The actual D_{15F}'s are less than the continuous erosion boundaries for all four cases. This suggests that it is reasonably likely that continuous erosion would not occur even for the case of the finest impervious fill adjacent to the coarsest pervious fill. However, segregation of the pervious fill could affect this conclusion in the same way that it could affect the earlier conclusion regarding the evaluation with respect to the criteria in Design Standards No. 13, Chapter 5 [16].

Other factors that should be considered in the assessment of the piping potential at Cle Elum Dam are:

1. The impervious fill section is very wide, the reservoir elevation is high for only a short period of time each year, and the reservoir is normally drawdown significantly ever year. These factors are favorable in two ways with respect to piping potential: (1) it is less likely that there are high gradients at the boundary between the impervious and pervious fill, and (2) it is possible that steady state seepage conditions through the impervious fill do not often, if ever, develop under high reservoir levels.
2. The foundations under most of the dam appear to be very pervious and may even act as a drain. It is possible that the phreatic surface through the impervious fill drops into the foundation and does not cross the impervious/pervious fill boundary, which would be favorable with respect to piping potential at that boundary. Although there are no data for phreatic surface levels in the impervious fill zone, this possibility is supported by the low phreatic levels in the downstream foundations and the lack of observed water in the pervious fill zone at piezometer PT-92-6.

Considering all of the information discussed above, it is judged that the likelihood of a piping failure through the embankment at Cle Elum Dam is low. This judgment is supported in part by the lack of observed evidence of seepage and piping problems in the embankment. However, the lack of observed surface evidence of piping problems cannot be taken as conclusive proof of the lack of such problems. All of the evaluations and factors discussed above should be considered in the risk analysis of this failure mode.

2. Seepage and Piping Along the Outlet Works Tunnel

The identification of voids around the outlet works tunnel during the modification of the outlet works gates in 1980 resulted in concern regarding the potential for seepage and piping along the tunnel. As discussed previously in this TM, an evaluation of available piezometer and observation well data indicates the following:

1. Although the reservoir level varies over a wide range of elevations on an annual basis, the piezometric levels in the ground in the vicinity of the outlet works tunnel vary over a much smaller range. During years when piezometer and observation well data are available, the annual reservoir level variations have ranged from 50 to 125 feet, while the annual variations in piezometeric level in the vicinity of the outlet works have ranged from 1 to 17 feet, but have typically been less than 5 feet. Therefore, the piezometric responses to changes in reservoir level are only a very small fraction (typically less than 5 percent) of the reservoir level changes.

2. At low reservoir levels, the piezometric levels in the vicinity of the outlet works downstream of the gate chamber are at elevations near the bottom of the outlet works tunnel. While at high reservoir levels, the piezometric levels in the vicinity of the outlet works are near the mid-height of the tunnel. No piezometric levels have been observed at elevations above approximately the mid-height of the tunnel.

3. According to the available piezometric data, the gradient along the outlet works is very flat, approximately 0.0015, from the gate chamber to the downstream end of the outlet works tunnel.

Based on the piezometric data, the following conclusions can be drawn regarding the seepage conditions along the outlet works tunnel:

1. From the gate chamber downstream, it does not appear that piezometric levels rise to within the upper half of the tunnel profile, which is where the voids were observed and where voids would most likely have resulted from tunneling activities. Therefore, it does not appear likely that voids along this section of the tunnel are wetted by piezometric conditions.

2. The gradient along the tunnel downstream of the gate chamber is very low and may not have sufficient energy to instigate piping.

3. The very small piezometric response, relative to changes in reservoir elevation, suggests that an increase of 3 feet in normal high reservoir level would not result in a significant change in seepage conditions along the outlet works tunnel downstream of the gate chamber.

The conclusions given above are limited to the conditions downstream of the gate chamber, because no piezometric data are available along the outlet works tunnel upstream of the gate chamber.

Based on the available information, it is judged that the likelihood of piping of foundation soils along the outlet works is low to medium.

C. Static Stability Analysis

1. Method of Analysis

A static stability analysis was performed to evaluate the steady state seepage and rapid drawdown stability of the dam (upstream and downstream) in the SEED analysis report using STABL2. For this report, the static stability of the upstream slope under rapid drawdown conditions was reanalyzed using subsurface information obtained during the 1992-93 and 1998 field investigations. This analysis was performed using the limit equilibrium UTEXAS3 computer program and Spencer's method (Appendix H).

2. Material Properties

Soil properties were obtained from the SEED report contained in the SEED data book [1]. The soil property values actually were derived from the original Construction Report for Cle Elum Dam. Previous analyses assumed the presence of liquefiable layers in the dam foundation. As discussed later, during the 1998 Becker drilling program, no evidence of liquefiable layers were observed. Table 7 lists the properties used in modeling the dam to perform the static and dynamic stability analyses, along with typical ranges of the parameters taken from Hoek and Bray, 1981 [13].

Table 7
MATERIAL PARAMETERS USED IN STABILITY ANALYSES

	Unit Weight		**Friction Angle**		**Cohesion**		
Material	**Range**	**Used**	**Range**	**Used**	**Range**	**Used**	**Undrained Shear Strength**
Impervious U/S blanket	105-130	115	30-32	30	1500-3000	0	0
Compacted impervious fill (U/S)	105-130	137	30-32	30	1500-3000	0	2000
Compacted pervious fill (D/S)	109-130	120	32-40	33	0	0	0
Uncompacted D/S pervious berm	90-118	115	28-34	30	0	0	0

Material	Unit Weight		Friction Angle		Cohesion		Undrained Shear Strength
	Range	Used	Range	Used	Range	Used	
Foundation sandy silty gravel (coarse-grained)	110-120	115	48-45	31	0	0	0
Foundation silty and clayey sand (finer-grained)	99-124	110	34-40	30	0	0	0

NOTE:

1. Ranges obtained from Hoek and Bray (1981) [13].

For the most part, the material parameters used in the stability analyses fall within the typical range, or on the conservative side of the ranges given. An exception to this is the unit weight for the upstream compacted impervious fill, for which the value used is slightly higher than the typical range. This value was used in the current analysis to be consistent with earlier analyses, and because it is judged to not have a significant effect on the results for two reasons: (1) the value used is only about 5 percent higher than the upper end of the range of values, and (2) small differences in unit weights do not have significant effects on the results of stability analyses because they affect both driving forces and resisting forces in ways that, at least in part, balance each other and moderate the effects of differences in unit weight. URSGWC believes that the parameters used are reasonable and appropriate, based on a review of the available information for the materials in the dam and its foundation.

3. Analysis Results

The inferred foundation materials were altered slightly after reviewing results from the more recent field investigations, suggesting that a previously inferred clay layer does not exist within the upstream section of the foundation. Because the most critical surfaces for the upstream and downstream steady seepage conditions pass through only the embankment, the factors of safety reported in the SEED analysis report remain valid.

According to Reclamation criteria [9], rapid drawdown static stability is not considered to be a deficiency if the factor of safety is greater than 1.3. The SEED-level investigations indicated a minimum factor of safety of 1.1 using a noncircular surface passing through the previously defined continuous clay layer. Using the updated internal geometry (no clay or liquefiable layers), the static stability of the upstream slope under rapid drawdown conditions was reanalyzed. Again, the critical failure surface on the upstream slope of the dam under rapid drawdown conditions produced a factor of safety of 1.1. This surface did not intersect into the foundation materials, passing only through the dam embankment. Appendix H includes the static stability results documented in the SEED analysis report (using STABL2) and the new stability analyses (using UTEXAS3). The results of the steady-state static stability analysis from the SEED analysis report [1], and the upstream rapid drawdown stability analysis performed for this report, are summarized in Table 8.

Table 8
STATIC STABILITY ANALYSES RESULTS

Case Considered	Computed Minimum Factor of Safety	Required Factor of Safety
Downstream slope, steady seepage	2.0	1.5
Upstream slope, steady seepage	2.1	1.5
Upstream slope, rapid drawdown	1.1	1.3

D. Dynamic Stability Analysis

1. Liquefaction

An empirical assessment of the liquefaction potential and an evaluation of the dam and dam's foundation resistance to seismic loading was performed for Cle Elum Dam in accordance with Bureau of Reclamation (Reclamation) procedures [9]. The process includes the following: (1) evaluate the potential for sufficient seismic activity to produce liquefaction, (2) use a method that empirically determines the soil's resistance to liquefy, and (3) perform a post-earthquake stability analysis. The analysis was performed based on data obtained during the 1998 Becker drilling program.

Liquefaction of the dam foundation was initially thought to be a dam safety deficiency based on data obtained from the field exploration program in 1992-93 and earlier programs. In 1992-93, lower velocity layers ($600<V_s<850$ fps and $V_s<1200$ fps) were identified during cross hole shear wave testing. Based on the USBR standard for seismic design [9], materials with a shear wave velocity greater than 1200 fps (feet per second) are considered nonliquefiable.

A subsequent Becker drilling program consisting of five Becker drill holes and one Becker sample hole was conducted in 1998. Complete details are included in Appendix B. This program was undertaken to obtain blow count values for the foundation materials in an effort to determine the existence and/or extent of potentially liquefiable layers within the foundation. Lower velocity layers ($600<V_s<850$ fps and $V_s<1200$ fps) identified during the 1992-93 drilling and geophysical program were not supported by low blow counts during the 1998 Becker drilling program. The uncorrected closed-bit blow counts for the layer ($600<V_s<800$ fps) located between elevations of 2095 and 2110 (45 to 60 feet depth) near BDH98-2 ranged from 86 to 342 bpf (blows per foot), while the uncorrected open-bit blow counts for the similar layer ($V_s<850$ fps) identified between elevations 2105 and 2120 (60 to 75 feet depth) near BDH98-4 ranged from 34 to 204 bpf. Additionally, the zones exhibiting shear wave velocities on the order of 1200 fps, identified between elevations 2010 and 2040 (115 to 145 feet depth) near BDH98-2 and between elevations 2040 and 2055 (125 to 140 feet depth) near BDH98-4, exhibited uncorrected closed-bit blow counts ranging from 60 bpf to refusal (>1200) and uncorrected open-bit blow counts ranging from 20 to 203 bpf for BDH98-2 and BDH98-4, respectively.

For this technical memorandum, analysis of the corrected Becker penetration test blow counts was conducted. Verification of the potential for liquefaction of the foundation soils was not evidenced by the corrected Becker Penetration Test blow counts obtained from BDH98-1, BDH98-1B, BDH98-2 and BDH98-3. The Becker blow counts converted to equivalent SPT N_{60} values, using both the Harder and Seed (1987) [7] and the Sy (1997) [8] methods, were greater than 100 (refusal) for nearly the entire penetration depths, as shown in Figures 8A through 8D. The calculation spreadsheets for determination of the correlated N_{60} values by the Sy (1997) and the Harder and Seed (1986) methods are included in Appendix I.

The foundation of the dam is glacial outwash and glacial drift consisting of a heterogeneous mixture of gravel, cobbles, boulders, sand, and some fines (silt and clay). Pockets and seams of these materials may be potentially susceptible to liquefaction; however, as evidenced by the Becker penetration test results, no extensive layers of potentially liquefiable materials appear to exist within the dam foundation. Failure of the dam due to liquefaction of foundation materials is considered low.

Because potentially liquefiable layers were not identified in the downstream portion of the dam, post-earthquake stability analyses were not performed.

2. Deformation

A deformation analysis is not required when the dam and foundation are not susceptible to liquefaction, if certain conditions are met [9]. These conditions and applicability to Cle Elum Dam are discussed below:

- The dam must be a well-built dam (densely compacted), and the peak accelerations at the base of the dam are 0.2g or less; or the dam is constructed out of clay soils, is on clay or rock foundations, and peak accelerations are 0.35g or less.

  As previously described, Cle Elum Dam is a zoned embankment with controlled compaction, thus qualifying as a "well-built dam." At typical return periods of 10,000 and 50,000 years, the estimated mean peak horizontal accelerations at the ground surface are 0.28g and 0.42g, respectively. Therefore, the 10,000-year earthquake is greater than the maximum value of 0.2g.

- The slopes of the dam must be 3:1 (Horizontal:Vertical) or flatter.

The upstream and downstream slopes of the dam are both 3:1, with upstream and downstream berms of even flatter slopes. Therefore, this condition is met.

- The static factors of safety of the critical failure surfaces involving loss of crest elevation are greater than 1.5 under loading conditions expected prior to an earthquake.

  As documented previously, the factors of safety for steady-state seepage static stability analyses are greater than 1.5.

- The freeboard at the time of the earthquake is a minimum of 2 to 3 percent of the embankment height (not less than 3 feet (0.9 m)). Fault displacement and reservoir seiches with regard to freeboard should be considered as separate problems.

  Freeboard at Cle Elum Dam, when at maximum reservoir, is 10 feet. The structural height of the dam is 165 feet, and, therefore, the freeboard is 6 percent of the height of the dam.

With the exception of the peak acceleration of 0.28g during the 10,000-year earthquake that is greater than the maximum value of 0.2g, all criteria were met for not performing a deformation analysis. A detailed ground motion analysis was not completed.

The duration of the magnitude 9 earthquake was long (up to 3 minutes), so a very simplified deformation analysis was conducted using Newmark methods. The simplified deformation analysis was performed using the time versus acceleration plot of the long duration magnitude 9, 10,000-year earthquake at the base of the dam and considering a full-height potential sliding surface. Because results of this analysis indicated that deformation along this surface would likely be negligible (less than 0.005 feet), no in-depth deformation analysis was completed for Cle Elum Dam. Results of this analysis are included in Appendix F. Use of the base input motion without propagation through the foundation and embankment soil column is believed to be a reasonable simplification for this case, because experience has shown that, for most cases, dynamic analyses result in a peak instantaneous acceleration at the crest of an embankment dam of less than twice the peak acceleration at the base, and a peak "average" acceleration of a mass extending from the crest to the base that is typically about one-half of the peak instantaneous acceleration at the crest. Therefore, the use of the peak acceleration at the base is a reasonable approximation of the peak "average" acceleration of a full-height sliding surface. Use of the base input motion results in the inclusion of more high frequency shaking than would be the case if a dynamic analysis was completed to estimate the time history of "average" acceleration for the sliding mass. However, because the resulting calculated deformations were extremely small, this error is judged to be acceptable in this case.

IV. CONCLUSIONS

The likelihood for failure of Cle Elum Dam with respect to liquefaction is judged to be low. Based on Becker penetration test results, the foundation materials tested are dense and are not potentially liquefiable. Cross hole shear wave tests performed in 1992-93 indicated zones with shear wave velocities lower than 1200 feet per second (fps), some as low as 600 to 850 fps, indicative of potentially liquefiable materials. Becker penetration tests performed adjacent to each of the cross hole shear wave test locations did not confirm the existence of potentially liquefiable materials. Based on the low potential for post-liquefaction failure, the dynamic deformation of the dam under earthquake loads is anticipated to be very small.

The likelihood for an instability failure of Cle Elum Dam under steady-state seepage is judged to be low. The computed minimum safety factors for both the upstream and downstream embankment slopes are greater than the USBR required minimum of 1.5.

The likelihood for failure of Cle Elum Dam under rapid drawdown conditions is judged to be low to medium. The calculated factor of safety of the upstream slope under rapid drawdown conditions was 1.1, less than the USBR recommended minimum value of 1.3. However, this is judged not to be a Safety of Dams concern, because (1) there have been no reported stability problems during drawdown and the reservoir is drawn down every year, (2) the calculated factor of safety is greater than 1.0 with a reasonably conservative strength value, and (3) the safety-related consequences of a stability failure during rapid drawdown are limited because of the low reservoir level.

The potential for failure of Cle Elum Dam due to piping through the embankment is judged to be low. Filter compatibility analyses were completed for the impervious fill/pervious fill boundary based on Reclamation's Design Standards No. 13, Chapter 5 [16] and a recent publication by Foster and Fell [18]. Those analyses indicated that: (1) the "no erosion" filter criteria of Design Standards No. 13 were probably met at most locations on the boundary, and (2) the pervious fill gradations are likely less than the no "continuing erosion" boundaries recommended by Foster and Fell at all locations. Hence, it is judged reasonably unlikely that continuing erosion would occur at the boundary between these two materials. Other favorable factors considered in this judgment were: (1) the likelihood that flow across this boundary may be confined to a limited area very low in the embankment or possibly even non-existent, (2) gradients at the boundary, if flow across the boundary exists, are likely low, and (3) no evidence has ever been reported of seepage and piping problems in the embankment. One unfavorable factor that was also considered was the fact that the maximum particle size and the gradations of the pervious fill indicate that it may have been susceptible to segregation during placement, which could have resulted in some in-place material coarser than would be indicated by the available gradation curves.

The potential for seepage-related problems in the vicinity of the outlet works is judged to be low to medium. There are existing voids in the foundation soils surrounding the upper portion of the outlet works tunnel. These voids are believed to have most likely developed during the original construction of the outlet works tunnel. Available piezometric data indicate that piezometric levels along the outlet works tunnel, from the gate chamber to the downstream end, vary between the bottom and the mid-height of the tunnel as the reservoir level varies. So, the piezometric levels do not likely wet the voids around the upper part of the tunnel. The piezometric data also indicates a very low gradient of about 0.0015 along the tunnel downstream of the gate chamber. Piezometric levels upstream of the gate chamber are not known.

It was judged that the 3-foot increase in the normal high reservoir pool level would have a negligible effect on the static stability, seismic stability, and seepage stability of the dam. Based on piezometer responses, the increases in piezometric levels in the outlet works area and within the dam embankment due to the 3-foot increase in reservoir level would likely be very small (<0.25 feet). In addition, the effect of the increased reservoir loading would likely be very small.

V. FUTURE ACTIONS

Monitoring of seepage in the vicinity of the right abutment should be performed in conjunction with the 3-foot rise of the reservoir pool level. Observance of seepage flow, sand boils, or sediment transport should be reported to the Regional and Denver Offices immediately.

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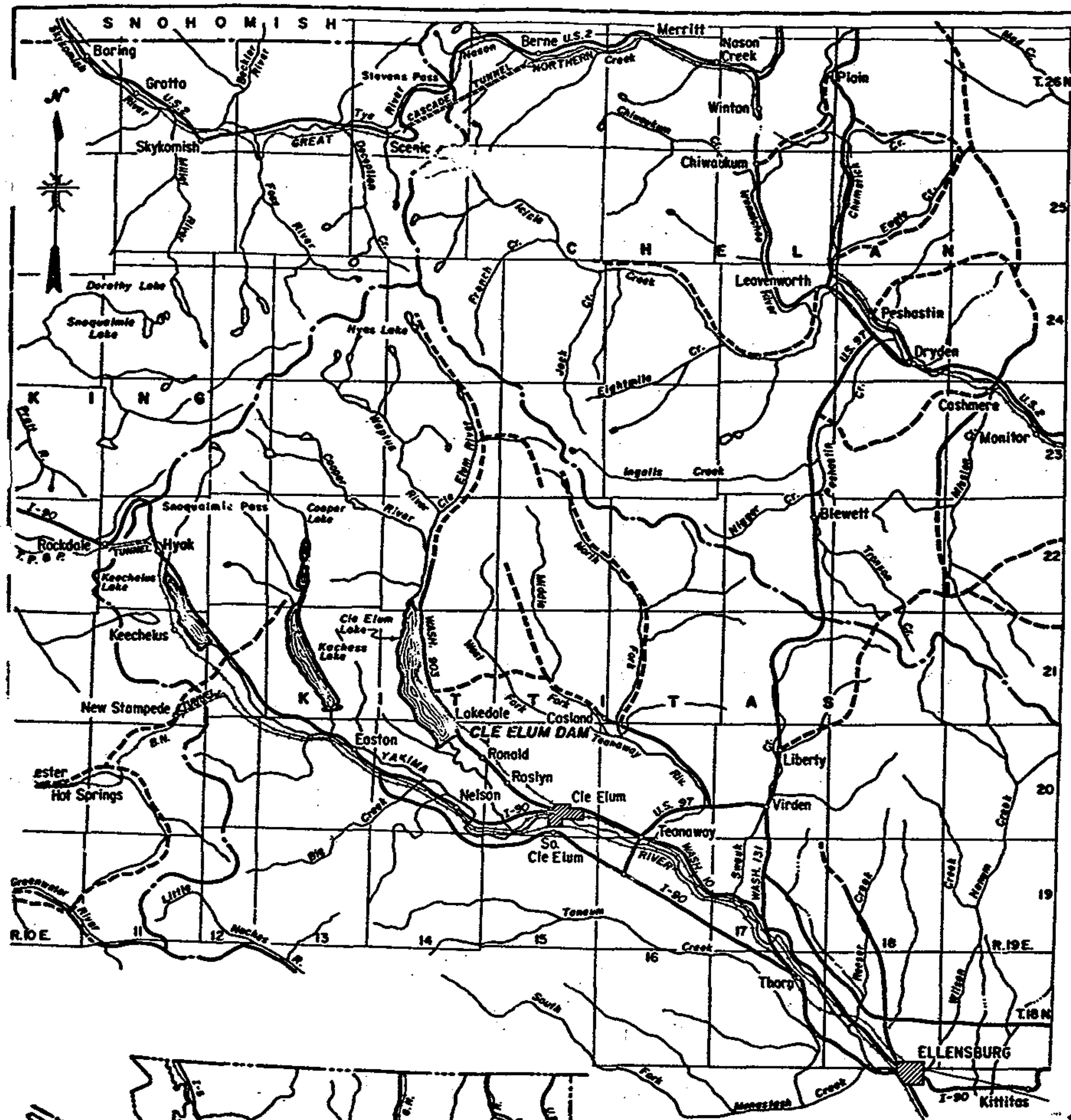
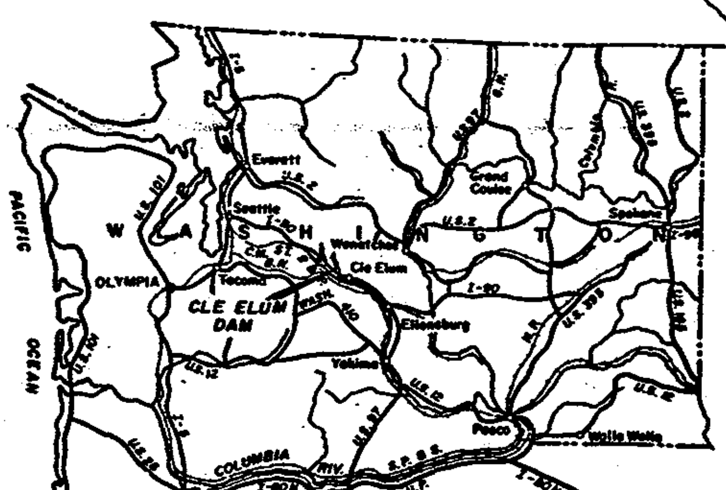
Figure 1

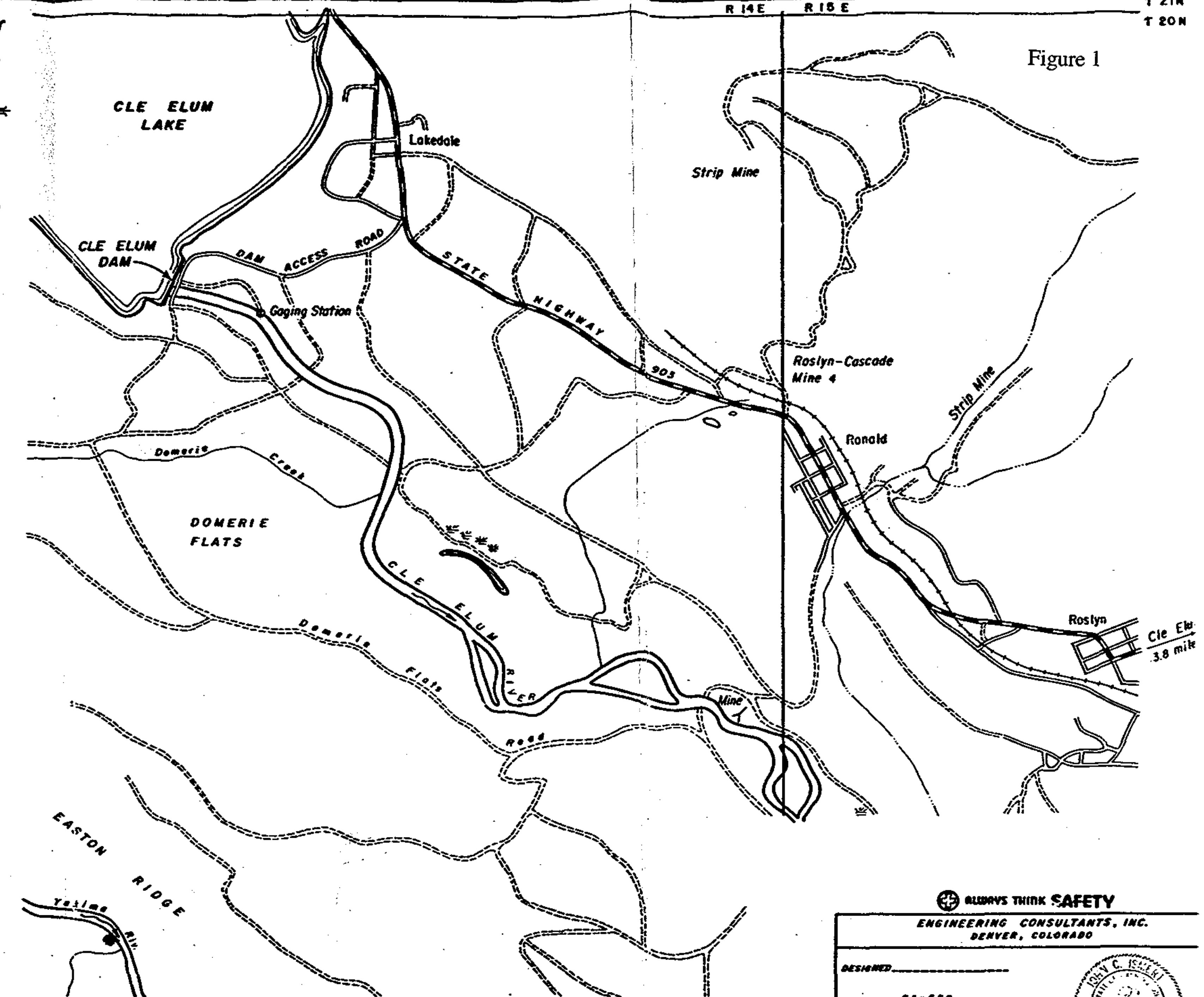


VICINITY MAP

SCALE OF MILES



KEY MAP



DAM VICINITY

SCALE OF FEET

ALWAYS THINK SAFETY

ENGINEERING CONSULTANTS, INC.
DENVER, COLORADO

DESIGNED ____
DRAWN S.A.-F.E.S.
CHECKED ____
DATE OCT. 10, 1977 APPROVED ____

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT-WASHINGTON

CLE ELUM DAM
OUTLET WORKS REHABILITATION

LOCATION MAP

DESIGNED ____ SUBMITTED ____
DRAWN ____ RECOMMENDED ____
CHECKED ____ APPROVED ____
DIRECTOR OF DESIGN AND CONSTR.

DENVER, COLORADO OCT. 10, 1977 33-D-399

Figure 2

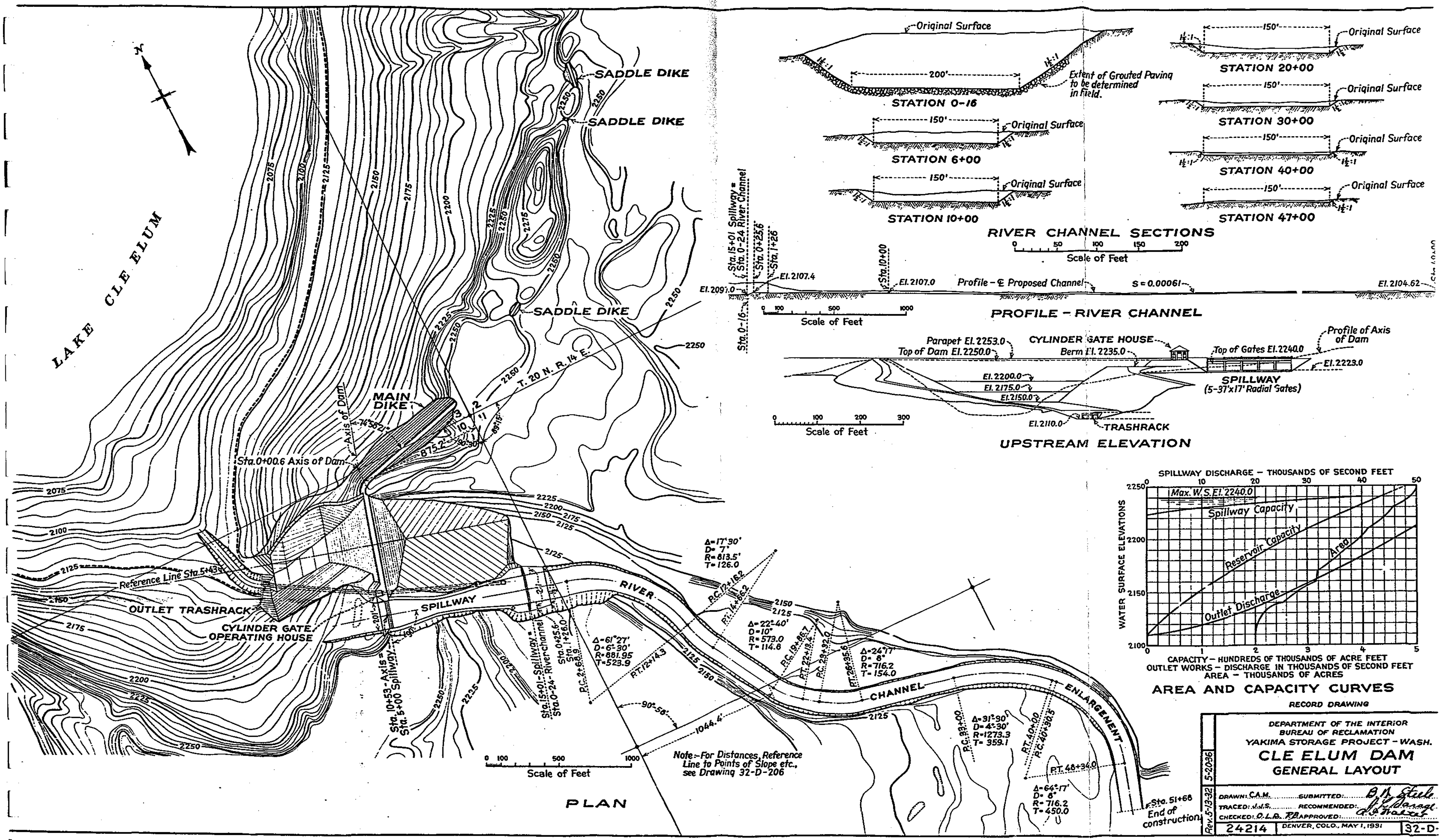
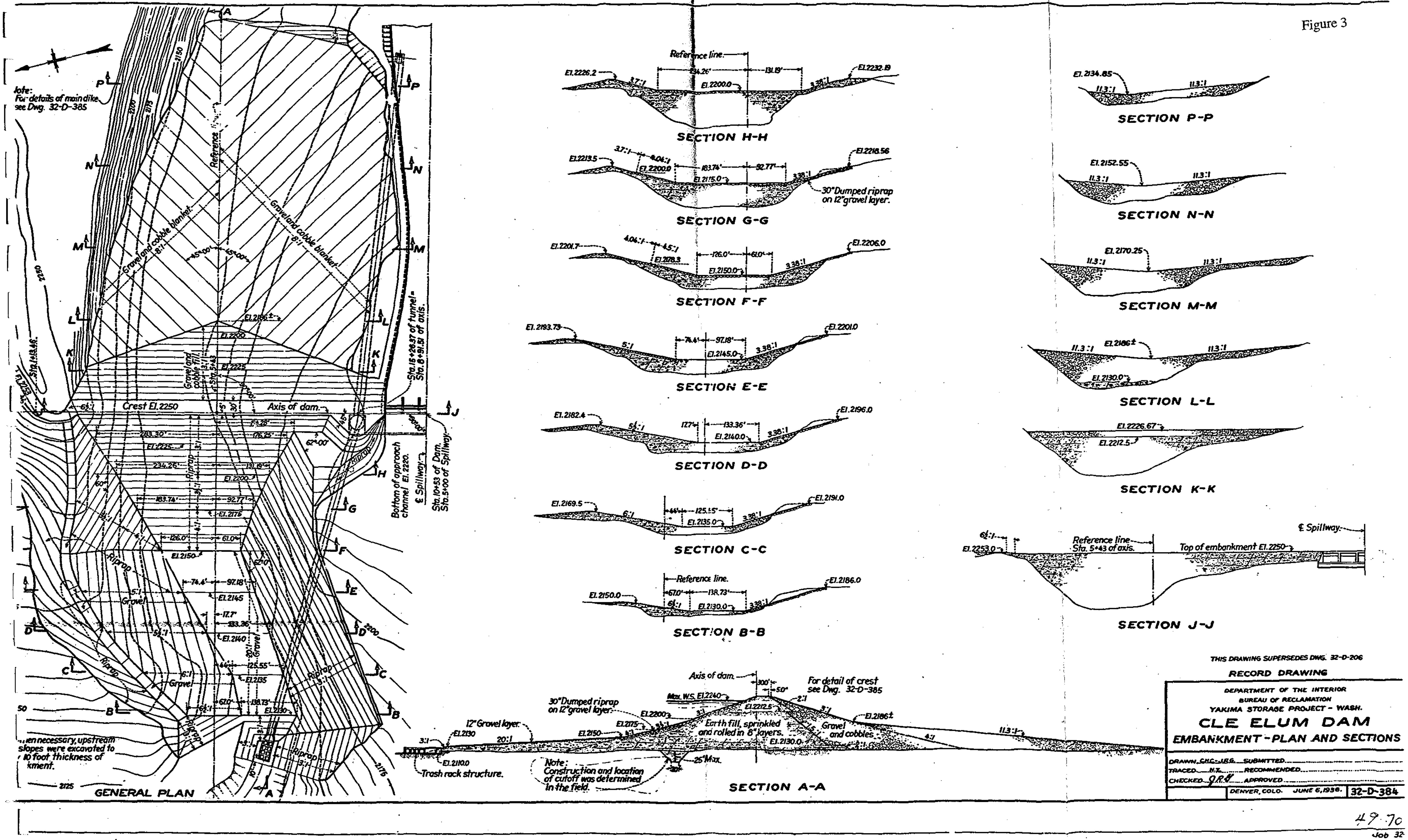

LAKE CLE ELUM
SADDLE DIKE
SADDLE DIKE
SADDLE DIKE
MAIN DIKE
T. 20 N. R. 14 E.
Axis of Dam
Sta. 0+00.6 Axis of Dam
Reference Line Sta. 5+43
OUTLET TRASHRACK
CYLINDER GATE OPERATING HOUSE
SPILLWAY
RIVER
CHANNEL
ENLARGEMENT
Sta. 10+53 - Axis = Sta. 5+00 Spillway
Sta. 15+01 - Spillway = Sta. 0-24 - River channel
Sta. 0+25.6
Sta. 1+26.0
Δ=17°30' D=7° R=813.5' T=126.0
Δ=61°27' D=6°-30' R=881.95 T=523.9
Δ=22°40' D=10° R=573.0 T=114.8
Δ=24°17' D=8° R=716.2 T=154.0
Δ=31°30' D=4°30' R=1273.3 T=359.1
Δ=64°17' D=8° R=716.2 T=450.0
Sta. 51+68 End of construction
Note:- For Distances, Reference Line to Points of Slope etc., see Drawing 32-D-206
Scale of Feet
PLAN
Original Surface
Extent of Grouted Paving to be determined in field.
STATION 0-16
STATION 6+00
STATION 10+00
STATION 20+00
STATION 30+00
STATION 40+00
STATION 47+00
RIVER CHANNEL SECTIONS
Scale of Feet
Profile - ℄ Proposed Channel
S = 0.00061
El. 2097.0
El. 2107.4
El. 2107.0
El. 2104.62
PROFILE - RIVER CHANNEL
Parapet El. 2253.0
Top of Dam El. 2250.0
CYLINDER GATE HOUSE
Berm El. 2235.0
Top of Gates El. 2240.0
Profile of Axis of Dam
El. 2223.0
SPILLWAY (5-37'x17' Radial Gates)
El. 2200.0
El. 2175.0
El. 2150.0
El. 2110.0
TRASHRACK
Scale of Feet
UPSTREAM ELEVATION
SPILLWAY DISCHARGE - THOUSANDS OF SECOND FEET
Max. W.S. El. 2240.0
Spillway Capacity
Reservoir Capacity
Area
Outlet Discharge
WATER SURFACE ELEVATIONS
CAPACITY - HUNDREDS OF THOUSANDS OF ACRE FEET
OUTLET WORKS - DISCHARGE IN THOUSANDS OF SECOND FEET
AREA - THOUSANDS OF ACRES
AREA AND CAPACITY CURVES
RECORD DRAWING
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA STORAGE PROJECT - WASH.
CLE ELUM DAM
GENERAL LAYOUT
DRAWN: C.A.M.
TRACED: J.J.S.
CHECKED: O.L.D.
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLO., MAY 1, 1931
24214
32-D-

Figure 3



Note: For details of main dike see Dwg. 32-D-385
Gravel and cobble blanket 8:1
Reference line
Crest El. 2250
Axis of dam
Riprap
Gravel
Bottom of approach channel El. 2220.
℄ Spillway
Sta. 10+53 of Dam. Sta. 5+00 of Spillway.
Sta. 16+28.37 of tunnel = Sta. 8+91.51 of axis.
When necessary, upstream slopes were excavated to 10 foot thickness of embankment.
GENERAL PLAN
SECTION H-H
SECTION G-G
30" Dumped riprap on 12" gravel layer.
SECTION F-F
SECTION E-E
SECTION D-D
SECTION C-C
SECTION B-B
SECTION P-P
SECTION N-N
SECTION M-M
SECTION L-L
SECTION K-K
Reference line Sta. 5+43 of axis.
Top of embankment El. 2250
SECTION J-J
Axis of dam.
For detail of crest see Dwg. 32-D-385
Max. W.S. El. 2240
Earth fill, sprinkled and rolled in 8" layers.
Gravel and cobbles
12" Gravel layer.
Trash rack structure.
Note: Construction and location of cutoff was determined in the field.
SECTION A-A
THIS DRAWING SUPERSEDES DWG. 32-D-206
RECORD DRAWING
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA STORAGE PROJECT - WASH.
CLE ELUM DAM
EMBANKMENT - PLAN AND SECTIONS
DRAWN
TRACED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLO. JUNE 6, 1938. 32-D-384

Figure 4

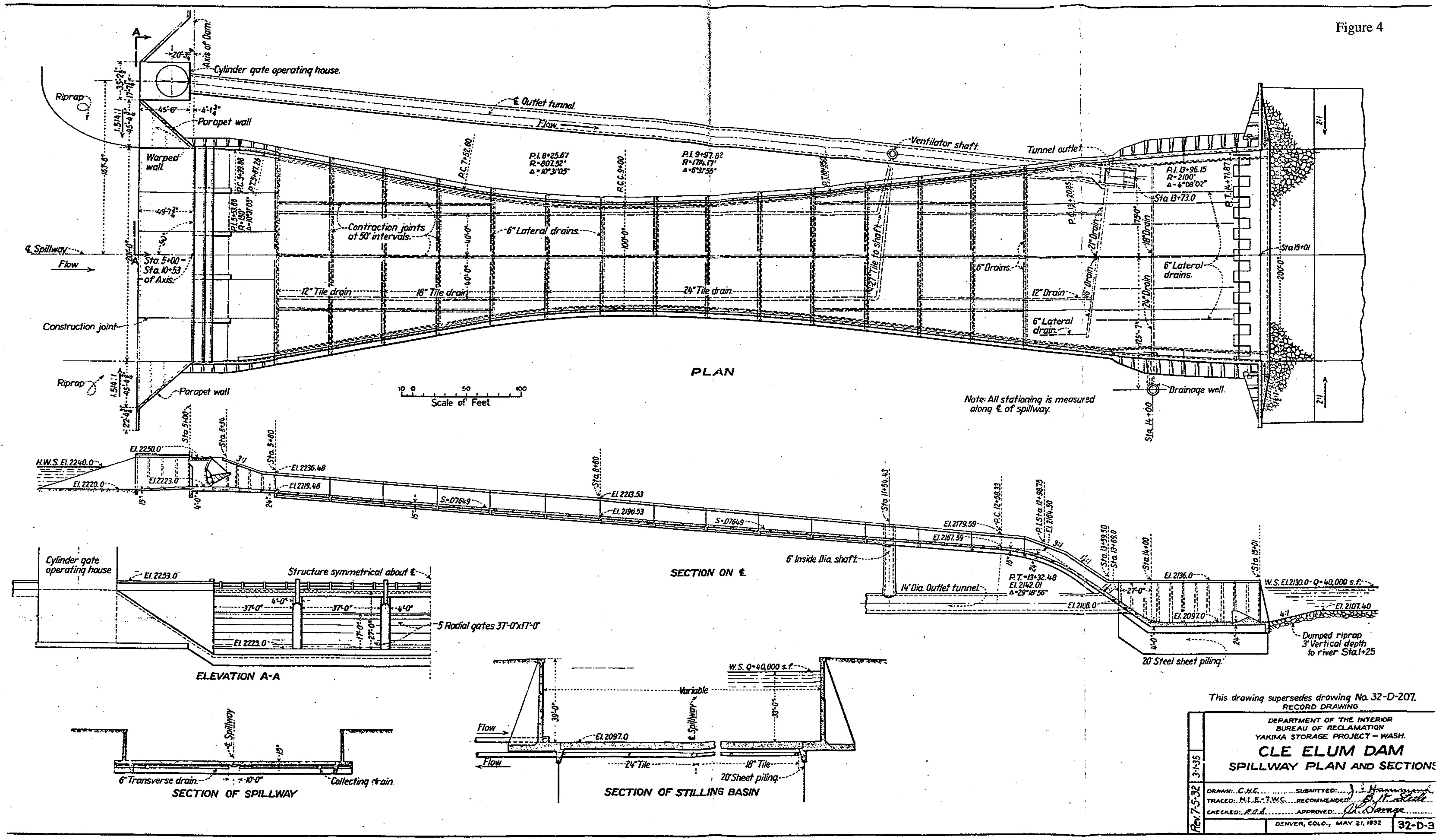
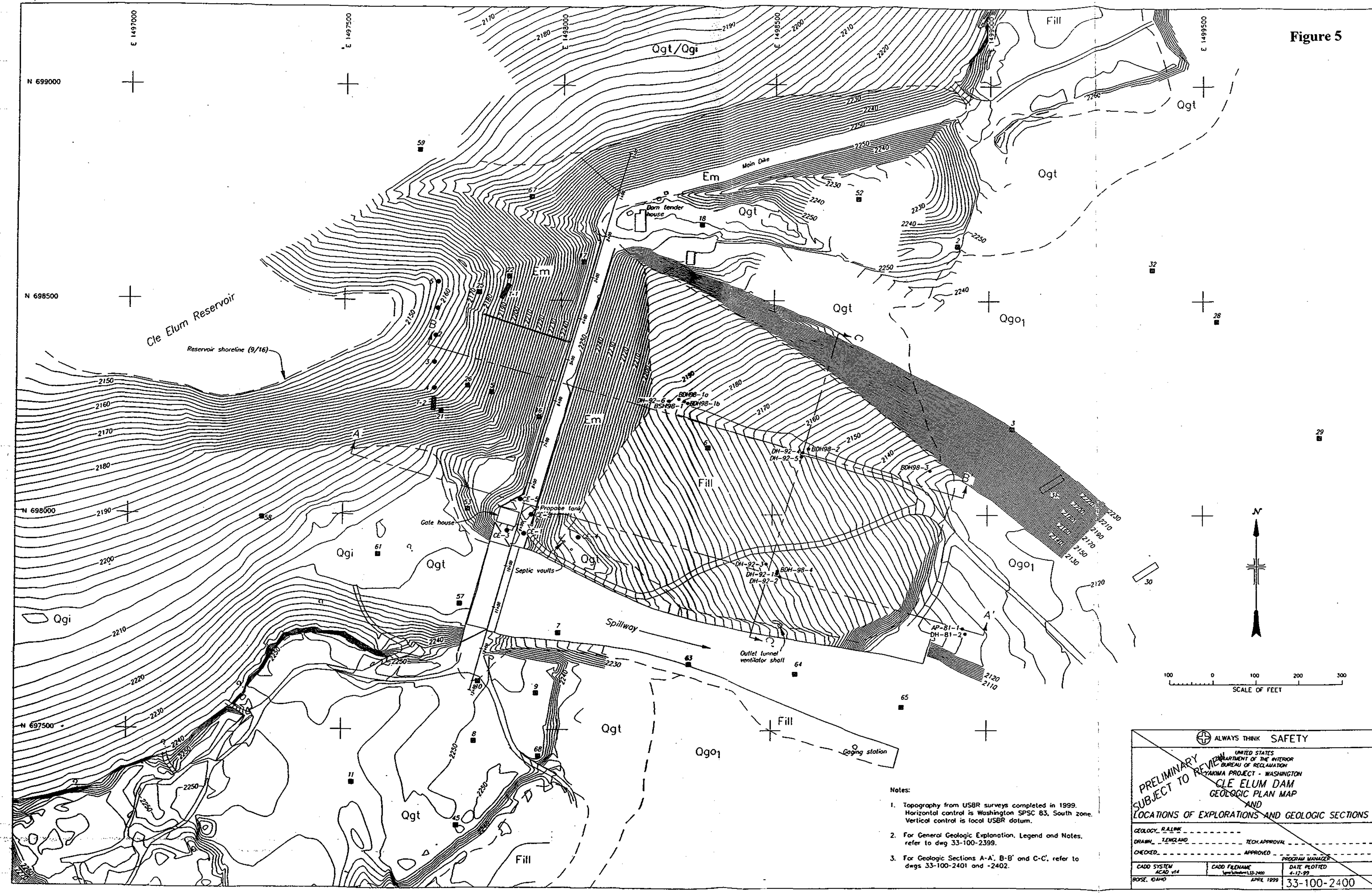

Cylinder gate operating house.
℄ Outlet tunnel.
Flow
Riprap
Parapet wall
Warped wall.
Ventilator shaft.
Tunnel outlet.
Contraction joints at 50' intervals.
6" Lateral drains.
℄ Spillway
Sta. 5+00 = Sta. 10+53 of Axis.
12" Tile drain
18" Tile drain
24" Tile drain
21" Tile to shaft
6" Drains.
12" Drain
6" Lateral drain.
6" Lateral drains.
Construction joint
Drainage well.
PLAN
Scale of Feet
Note: All stationing is measured along ℄ of spillway.
H.W.S. El. 2240.0
SECTION ON ℄
6' Inside Dia. shaft.
14' Dia. Outlet tunnel.
W.S. El. 2130.0 - Q = 40,000 s.f.
Dumped riprap 3' Vertical depth to river Sta. 1+25
20' Steel sheet piling.
Cylinder gate operating house
Structure symmetrical about ℄
5 Radial gates 37'-0" x 17'-0"
ELEVATION A-A
6" Transverse drain.
Collecting drain.
SECTION OF SPILLWAY
W.S. Q = 40,000 s.f.
Variable
24" Tile
18" Tile
20' Sheet piling
SECTION OF STILLING BASIN
This drawing supersedes drawing No. 32-D-207.
RECORD DRAWING
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA STORAGE PROJECT — WASH.
CLE ELUM DAM
SPILLWAY PLAN AND SECTIONS
DRAWN: C.H.C.
TRACED: H.I.E.-T.W.C.
CHECKED:
SUBMITTED:
RECOMMENDED:
APPROVED:
DENVER, COLO., MAY 21, 1932
32-D-3
Rev. 7-5-32
3-1-35

Figure 5


Cle Elum Reservoir
Reservoir shoreline (9/16)
Qgt/Qgi
Qgt
Qgo1
Qgi
Em
Fill
Main Dike
Dam tender house
Gate house
Propane tank
Septic vaults
Spillway
Outlet tunnel ventilator shaft
Gaging station
N 699000
N 698500
N 698000
N 697500
E 1497000
E 1497500
E 1498000
E 1498500
E 1499000
E 1499500
SCALE OF FEET
Notes:
1. Topography from USBR surveys completed in 1999. Horizontal control is Washington SPSC 83, South zone. Vertical control is local USBR datum.
2. For General Geologic Explanation, Legend and Notes, refer to dwg 33-100-2399.
3. For Geologic Sections A-A', B-B' and C-C', refer to dwgs 33-100-2401 and -2402.
ALWAYS THINK SAFETY
PRELIMINARY SUBJECT TO REVIEW
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT - WASHINGTON
CLE ELUM DAM
GEOLOGIC PLAN MAP
AND
LOCATIONS OF EXPLORATIONS AND GEOLOGIC SECTIONS
GEOLOGY R.A.LINK
DRAWN T.ENGLAND
TECH.APPROVAL
CHECKED
APPROVED
PROGRAM MANAGER
CADD SYSTEM ACAD v14
CADD FILENAME
DATE PLOTTED 4-12-99
BOISE, IDAHO
APRIL 1999
33-100-2400

CLE ELUM DAM, WA
S-WAVE VELOCITY PROFILE
CH-93-01: d/s toe @ Sta. 8+45
DATA AVERAGED FROM FORWARD AND REVERSE ARRAYS

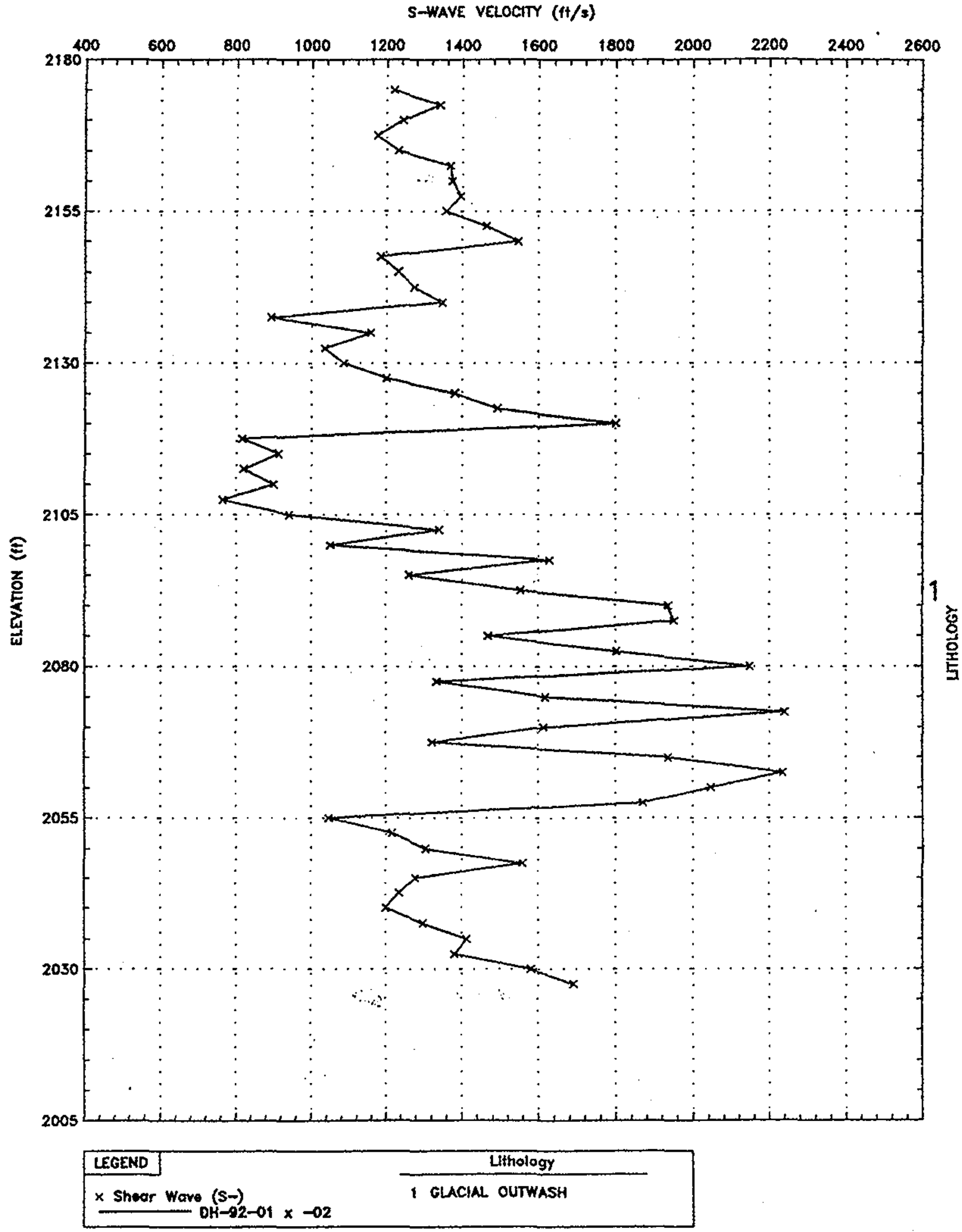


FIGURE: **6A**

CLE ELUM DAM, WASHINGTON
S-WAVE VELOCITY PROFILES
CH-93-02: d/s toe @ Sta. 5+60
DATA AVERAGED FROM FORWARD AND REVERSE ARRAYS

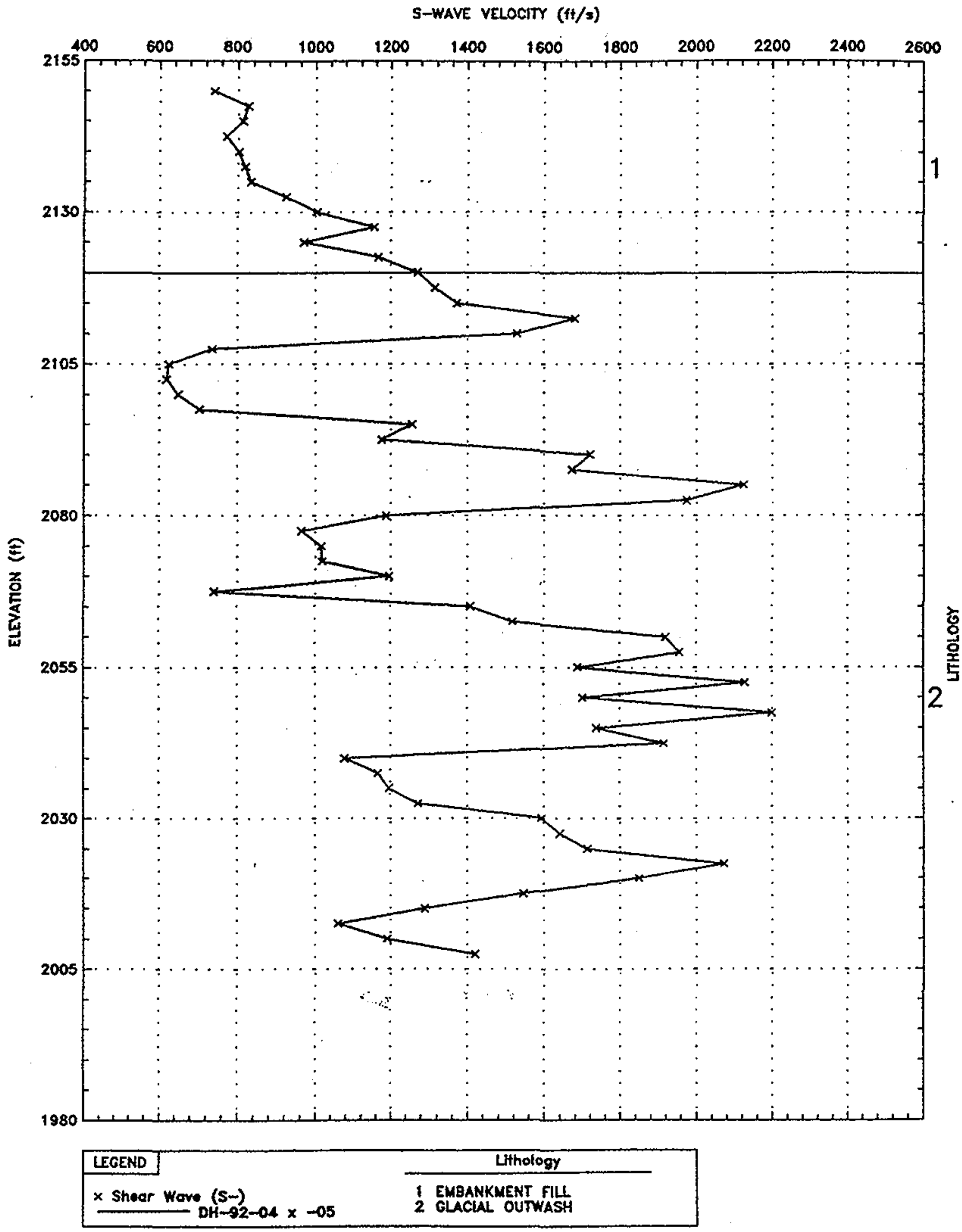
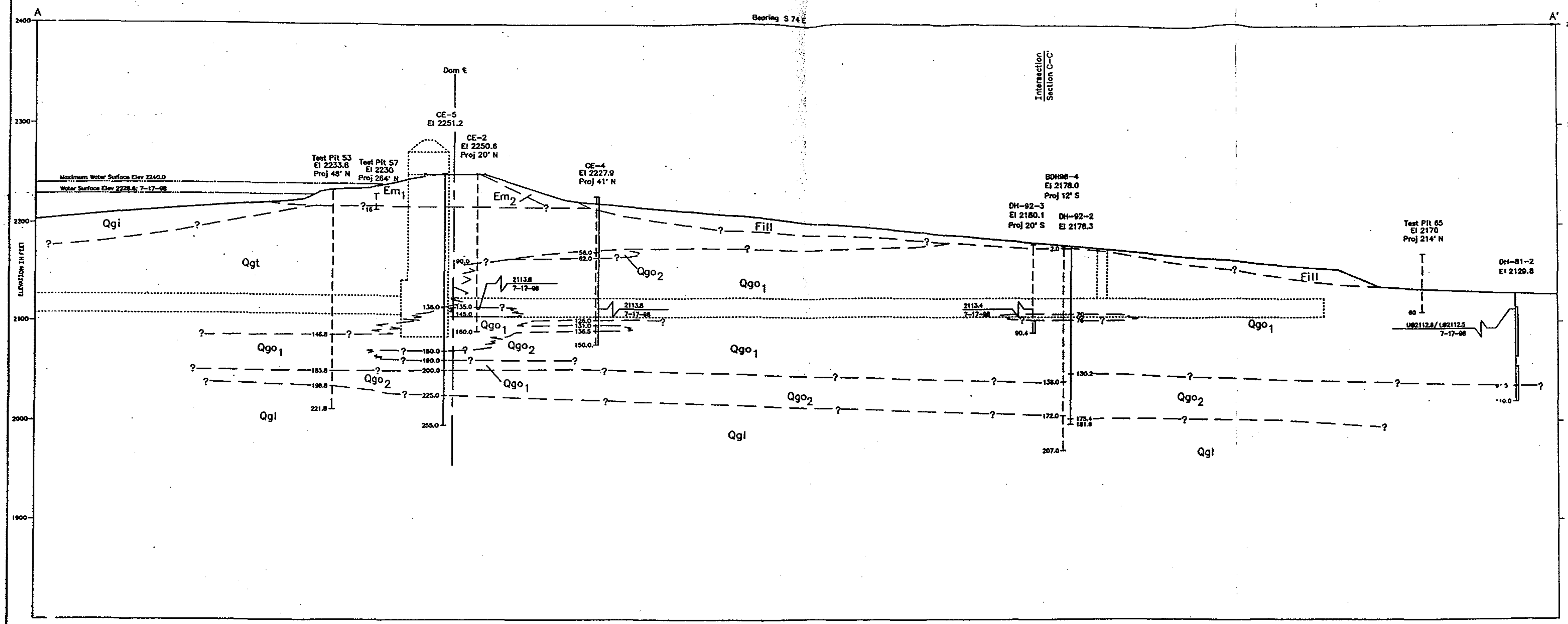


FIGURE: **6B**

Figure 7A



50 0 50 100 150
SCALE OF FEET

Notes:

1. For General Geologic Explanation, Legend and Notes, refer to dwg 33-100-2399.
2. For location of sections refer to dwg 33-100-2400.
3. Projection of outlet works gate shaft and tunnel conduit from dwg 33-D-3999.

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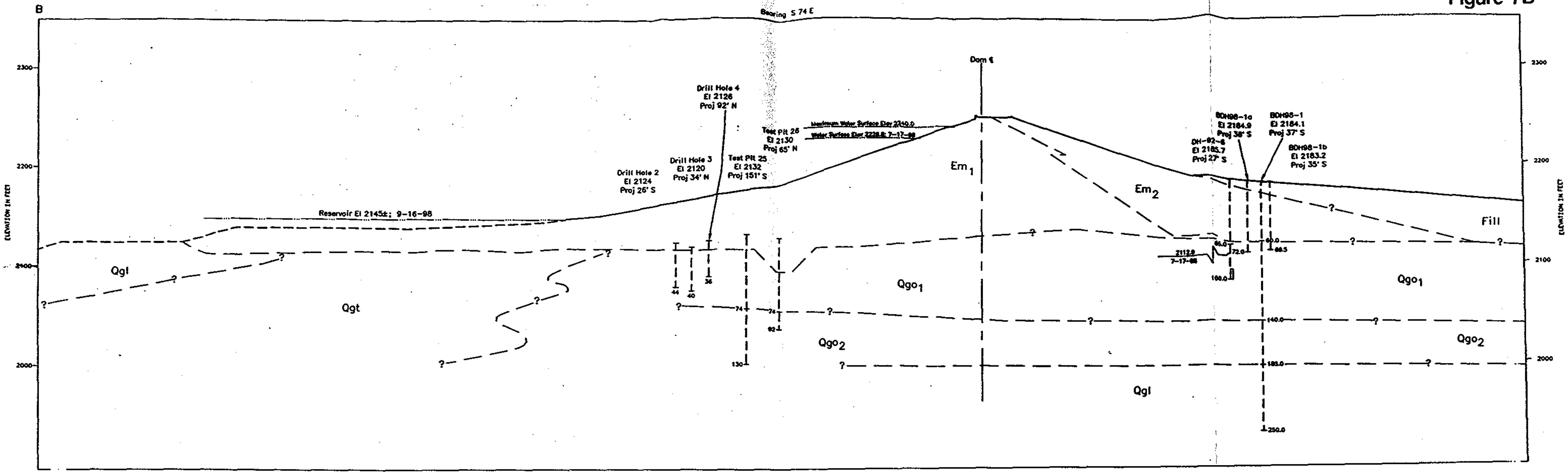
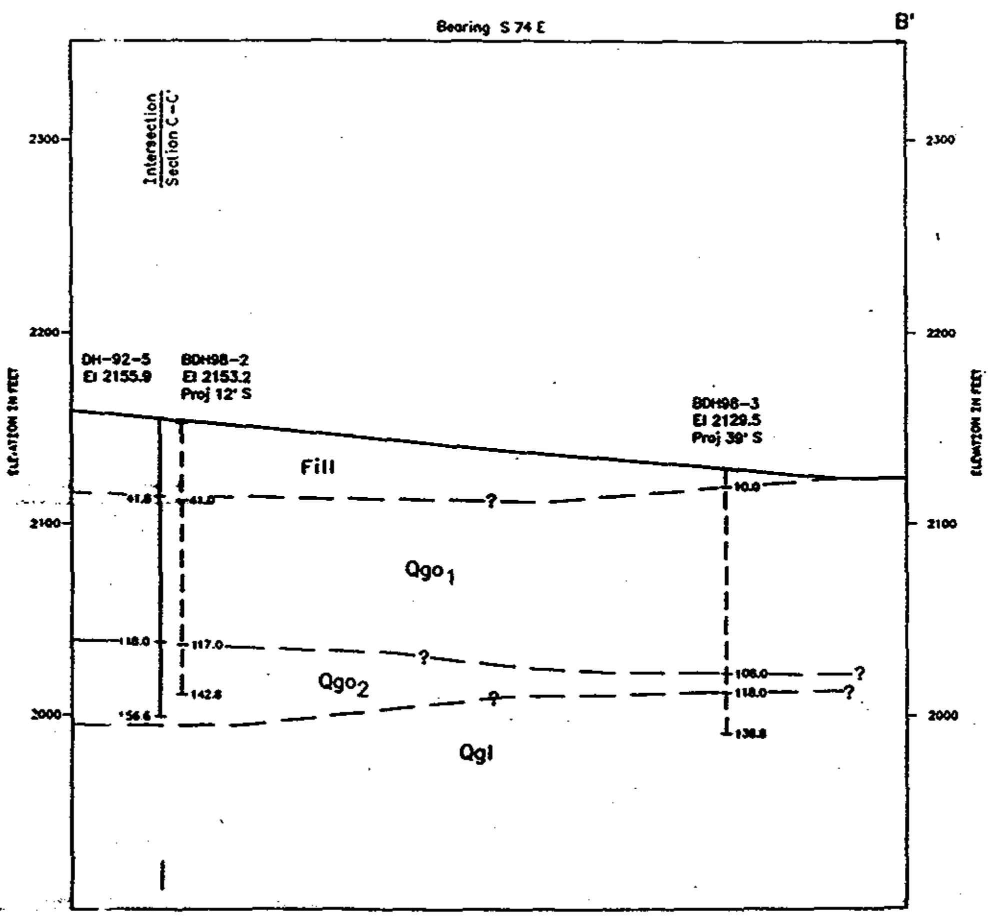
PRELIMINARY SUBJECT TO REVIEW

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT – WASHINGTON
CLE ELUM DAM
GEOLOGIC SECTION A-A'
STATION 8+50

GEOLOGY B.LINK
DRAWN T.ENGLAND TECH.APPROVAL
CHECKED APPROVED
PROGRAM MANAGER
CADD SYSTEM ACAD v14 | CADD FILENAME ...\cleelum\33-2401 | DATE PLOTTED 6-9-99
BOISE, IDAHO APRIL 1999 | 33-100-2401

Figure 7B





Notes:

1. For General Geologic Explanation, Legend and Notes, refer to dwg 33-100-2399.
2. For location of sections and explorations, refer to dwg 33-100-2400.
3. Embankment zonations, upstream submerged surface and configuration adapted from dwg 32-D-364; submerged surface shown as dashed line.
4. Location and configuration of cutoff trench from dwg 33-109-4029.

50 0 50 100 150
SCALE OF FEET

ALWAYS THINK SAFETY

PRELIMINARY SUBJECT TO REVIEW

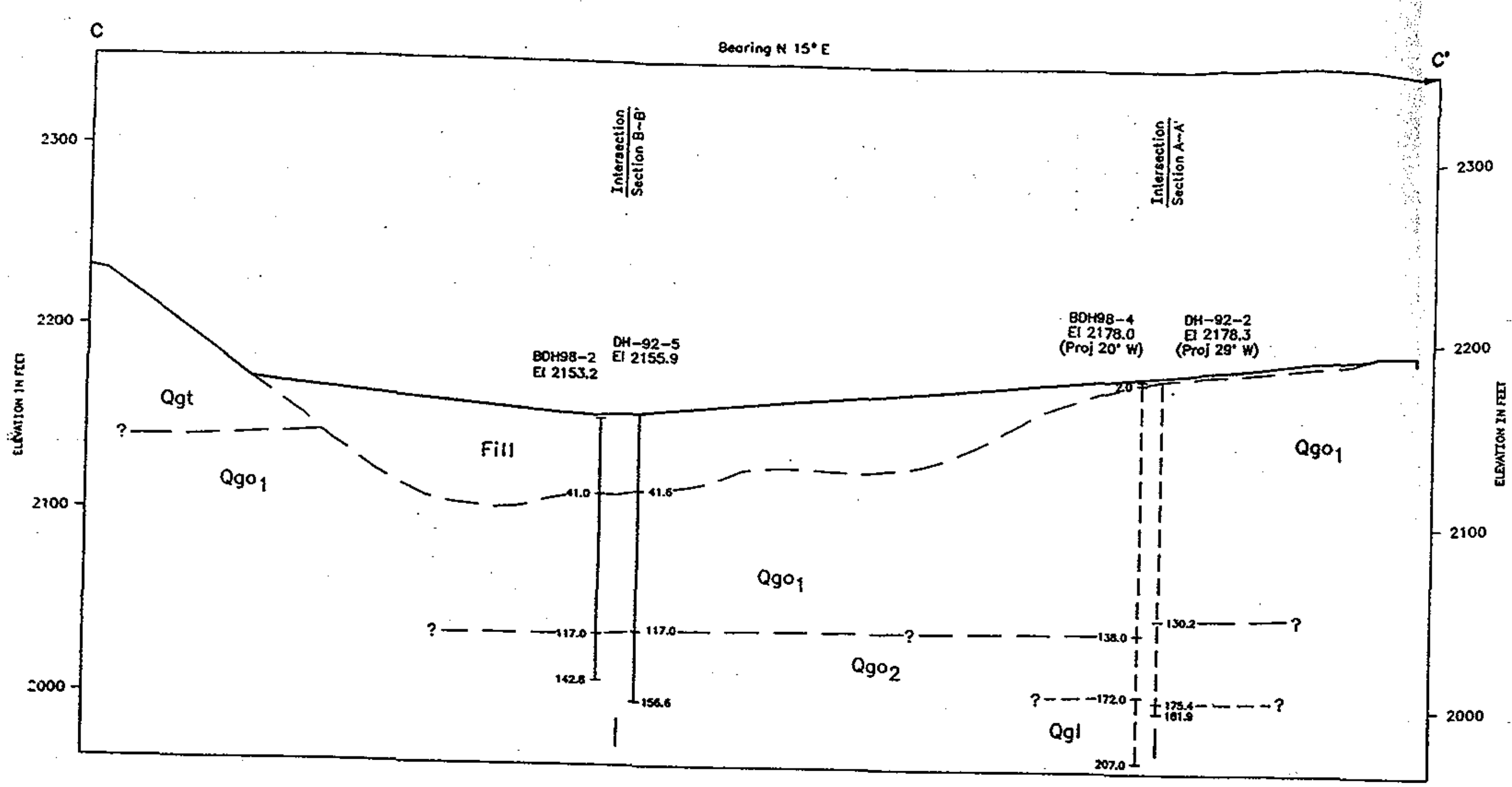
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT – WASHINGTON

CLE ELUM DAM

GEOLOGIC SECTION B-B' STATION 5+48

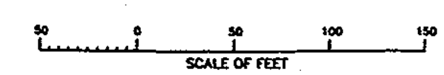
GEOLOGY R.LINK
DRAWN T.ENGLAND
TECH.APPROVAL
CHECKED
APPROVED
PROGRAM MANAGER
CADD SYSTEM ACAD v14
CADD FILENAME
DATE PLOTTED
BOISE, IDAHO
APRIL 1999
33-100-2402

Figure 7C



Notes:

1. For General Geologic Explanation, Legend and Notes, refer to dwg 33-100-2399.
2. For location of sections and explorations, refer to dwg 33-100-2400.



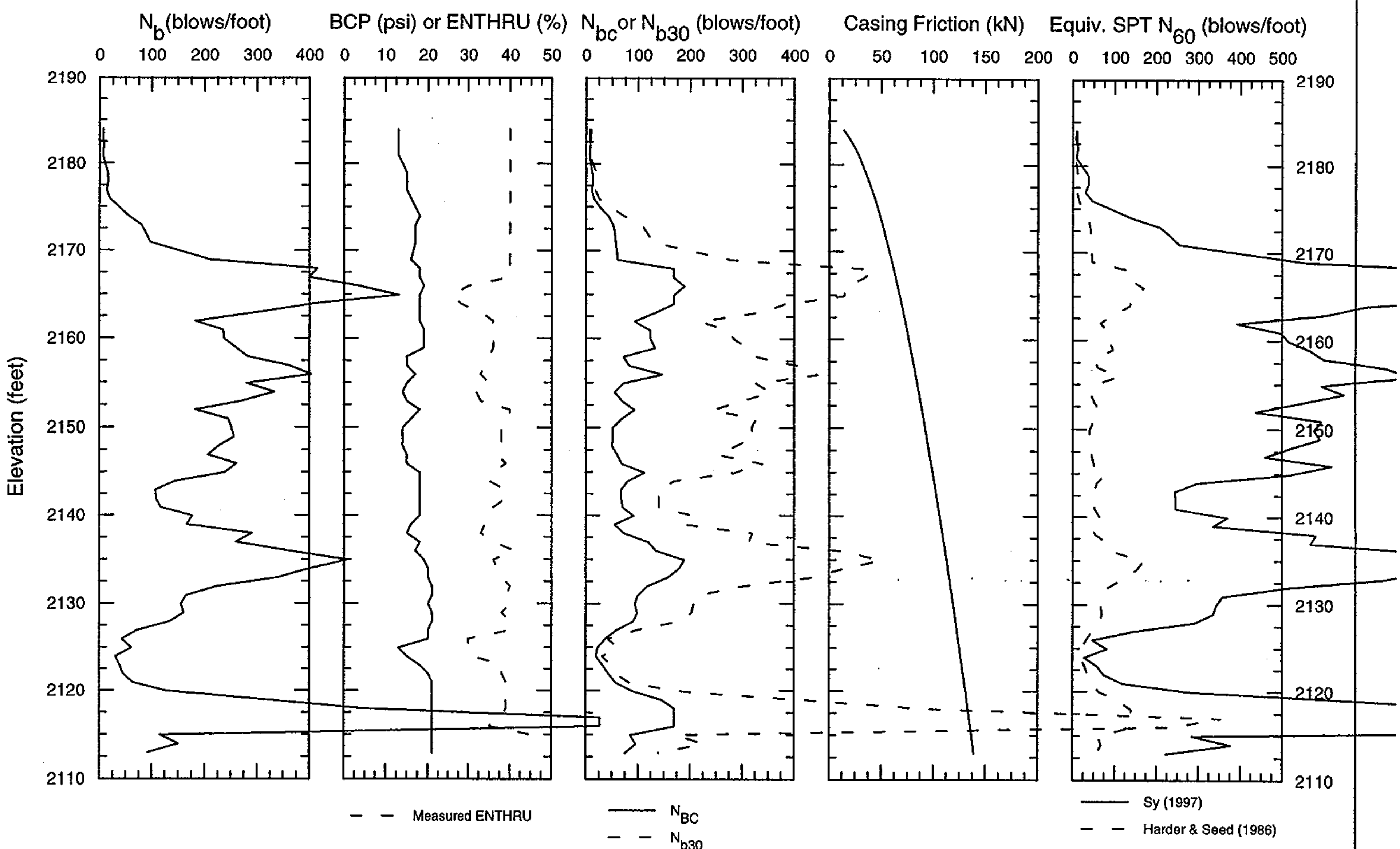
ALWAYS THINK SAFETY

PRELIMINARY SUBJECT TO REVIEW

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA PROJECT – WASHINGTON
CLE ELUM DAM
GEOLOGIC SECTION C–C' 600' D/S OF DAM AXIS

GEOLOGY R.LINK
DRAWN T.ENGLAND TECH.APPROVAL
CHECKED APPROVED
PROGRAM MANAGER

CADD SYSTEM ACAD v14	CADD FILENAME geo\cleelum\33-2820	DATE PLOTTED 6-3-99
BOISE, IDAHO	APRIL 1999	33-100-2820

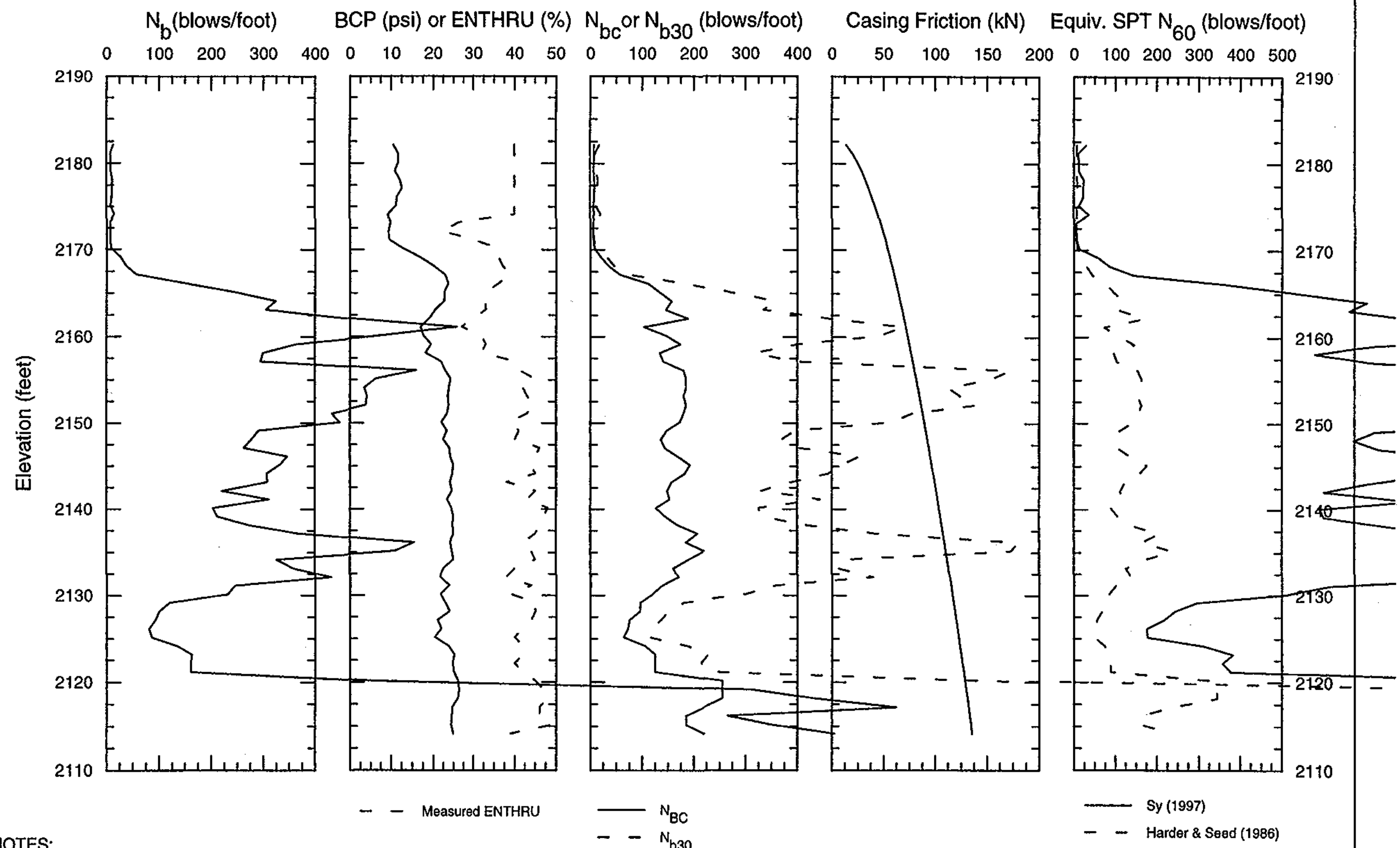


NOTES:

1. Correlations are valid only for closed-bit blowcounts.
2. Correlations by Sy and Harder & Seed were extrapolated for corrected Becker blowcounts over 100 (See Appendix I).

N60-981x.GRF with n60-981x.xls / 02/03/00/ KAF

Project No. 68F0D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Becker Penetration Test Corrections BDH98-1	Figure 8A
URS Greiner Woodward Clyde			

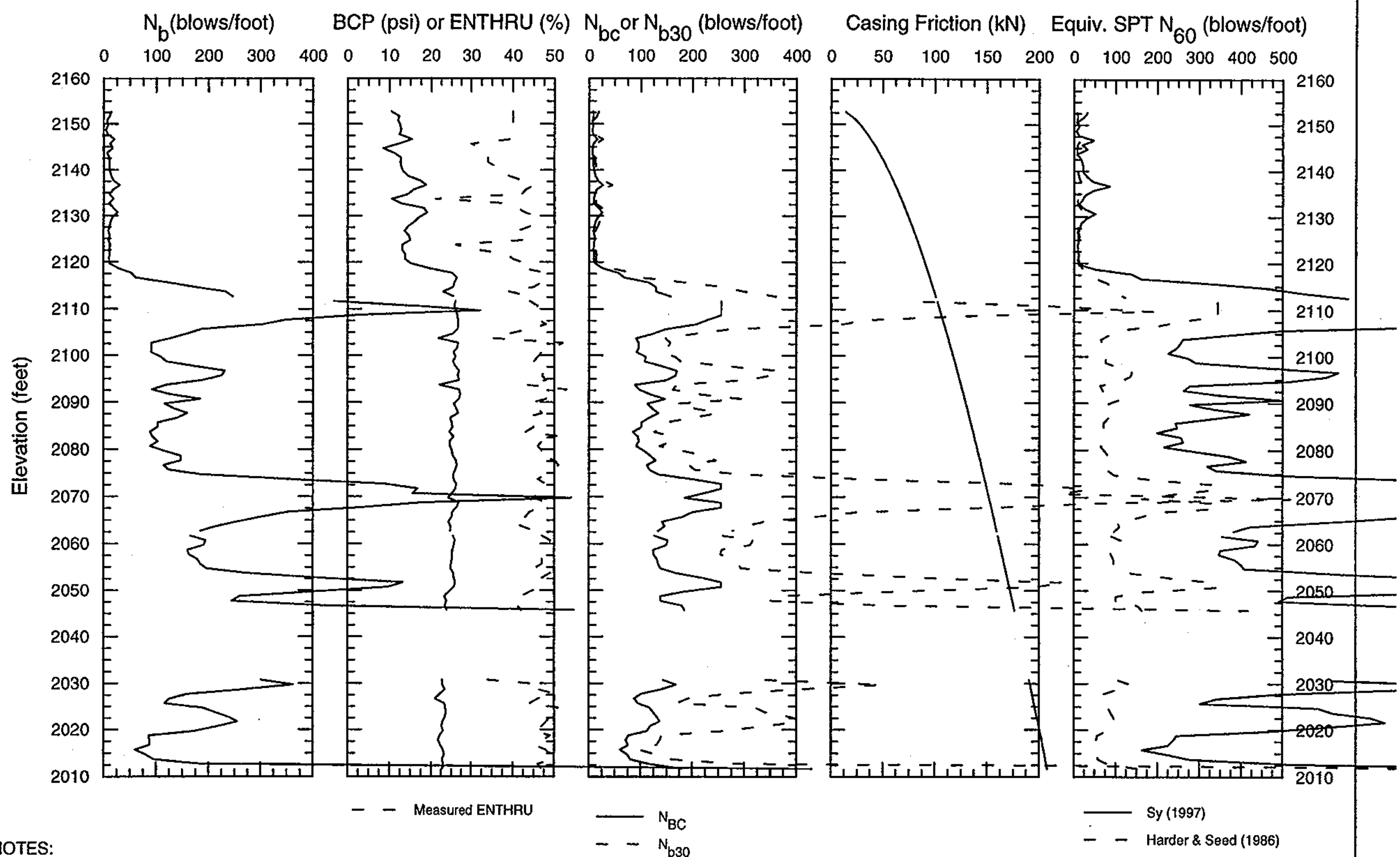


NOTES:

1. Correlations are valid only for closed-bit blowcounts.
2. Correlations by Sy and Harder & Seed were extrapolated for corrected Becker blowcounts over 100 (See Appendix I).

N60981BX.GRF with n60-981bx.xls / 02/03/00/ KAF

Project No. 68F0D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Becker Penetration Test Corrections BDH98-1B	Figure 8B
URS Greiner Woodward Clyde			

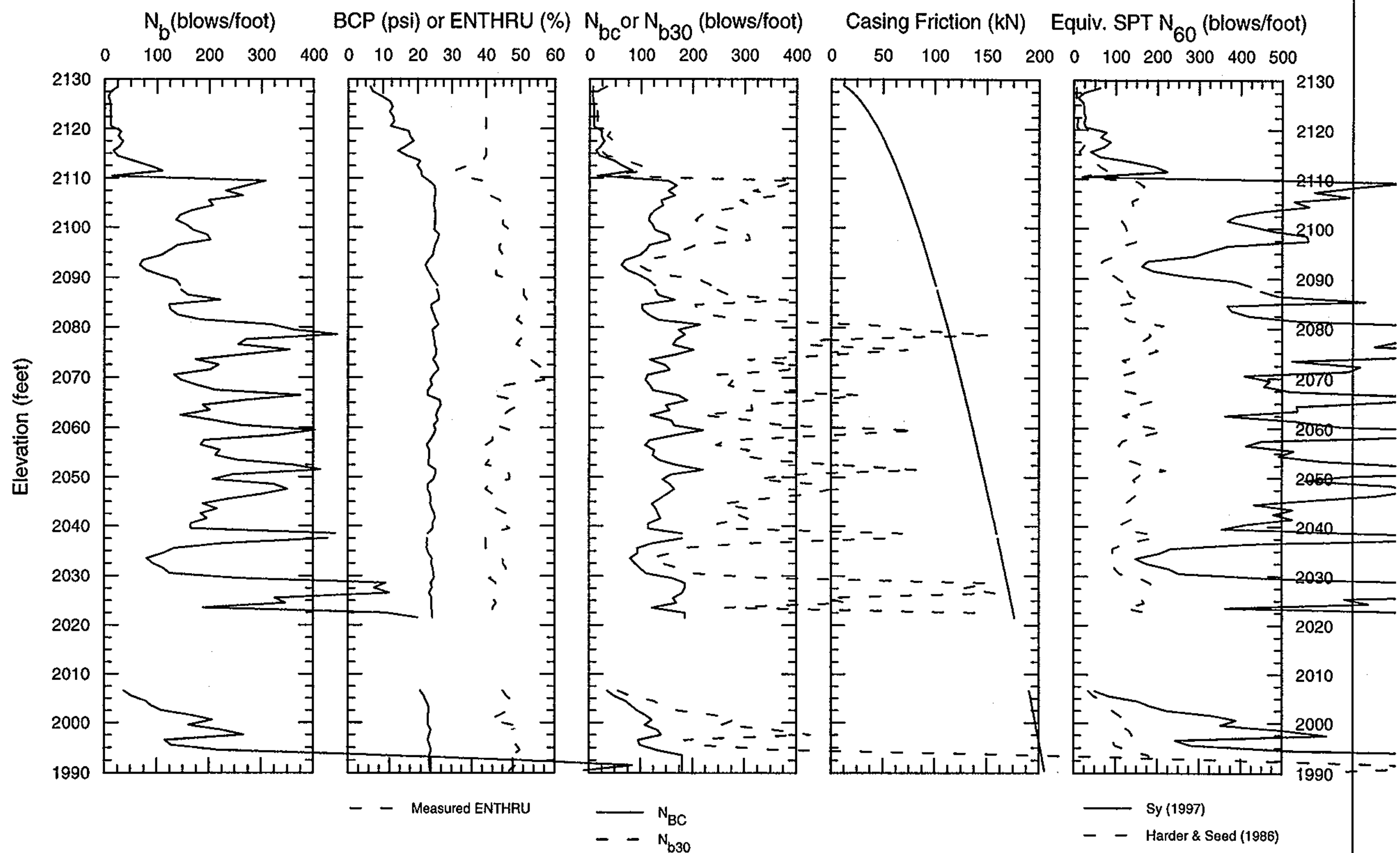


NOTES:

1. Correlations are valid only for closed-bit blowcounts.
2. Correlations by Sy and Harder & Seed were extrapolated for corrected Becker blowcounts over 100 (See Appendix I).

N60982X.GRF with n60-982x.xls / 02/03/00/ KAF

Project No. 68F0D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Becker Penetration Test Corrections BDH98-2	Figure 8C
	URS Greiner Woodward Clyde		



NOTES:

1. Correlations are valid only for closed-bit blowcounts.
2. Correlations by Sy and Harder & Seed were extrapolated for corrected Becker blowcounts over 100 (See Appendix I).

N60983X.GRF with n60-983x.xls / 02/03/00/ KAF

Project No. 68F0D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Becker Penetration Test Corrections BDH98-3	Figure 8D
	URS Greiner Woodward Clyde		

Appendix A

APPENDIX A

Summary of Test Drilling

SUMMARY OF TEST DRILLING

FEATURE Cle Elum Dam PROJECT Yakima STATE Washington

Hole Number	Location		Coordinates		Collar Elevation	Depth of Hole	Date Completed	Depth of Water Date Measured	Remarks
	Station	Offset	North	East					
DH-92-1	8+43.0	613.9' d/s	4394.8	5451.4	2178.8	161.0'	09-22-92	72.3'; 9-22-92	CHSW
DH-92-2	8+48.6	622.5' d/s	4387.6	5458.4	2178.3	181.9'	10-26-92	71.3'; 9-30-92	CHSW/SPT
DH-92-3	8+28.6	583.7' d/s	4416.8	5426.2	2180.1	90.0'	11-02-92	72.5'; 11-2-92	Piezometer
DH-92-4	5+55.1	593.2' d/s	4677.8	5508.4	2154.7	155.6'	11-18-92	50.4'; 11-5-92	CHSW
DH-92-5	5+65.3	592.9' d/s	4668.0	5505.3	2155.9	156.6'	12-19-92	49.3'; 12-9-92	CHSW/SPT
DH-92-6	5+28.1	251.5' d/s	4795.1	5186.7	2185.7	100.0'	12-18-92	79.0'; 12-18-92	Piezometer
CE-1	9+16	19' d/s	4483	4859	2251	77'	06-22-77		Abandoned
CE-2	8+69.2	23.5' d/s	4527	4875	2250.6	160'	08-18-77		Piezometer
CE-3	9+17.4	18.0' u/s	4492	4823	2250.6	160'	08-18-77		Piezometer
CE-4	9+04.4	109.3' d/s	4473	4949	2227.9	150'	08-23-78		Piezometer
CE-5	8+04.0	12.1' u/s	4567	4853	2251.2	255'	09-08-78		Pump Well
AP-81-1	8+48	1063' d/s	4270	5883	2129.7	5.0'	03-27-81		
DH-81-2	8+57	1073' d/s	4253	5890	2129.8	110.0'	04-08-81		Piezometers

Final Draft

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-1

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+43.0, 613.9' D/S
BEGUN: 08-24-92 FINISHED: 09-22-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 72.3 (2106.50) 09-22-92

PROJECT: YAKIMA
COORDINATES: N 4394.8 E 5451.4
TOTAL DEPTH: 161.0
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: A. LOCKHART & R. LINK
REVIEWED BY:

Columns: NOTES | DEPTH | SAMPLE TYPE | % CORE RECOVERY | % MOIST CONTENT | SPT | SHEAR WAVE VEL | VISUAL CLASS | LAB CLASS | FLD CLASS/LITH | ELEVATION | CLASSIFICATION AND PHYSICAL CONDITION

NOTES

All depths are measured in feet from ground surface and are the same as those used by the driller.

PURPOSE OF HOLE
To determine the stratigraphy and engineering properties of the foundation materials present at Cle Elum Dam; to provide instrumentation for cross-hole seismic testing.

DRILL EQUIPMENT
Gus Pech Brat/22R truck-mounted drill with Tigre Tierra Badger top-drive air hammer, Ingersoll Rand 750 cfm/250 psi air compressor, and Bean 75-gpm mud pump.

DRILLER
Ben Horton

DRILL SETUP
Set up on d/s fill blanket about 610' d/s of center line Sta. 8+43.

DRILLING METHODS
0.0-7.5': Drill and drive with 7-7/8" tricone roller RB and 8" Cs using clear water as drilling fluid; Cs shoe split on boulder or cobble at 7.0'; pulled 8" Cs and replaced shoe.
7.5-12.5': Drill and drive, as described for 0.0-7.5', above. Cs shoe caved in at 12.5'.
12.5-42.0': Drilled open hole with 7-7/8" RB using bentonite mud as drilling fluid. Installed 6" Cs to 32.0' and cleaned hole to 42.0' with 5-7/8" RB, advancing Cs behind drilling.
42.0-57.4': Drill and drive with 5-7/8" RB and 6" Cs using bentonite mud as drilling fluid. RB lost roller cone at 57.4'; retrieved roller with magnet mounted on NW Mobilok rods. Cs stopped on boulder at 56.6' and was bent out of round; RB unable to pass shoe; changed to 5-3/4" RB.
57.4-81.0': Drilled open hole with 5-3/4" RB using bentonite mud as drilling fluid. Pulled 6" Cs and installed 6" TUBEX system using air as drilling fluid; reamed hole to 81.0'.
81.0-161.0': Drilled with TUBEX 115 (6") system and COP-4 downhole drill with button bit using compressed air as drilling fluid.

Center columns (depth 0–50')

Depth marks: 5, 10, 15, 20, 25, 30, 35, 40, 45

Shear wave velocities (top to bottom): 1221, 1342, 1244, 1175, 1231, 1368, 1373, 1394, 1357, 1463, 1547, 1185, 1233, 1275, 1348, 893, 1157, 1036, 1086

FLD CLASS/LITH: Fill (to elevation 2176.8); Qgo1

ELEVATION: 2176.8; 2128.8

CLASSIFICATION AND PHYSICAL CONDITION

0.0-2.0': FILL.

GRAVEL AND COBBLES. Includes some sand and silt. Description based on drilling conditions and cuttings return.
INTERPRETIVE NOTE: Contact with foundation is from as-built cross section on drawing 32-D-384; unable to distinguish fill from foundation on basis of drilling conditions or cuttings return due to similarity of materials.

2.0-161.0': QUATERNARY GLACIAL OUTWASH (Qgo).

2.0-12.5': GRAVEL AND COBBLES. Includes some sand and silt. Description based on drilling conditions and cuttings return.

12.5-52.0': SAND AND GRAVEL. Includes occasional large cobbles. Description based on drilling conditions and cuttings return.

52.0-57.4': COBBLES AND GRAVEL. Description based on drilling conditions and cuttings return.

57.4-60.0': BOULDER. Description based on action of drill, drilling conditions, and cuttings return.

60.0-81.0': COBBLES WITH SAND AND GRAVEL. Driller reported trace of silty clay returned as balls in cuttings from 60.0-70.0'. Description based on drilling conditions and cuttings return.

62-66': Wash Sample. Consisted of greater than 95% angular cuttings with less than 5% subangular to subrounded particles; majority of cuttings ranged in size from fine to coarse sand with about 5% fine gravel; maximum size returned, 5mm; cuttings are hard, mostly dark rock types composed chiefly of basalt, schist, sandstone, and other unidentified types with minor clear and white quartz and tan to red volcanics and sandstone; generally dark green to dark gray. No fines observed in sample.

76-81': Wash Sample. Consisted of greater than 95% angular cuttings with less than 5% subangular to subrounded particles; majority of

COMMENTS:

1. Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, distributed by letter December 7, 1988.

RB - Rock Bit
WS - Wash Sample
Cs - Casing
Sz - Size of Casing
I.D. - Inside Diameter
O.D. - Outside Diameter
NR - Not Reported by Driller

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-1

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+43.0, 613.9' D/S
BEGUN: 08-24-92 FINISHED: 09-22-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 72.3 (2106.50) 09-22-92

PROJECT: YAKIMA
COORDINATES: N 4394.8 E 5451.4
TOTAL DEPTH: 161.0
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: A. LOCKHART & R. LINK
REVIEWED BY:

NOTES

SAMPLE INTERVALS

Interval	Type
62.0-66.0'	WS
76.0-81.0'	WS
85.0-86.0'	WS
135.0-140.0'	WS
140.0-145.0'	WS
145.0-150.0'	WS
155.0-161.0'	WS

DRILLING CONDITIONS

0.0-7.5': Very rough and slow. 8" Cs shoe split on cobbles or boulder at 7.5'.
7.5-12.5': Slow, hard, and rough. 8" Cs shoe caved in at 12.5'.
12.5-42.0': Fairly slow and rough; hole caving at 42.0'.
42.0-52.0': Fairly slow, rough in spots.
52.0-57.4': Fairly slow and rough. Lost roller cone off RB at 57.4'; retrieved cone with magnet mounted on Nw Hobilok rods. 6" Cs stopped on boulder at 56.6', Cs shoe bent out of round so that 5-7/8" RB could not pass through shoe; replaced RB with 5-3/4" RB.
57.4-60.0': Slow and smooth, drilling through boulder.
60.0-81.0': Slow and rough; hole caving at 81.0'.
81.0-101.0': Slow, rough in spots.
101.0-112.0': Slow. TUBEX plugged off and stuck in hole; pulled string and reamed hole with 5-1/2" RB using bentonite mud; blew hole with air to flush cuttings, hole making water in excess of 60 gpm. Inserted TUBEX string and continued hole.
112.0-119.0': Fairly slow and rough.
119.0-131.0': Fairly fast, but rough. TUBEX bit plugged off at 131.0'; pulled string and cleaned out bit.
131.0-140.0': Fairly fast and fairly rough.
140.0-147.3': Fast and rough; very loose material, driller noted hole was making a lot of water. TUBEX bit plugged off at 147.3'; pulled string and cleaned out bit.
147.3-161.0': Fairly slow. TUBEX bit plugged off at 156.0'; pulled string and cleaned out bit.

LOG COLUMNS

DEPTH | SAMPLE TYPE | % CORE RECOVERY | % MOIST CONTENT | SPT | SHEAR WAVE VEL | VISUAL CLASS | LAB CLASS | FLD CLASS/LITH | ELEVATION

Depth scale: 55, 60, 65, 70, 75, 80, 85, 90, 95

Sample type: WS (approx. 62-66), WS (approx. 76-81), WS (85-86)

Shear wave vel (top to bottom): 1201, 1381, 1492, 1800, 815, 913, 820, 901, 764, 942, 1341, 1050, 1628, 1261, 1553, 1936, 1952, 1468, 1802, 2149

FLD class/lith: Qgo1

Elevation at bottom: 2078.8

CLASSIFICATION AND PHYSICAL CONDITION

cuttings ranged in size from medium to coarse sand with trace of fine gravel; sample is noticeably finer grained than that collected from 62-66', described above; maximum size returned, 5mm; cuttings are hard with rock types similar to those described for 62-66', except noted some granitic and gneissic fragments medium to dark gray in color; generally dark green to dark gray. No fines observed in sample.

81.0-101.0': COBBLES AND GRAVEL WITH BOULDERS. Description based on action of drill, drilling conditions and cuttings return.

85-86': Wash Sample. Consisted of greater than 85% angular cuttings with less than 15% subangular to subrounded particles; majority of cuttings ranged in size from predominantly medium to coarse sand with about 10% predominantly fine gravel; sample is noticeably coarser grained than either of the two previous samples described above; maximum size returned, 20mm; cuttings are hard, mostly dark rock types composed chiefly of basalt, schist, sandstone, granite, gneiss, and other unidentified types with minor clear and white quartz and tan to red volcanics and sandstone which are prominently iron stained; generally green to dark gray. No fines observed in sample.

101.0-112.0': COBBLES. Includes occasional boulders. Description based on action of drill, drilling conditions and cuttings return.

112.0-130.0': COBBLES AND GRAVEL. Includes occasional boulders from 119.0-130.0', as indicated by action of drill. Description based on drilling conditions and cuttings return.

130.0-140.0': SANDY GRAVEL. Includes occasional cobbles from 131.0-140.0'. Description based on drilling conditions and cuttings return.

135-140': Wash Sample. Consisted of less than 25% angular cuttings with greater than 75% subangular to rounded particles; about 75%

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-1

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+43.0, 613.9' D/S
BEGUN: 08-24-92 FINISHED: 09-22-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 72.3 (2106.50) 09-22-92

PROJECT: YAKIMA
COORDINATES: N 4394.8 E 5451.4
TOTAL DEPTH: 161.0
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: A. LOCKHART & R. LINK
REVIEWED BY:

NOTES

CASING RECORD

1992 Date	Cs Sz	Depth Hole	Depth Cs
08-25	8"	7.5	7.5
08-26	8"	12.5	12.5
08-27	8"	42.0	12.5
	6"	42.0	32.0
08-28	6"	57.4	56.6
08-31	6"	81.0	56.6
09-01	6"	74.0	74.0
09-02	6"	101.0	101.0
09-03	6"	112.0	112.0
09-04	6"	113.0	113.0
09-08	6"	114.3	114.0
09-09	6"	119.0	119.0
09-17	6"	147.3	147.0
09-18	6"	161.0	160.0

FLUID RETURN

Interval	% Return
0.0-7.5'	30
7.5-12.5'	NR
12.5-42.0'	90
42.0-81.0'	95
81.0-161.0'	Air

FLUID COLOR

Interval	Color
0.0-7.5'	Brown
7.5-12.5'	NR
12.5-81.0'	Gray
81.0-161.0'	Air

FLUID LEVEL DURING DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
08-26	7.5	7.5	Dry
08-27	12.5	12.5	Dry
08-28	42.0	32.0	2.3
08-31	57.4	56.6	2.5
09-01	81.0	56.6	13.3
09-02	81.0	74.0	Dry
09-03	101.0	101.0	Dry
09-04	112.0	112.0	109.0
09-08	113.0	113.0	53.6
09-09	114.3	114.0	67.5
09-10	119.0	119.0	68.3
09-14	119.0	119.0	72.3
09-15	119.0	119.0	71.5
09-16	119.0	119.0	71.5
09-17	119.0	119.0	72.3
09-18	147.3	147.0	71.5

FLUID LEVEL AFTER DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
09-21	161.0	160.0	74.3
09-22	161.0	160.0	72.3

DRILLING TIME
Drilling: 112 hours
Moving/Setup: 15 hours
Down: 53 hours
Travel: 20 hours

HOLE COMPLETION
Installed 4" I.D. PVC pipe to 159.0' and pulled 8" Cs; grouted hole through one-way valve at bottom of string while pulling 6" Cs in 10' increments; placed 1575 gallons of grout mixed in batches of 5 bags cement, 1.5 bags bentonite.

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
					1334				
					1617				
105					2239				
					1612				
110					1324				
					1937				
115					2236			Ggo1	
					2046				
120					1870				
					1046				
125					1217				
					1306				
130					1559				2048.8
					1279				
135	WS				1236				
					1200				
140	WS				1299			Ggo2	
					1413				
145	WS				1381				
					1580				2028.8

CLASSIFICATION AND PHYSICAL CONDITION

cuttings ranging in size from fine to coarse sand with about 25% fine to coarse gravel; majority of cuttings are stream-worn particles with much rounding of corners and faces; maximum size returned, 25mm; cuttings are hard, mostly dark rock types composed chiefly of basalt, schist, sandstone, granite, gneiss, and other unidentified types with minor clear and white quartz and tan to red volcanics and sandstone; generally dark gray to black. No fines observed in sample.

140.0-147.3': SAND AND GRAVEL. Very loose material; hole made a lot of water. Description based on drilling conditions and cuttings return.

140-145': Wash Sample. Very similar to previous wash sample from 135-140', but with more coarse gravel and also fine sand; majority of cuttings are stream-worn particles with much rounding of corners and faces; maximum size returned, 30mm. No fines observed in sample.

147.3-156.0': SAND WITH GRAVEL. Loose material; hole continuing to make water. Description based on drilling conditions and cuttings return.

147-150': Wash Sample. Consisted of less than 25% angular cuttings with greater than 75% subangular to rounded particles; about 95% cuttings ranging in size from predominantly fine to medium sand with only about 5% predominantly fine gravel; sample is significantly finer grained than either of the two previous wash samples collected from 135-140' and from 140-145'; maximum size returned, 20mm; generally dark gray to black. No fines observed in sample. Sample includes some cuttings from 145-147'.

150-155': Wash Sample. Consisted of less than 20% angular cuttings with greater than 80% subangular to rounded particles; about 85% of cuttings ranging in size from fine to coarse sand with about 15% fine to coarse gravel; sample shows increase in gravel and coarse sand fractions from those seen in previous sample from 145-150';

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-1

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+43.0, 613.9' D/S
BEGUN: 08-24-92 FINISHED: 09-22-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 72.3 (2106.50) 09-22-92

PROJECT: YAKIMA
COORDINATES: N 4394.8 E 5451.4
TOTAL DEPTH: 161.0
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: A. LOCKHART & R. LINK
REVIEWED BY:

NOTES	DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
		WS				1690				
	155								Qgo2	
		WS								
	160									2017.8
		BOTTOM OF HOLE								
	165									

CLASSIFICATION AND PHYSICAL CONDITION

maximum size returned, 25mm; generally dark gray to black. No fines observed in sample.

156.0-161.0': SAND AND GRAVEL. Hole continuing to make water. Description based on drilling conditions and cuttings return.

156-160': Wash Sample. Very similar to previous sample from 150-155', based on field logging of sample; maximum size returned, 30mm. No fines observed in sample. Includes some cuttings from 155-156'.

161.0': Bottom of hole. Hole terminated at predetermined depth.

GEOLOGIC INTERPRETATION:

0.0-2.0': FILL.
2.0-161.0': QUATERNARY GLACIAL OUTWASH (Qgo).
2.0-130.0': Coarse Outwash (Qgo1).
130.0-161.0': Fine Outwash (Qgo2).

COMMENTS:

Final Draft

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-2

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+48.6, 622.5' D/S
BEGUN: 09-23-92 FINISHED: 10-26-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 71.3 (2107.00) 09-30-92

PROJECT: YAKIMA
COORDINATES: N 4387.6 E 5458.4
TOTAL DEPTH: 181.9
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.3
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

All depths are measured in feet from ground surface and are the same as those used by the driller.

PURPOSE OF HOLE
To determine the stratigraphy and engineering properties of the foundation materials present at Cle Elum Dam; to provide instrumentation for cross-hole seismic testing.

DRILL EQUIPMENT
Gus Pech Brat/22R truck-mounted drill with Tigre Tierra Badger top-drive air hammer, Ingersoll Rand 750 cfm/250 psi air compressor, and Bean 75-gpm mud pump.

DRILLER
0.0-165.9': Ben Horton
165.9-181.9': Chuck Whisnant

DRILL SETUP
Set up on d/s fill blanket about 620' d/s of center line Sta. 8+49.

DRILLING METHODS
0.0-26.3': Drilled with TUBEX 165 (8") system and COP 62 downhole drill with button bit using compressed air as drilling fluid. Took DS on approx. 20' intervals using 3.75" I.D. heavy-walled, spilt-tube barrel mounted on API rods and advanced with 350-lbm slide hammer and cathead with rope.
26.3-129.0': Drilled with TUBEX 115 (6") system and COP 42 downhole drill with button bit using compressed air as drilling fluid; used air/foam slurry below 44.0'. Took DS on approx. 20' intervals to 129', as described above.
129.0-148.6': Drilled with TUBEX 115 (6") system, as described above. Took SPT's on approx. 5' intervals using USBR-design 1-3/8" constant I.D. split-tube barrel mounted on Nw Mobilok rods with 140-lbm safety hammer, 30" drop and cathead with rope.
148.6-181.9': Drilled with TUBEX 115 (6") system, as described above. Took DS on approx. 10' intervals to 181.9', as described for 0.0-26.3' above.

SAMPLE INTERVALS

Interval	Type
26.3-27.0'	DS

LOG COLUMNS

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0-2.0								Fill	2176.3
2.5-5					1221				
5-7.5					1342				
7.5-10					1244				
10-12.5					1175				
12.5-15					1231				
15-17.5					1368				
17.5-20					1373				
20-22.5					1394				
22.5-25					1357				
25-27.5					1463				
26.3-27.0	DS	100	5			GM	GP	Ggo1	
27.5-30					1547				
30-32.5					1185				
32.5-35					1233				
35-37.5					1275				
37.5-40					1348				
40-42.5					893				
42.5-45					1157				
44.0-44.7	DS	71							
45-47.5					1036				
47.5-50					1086				2128.3

CLASSIFICATION AND PHYSICAL CONDITION

0.0-2.0': FILL.

GRAVEL AND COBBLES. Includes occasional boulders. Description based on drilling conditions and cuttings return.
INTERPRETIVE NOTE: Contact with foundation is from as-built cross section on drawing 32-D-384; unable to distinguish fill from foundation on basis of drilling conditions or cuttings return due to similarity of materials.

2.0-181.9': QUATERNARY GLACIAL OUTWASH (Qgo).

2.0-26.3': COBBLES AND GRAVEL. Includes occasional boulders noted from 2.0-19.0', but particularly at 7', 10', and 13'; includes generally rounded sand particles. Description based on action of drill, drilling conditions and cuttings return.

26.3-27.0': SILTY GRAVEL (GM). About 75% predominantly fine, hard, subangular to rounded gravel; about 15% nonplastic fines with rapid dilatancy, no dry strength; about 10% fine to coarse, hard, subangular to rounded sand; maximum size, 25 mm; moist, brown; homogeneous; no reaction with HCl.
LAB TEST DATA: 85% gravel, 14% sand, 1% fines; Cu = 5.930, Cc = 10.931; SPG = 2.73; insufficient sample mass to perform consistency tests; laboratory classification of sample is POORLY GRADED GRAVEL (GP).

27.0-38.6': COBBLES AND GRAVEL. Description based on drilling conditions and cuttings return.

38.6-44.0': GRAVEL. Includes occasional cobbles. Description based on drilling conditions and cuttings return.

44.0-44.7': Poor recovery. Sample limited to 0.5' of washed cuttings composed chiefly of coarse gravel and gravel-sized cuttings; maximum size recovered, 45 mm.

44.7-54.0': COBBLES AND GRAVEL. Includes silt and sand in wash cuttings. Description based on drilling conditions and cuttings return.

COMMENTS:

1. Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, distributed by letter December 7, 1988.

RB = Rock Bit DS = Drive Sample

SPT = Standard Penetration Resistance Test

CS = Casing Sz = Size of Casing

I.D. = Inside Diameter O.D. = Outside Diameter

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-2

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+48.6, 622.5' D/S
BEGUN: 09-23-92 FINISHED: 10-26-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 71.3 (2107.00) 09-30-92

PROJECT: YAKIMA
COORDINATES: N 4387.6 E 5458.4
TOTAL DEPTH: 181.9
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.3
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

44.0-44.7'	DS
54.0-54.8'	DS
64.0-64.9'	DS
84.0-84.7'	DS
94.0-94.8'	DS
114.0-114.9'	DS
129.0-130.2'	SPT
133.9-134.8'	SPT
138.7-139.8'	SPT
144.2-145.2'	SPT
148.6-150.6'	DS
153.7-155.7'	DS
163.7-165.9'	DS
175.4-176.9'	DS
180.4-181.9'	DS

DRILLING CONDITIONS
0.0-19.0': Fairly slow; drilling hard on boulders at 7', 10' and 13'; difficult to keep the hole straight.
19.0-21.0': Fast and rough.
21.0-26.3': Fairly fast. Unable to flush cuttings from 8" TUBEX; bit jamming inside Cs. Installed 6" TUBEX system to 26.3'.
26.3-38.6': Slow and rough.
38.6-64.0': Fairly slow. Injection of air/foam slurry below 44.0' greatly aided in flushing out cuttings.
64.0-74.0': A little faster; noted some moist cuttings in return.
74.0-84.0': Faster.
84.0-181.9': Fairly fast. Noted wet cuttings at 84' where hole started making water; grout observed in return from 129-142'. Bit stuck in Cs at 170', pulled string and reamed hole to 175'. Noted temporary loss of return at 149'.

CASING RECORD

1992 Date	Cs Sz	Depth Hole	Depth Cs
09-23	8"	19.0	19.0
09-24	8"	21.0	20.0
09-25	8"	27.0	26.3
	6"	27.0	26.0
09-28	6"	39.1	38.6
09-29	6"	74.0	74.0
09-30	6"	94.8	94.0
10-1	6"	128.5	128.1
10-5	6"	139.8	138.7
10-6	6"	150.6	148.0
10-7	6"	165.9	163.1
10-14	6"	165.9	0.0
10-15	6"	165.9	30.0
10-19	6"	165.9	90.0
10-20	6"	175.0	175.0
10-21	6"	181.9	180.0

FLUID RETURN & FLUID COLOR
Drilled with air; fluid return and color not reported. Geologist's notes on return color as

LOG

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
					1201				
					1381				
55	DS	63	10			(GM)s	(GP)s		
					1492				
					1800				
60					815				
					913				
65	DS	100	7			(GM)s	(GW-GM)s		
					820				
					901				
70					764				
					942				
75					1341			Qgo1	
					1050				
80					1628				
	DS	0			1261				
85					1553				
					1936				
90					1952				
	DS	0			1468				
95					1802				
					2149				2078.3

CLASSIFICATION AND PHYSICAL CONDITION

54.0-54.8': SILTY GRAVEL WITH SAND (GM)s. About 65% fine to coarse, hard, subangular to rounded gravel; about 25% fine to coarse, hard, angular to rounded sand; about 15% nonplastic fines with rapid dilatancy, no dry strength; maximum size, 65 mm; moist, gray; homogeneous; no reaction with HCl.
LAB TEST DATA: 79% gravel, 18% sand, 3% fines; insufficient sample mass to perform consistency tests; Cu = 40.232, Cc = 5.390; SPG = 2.67; laboratory classification of sample is POORLY GRADED GRAVEL WITH SAND (GP)s.

54.8-64.0': GRAVEL. Includes occasional cobbles. Description based on drilling conditions and cuttings return.

64.0-64.9': SILTY GRAVEL WITH SAND (GM)s. About 55% fine to coarse, hard, subangular to rounded gravel; about 30% fine to coarse, hard, angular to rounded sand; about 15% nonplastic fines with rapid dilatancy, no dry strength; maximum size, 50 mm; moist, gray; homogeneous; no reaction with HCl.
LAB TEST DATA: 65% gravel, 30% sand, 5% fines; insufficient sample mass to perform consistency tests; Cu = 73.112, Cc = 1.474; SPG = 2.68; laboratory classification of sample is WELL-GRADED GRAVEL WITH SILT AND SAND (GW-GM)s.

64.9-84.0': SAND AND GRAVEL. Includes occasional cobbles; noted additional water in air foam return slurry at 74'. Description based on drilling conditions and cuttings return.

84.0-84.7': No recovery. Sample limited to several coarse, subangular to rounded, gravel-sized cuttings trapped above the basket catcher; maximum size recovered, 60 mm.

84.7-94.0': SAND AND GRAVEL. Includes occasional cobbles. Description based on drilling conditions and cuttings return.

94.0-94.8': No recovery. Sample limited to about 0.3' of washed cuttings composed of coarse gravel with minor medium sand; maximum size recovered, 75 mm.

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-2

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+48.6, 622.5' D/S
BEGUN: 09-23-92 FINISHED: 10-26-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 71.3 (2107.00) 09-30-92

PROJECT: YAKIMA
COORDINATES: N 4387.6 E 5458.4
TOTAL DEPTH: 181.9
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.3
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

follows:

0.0-84.0': Air (no color).
84.0-124.0': Tan.
124.0-130.2': Blue gray.
130.2-142.0': Greenish gray (grout).
142.0-181.9': Reddish tan to reddish brown alternating with greenish gray (grout).

FLUID LEVEL DURING DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
09-24	19.0	19.0	Dry
09-25	21.0	20.0	Dry
09-28	27.0	26.3	Dry
09-29	39.1	38.6	Dry
09-30	74.0	74.0	71.3
10-1	94.8	94.0	70.1
10-5	128.5	128.1	69.2
10-6	139.8	138.7	70.5
10-7	150.6	148.0	70.3
10-20	165.9	90.0	71.5
10-21	175.0	175.0	71.8

FLUID LEVEL AFTER DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
10-22	181.9	180.0	70.4

DRILLING TIME
Drilling: 122 hours
Moving/Setup: 4 hours
Down: 39 hours
Travel: 15 hours

HOLE COMPLETION
Installed 4" I.D. PVC pipe to 180.4' and pulled 8" Cs; grouted hole through one-way valve at bottom of string while pulling 6" Cs in 10' increments; placed grout in 7 batches totaling 42 bags cement; grout weight = 12.3, viscosity = 82 seconds/quart, as measured with Marsh funnel.

LOG

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
					1334				
					1617				
105					2239				
					1612				
110					1324				
					1937				
	DS	0							
115					2236			Qgo1	
					2046				
120					1870				
					1046				
125					1217				
					1306				
130	SPT	0		50					2048.1
					1559				
					1279				
	SPT	0		50					
135					1236				
					1200				
	SPT	0		50					
140					1299			Qgo2	
					1413				
145	SPT	0		50					
					1381				
					1580				
	DS	45	13			(SP-SM)	g(GP) s		2028.3

CLASSIFICATION AND PHYSICAL CONDITION

94.8-114.0': SAND, GRAVEL, AND COBBLES. Description based on drilling conditions and cuttings return.

114.0-114.9': No recovery. Sample limited to washed cuttings composed of fine to coarse, angular to subrounded gravel; maximum size recovered, 45 mm.

114.9-129.0': SAND AND GRAVEL. Includes occasional cobbles. Description based on drilling conditions and cuttings return.

129.0-130.2': No recovery. Sample limited to single gravel particle 35 mm in diameter lodged in shoe of sampler; cleanout run through interval returned fine to coarse, angular to rounded sand with fine gravel; heavy color of return water suggests greater than 15% of fines present; maximum size returned, 15 mm.

130.2-133.9': SAND AND GRAVEL. Noted grout in return flow. Description based on drilling conditions and cuttings return.

133.9-134.8': No recovery.

134.8-138.7': SAND AND GRAVEL. Noted grout in return flow. Description based on drilling conditions and cuttings return.

138.7-139.8': No recovery. Cleanout run through interval returned predominantly medium to coarse, subangular to rounded sand with some fine gravel; maximum size returned, 15 mm.

139.8-144.4': SAND AND GRAVEL. Cuttings consist of broadly graded sand and gravel with little or no fines. Noted grout in return flow to 142', where color changed from dark gray to reddish tan to reddish brown. Description based on drilling conditions and cuttings return.

144.4-145.2': No recovery. Cleanout run through interval returned fine to coarse, subangular to rounded sand with predominantly fine gravel; dark gray, but many particles are iron stained; maximum size returned, 20 mm.

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-2

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+48.6, 622.5' D/S
BEGUN: 09-23-92 FINISHED: 10-26-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 71.3 (2107.00) 09-30-92

PROJECT: YAKIMA
COORDINATES: N 4387.6 E 5458.4
TOTAL DEPTH: 181.9
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.3
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
	DS	45	13		1690	(SP-SM)	g (GP) s		
155	DS	55	10			(SW) g	(GP) s		
160									
165	DS	55	11			(SW-SM)	g (GW) s	Qgo2	
170									
175	DS	100	28			ML	SM		
180	DS	100	24			(CL/ML)	ss (CL-ML		1996.4
				BOTTOM OF HOLE					
185									

CLASSIFICATION AND PHYSICAL CONDITION

145.2-148.6': SAND AND GRAVEL. Description based on drilling conditions and cuttings return.

148.6-150.6': POORLY GRADED SAND WITH SILT AND GRAVEL (SP-SM)g. About 55% fine to coarse, hard, subangular to rounded sand; about 35% fine to coarse, hard, subangular to rounded gravel; about 10% nonplastic fines with rapid dilatancy, no dry strength; maximum size, 50 mm; wet, blue gray; homogeneous; weak reaction with HCl.
LAB TEST DATA: 61% gravel, 37% sand, 2% fines; insufficient sample mass to perform consistency tests; Cu = 15.887, Cc = 0.958; SPG = 2.72; laboratory classification of sample is POORLY GRADED GRAVEL WITH SAND (GP)s.

150.6-153.7': SAND AND GRAVEL. Description based on drilling conditions and cuttings return.

153.7-155.7': WELL-GRADED SAND WITH GRAVEL (SW)g. About 55% fine to coarse, hard, angular to rounded sand; about 40% fine to coarse, hard, subangular to rounded gravel; about 5% nonplastic fines with rapid dilatancy, no dry strength; maximum size, 45 mm; wet, blue gray; homogeneous; weak reaction with HCl.
LAB TEST DATA: 54% gravel, 44% sand, 2% fines; insufficient sample mass to perform consistency tests; Cu = 30.620, Cc = 0.351; SPG = 2.56; laboratory classification of sample is POORLY GRADED GRAVEL WITH SAND (GP)s.

155.7-163.7': SAND AND GRAVEL. Description based on drilling conditions and cuttings return.

163.7-165.9': WELL-GRADED SAND WITH SILT AND GRAVEL (SW-SM)g. About 50% fine to coarse, hard, angular to rounded sand; about 40% fine to coarse, hard, subangular to rounded gravel; about 10% nonplastic fines with rapid dilatancy; maximum size, 50 mm; wet, blue gray; homogeneous; no reaction with HCl.
LAB TEST DATA: 66% gravel, 30% sand, 4% fines; insufficient sample mass to perform consistency tests; Cu = 31.263, Cc = 1.992; SPG = 2.52; laboratory classification of sample is WELL-GRADED GRAVEL WITH SAND (GW)s.

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-2

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+48.6, 622.5' D/S
BEGUN: 09-23-92 FINISHED: 10-26-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 71.3 (2107.00) 09-30-92

PROJECT: YAKIMA
COORDINATES: N 4387.6 E 5458.4
TOTAL DEPTH: 181.9
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2178.3
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)

165.9-175.4': SAND AND GRAVEL. Description based on drilling conditions and cuttings return.

175.4-176.9': SILT (ML). About 90% nonplastic fines with rapid dilatancy, low dry strength; about 10% predominantly fine, hard, angular to subrounded sand; trace of fine, hard, subangular gravel; maximum size, 10 mm; wet, dark gray; fine, oxidized organic debris present; stratified with horizontal layers of predominantly fine sand 5-10 mm thick spaced on intervals of 25-75 mm; sample composed mostly of rock flour; no reaction with HCl.
LAB TEST DATA: 58% sand, 42% nonplastic fines; LL = 28, PI = 0; SPG = 2.47; laboratory classification of sample is SILTY SAND (SM).

176.9-180.4': SAND WITH CLAY SEAMS. Description based on drilling conditions and cuttings return.

180.4-181.9': SILTY CLAY WITH SAND (CL/ML)s. About 85% fines with low plasticity, slow dilatancy, low to medium dry strength, low to medium toughness; about 15% predominantly fine, hard, angular to subrounded sand; maximum size, coarse sand; moist to wet, dark gray; fine, oxidized organic debris present as laminations; laminated to stratified in horizontal layers 1-50 mm thick; includes prominent laminations of predominantly fine sand and organics; includes layers of nonplastic rock flour and light gray clay; no reaction with HCl.
LAB TEST DATA: 64% fines, 36% sand; LL = 27, PI = 5; SPG = 2.38; laboratory classification of sample is SANDY SILTY CLAY s(CL-ML).

181.9': Bottom of hole. Hole terminated at predetermined depth.

GEOLOGIC INTERPRETATION:

0.0-2.0': FILL.
2.0-181.9': QUATERNARY GLACIAL OUTWASH (Qgo).
2.0-130.2': Coarse Outwash (Qgo1).
130.2-181.9': Fine Outwash (Qgo2).

Final Draft

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-3

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+28.6, 583.7' D/S
BEGUN: 10-27-92 FINISHED: 11-02-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 72.54 (2107.56) 11-17-92

PROJECT: YAKIMA
COORDINATES: N 4416.8 E 5426.2
TOTAL DEPTH: 90.4
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2180.1
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES	DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	HOLE COMPLETION	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH / ELEVATION	CLASSIFICATION AND PHYSICAL CONDITION

NOTES

All depths are measured in feet from ground surface and are the same as those used by the driller.

PURPOSE OF HOLE
To determine the stratigraphy and engineering properties of the foundation materials present at Cle Elum Dam; to provide instrumentation for monitoring of water level fluctuations in the foundation.

DRILL EQUIPMENT
Gus Pech Brat/22R truck-mounted drill with Tigre Tierra Badger top-drive air hammer, Ingersoll Rand 750 cfm/250 psi air compressor, and Bean 75-gpm mud pump.

DRILLER
Chuck Whisnant

DRILL SETUP
Set up on d/s fill blanket about 580' d/s of center line Sta. 8+29.

DRILLING METHODS
Drilled with TUBEX 90 (4") system and COP 32 downhole drill with button bit using compressed air/foam slurry as circulating fluid.

SAMPLE INTERVALS
Samples were not collected.

DRILLING CONDITIONS
0.0-1.3': Fast and easy.
1.3-40.0': Slow, hard, and rough. Action of drill indicated presence of boulders throughout interval with large boulder located from 34.3-37.2'.
40.0-90.4': Slow and rough. Hit water at 72.5'.

CASING RECORD

1992 Date	Cs Sz	Depth Hole	Depth Cs
10-27	4"	14.9	14.5
10-28	4"	40.0	39.6
10-29	4"	70.0	69.6
11-02	4"	90.4	90.0

FLUID RETURN & FLUID COLOR
Drilled with air; fluid return and color not reported.

FLUID LEVEL DURING DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
10-28	14.9	14.5	Dry
10-29	40.0	39.6	Dry
11-02	70.0	69.6	Dry

FLUID LEVEL AFTER

DEPTH / FLD CLASS / ELEVATION

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45

Fill — 2177.1
Qgo1 — 2130.1

CLASSIFICATION AND PHYSICAL CONDITION

0.0-3.0': FILL.

0.0-1.3': SILT, SAND AND GRAVEL. Description based on drilling conditions and cuttings return.

1.3-3.0': COBBLES AND BOULDERS. Includes gravel and sand. Description based on action of drill, drilling conditions and cuttings return. INTERPRETIVE NOTE: Contact with foundation is from as-built cross section on drawing 32-D-384; unable to distinguish fill from foundation on basis of drilling conditions or cuttings return due to similarity of materials.

3.0-90.4': QUATERNARY GLACIAL OUTWASH (Qgo).

3.0-34.3': COBBLES AND BOULDERS. Includes gravel and sand. Description based on action of drill, drilling conditions and cuttings return.

34.3-37.2': BOULDER. Description based on action of drill, drilling conditions and cuttings return.

37.2-40.0': COBBLES AND BOULDERS. Includes gravel and sand. Description based on action of drill, drilling conditions and cuttings return.

40.0-90.4': COBBLES AND GRAVEL. Includes sand. Description based on drilling conditions and cuttings return.

90.4': Bottom of hole. Hole terminated at predetermined depth.

GEOLOGIC INTERPRETATION:

0.0-3.0': Fill.
3.0-90.4': QUATERNARY GLACIAL OUTWASH (Qgo).
3.0-90.4': Coarse Outwash (Qgo1).

COMMENTS:

1. Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, distributed by letter December 7, 1988.

RB = Rock Bit WS = Wash Sample

Cs = Casing Sz = Size of Casing

I.D. = Inside Diameter O.D. = Outside Diameter

NR = Not Reported by Driller

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-3

FEATURE: CLE ELUM DAM
LOCATION: STA. 8+28.6, 583.7' D/S
BEGUN: 10-27-92 FINISHED: 11-02-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 72.54 (2107.56) 11-17-92

PROJECT: YAKIMA
COORDINATES: N 4416.8 E 5426.2
TOTAL DEPTH: 90.4
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2180.1
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES	DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	HOLE COMPLETION	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION	CLASSIFICATION AND PHYSICAL CONDITION
DRILLING 1992 Depth Date Water Elevation 11-17 72.54 2107.56											
DRILLING TIME Drilling: 31.5 hours Moving/Setup: 6 hours Down: 0 hours Travel: 2.5 hours	55										
HOLE COMPLETION 0.0-20.3': Installed surface seal composed of neat cement mixed with bentonite; installed locking steel cap to protect riser pipe; stickup of riser pipe is about 3.16' (surveyed elevation is 2183.26).	60 65										
20.3-74.5': Backfilled hole with random sand and gravel. 74.5-80.0': Installed bentonite seal. 80.0-90.4': Backfilled hole with silica sand; installed 2'-long porous-tube piezometer tip with 3/4" riser pipe to 89.0'.	70 75								Qgo1		
	80 85										
	90									2089.7	
				BOTTOM OF HOLE							
	95										

COMMENTS:

Final Draft

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-4

SHEET 1 OF 4

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+55.1, 593.2' D/S
BEGUN: 11-03-92 FINISHED: 11-19-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 51.3 (2103.40) 11-12-92

PROJECT: YAKIMA
COORDINATES: N 4677.8 E 5508.4
TOTAL DEPTH: 155.6
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2154.7
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

All depths are measured in feet from ground surface and are the same as those used by the driller.

PURPOSE OF HOLE
To determine the stratigraphy and engineering properties of the foundation materials present at Cle Elum Dam; to provide instrumentation for cross-hole seismic testing.

DRILL EQUIPMENT
Gus Pech Brat/22R truck-mounted drill with Tigre Tierra Badger top-drive air hammer, Ingersoll Rand 750 cfm/250 psi air compressor, and Bean 75-gpm mud pump.

DRILLER
Chuck Whisnant

DRILL SETUP
Set up on d/s fill blanket about 595' d/s of center line Sta. 5+55.

DRILLING METHODS
0.0-31.3': Drilled with TUBEX 115 (6") system and COP-4 downhole drill with button bit using compressed air as drilling fluid.
31.3-155.6': Drilled with TUBEX 115 (6") system, as described above, using compressed air/foam slurry as circulating fluid.

SAMPLE INTERVALS
Samples were not collected.

DRILLING CONDITIONS
0.0-31.3': Slow and rough. Started to lose circulation at 31'; switched to air/foam slurry to improve return.
31.3-155.6': Slow and rough with faster spots. Hit water at 50.4'.

CASING RECORD

1992 Date	Cs Sz	Depth Hole	Depth Cs
11-04	6"	31.3	29.7
11-05	6"	60.0	59.6
11-09	6"	92.0	91.6
11-10	6"	122.0	121.6
11-12	6"	155.6	155.0

FLUID RETURN & FLUID COLOR
Drilled with air; fluid return and color not reported.

FLUID LEVEL DURING DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
11-05	31.3	29.7	Dry
11-09	60.0	59.6	51.3

DEPTH | SAMPLE TYPE | % CORE RECOVERY | % MOIST CONTENT | SPT | SHEAR WAVE VEL | VISUAL CLASS | LAB CLASS | FLD CLASS/LITH | ELEVATION

SHEAR WAVE VEL: 740, 826, 813, 771, 802, 816, 833, 923, 1003, 1156, 970, 1166, 1271, 1315, 1372, 1680, 1529, 736, 625

FLD CLASS/LITH: Fill; Qgo1

ELEVATION: 2113.7; 2104.7

CLASSIFICATION AND PHYSICAL CONDITION

0.0-41.0': FILL (F).

0.0-17.5': COBBLES AND BOULDERS. Description based on action of drill, drilling conditions and cuttings return.

17.5-23.0': COBBLES, GRAVEL AND SAND. Description based on drilling conditions and cuttings return.

23.0-27.3': SAND AND GRAVEL. Description based on drilling conditions and cuttings return.

27.3-29.7': SAND AND GRAVEL. Chiefly fine sand with gravel; includes numerous wood fragments noted in return. Description based on drilling conditions and cuttings return.

29.7-31.3': SAND AND GRAVEL. Description based on drilling conditions and cuttings return.

31.3-41.0': SAND AND GRAVEL. Chiefly medium to coarse sand with coarse gravel. Description based on drilling conditions and cuttings return. INTERPRETIVE NOTE: Contact with foundation is from as-built cross section on drawing 32-D-384; unable to distinguish fill from foundation on basis of drilling conditions or cuttings return due to similarity of materials.

41.0-155.6': QUATERNARY GLACIAL OUTWASH (Qgo).

41.0-60.0': SAND AND GRAVEL. Chiefly medium to coarse sand with coarse gravel. Description based on drilling conditions and cuttings return.

60.0-87.4': GRAVEL WITH SAND. Chiefly coarse gravel with sand. Description based on drilling conditions and cuttings return.

87.4-88.7': SAND WITH GRAVEL. Chiefly coarse sand with gravel. Description based on drilling conditions and cuttings return.

88.7-114.0': GRAVEL WITH SAND. Description based on drilling conditions and cuttings return.

114.0-129.7': SAND WITH GRAVEL.

COMMENTS:

1. Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, distributed by letter December 7, 1988.

Cs = Casing　　Sz = Size of Casing

I.D. = Inside Diameter　　O.D. = Outside Diameter

NR = Not Reported by Driller

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-4

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+55.1, 593.2' D/S
BEGUN: 11-03-92 FINISHED: 11-19-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 51.3 (2103.40) 11-12-92

PROJECT: YAKIMA
COORDINATES: N 4677.8 E 5508.4
TOTAL DEPTH: 155.6
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2154.7
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

11-10	92.0	91.6	50.4
11-12	122.0	121.6	51.3
11-16	155.6	155.0	52.3

FLUID LEVEL AFTER DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
11-17	155.6	155.0	52.3

DRILLING TIME
Drilling: 70.5 hours
Moving/Setup: 9.5 hours
Down: 15 hours
Travel: 5 hours

HOLE COMPLETION
Installed 4" I.D. PVC pipe to 153.0' and grouted hole through one-way valve at bottom of string while pulling 6" Cs in 10' increments; grout weight = 12.6, viscosity = 82 seconds/quart, as measured with Marsh funnel.

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
					620				
55					650				
					705				
					1256				
60					1175				
					1720				
65					1672				
					2124				
70					1974				
					1187				
75					964			Ggo1	
					1015				
80					1018				
					1195				
85					741				
					1408				
90					1518				
					1920				
95					1957				
					1688				2054.7

CLASSIFICATION AND PHYSICAL CONDITION

Chiefly fine to coarse sand with gravel. Description based on drilling conditions and cuttings return.

129.7-143.9': SAND. Chiefly sand with some fine gravel; very little fines noted in return. Description based on drilling conditions and cuttings return.

143.9-155.6': GRAVEL WITH SAND. Chiefly coarse gravel with sand. Description based on drilling conditions and cuttings return.

155.6': Bottom of hole. Hole terminated at predetermined depth.

GEOLOGIC INTERPRETATION:

0.0-41.0': Fill.
41.0-155.6': QUATERNARY GLACIAL OUTWASH (Qgo).
41.0-114.0': Coarse Outwash (Qgo1).
114.0-155.6': Fine Outwash (Qgo2).

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-4

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+55.1, 593.2' D/S
BEGUN: 11-03-92 FINISHED: 11-19-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 51.3 (2103.40) 11-12-92

PROJECT: YAKIMA
COORDINATES: N 4677.8 E 5508.4
TOTAL DEPTH: 155.6
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2154.7
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES	DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION	CLASSIFICATION AND PHYSICAL CONDITION
						2128					
						1701					
	105					2199			Qgo1		
						1737					
	110					1915					
						1078				2040.7	
	115					1166					
						1196					
	120					1273					
						1594					
	125					1641					
						1713					
	130					2073			Qgo2		
						1850					
	135					1546					
						1290					
	140					1061					
						1191					
	145					1420					
										2004.7	

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-4

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+55.1, 593.2' D/S
BEGUN: 11-03-92 FINISHED: 11-19-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 51.3 (2103.40) 11-12-92

PROJECT: YAKIMA
COORDINATES: N 4677.8 E 5508.4
TOTAL DEPTH: 155.6
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2154.7
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES	DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION	CLASSIFICATION AND PHYSICAL CONDITION
									Qgo2		
	155									1999.1	
				BOTTOM OF HOLE							
	160										

COMMENTS:

Final Draft

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-5

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+65.3, 592.9' D/S
BEGUN: 11-23-92 FINISHED: 12-19-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 49.3 (2106.60) 12-09-92

PROJECT: YAKIMA
COORDINATES: N 4668.0 E 5505.3
TOTAL DEPTH: 156.6
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2155.9
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

All depths are measured in feet from ground surface and are the same as those used by the driller.

PURPOSE OF HOLE
To determine the stratigraphy and engineering properties of the foundation materials present at Cle Elum Dam; to provide instrumentation for cross-hole seismic testing.

DRILL EQUIPMENT
Gus Pech Brat/22R truck-mounted drill with Tigre Tierra Badger top-drive air hammer, Ingersoll Rand 750 cfm/250 psi air compressor, and Bean 75-gpm mud pump.

DRILLER
Gregg Purdome

DRILL SETUP
Set up on d/s fill blanket about 595' d/s of center line Sta. 5+65.

DRILLING METHODS
Drilled with TUBEX 115 (6") system and COP 42 downhole drill with button bit using compressed air as circulating fluid; used air/foam slurry below 39'. Took SPT's on approx. 20' intervals to 117' using USBR-design 1-3/8" constant I.D. split-tube barrel mounted on Nw Mobilok rods with 140-lbm safety hammer, 30" drop and cathead with rope; where no or poor recovery was obtained in SPT, collected sample using 3.75" I.D. heavy-walled, spilt-tube barrel mounted on API rods and driven using downhole hammer and bonnet mounted on top of API drill rods.

SAMPLE INTERVALS

Interval	Type
37.6-30.0'	SPT/DS
55.6-56.3'	SPT/DS
76.2-76.8'	SPT
96.8-98.3'	SPT/DS
115.6-117.2'	SPT/DS

DRILLING CONDITIONS
0.0-98.3': Rough and very slow.
98.3-119.0': Rough and slow, but faster; drilling on cobble from 102.0-102.4'. Hole started making water at 103' with amount of water in return gradually increasing with depth.
119.0-141.7': Very soft, except hard at 139.5': Cs advanced very rapidly with minimal down

LOG

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0-2									
2-4					740				
5					826				
					813				
10					771				
					802				
15					816				
					833				
20					923			Fill	
					1003				
25					1156				
					970				
30					1166				
					1271				
35					1315				
37.6-39.0	SPT	100	10	50	1372	(GP-GM)s	(GW-GM)s		
40					1680				2114.3
					1529				
45					736			Qgo1	
					625				2105.9

CLASSIFICATION AND PHYSICAL CONDITION

0.0-41.6': FILL.

0.0-13.0': SAND AND GRAVEL WITH COBBLES. Description based on drilling conditions and cuttings return.

13.0-36.0': SAND AND GRAVEL WITH COBBLES AND BOULDERS. Description based on action of drill, drilling conditions and cuttings return.

36.0-37.6': SAND AND GRAVEL WITH COBBLES. Description based on drilling conditions and cuttings return.

37.6-39.0': POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s. About 60% fine to coarse, hard, subangular to rounded gravel; about 30% fine to coarse, hard, angular to rounded sand; about 10% nonplastic fines with rapid dilatancy; maximum size, 80 mm; moist, dark gray; heterogeneous; no reaction with HCl.
LAB TEST DATA: 64% gravel, 31% sand, 5% fines; Cu = 47.998, Cc = 1.289; laboratory classification of sample is WELL-GRADED GRAVEL WITH SILT AND SAND (GW-GM)s.
NOTE: SPT interval is 37.6-38.4'; drove heavy-walled DS from 37.6-39.0' to obtain additional sample material.

39.0-41.6': SAND, GRAVEL AND COBBLES. Description based on drilling conditions and cuttings return.
INTERPRETIVE NOTE: Contact with foundation is from as-built cross section on drawing 32-D-384; unable to distinguish fill from foundation on basis of drilling conditions or cuttings return due to similarity of materials.

41.6-181.9': QUATERNARY GLACIAL OUTWASH (Qgo).

41.6-55.6': SAND, GRAVEL AND COBBLES. Description based on drilling conditions and cuttings return.

55.6-56.3': POORLY GRADED GRAVEL WITH SAND (GP)s. About 75% fine to coarse, hard, angular to subrounded gravel; about 20% fine to coarse, hard, angular to rounded sand; about 5% nonplastic fines with rapid dilatancy; maximum size, 40 mm; wet, dark gray;

COMMENTS:

1. Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, distributed by letter December 7, 1988.

RB = Rock Bit DS = Drive Sample

SPT = Standard Penetration Resistance Test

Cs = Casing Sz = Size of Casing

I.D. = Inside Diameter O.D. = Outside Diameter

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-5

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+65.3, 592.9' D/S
BEGUN: 11-23-92 FINISHED: 12-19-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 49.3 (2106.60) 12-09-92

PROJECT: YAKIMA
COORDINATES: N 4668.0 E 5505.3
TOTAL DEPTH: 156.6
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2155.9
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

pressure; drilled in 10' runs with less than 10 minutes drilling time per run. Sand heaved 2.8' up into Cs prior to SPT at 120.8'; sand continued to heave 2-3' up into Cs after each run. No sampling performed below 120' due to artesian pressures and heaving sand; drilled through this interval in most expeditious manner possible to minimize disturbance of in-place foundation materials.

141.7-156.6': Hard and slow with very soft intervals up to 0.6' thick; drilled in 10' runs with about 20 minutes drilling time per run. Noted heaving sand at 123' when trying to install 4" PVC pipe during hole completion; washed hole to bottom and set PVC. Driller noted hole took all grout during initial grouting of hole on 12-10-92; reported hearing grout sucking out of bottom of PVC string.

CASING RECORD

1992 Date	Cs Sz	Depth Hole	Depth Cs
11-30	6"	13.0	12.4
12-01	6"	39.0	36.2
12-02	6"	56.3	55.0
12-03	6"	76.8	75.9
12-04	6"	98.3	96.7
12-05	6"	117.2	115.0
12-07	6"	145.0	144.4
12-08	6"	156.6	156.0

FLUID RETURN

0.0-13.0': 80%.
13.0-39.0': 70%.
39.0-55.4': 95%.
55.4-98.3': 90%.
98.3-156.6': NR.

FLUID COLOR

0.0-102.0': Brown to tan.
102.0-117.2': Blue gray.
117.2-156.6': Gray.

FLUID LEVEL DURING DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
12-01	13.0	12.4	Dry
12-02	39.0	36.2	Dry
12-03	56.3	55.0	NR
12-04	76.8	75.9	49.7
12-05	98.3	96.7	49.0
12-06	117.2	115.0	49.2
12-08	145.0	144.4	49.0

FLUID LEVEL AFTER DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
12-09	156.6	156.0	49.3

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
					620				
					650				
55	SPT	38	11	50	705	(GP)s	(GP)s		
					1256				
60					1175				
					1720				
65					1672				
					2124				
70					1974				
					1187				
75	SPT	56	12	50	964	(GP)s		Qgo1	
					1015				
80					1018				
					1195				
85					741				
					1408				
90					1518				
					1920				
95					1957				
	SPT	35	8	50		(GP)s	(GW)s		
					1688				2055.9

CLASSIFICATION AND PHYSICAL CONDITION

heterogeneous; no reaction with HCl. LAB TEST DATA: 80% gravel, 18% sand, 2% fines; Cu = 40.495, Cc = 7.448. NOTE: No recovery in SPT interval from 55.6-56.3'; drove heavy-walled DS from 55.6-56.0' to obtain sample.

56.3-76.2': SAND AND GRAVEL WITH COBBLES. Description based on drilling conditions and cuttings return.

76.2-76.8': POORLY GRADED GRAVEL WITH SAND (GP)s. About 55% fine to coarse, hard, angular to subrounded gravel; about 40% fine to coarse, hard, angular to rounded sand; about 5% nonplastic fines with rapid dilatancy; maximum size, 50 mm; wet, dark gray; heterogeneous; no reaction with HCl. NOTE: Insufficient sample mass for standard properties tests; only moisture content determined for this interval.

76.8-96.8': SAND AND GRAVEL WITH COBBLES. Description based on drilling conditions and cuttings return.

96.8-98.3': POORLY GRADED GRAVEL WITH SAND (GP)s. About 60% fine to coarse, hard, angular to subrounded gravel; about 35% fine to coarse, hard, angular to rounded sand; about 5% nonplastic fines with rapid dilatancy; maximum size, 55 mm; wet, dark gray; heterogeneous; no reaction with HCl. LAB TEST DATA: 72% gravel, 26% sand, 2% fines; Cu = 30.347, Cc = 1.985; laboratory classification of sample is WELL-GRADED GRAVEL WITH SAND (GW)s. NOTE: Poor recovery in SPT from 96.8-97.7'; drove heavy-walled DS from 96.8-98.3' to obtain additional sample material.

98.3-115.6': SAND AND GRAVEL. Drilled on hard cobble from 102.0-102.4'. Noted distinct blue gray coloration in return below 102'. Hole began making considerable water below 102' which gradually increased with depth. Description based on drilling conditions and cuttings return.

115.6-117.2': POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s. About 55% fine to coarse, hard, subangular to rounded gravel; about 35% fine to

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-5

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+65.3, 592.9' D/S
BEGUN: 11-23-92 FINISHED: 12-19-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 49.3 (2106.60) 12-09-92

PROJECT: YAKIMA
COORDINATES: N 4668.0 E 5505.3
TOTAL DEPTH: 156.6
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2155.9
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

DRILLING TIME
Drilling: 79 hours
Moving/Setup: 31.5 hours
Down: 29 hours
Travel: 8.5 hours

HOLE COMPLETION
Installed 4" I.D. PVC pipe to 156.6' and grouted hole through one-way valve at bottom of string while pulling 6" Cs in 10' increments; placed total of 5400 lbm of cement, 1400 lbm of bentonite, and 100 lbm of CalSeal.

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
					2128				
					1701				
105					2199				
					1737			Qgo1	
110					1915				
					1078				
115	SPT	65	9	50	1166	(GP-GM)	s(GW) s		
									2037.9
					1196				
120					1273				
					1594				
125					1641				
					1713				
130					2073				
					1850			Qgo2	
135					1546				
					1290				
140					1061				
					1191				
145					1420				
									2005.9

CLASSIFICATION AND PHYSICAL CONDITION

coarse, hard, angular to rounded sand; about 10% nonplastic fines with rapid dilatancy; maximum size, 55 mm; wet, blue gray; heterogeneous, bottom 0.8' of sample is gap-graded and completely lacking in fine sand; no reaction with HCl.
LAB TEST DATA: 64% gravel, 34% sand, 2% fines; Cu = 20.892, Cc = 1.399; laboratory classification of sample is WELL-GRADED GRAVEL WITH SAND (GW)s.

117.2-141.7': SAND WITH GRAVEL. Chiefly fine to coarse sand with minor, predominantly fine gravel; maximum size returned, 25 mm; blue gray; stratified, as indicated by intervals of very fast penetration under minimal down pressure up to 1' thick. Description based on drilling conditions and cuttings return.

141.7-156.6': SAND AND GRAVEL. Chiefly sand and gravel with rock flour; gravel content appeared to increase with depth; maximum size returned, 30 mm; blue gray; stratified, as indicated by prominent zones of very rapid penetration with minimal down pressure up to 0.6' thick. Noted numerous wood fragments in return at about 146.8'; maximum fragment returned, 35 mm by 10 mm by 5 mm. Description based on drilling conditions and cuttings return.

NOTE: No sampling performed from 117.2-156.6' due to artesian pressures and heaving sand; drilled through this interval in most expeditious manner possible to minimize disturbance of in-place foundation materials.

161.9': Bottom of hole. Hole terminated at predetermined depth.

GEOLOGIC INTERPRETATION:

0.0-41.6': Fill.
41.6-156.6': QUATERNARY GLACIAL OUTWASH (Qgo).
41.6-118.0': Coarse Outwash (Qgo1).
118.0-156.6': Fine Outwash (Qgo2).

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-5

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+65.3, 592.9' D/S
BEGUN: 11-23-92 FINISHED: 12-19-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 49.3 (2106.60) 12-09-92

PROJECT: YAKIMA
COORDINATES: N 4668.0 E 5505.3
TOTAL DEPTH: 156.6
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2155.9
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES	DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	SHEAR WAVE VEL	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION	CLASSIFICATION AND PHYSICAL CONDITION
									Qgo2		
	155									1999.3	
					BOTTOM OF HOLE						
	160										

COMMENTS:

Final Draft

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-6

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+28.1, 251.5' D/S
BEGUN: 12-12-92 FINISHED: 12-16-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 79.0 (2106.70) 12-16-92

PROJECT: YAKIMA
COORDINATES: N 4795.1 E 5186.7
TOTAL DEPTH: 100.0
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2185.7
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

All depths are measured in feet from ground surface and are the same as those used by the driller.

PURPOSE OF HOLE
To determine the stratigraphy and engineering properties of the foundation materials present at Cle Elum Dam; to provide instrumentation for monitoring of water level fluctuations in the foundation.

DRILL EQUIPMENT
Gus Pech Brat/22R truck-mounted drill with Tigre Tierra Badger top-drive air hammer, Ingersoll Rand 750 cfm/250 psi air compressor, and Bean 75-gpm mud pump.

DRILLER
Gregg Purdome

DRILL SETUP
Set up on d/s fill blanket about 250' d/s of center line Sta. 5+28.

DRILLING METHODS
Drilled with TUBEX 90 (4") system and COP 32 downhole drill with button bit using compressed air as circulating fluid.

SAMPLE INTERVALS
Samples were not collected.

DRILLING CONDITIONS
0.0-7.0': Slow and rough.
7.0-27.0': Slow, hard, and rough. Action of drill indicated presence of boulders throughout interval.
27.0-90.0': Slow and rough. Hit water at 88.0'.
90.0-100.0': Softer.

CASING RECORD

1992 Date	Cs Sz	Depth Hole	Depth Cs
12-12	4"	7.0	6.6
12-14	4"	27.0	26.6
12-15	4"	100.0	99.6

FLUID RETURN
Drilled with air; fluid return not reported.

FLUID COLOR
0.0-62.0': Brown.
62.0-100.0': Dark brown.

FLUID LEVEL DURING DRILLING

1992 Date	Depth Hole	Depth Cs	Depth Fluid
12-14	7.0	6.6	Dry
12-15	27.0	26.6	Dry
12-16	100.0	99.6	79.2

Log columns

DEPTH | SAMPLE TYPE | % CORE RECOVERY | % MOIST CONTENT | SPT | HOLE COMPLETION | VISUAL CLASS | LAB CLASS | FLD CLASS/LITH | ELEVATION

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45

FLD CLASS/LITH: Fill (0.0-7.0); 2178.7; Em; 2135.7

CLASSIFICATION AND PHYSICAL CONDITION

0.0-7.0': FILL.

SAND AND GRAVEL WITH COBBLES. Description based on drilling conditions and cuttings return.

7.0-65.0': DAM EMBANKMENT (Em).

7.0-27.0': SAND AND GRAVEL WITH COBBLES AND BOULDERS. Description based on action of drill, drilling conditions and cuttings return.

27.0-65.0': SAND AND GRAVEL WITH COBBLES. Description based on drilling conditions and cuttings return.

65.0-100.0': QUATERNARY GLACIAL OUTWASH (Qgo).

65.0-90.0': SAND AND GRAVEL WITH COBBLES. Description based on drilling conditions and cuttings return.

90.0-100.0': SAND AND GRAVEL. Description based on drilling conditions and cuttings return.

100.0': Bottom of hole. Hole terminated at predetermined depth.

GEOLOGIC INTERPRETATION:

0.0-7.0': Fill.
7.0-65.0': Dam Embankment (Em).
65.0-100.0': QUATERNARY GLACIAL OUTWASH (Qgo).
65.0-100.0': Coarse Outwash (Qgoi).

COMMENTS:

1. Center column descriptors are defined in the Reclamation Engineering Geology Field Manual, distributed by letter December 7, 1988.

Cs = Casing   Sz = Size of Casing

I.D. = Inside Diameter   O.D. = Outside Diameter

NR = Not Reported by Driller

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-6

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+28.1, 251.5' D/S
BEGUN: 12-12-92 FINISHED: 12-18-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 79.0 (2106.70) 12-18-92

PROJECT: YAKIMA
COORDINATES: N 4795.1 E 5186.7
TOTAL DEPTH: 100.0
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2185.7
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES

FLUID LEVEL AFTER DRILLING

1992 Date	Depth Water	Elevation
12-17	78.8	2106.9
12-18	79.0	2106.7

DRILLING TIME
Drilling: 39.5 hours
Moving/Setup: 13 hours
Down: 4 hours
Travel: 3.5 hours

HOLE COMPLETION
0.0-20.0': Installed surface seal composed of neat cement mixed with bentonite; installed locking steel cap to protect riser pipe; stickup of riser pipe is about 2.80' (surveyed elevation is 2188.50).
20.0-62.0': Backfilled hole with random sand and gravel.
62.0-68.0': Installed bentonite seal.
68.0-87.0': Backfilled hole with random sand and gravel.
87.0-90.0': Installed bentonite seal.
90.0-100.0': Backfilled hole with silica sand; installed 2'-long porous-tube piezometer tip with 3/4" riser pipe to 96.0'.

DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	HOLE COMPLETION	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
55									
								Em	
60									
65									2120.7
70									
75									
80									
								Qgo1	
85									
90									
95									
									2085.7

CLASSIFICATION AND PHYSICAL CONDITION

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. DH-92-6

FEATURE: CLE ELUM DAM
LOCATION: STA. 5+28.1, 251.5' D/S
BEGUN: 12-12-92 FINISHED: 12-18-92
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 79.0 (2106.70) 12-18-92

PROJECT: YAKIMA
COORDINATES: N 4795.1 E 5186.7
TOTAL DEPTH: 100.0
DEPTH TO BEDROCK:

STATE: WASHINGTON
GROUND ELEVATION: 2185.7
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. LINK
REVIEWED BY:

NOTES	DEPTH	SAMPLE TYPE	% CORE RECOVERY	% MOIST CONTENT	SPT	HOLE COMPLETION	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION	CLASSIFICATION AND PHYSICAL CONDITION
				BOTTOM OF HOLE							
	105										

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE

FEATURE Cle Elum Dam, Observation Well **PROJECT** Yakima **STATE** Washington

HOLE NO. CE-4 **LOCATION** Sta. 16+63.37 ℄ Tunnel, Offset 16' left* **GROUND ELEV.** 2227.3 (collar elev. 2228.10)* **DIP (ANGLE FROM HORIZ.)** 90°

COORDS. N. .... E. ....

BEGUN 7-20-78 **FINISHED** 8-23-78 **DEPTH OF OVERBURDEN** -- **TOTAL DEPTH** 150' **BEARING** --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See note below **LOGGED BY** R. A. Link **LOG REVIEWED BY** B. H. Carter

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill Equipment
Bucyrus-Eerie 22W Series Three churn drill.

Driller
Allen McCorkindale of Mike Bach Drilling Co.

Drilling Method
Hole was drilled with 5" churn drill bit. 5-10 gallons of water used to return cuttings in bailer. Hole bailed out prior to casing advance.
0-131': 6" casing advanced behind drilling on intervals of 1-5'.
131-150': 6" casing advanced ahead of drilling up to 2' beyond bottom of [illegible].

Dri[illegible]ing Conditions
0-28': Rough and slow
28-85': Slow, loose material with caving
85-93': Slow, hole holding open
93-114': Moderately slow and caving
114-126': Moderate drilling in loose, poorly consolidated material
126-150': Fast, in loose to very loose, poorly consolidated material

Casing Record

Date	Hole Depth	Casing Depth
7-20-78	3'	0'
7-21-78	10'	10'
7-24-78	16'	15'
7-25-78	21'	19'
7-26-78	28'	27'
7-28-78	34'	33'
7-31-78	39'	38'
8-1-78	45'	43'
8-2-78	52'	51'
8-3-78	62'	58'

Type and size of hole: 6" C (0' to about 75')

CLASSIFICATION AND PHYSICAL CONDITION

Elevation (feet)	Depth (feet)	Classification and Physical Condition
2227.3	0'	0-10'±: DAM EMBANKMENT. Large boulders cobbles and gravel of predominantly volcanic and metamorphic origin. Contact with underlying glacial moraine only approximately located.
	10	10±-150': QUATERNARY GLACIAL MORAINE (Domerie Terminal Moraine). Glacial debris composed of poorly sorted boulders, cobbles, gravel and sand in a silt matrix, generally poor to very poorly consolidated. 10±-28': Boulders; large boulders, cobbles and gravel of mainly volcanic and metamorphic types, including basalt, diorite, and quartzite. Medium brown to tan matrix of silt and sand; minor amounts of clay in variable proportions from 10-21'.
2199.3	28'	28-52': Gravel; cobbles and gravel of mainly volcanic and metamorphic origin in a medium brown to tan matrix comprised mainly of sand, but with some silt and very little clay.
2175.3	52'	52-56': Boulders, cobbles and gravel tightly packed with some silty matrix.
2171.3	56'	56-62': Sand; water bearing sand, gray in color and possibly containing some gravel; compact and well consolidated.
2165.3	62'	62-114': Sandy Gravel; cobbles and gravel in a medium brown to tan matrix of sand with some silt. 62-85': Cobbles and gravel in a matrix of sand; poorly indurated resulting in caving.
2142.3	85'	85-93': Gravel and sand, moderately consolidated with no caving.
2134.3	93'	93-105': Fine gravel up to 2" in diameter. Sandy medium brown to tan silt; clay present as small balls from 96-105'. Poorly consolidated.
	100'	

EXPLANATION

*Location of hole approximate as hand level and tape were used to survey in drill hole.

[illegible]RE LOSS / CORE RECOVERY

Type of hole . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

FEATURE Cle Elum Dam, Observation Well PROJECT Yakima STATE Washington

HOLE NO. CE-4 LOCATION Sta. 16+63.37 ℄ Tunnel, offset 16' left* GROUND ELEV. 2227.3 (collar elev. 2228.10)* DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. E. TOTAL DEPTH 150' BEARING --

BEGUN 7-20-78 FINISHED 8-23-78 DEPTH OF OVERBURDEN --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See note below LOGGED BY R. A. Link LOG REVIEWED BY B. H. Carter

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Casing Record (Cont)

Date	Hole Depth	Casing Depth
8-4-78	68'	68'
8-7-78	71'	71'
8-8-78	81'	78.5'
8-9-78	93'	89'
8-10-78	105'	98'
8-11-78	111'	108'
8-14-78	118'	118'
8-15-78	126'	125'
8-16-78	136'	136'
8-17-78	146'	146'
8-18-78	150'	150'

Depths to Water During Drilling

Date	Hole Depth	Water Depth
7-20-78	3'	dry
7-21-78	10'	"
7-24-78	16'	"
7-25-78	21'	"
7-26-78	28'	"
7-28-78	34'	"
7-[illegible]-78	39'	"
8-[illegible]-78	45'	"
8-[illegible]-78	52'	"
8-3-78	62'	"
8-4-78	68'	38'
8-7-78	71'	"
8-8-78	81'	"
8-9-78	93'	"
8-10-78	105'	"
8-11-78	111'	"
8-14-78	118'	"
8-15-78	126'	118'
8-16-78	136'	112'
8-17-78	146'	105'
8-18-78	150'	136'

Drilling Time
176.25 hours

TYPE AND SIZE OF HOLE: 6" C (105'–150')

Bottom of Hole (150')

ELEVATION (FEET)	DEPTH (FEET)
2122.3	105'
2113.3	114'
2101.3	126'
2096.3	131'
2094.3	133'
2093.3	134'
2090.8	136.5'
2078.3	149'
Bottom	of Hole

CLASSIFICATION AND PHYSICAL CONDITION

105-114': Gravel with some scattered cobbles in a fine grained matrix of sand and silt. No clay present. Poorly indurated with caving.

114-126': Sandy Pea Gravel; small gravel with size recovered up to 1.5" in diameter. Matrix of fine to medium grained sand, medium brown to tan in color. Some silt, but no clay present. Poorly consolidated with caving.

126-150': Sand; poorly sorted sand, coarse to medium grained, but fine to very fine grained from 149-150'. Sand composition of 25% basalt, 20% quartz, 15% feldspar and the remainder composed of various unidentified rock fragments and minerals, gray in color. Some gravel with minor amounts of silt and clay.

126-131': Sand, medium to fine grained with some silt; very few gravels and no clay. Poorly consolidated with caving.

131-133': Gravelly sand, medium to fine grained with some gravel. Very poorly indurated with much caving.

133-134': Sand, medium to fine grained with some silt, but no gravel or clay. Very poorly consolidated with caving.

134-136.5': Gravelly sand, coarse to fine grained with gravel ranging from pea size to coarse. Poorly consolidated with caving.

136.5-149': Sand, generally coarse grained, but ranging down to medium. Composed primarily of quartz, feldspar and basalt. Some gravel and silt present, but no clay.

149-150': Sand, fine to very fine grained with some coarse to medium sand. Very little silt, gravel or clay present. Very poorly consolidated with caving.

NOTE: 0-150'=Geologic log based on drill cuttings return and drilling conditions.

EXPLANATION

CORE LOSS / CORE RECOVERY

*Location of hole approximate as hand level and tape were used to survey in drill hole.

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

FEATURE Cle Elum Dam, Observation Well PROJECT Yakima STATE Washington
HOLE NO. CE-4 LOCATION Sta. 16+63.37 ℄ Tunnel, Offset 16' left* GROUND ELEV. 2227.3 (collar elev. 2228.10)* DIP (ANGLE FROM HORIZ.) 90°
COORDS. N. E.
BEGUN 7-20-78 FINISHED 8-23-78 DEPTH OF OVERBURDEN -- TOTAL DEPTH 150' BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See note below LOGGED BY R. A. Link LOG REVIEWED BY B. H. Carter

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
<u>Hole Completion</u> Installed 1½" diameter plastic PVC pipe, capped on both ends, to 150'; pipe was perforated from 145-150' and had a stick up of 0.7'. Backfilled hole with 5 yards of pea gravel from 1-150'. Pulled 6" casing. Sealed hole with cement from 0-1'. <u>Purpose of Drilling</u> To establish a point of observation for monitoring during test pumping and to obtain data on the foundation material and the conditions thereof.									10–90			<u>Interpretive Note</u>: Photographs in the Yakima Project History for 1932 and 1933 indicate that the majority of this hole is located within undisturbed original foundation material, the glacial till of a terminal moraine. According to Porter (1976)**, this moraine is the Domerie Member of the Lakedale Drift and is Quaternary in age (13,570± 130 years).

Water Level Measurements

Date (1978)	Depth	Elevation
8/30	116.40	2111.70
9/6	117.00	2111.10
9/7	117.00	2111.10
9/8	117.00	2111.10
9/11	117.25	2110.85
9/12	117.35	2110.75

EXPLANATION

*Location of hole approximate as hand level and tape were used to survey in drill hole.
**Porter, Stephen C., 1976, Pleistocene glaciation in the southern part of the North Cascade Range, Washington: Geological Society of America Bulletin, V. 87, pp 61-75.

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

7-1337 (6-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET .... OF ....

FEATURE Cle Elum Dam Test Well PROJECT Yakima STATE Washington

HOLE NO. CE-5 LOCATION Sta. 0+37.5 ℄ dam axis, 9.0' right of ℄ dam axis* GROUND ELEV. 2250.60 DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. .... E. ....

BEGUN 8/19/78 FINISHED 9/8/78 DEPTH OF OVERBURDEN -- TOTAL DEPTH 255' BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 142.3', 2108.3 (10/12/78) LOGGED BY R. A. Link LOG REVIEWED BY B. E. Carter

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	Hole Completion	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Drilling Equipment Bucyrus-Eerie 22W Series Three air rotary/churn drill. Drillers Mike Ring and Jim Hooper of Mike Bach Drilling Company. Drilling Method Hole was drilled with 12" standard bit tool 5-15 gallons of water used to return cuttings in bailer to 215'. Hole bailed out on intervals of 3-5', prior to casing advance. 20" diameter temporary surface casing installed to 21'; 16" diameter casing advanced from 21-252'. 0-152': casing a[illegible]nced behind [illegible]ing on intervals up to 20', but averaging 5'. 152-252': casing advanced ahead of drilling on intervals of 3-5', but reaching a maximum of 20'.	20" C 16" C			16" casing				2250.60	0'			Note: 0-255': Geologic log based on drill cuttings return and drilling conditions. 0-67': DAM EMBANKMENT. Silt, medium brown to tan in color with highly variable amounts of clay up to 35 percent which sometimes occurs as small clay balls. Minor amounts of medium to fine grained sand. Gravel occurs as small, thin layers or lenses dispersed randomly throughout, present as gravel with size recovered up to 1.5" in diameter and possibly some cobbles.
Drilling Conditions 0-67': Fast and easy; hole holding open. 67-74': Slow and hard. 74-75': Slow and very hard; boulders rolling into hole. 75-105': Slow and hard, caving. 105-215': Fast and easy, caving. 215-255': Fast and easy, sand flowing into hole.								2183.60	67'			67-255': QUATERNARY GLACIAL TILL (Domerie Terminal Moraine). Glacial debris composed of poorly sorted boulders, cobbles, gravel, sand, and silt, generally poorly to very poorly consolidated.
								2174.60	76'			67-76': Boulders; boulders and cobbles of basalt, andesite, granite and/or granodiorite among others. Matrix of medium brown to tan silt with variable proportions of clay and minor amounts of sand.
Casing Record								2160.60	90'			76-90': Silty Gravel; gravel and silt in nearly equal proportions. Gravel occurs as fine gravel and cobbles. Matrix is silt, medium brown to tan in color with up to 25 percent clay; medium to fine sand present in minor amounts.
									100'			

Casing Record

Date	Hole Depth	Casing Depth
8/18/78	18'	17'
8/21/78	22'	21'

EXPLANATION

* Location of hole approximate as hand level and tape were used to survey in drill hole.

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Cle Elum Dam, Test Well — PROJECT: Yakima — STATE: Washington

HOLE NO. CE-5 — LOCATION: Sta. 8+37.5 ℄ dam axis, 9.0' right of ℄ dam axis* — GROUND ELEV. 2250.60* — DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. .... E. ....

BEGUN 8/19/78 — FINISHED 9/8/78 — DEPTH OF OVERBURDEN [illegible] — TOTAL DEPTH 255' — BEARING [illegible]

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 142.3', 2108.3 (10/12/78) — LOGGED BY R. A. Link — LOG REVIEWED BY B. H. Carter

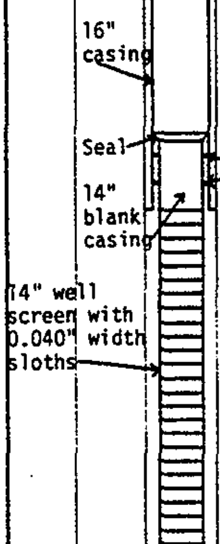
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS			TYPE AND SIZE OF HOLE
8/21/78	39'	21'	16" C
8/22/78	60'	41'	
8/22/78	69'	61'	
8/23/78	74'	74'	
8/24/78	75'	75'	
8/24/78	88'	81'	
8/25/78	90'	85'	
8/25/78	97'	96'	
8/28/78	100'	101'	
8/28/78	105'	105'	
8/29/78	120'	120'	
8/29/78	132'	131'	
8/30/78	137'	137'	
8/31/78	152'	150'	
9/1/78	161'	161'	
9/5/78	170'	182'	
9/5/78	182'	182'	
9/6/78	190'	200'	
9/6/78	215'	202'	
9/7/78	225'	240'	
9/7/78	241'	241'	
9/8/78	255'	252'	

Depth to Water

Date	Hole Depth	Water Depth
8/19/78	18'	Dry
8/[illegible]/78	22'	Dry
8/[illegible]/78	39'	Dry
8/22/78	60'	Dry
8/22/78	69'	Dry
8/23/78	74'	73'
8/24/78	75'	Dry
8/24/78	88'	Dry
8/25/78	90'	88'
8/25/78	97'	Dry
8/28/78	100'	Dry
8/28/78	105'	Dry
8/29/78	120'	Dry
8/29/78	132'	Dry
8/30/78	137'	Dry
8/31/78	152'	150'
9/1/78	161'	Dry
9/5/78	170'	Dry
9/5/78	182'	Dry
9/6/78	190'	Dry
9/6/78	215'	Dry
9/7/78	225'	147.14
9/7/78	241'	148'
9/8/78	255'	174'

Drilling Time
190 hours.

PERCOLATION TESTS — DEPTH (FEET) FROM / TO — Hole Completion — PRESSURE (P.S.I.) — LENGTH OF TEST (MIN.)



ELEVATION (FEET)	DEPTH (FEET)
	100'
2114.60	136'
2107.60	143'
2103.60	147'
2070.60	180'
2060.60	190'
2050.60	200'

CLASSIFICATION AND PHYSICAL CONDITION

90-136': Silty Gravel; gravel with size recovered up to 2" in diameter composed of basalt, andesite, granite, granodiorite, rhyolite, sandstone, mudstone and other unidentified rock types including metamorphics. Matrix of medium brown to tan silt; clay present in variable proportions up to 15 percent. Medium to fine grained sand occurs in very small amounts from 90-100'; from 100-136' sand steadily increases to maximum of 20 percent.

136-143': Sandy Gravel, gravel and small cobbles of basalt, granite, diorite, shale, greenstone and other unidentified lithologies. Matrix is predominantly medium grained sand, but varies into fine and coarse ranges; composition of sand similar to that of gravels, but also includes quartz, feldspars, and epidote. Silt occurs in small amounts; no clay present.

143-147': Silty Gravel; small gravels and cobbles of andesite, basalt, and diorite among others. Matrix of silt and fine sand, medium brown to tan in color. Coarse to medium grained sand present up to 15 percent. Minor amounts of clay present.

147-180': Sandy Gravel; gravel and cobbles of granite, diorite, greenstone, basalt, quartzite, rhyolite, shale, and unidentified lithologies. Matrix primarily composed of medium to fine grained sand with smaller amounts of silt and coarse sand. Clay occurs as small balls up to 1" in diameter.

180-190': Sand; coarse to medium grained sand, dark grayish blue in color. Some fine gravel present. Very little clay or silt occurs.

190-200': Sandy Gravel; Fine gravel of unidentified igneous intrusives and some basalt. Matrix of medium to fine grained sand and some silt, dark grayish blue in color. Clay present in very small amounts.

EXPLANATION

* Location of hole approximate as hand level and tape were used to survey in drill hole.

CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Cle Elum Dam Test Well PROJECT Yakima STATE Washington

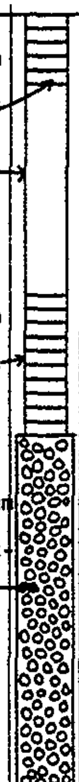
HOLE NO. CE-5 LOCATION Sta. 8+37.5 ℄ dam axis, 5.0' right of ℄ dam axis* GROUND ELEV. 2250.60* DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. E.

BEGUN 8/19/78 FINISHED 9/8/78 DEPTH OF OVERBURDEN -- TOTAL DEPTH 255' BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 142.3', 2108.3 (10/12/78) LOGGED BY R. A. Link LOG REVIEWED BY B. H. Carter

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: Hole Completion	ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
Hole Completion Pulled 16" casing to 230'. Backfilled hole with 3/4" minimum diameter gravel from 230-255'. Set 14" well screen with 0.020" width slots from 220-230'. Installed blank 14" casing from 205-220'. Set 14" well screen with 0.040" width slots from 175-205'. Installed blank 14" casing from 170-175'. Pulled 16" casing to 175' and set seals between 14" and 16" casing in telescoped section from 170-175'.	16" C		14" well screen with 0.040" width slots; 14" blank casing; 14" well screen with 0.020" width slots; 3/4" minimum diameter gravel backfill	2050.60	200'	200-205': Sand; dark grayish blue sand, medium to coarse grained with very little silt or clay. Scattered gravel present.
Purpose of Drilling To provide a large diameter well for test pumping and to obtain data on the formation material and the conditions thereof.				2045.60	205'	205-215': Silt; silt and clay with a slightly less amount of fine sand, dark grayish blue in color. Well sorted with almost no coarse material.
				2035.60	215'	215-225': Sand; medium to fine grained sand dark grayish blue in color with small amounts of coarse sand. Gravel present, but with little or no silt and clay.
				2025.60	225'	225-235': Sandy Silt; silt and fine sand, dark grayish blue in color. Medium to coarse grained sand in minor amounts; small proportions of clay also present. Gravel occurs in very small amounts.
				2015.60	235'	235-255': Silt; very fine to fine grained silt, dark grayish blue in color with some clay and fine grained sand present. Well sorted with medium to coarse sand and gravel totally lacking.
	Bottom of Hole			1995.60 Bottom of Hole	255'	



EXPLANATION

* Location of hole approximate as hand level and tape were used to survey in drill hole.

CORE RECOVERY

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Ca = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series).. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

7-1687 (8-74)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Cle Elum Dam PROJECT Yakima Project STATE Washington

HOLE NO. DH-81-2 LOCATION Right d/s toe GROUND ELEV. 2129.8 DIP (ANGLE FROM HORIZ.) 90°

COORDS. N. 4253 E. 5890

BEGUN 3-27-81 FINISHED 4-8-81 DEPTH OF OVERBURDEN --- TOTAL DEPTH 110.0' BEARING ---

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY J. Brad Buebler LOG REVIEWED BY D. N. Magleby

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill Equipment
Mobile B-80 truck mounted drill with Bean 35 pump.

Driller
Don Jackson

Drill Setup
Drill setup near the righr d/s toe of the dam.

Drilling Methods
0.0-5.0': Started the hole using a solid stem auger.
5.0-38.0': Advanced the hole using a 5-7/8" roller rock bit and clear water.
38.0-85.0': Advanced the hole using a 3-3/4" roller rock bit and clear water.
85.0-110.0': Advanced the hole using a 2-15/16" roller rock bit and clear water.

Open-end gravity water tests were conducted on 10-foot intervals.

Standard Pneetration Tests were conducted when possible.

Sample Interval
SPT 59.7-60.8'

Drilling Conditions
0.0-94.5': Slow and rough.
94.5-110.0': Faster and smooth.

TYPE AND SIZE OF HOLE / CORE RECOVERY

Type and size of hole	Core recovery (%)
AP	0
5-7/8" RB	WS
3-3/4" RB	WS
SPT	27
3-3/4" RB	WS
2-15/16" RB	WS

PERCOLATION TESTS

Depth (feet) From (P, Cs, or Cm)	To	Loss (G.P.M.)	Pressure (P.S.I.)	Length of test (min.)
10.0	10.5	0.1	G	5
20.0	24.0	4.2	G	5
29.3	30.5	0.4	G	5
40.0	40.5	4.2	G	5
50.0	50.5	25.4	G	5
60.0	60.5	40.0*	G	5
70.0	70.5	40.0*	G	5
80.0	80.5	28.0	G	5
90.0	90.5	11.2	G	5
100.0	109.0	1.4	G	5

ELEVATION (FEET): 2129.8

CLASSIFICATION AND PHYSICAL CONDITION

0.0-110.0': GLACIAL DRIFT composed of: GLACIAL TILL characterized by a heterogeneous mixture of mostly subrounded to rouned igneous and metamorphic cobbles and gravel, with sand and fines, and a few boulders, lacks stratification. GLACIAL OUTWASH which is typified by well sorted, stratified gravel, sand, and fines in layers and/or lenses.

0.0-15.7': Mostly Cobbles, Gravel and and Fines with some Boulders and Sand based on drilling conditions and wash samples.

15.7-59.7': Mostly Cobbles, and Gravel with Sand, and Fines based on drilling conditions and wash samples.

59.7-60.8': Standard Penetration Resistance Test 50 blows per 0.6 feet penetration.

59.7-60.8': Gravel, hard, angular, maximum size 60 mm, moist, blue.

60.8-70.5': Cobbles, Gravel, Sand, Fines with some Boulders based on drilling conditions and wash samples.

70.5-80.5': Mostly Gravel, Sand and Fines, with some Boulders and Cobbles based on drilling conditions and wash samples.

80.5-94.5': Mostly Gravel, Sand and Fines, with a few Cobbles based on drilling conditions and wash samples.

94.5-110.0': Sand and Fines based on drilling conditions and wash samples. Unable to conduct Standard PR due to heaving conditions, but tried PR tube for sample (no recovery).

110.0': BOTTOM OF HOLE

Geologic Interpretation
0.0-110.0': GLACIAL DRIFT, Quaternary Age.

EXPLANATION

CORE LOSS / CORE RECOVERY

RB = Rock Bit
SPT = Standard Penetration Resistance Test
WS = Wash Sample
G = Gravity Water Test
AP = 6" Solid Stem Auger
* = Maximum output of pump

Local coordinate grid system.

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

FEATURE: Cle Elum Dam | PROJECT: Yakima Project | STATE: Washington

HOLE NO: DH-81-2 | LOCATION: Right d/s toe | COORDS: N. 4253, E. 5890 | GROUND ELEV: 2129.8 | DIP (ANGLE FROM HORIZ): 90°

BEGUN: 3-27-81 | FINISHED: 4-8-81 | DEPTH OF OVERBURDEN: --- | TOTAL DEPTH: 110.0' | BEARING: ---

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See Notes | LOGGED BY: J. Brad Buehler | LOG REVIEWED BY: D. N. Magleby

Column headings: NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

Type and size of hole: 2 15/16" RB (to 110), WS

Elevation 2019.8 at depth 110 — BOTTOM OF HOLE

Casing Record

Date	Sz	Depth Hole	Depth Cs.
3-27	6"	5.0'	5.0'
3-30	6"	12.0'	10.0'
3-31	6"	14.0'	14.0'
4-1	6"	24.0'	20.0'
4-2	6"	38.0'	35.0'
4-3	4"	60.5'	60.0'
4-6	4"	80.5'	80.0'
4-6	3"	80.5'	80.0'
4-7	3"	110.0'	105.0'

Water Return

0.0-40.5'	100%
40.5-60.0'	75%
60.0-80.5'	50%
80.5-110.0'	75%

Water Color

0.0-12.0'	Tan
12.0-91.5'	Gray
91.5-110.0'	Brown

Water Level During Drilling

Date	Depth Hole	Water Level
3-30	5.0'	dry
3-31	12.0'	dry
4-1	14.0'	11.0'
4-2	24.0'	dry
4-3	38.0'	22.7'
4-6	60.0'	21.8'
4-7	80.5'	20.8'

Water Level After Drilling

Piezometer Readings (see hole completion)

Date	Upper	Lower
4-17	2107.14	---
5-11	2107.42	---
5-29	2110.44	2110.34
6-15	2111.44	2111.34
6-22	2112.09	2112.09
7-2	2112.09	2112.09
7-9	2112.04	2111.99
7-20	2112.04	2111.99
7-28	2112.04	2111.99
8-4	2111.99	2111.99
8-25	2111.44	2111.14
8-31	2110.84	2110.62
9-2	2110.74	2110.54
9-25	2109.34	2109.04
9-28	2109.34	2109.04
9-30	2109.09	2108.99
10-6	2109.1	2108.9
10-15	2109.1	2108.9
10-22	2109.1	2108.9
10-30	2108.5	2108.4

Hole Completion

Installed 2 piezometers consisting of 1-1/4" PVC with the bottom 30 feet perforated in the lower piezometer and 15 feet perforated in the upper piezometer. The lower piezometers influence zone is from 75-110' and the upper piezometers influence zone is from 15-65'.

Purpose of Hole

Feasibility Study; Foundation Investigation for Powerplant.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature: Cle Elum Dam — Project: Yakima — Area Designation: Right d/s toe

Hole No.: AP-81-1 — Coordinates N: 4270 E: 5883 — Ground Elevation: 2129.7 — Approx. Dimensions1/: 6" solid stem

Depth to Water Level1/ & 2/: not encountered — Method of Excavation: power auger — Date: 3-27-81 — Logged by: J Brad Buehler

CLASSIFICATION SYMBOL	DEPTH (m)1/	SIZE AND TYPE OF SAMPLE TAKEN3/	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE DESIGNATION E-3, EARTH MANUAL, FOR METHOD OF DESCRIPTION; GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS4/: VOLUME OF HOLE SAMPLED (m³)5/	MASS OF 75 TO 125 mm SAMPLED (kg)3/	% BY VOLUME OF 75 TO 125 mm6/	MASS OF PLUS 125 mm SAMPLED (kg)3/	% BY VOLUME PLUS 125 mm
GM	5.0'	0	0.0- 5.0 ft SILTY GRAVEL WITH COBBLES: approx. 50% coarse to fine, subrounded to rounded, hard, gravel; approx. 30% coarse to fine, subangular to subrounded sand; 20% fines with low plasticity; brown, dry, no reaction to HCl TOTAL SAMPLE (BY VOLUME): approx. 40% subrounded, hard, cobbles; remainder minus 75 mm; max. size 200 mm GEOLOGIC INTERPRETATION: GLACIAL DRIFT					

REMARKS:

Depth measured in feet.
Met refusal at 5.0 feet.
Difficult to auger.

Note local coordinate grid system.

NOTES:
1/Report to nearest 0.01 m
2/Record after water has reached its natural level and give date of reading
3/Report to nearest 0.5 kg
4/Applicable only to borrow pits and to foundations which are potential sources of construction materials
5/Report to nearest 0.001 m³
6/ (1) % = (mass of rock sampled) / ((Bulk density) X (cubic metres of hole sampled)) X 100
(2) Record bulk density in Remarks, stating how obtained (measured or estimated)
Report to nearest 0.1%

Appendix B

APPENDIX B

Becker Drilling Program Results

Becker Drilling Program Results

Tables:

Figures:

Attachments:

Becker Drilling Program Results

A drilling program consisting of Becker penetration and sample tests was conducted at the Cle Elum Dam near Cle Elum, Washington. The purpose of the investigation was to provide data to evaluate the coarse-grained foundation materials with respect to their potential for liquefaction under earthquake loads. The potential for liquefaction of the foundation soils was questioned after lower shear wave velocity zones were measured in the foundation materials during the 1992-93 cross-hole shear wave (CHSW) tests performed at the site. Zones with lower velocities included a layer between elevation 2105 and 2120 near the spillway (DH-92-1 and DH-92-2) exhibiting a shear wave velocity on the order of 850 feet per second (fps); and a similar layer between elevation 2095 and 2110 near the center of the downstream berm (DH-92-4 and DH-92-5), having a shear wave velocity ranging from 600 to 800 fps. In addition, both CHSW tests showed the velocity of the foundation materials exhibited a decrease to approximately 1200 fps near the bottoms of the test holes, between approximate elevations 2040 and 2055 near the spillway (DH-92-1 and DH-92-2), and between approximate elevations 2010 and 2040 near the center of the downstream berm (DH-92-4 and DH-92-5).

Field work for the Becker drilling program at Cle Elum Dam near Cle Elum, Washington, began on November 11, 1998. The work was completed in conjunction with personnel from the U.S. Bureau of Reclamation (Reclamation). Layne Christensen Company of Tacoma, Washington, was the drilling subcontractor for the Becker penetration testing. Figure B-1 shows one of the Becker tests performed by Lane Christensen at Cle Elum. Five (5) Becker drill holes and one (1) Becker sample hole were completed during the field investigation performed between November 11 and 22, 1998. Daily reports completed by the URS Greiner Woodward Clyde field geotechnical engineer are included in Attachment A.

Approximate locations of the Becker drill holes performed during the November 1998 investigation program are shown in Figure B-2. Exact locations and elevations of the drill holes have been surveyed by Reclamation, as reported in Table B-1. Drill holes BDH98-1 and BDH98-1B, and sample hole BSH98-1 were performed near the break in slope between the main body of the dam embankment and the downstream berm at the maximum-height section of the dam. Drill hole BDH98-2 was conducted adjacent to cross-hole shear wave (CHSW) location DH-92-5, near the midpoint of the downstream berm at the approximate maximum-height section of the dam. Drill hole BDH98-3 was located near the toe of the downstream berm, but about 50 feet upstream of the planned location, as that location would have required cutting and clearing of a substantial number of trees. The final drill hole, BDH98-4, was sited adjacent to CHSW location DH-92-1, on the downstream berm near the spillway.

The details and results of the Becker drill and sample holes are summarized in the following paragraphs.

Table B-1
BECKER TESTS SURVEY DATA

Survey Pt. No.	Northing	Easting	Elevation (feet)	Becker Test Hole
8601	270.39	270.79	2184.94	BDH-98-1
8602	265.16	283.53	2184.14	BSH-98-1
8603	261.01	292.24	2183.16	BDH-98-1B
8604	154.80	584.19	2153.72	BDH-98-2
8605	226.05	148.79	2129.53	BDH-98-3
8606	857.22	942.33	2177.97	BDH-98-4

Becker Hammer Drilling

Becker drilling was carried out from November 11 through November 22, 1998, using a truck-mounted Becker hammer drill (ICE 180 double-acting diesel hammer) supplied and operated by Layne Christensen of Tacoma, Washington. Becker drilling was used for two types of tests: the Becker Penetration Tests (designated as BDH98-2, etc.) and the Becker Hammer Sampling Test (designated as BSH98-1). The Becker Penetration Test (BPT) consists of driving a 6-5/8-inch outside-diameter (O.D.) closed-end casing into the ground, with a double-acting diesel pile hammer, and recording the blow counts for each foot of casing penetration. Where refusal was met using the closed-end bit, an open-end bit was used. As such, open-bit drilling was performed for various intervals in some of the Becker Penetration Test drill holes. The closed-bit penetration values can be used to infer relative densities of soil and to assess liquefaction potential. The Becker Hammer Sampling Test is a variation of the BPT where an open-end casing is used, allowing samples to be collected by operating a rotary blower supercharger connected to the inlet ports of the diesel pile hammer combustion chamber.

Penetration resistance, measured in blows per foot (bpf), and bounce chamber pressure measurements (in psi) were recorded by the field team for all six Becker test holes. Bounce chamber pressure, the pressure in the sealed chamber above the ram, is an indicator of the kinetic energy imparted to the falling ram on completion of the stroke. Bounce chamber pressures were measured and blow counts were recorded using a pressure transducer and an analog/digital converter unit (data logger) borrowed from Reclamation. Attachment B contains the raw Becker hole test data, including penetration resistance and bounce chamber pressure measurements. At the time that this Becker memo was prepared, the Becker penetration test data at Cle Elum Dam had not been evaluated using the equivalent $(N1)_{60}$ due to high raw Becker blowcounts, assumed to correlate to high $(N1)_{60}$ values. Since that time, evaluations of $(N1)_{60}$ have been performed, as shown in Figures 8A through 8D in the main portion of the Technical Memorandum.

Becker Drilling Program Results

Goble Rausche Likins and Associates, Inc. (GRL) from Seattle, Washington, monitored the Becker penetration tests with a Pile Driving Analyzer (PDA). A 2-foot section of Becker casing was outfitted with PDA instrumentation and was situated below the drive helmet. The measurements of force and velocity from the PDA were used to measure the energy transmitted from the hammer/helmet system into the casing. From this, the efficiency of the Becker hammer (ratio of transmitted energy to hammer rated energy) was calculated. The PDA was also used to assess the skin friction of the casing. The PDA field results obtained from GRL are presented in Attachment C. The PDA results were not used to evaluate the Becker penetration test data in detail at the time of this Becker memo. However, PDA data was used to evaluate the $(N1)_{60}$ values as shown in the main body of the Technical Memorandum.

Becker Drill Hole BDH98-1 (approx. 269 feet downstream of Sta. 5+16)

The first Becker drill hole was drilled adjacent to piezometer DH-92-6, near the break in slope between the mainbody of the dam embankment and the downstream berm at the maximum-height section of the dam. Initial closed-bit penetration testing was completed to a depth of 68.5 feet where refusal was met, with 960 blows for 6" of penetration. Refusal occurred about 10.5 feet into the glacial outwash foundation material. The casing was pulled and the hole was drilled to a depth of 72 feet with the open-bit casing to attempt to drill through the cobbles and boulders causing the obstruction. With the open-bit casing, blow counts ranged between 90 and 150 bpf from 68.5 to 72 feet. The closed-bit casing was inserted back down hole to continue the penetration test. Caving within the fill materials occurred and refusal was encountered at 68 feet in the caved material. Testing was terminated at this point and the hole was backfilled with grout.

Figure B-3 shows the penetration resistance and average bounce chamber pressures recorded for drill hole BDH98-1. An approximate breakdown of the measured blow counts (blows from the hammer per foot of penetration) for drill hole BDH98-1 during closed-bit penetration are as follows:

Material	Depth (feet)	Blows/Foot (Closed-bit)
Downstream Berm (Fill)	0-10	6-37
Dam Embankment (Fill)	10-58	55-572
Coarse-grained Glacial Outwash (Qgo_1)	58-72	30->900/6"

Becker Sample Hole BSH98-1 (approx. 283 feet downstream of Sta. 5+15)

An open-bit sample hole was drilled adjacent to drill hole BDH98-1. Bag samples of cuttings were collected from the hole, using a cyclone-type retrieval system, on approximate 5-foot intervals, beginning at the bottom of the embankment fill (approximate depth of 65 feet). Blow counts were logged for a relative indication of the in-place densities of the fill and foundation materials. Drilling was completed to the planned depth of 250 feet. The following stratigraphy was encountered in this hole:

0-10':	Downstream Berm (Fill)
10'-65':	Dam Embankment (Fill)
65'-141':	Coarse-grained Glacial Outwash (Qgo_1)
141'-185':	Fine-grained Glacial Outwash (Qgo_2)
185'-250':	Glaciolacustrine Sediments (Qgl). Primarily fine sand and silt to 202', then silty clay and lean clay to 250'.

The penetration resistance (open-bit) and bounce chamber pressures for sample hole BSH98-1 are shown graphically in Figure B-4. The open-bit blow counts of the materials ranged from 8 to 30 bpf in the downstream berm, 19 to 107 bpf in the dam embankment, 13 to 470 bpf in the coarse-grained glacial outwash, 5 to 30 bpf in the fine-grained glacial outwash, and 18 to 183 bpf in the glaciolacustrine sediments. Water was encountered during sampling at an approximate depth of 70 feet.

The hole was backfilled with grout and selected samples were delivered to Reclamation's soils lab at the Pacific Northwest Construction Office in Yakima, Washington, for standard index properties testing (gradation, hydrometer, and Atterberg limits). The laboratory test results are included in Attachment D.

Becker Drill Hole BDH98-1B (approx. 293 feet downstream of Sta. 5+16)

A second attempt was made to complete a closed-bit Becker penetration test adjacent to the location of Becker drill hole BDH98-1 and Becker sample hole BSH98-1. The goal was to reach depths within the dam foundation for correlation of closed-bit blow counts with the profile of open-bit blow counts obtained in BSH98-1. An error with the Pile Driving Analyzer (PDA) occurred at 26 feet depth, resulting in retraction of the casing to check for damage. The casing was intact, thus drilling resumed. Retraction of the casing resulted in severe caving at approximately 15 feet depth. Redrilling was completed to 26 feet with very high blow counts. Testing continued to a depth of 68.5 feet. Very high blow counts were attained below 58 feet, frequently exceeding 1000 bpf, and testing was terminated at 68.5 feet after recording over 1500 blows for 6" of penetration. The hole was backfilled with grout.

The materials encountered and the blow counts achieved were very similar to those of Becker drill hole BDH98-1. Figure B-5 presents the penetration resistance and bounce chamber pressure measurements for BDH98-1B.

Becker Drill Hole BDH98-2 (approx. 600 feet downstream of Sta. 5+54)

Becker drill hole BDH98-2 was drilled adjacent to cross-hole shear wave (CHSW) hole DH-92-5, near the midpoint of the downstream berm at the approximate maximum-height section of the dam. Initial closed-bit penetration testing was completed to a depth of 108.7 feet where refusal (845 blows with 0.7 feet of penetration) was attained. The closed-bit casing was retracted and the hole was redrilled to a depth of 122 feet with the open-bit to penetrate through the refusal zone, enabling collection of test data from the finer-grained outwash present at depth. The hole was grouted with a bentonite cement to stabilize the bore hole sidewalls during insertion of the closed-bit for continued Becker hammer testing. Closed-bit Becker penetration testing was then conducted from 122 feet to refusal at 142.8 feet (1367 blows with 0.8 feet of penetration). Testing was terminated at this point as correlation with holes DH-92-2 and BSH98-1 indicated that the underlying glaciolacustrine sediments (predominantly silts and clays) would have been intercepted at a depth of about 155 feet.

A zone with a shear wave velocity ranging between 600 and 800 fps, identified between the elevations of 2095 to 2110 (45 to 60 feet depth) in the 1992-93 cross-hole shear wave data, was not supported by low penetration resistance, as blow counts ranged from 86 to 342 bpf through this interval. Similarly, the zone between the elevations of 2010 and 2040 (115 and 145 feet depth) characterized by a shear wave velocity of approximately 1200 fps exhibited closed-bit blow counts ranging from 60 bpf to refusal (>1200).

The penetration resistance and average bounce chamber pressures recorded for drill hole BDH98-2 are shown in Figure B-6. The approximate breakdown of materials encountered in BDH98-2 and their corresponding blow counts are as follows:

Material	Depth (feet)	Blows/Foot (Closed-bit)
Downstream Berm (Fill)	0-35	6-28
Coarse-grained Glacial Outwash (Qgo_1)	35-118	49->840/0.7'
Fine-grained Glacial Outwash (Qgo_2)	118-141.8	60->1300/0.8'

Becker Drill Hole BDH98-3 (approx. 888 feet downstream of Sta. 5+10)

Becker penetration test BDH98-3 was conducted near the toe of the downstream berm, but about 50 feet upstream of the location indicated in the drilling program plan. Closed-bit penetration testing was conducted to a depth of 108.1 feet where refusal was encountered at 444 blows for 0.1 feet of penetration. No low density materials were noted in this test hole, with blow counts ranging from 8 to 54 bpf in the downstream berm (0-16') and 81 to 595 bpf in the coarse-grained glacial outwash (16-108'). The open-bit casing was inserted into the hole and advanced to a depth of 122 feet where open-bit blow counts of 11 to 38 bpf were recorded. The hole was grouted as the open-bit casing was retracted. Becker penetration testing with the closed-bit was resumed from 122 to 138.8 feet, where refusal was again encountered (926 blows with 0.8 feet of penetration). The blow counts at depths greater than 122 feet ranged from 37 to 1018 bpf. No further testing was attempted in this hole, as the underlying glaciolacustrine sediments were inferred to have been intercepted at a depth of approximately 120 feet. Figure B-7 presents the penetration resistance and bounce chamber pressure measurements for Becker drill hole BDH98-3.

Becker Drill Hole BDH98-4 (approx. 613 feet downstream of Sta. 8+37)

Becker drill hole BDH98-4 was sited adjacent to cross-hole shear wave (CHSW) location DH-92-1, to evaluate the blow counts in two zones identified in the 1992-93 CHSW data: (1) a upper zone with a shear wave velocity of approximately 850 fps at an elevation between 2105 and 2120 (60 to 75 feet depth), and (2) a lower zone with a shear wave velocity of approximately 1200 fps at an elevation between 2040 and 2055 (125 and 140 feet depth). Because of the large number of boulders encountered at this drill site during previous drilling programs, the initial plan for this hole was to drill with the open-bit to the top of the upper zone ($V_s \approx 850$ fps) at about 60 feet. Blow counts were recorded during open-bit drilling for an indication of the relative density of the layers. Initial penetration into the upper zone did not yield blow counts low enough to warrant pulling the open-bit casing. Open-bit testing was continued through this upper zone, yielding blow counts ranging from 34 to 204 bpf. Blow counts did not drop below 34 bpf, and the decision was made in the field to continue with the open-bit until blow counts became low enough to require Becker hammer testing with the closed-bit. Becker open-bit blow counts through the 1200 fps shear wave velocity zone (125 to 140 feet depth) were not low, ranging from 20 to 203. As the majority of the blow counts remained high, drilling with the open-bit was continued to a depth of 145 feet, where blow counts ranged between 11 and 20 bpf from 139 to 145 feet. The hole was grouted with bentonite cement while extracting the open-bit, and Becker penetration closed-bit testing began at that depth. About 5 feet of caved material was noted in the hole and the casing experienced considerable difficulty reaching the bottom depth of the hole. Becker penetration testing was initiated at a depth of 145 feet, but refusal was soon reached at 146 feet (1990 blows with 1.0 foot penetration). Drilling was resumed with the open-bit casing to obtain some general density data from the deeper outwash foundation materials. A zone of relatively low blow counts was noted from 148 to 158 feet (ranging from 5 to 10 bpf with the open bit), but these materials would likely have yielded fairly high closed-bit blow counts based on field experience seen in BDH98-2 and BDH98-3, where similar soils with open-bit blow counts of 10 to 13 bpf later tested in excess of 100 bpf with closed-bit drilling. The glaciolacustrine sediments were intercepted at 172 feet and drilling was terminated, after penetrating to a final depth of 207 feet. Figure B-8 illustrates the penetration resistance and average bounce chamber pressures recorded for BDH98-4.

SUMMARY

Five (5) Becker drill holes and one (1) Becker sample hole were completed to depths up to 250 feet at the Cle Elum Dam site. This report summarizes the raw Becker test data. Lower velocity layers ($600<V_s<850$ fps and $V_s \approx 1200$ fps) identified during the 1992-93 drilling and geophysical program were not supported by low blow counts during the 1998 Becker drilling program. The closed-bit blow counts for the layer ($600<V_s<800$ fps) located between elevations of 2095 to 2110 (45 to 60 feet depth) near BDH98-2 ranged from 86 to 342 bpf, while the open-bit blow counts for the similar layer ($Vs \approx 850$ fps) identified between elevations 2105 and 2120 (60 to 75 feet depth) near BDH98-4 ranged from 34 to 204 bpf. Additionally, the zones exhibiting shear wave velocities on the order of 1200 fps, identified between elevations 2010 and 2040 (115 to 145 feet depth) near BDH98-2 and between elevations 2040 and 2055 (125 to 140 feet depth) near BDH98-4, exhibited closed-bit blow counts ranging from 60 to refusal (>1200) and open-bit blow counts ranging from 20 to 203, for BDH98-2 and BDH98-4, respectively.

A saturated sand layer located at depths of 170 and 190 feet (approximate El. 1995 and 2015) produced open-bit blow counts ranging from 10 to 20 bpf during the drilling of Becker sample hole BSH98-1. Becker drill hole BDH98-3 penetrated through the same elevations, and what is believed to be the same soil type, using a closed-bit casing. A fourteen-foot portion of BDH98-3 (El. 2008 to 2021) was drilled using the open-bit to penetrate through a refusal zone, which was located directly above the elevation interval corresponding to the 10 to 20 bpf encountered during open-bit penetration in BSH98-1. In addition, Becker drill hole BDH98-2 reached refusal with the closed-bit casing within the upper portion of the same zone (El. 2012). Figure B-10 shows a comparison of the measured penetration resistances for BSH98-1, BDH98-2, and BDH98-3. The figure shows that the lower blow counts measured with the open-bit casing do not correspond to low blow counts with the closed-bit casing. The relatively large difference between blow counts for the closed-bit casing and the open-bit casing is most likely explained by the fact that this stratum is predominantly a fine sand. The open-bit casing would likely penetrate relatively easily through a fine sand, even if it is dense. As shown in Figure B-10, low closed-bit blowcounts were not measured in the saturated sand layer.

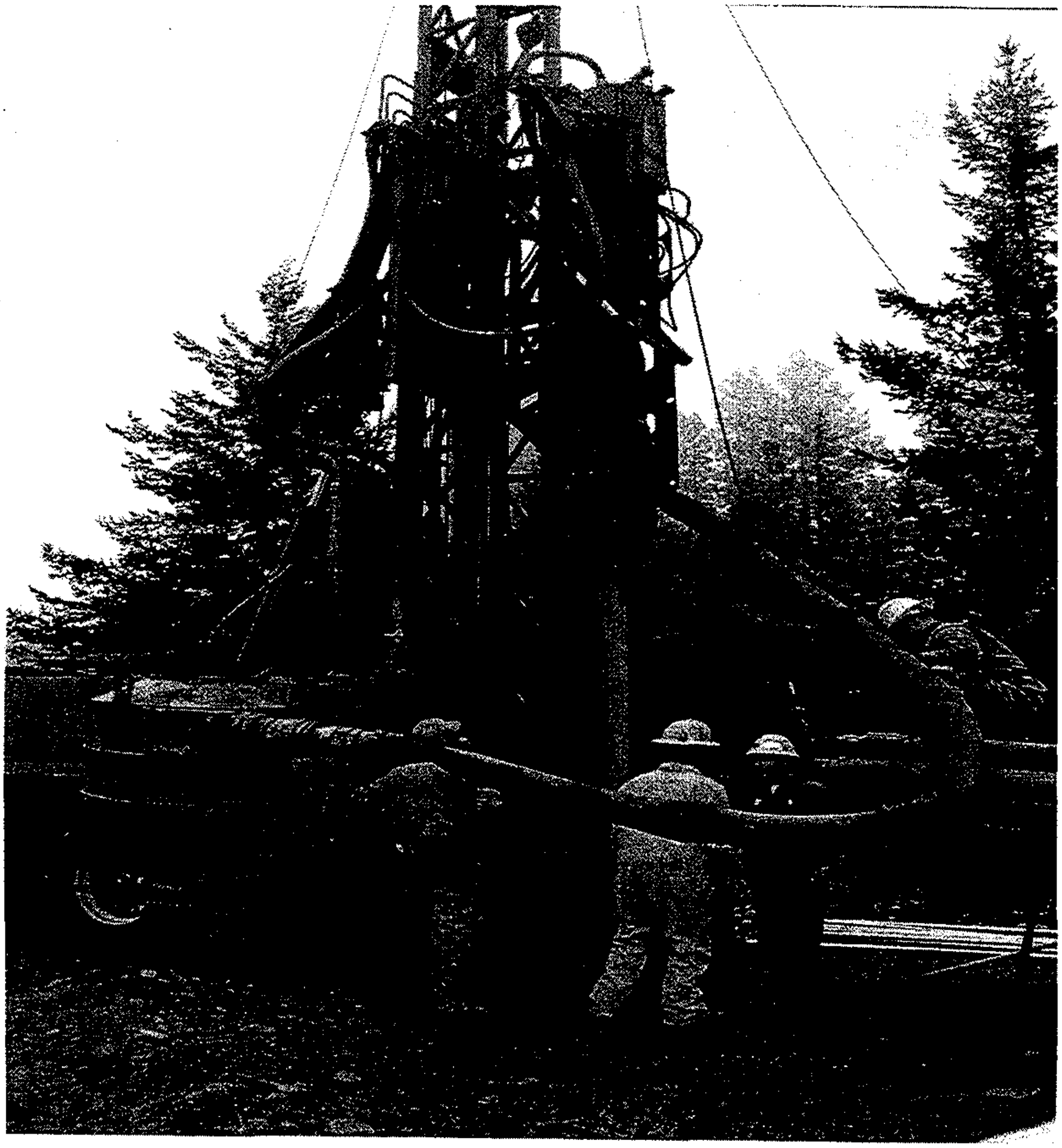
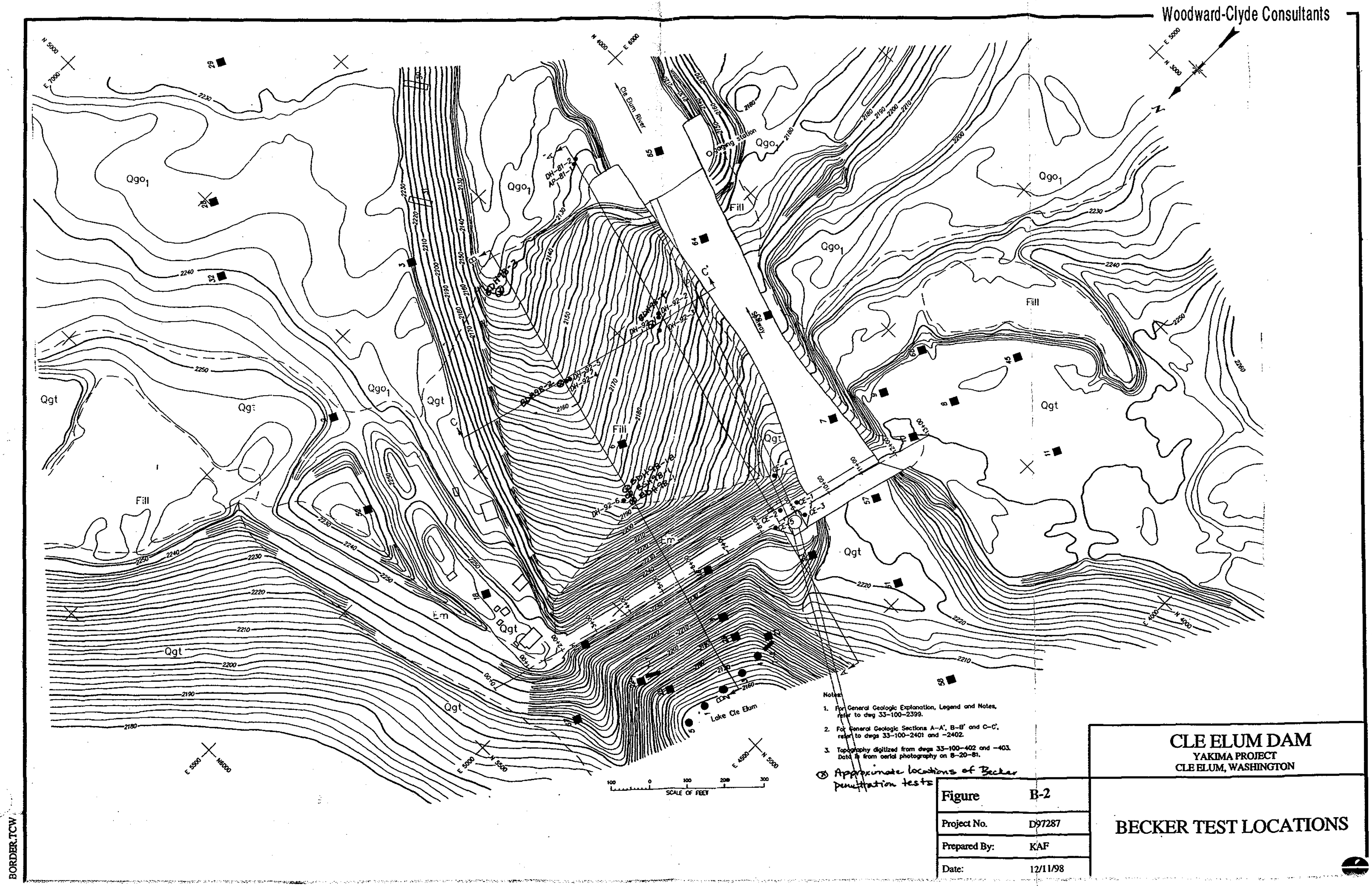
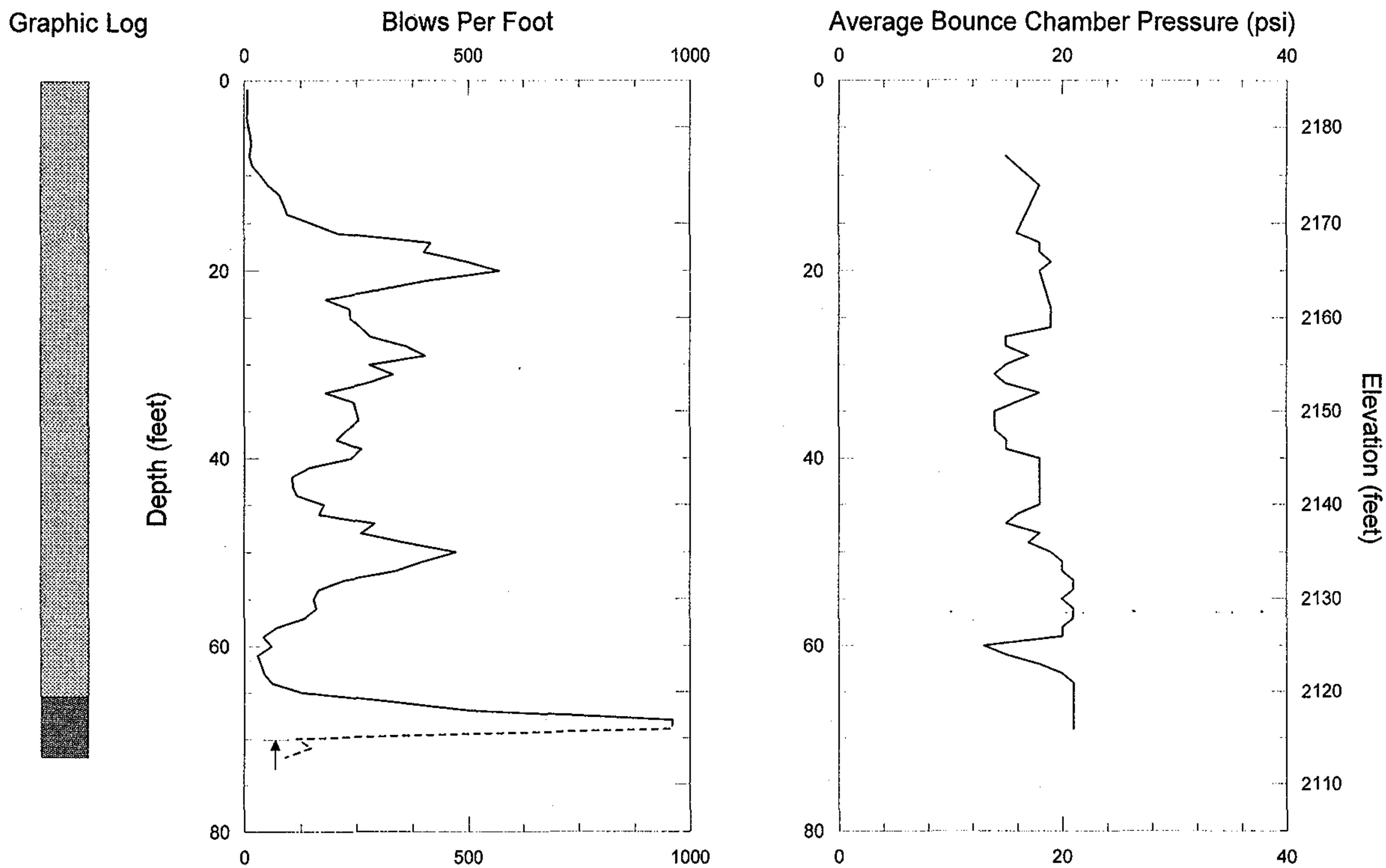


Figure B-1
BECKER SAMPLE HOLE BEING DRILLED AT CLE ELUM DAM

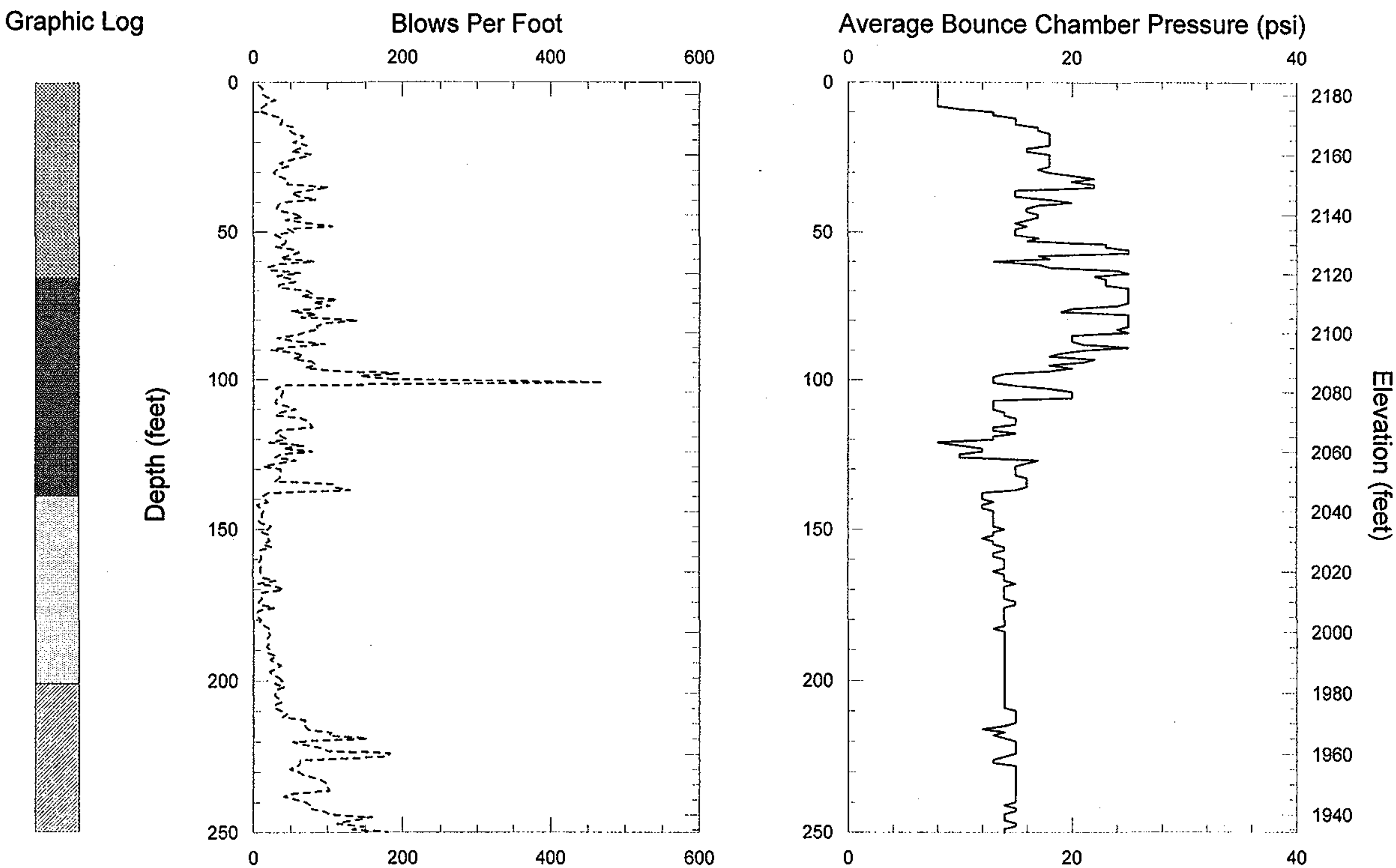

Woodward-Clyde Consultants
Cle Elum River
Gaging station
Spillway
Lake Cle Elum
Qgo1
Qgt
Fill
Em
DH-81-2
AP-81-1
DH-92-2
DH-92-5
DH-92-4
DH-92-6
CE-1
CE-2
CE-3
SCALE OF FEET
Notes:
1. For General Geologic Explanation, Legend and Notes, refer to dwg 33-100-2399.
2. For General Geologic Sections A-A', B-B' and C-C', refer to dwgs 33-100-2401 and -2402.
3. Topography digitized from dwgs 33-100-402 and -403. Data is from aerial photography on 8-20-81.
Approximate locations of Becker penetration tests
CLE ELUM DAM
YAKIMA PROJECT
CLE ELUM, WASHINGTON
Figure B-2
Project No. D97287
Prepared By: KAF
Date: 12/11/98
BECKER TEST LOCATIONS
BORDER.TCW



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-1	Figure B-3
Woodward-Clyde			

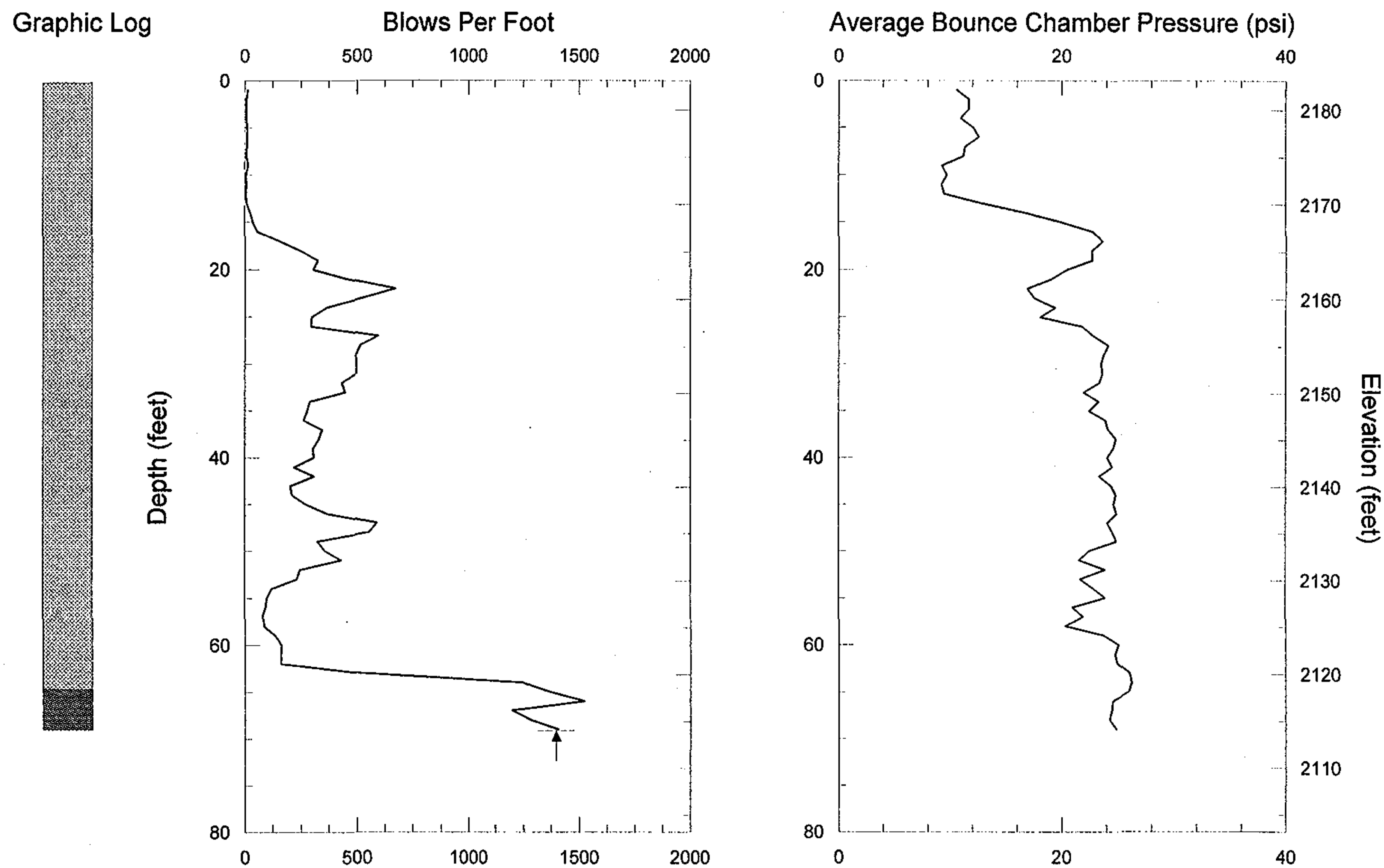
BDH98-1.GRF with bdh98-1.xls / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER SAMPLE HOLE BSH98-1	Figure B-4
Woodward-Clyde			

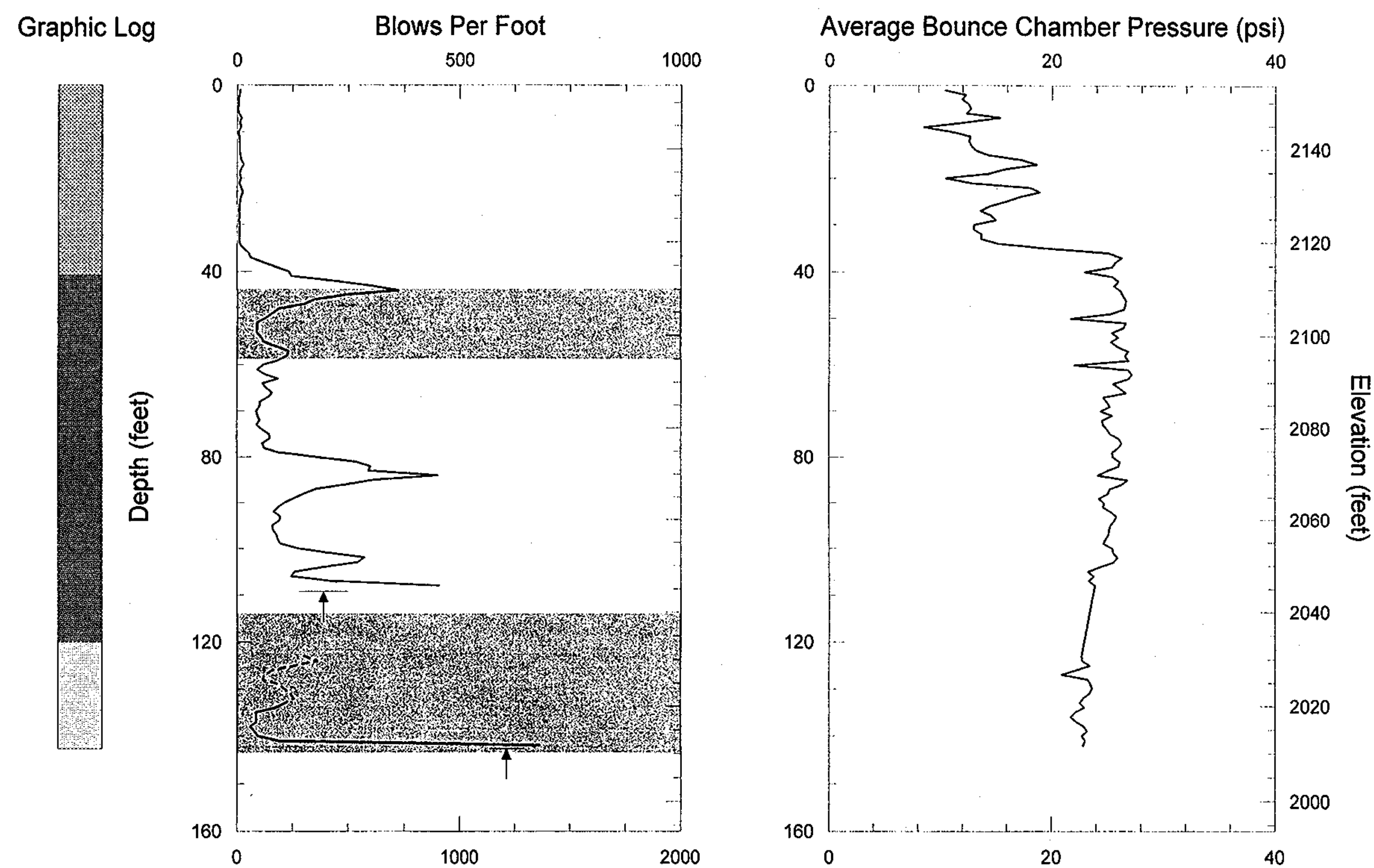
BSH98-1.GRF with bsh98-1.xls / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-1B	Figure B-5
Woodward-Clyde			

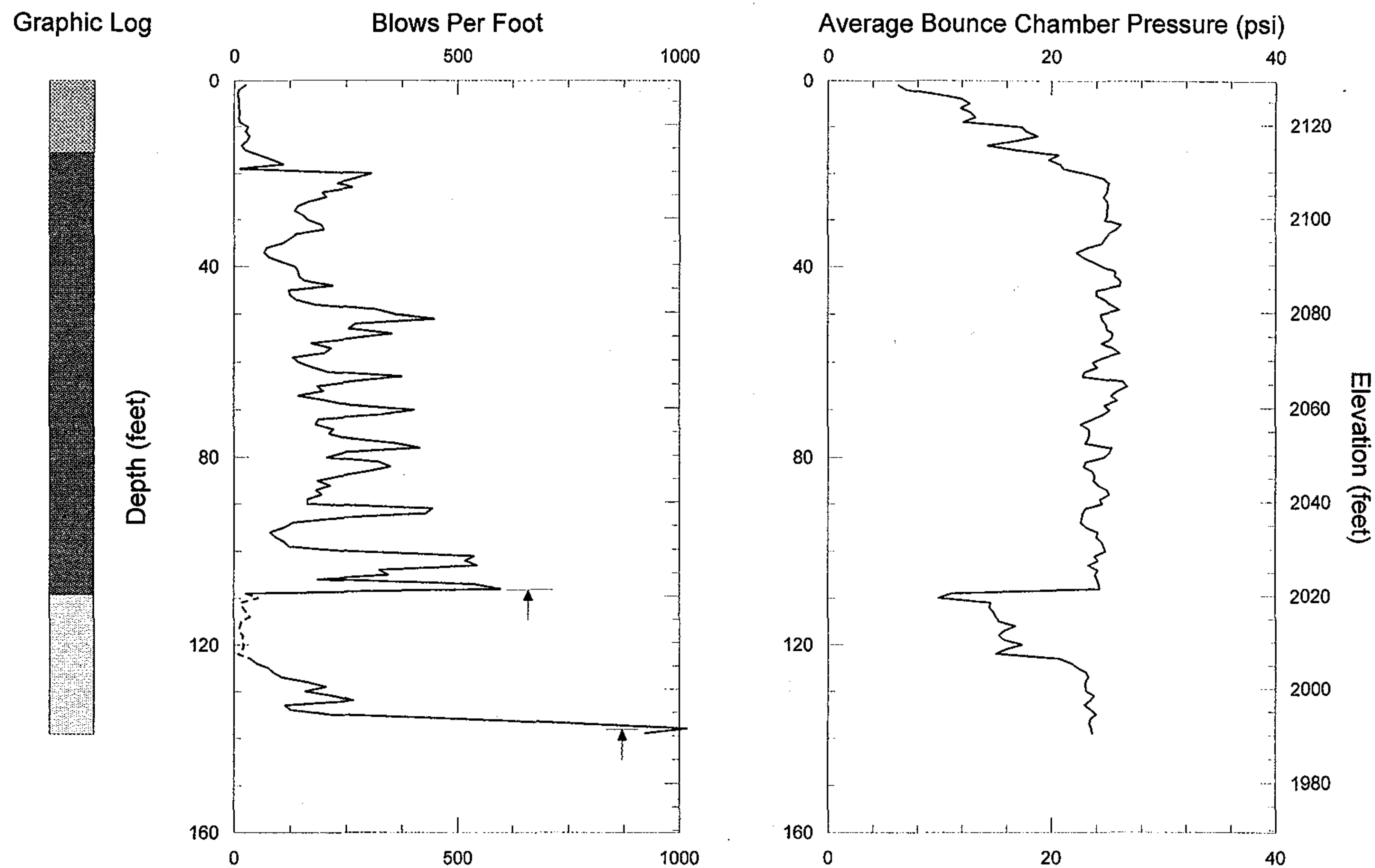
BDH98-1B.GRF with bdh98-1b.xls / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-2	Figure B-6
Woodward-Clyde			

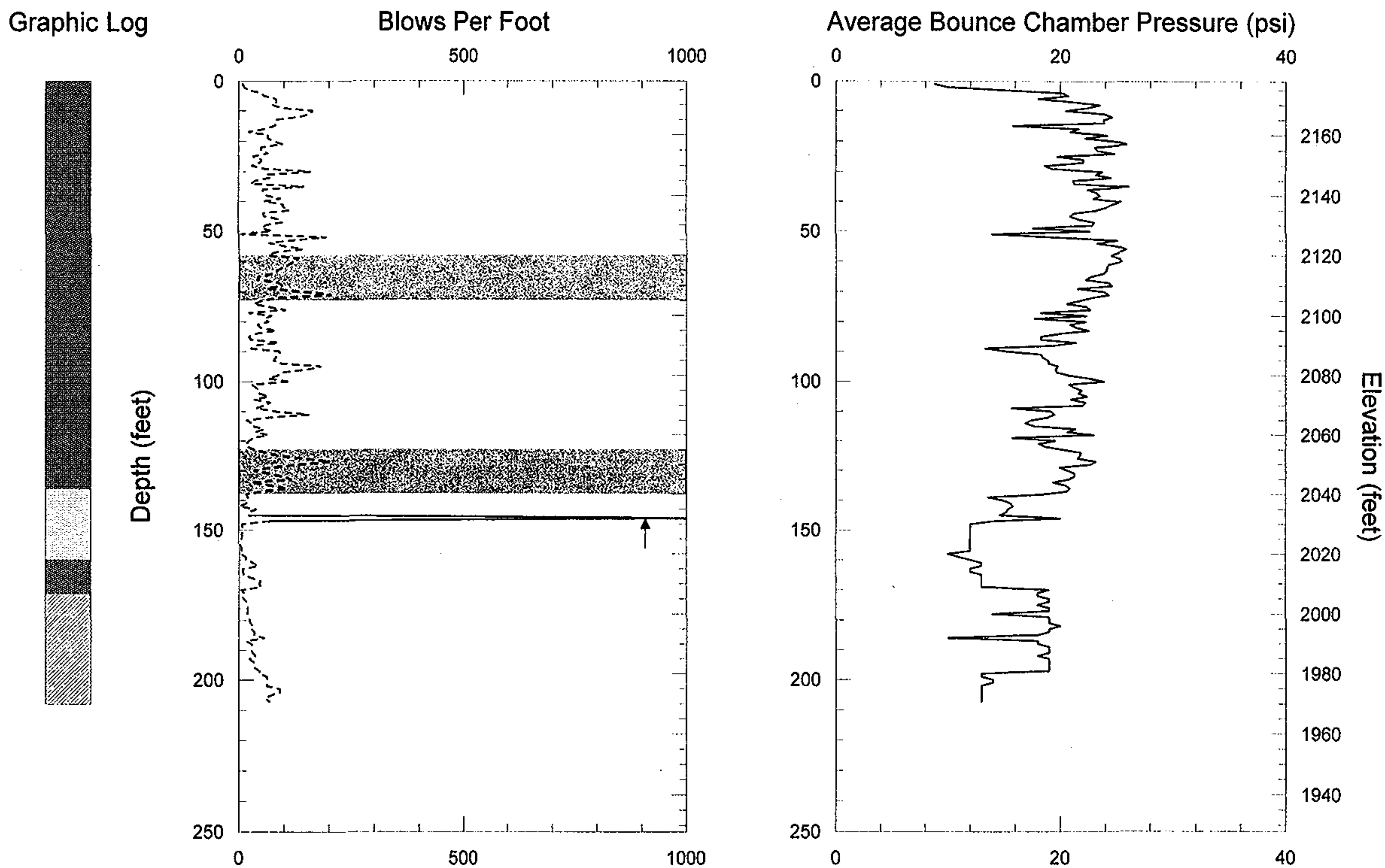
BDH98-2.GRF with bdh98-2.xls / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-3	Figure B-7
Woodward-Clyde			

BDH98-3.GRF with bdh98-3.xls / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

BDH98-4.GRF with bdh98-4.xls / 11/30/98 / KAF

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-4	Figure B-8
	Woodward-Clyde		

LEGEND

EMBANKMENT AND/OR DOWNSTREAM BERM - FILL

GLACIAL OUTWASH (COARSE-GRAINED) - SANDY GRAVELS, COBBLES, BOULDERS

GLACIAL OUTWASH (FINE-GRAINED) - SAND

LAKEBED SEDIMENTS - CLAY

CLOSED-BIT DRILLED INTERVAL

OPEN-BIT DRILLED INTERVAL

PRACTICAL RIG REFUSAL

LOWER SHEAR WAVE VELOCITY LAYER

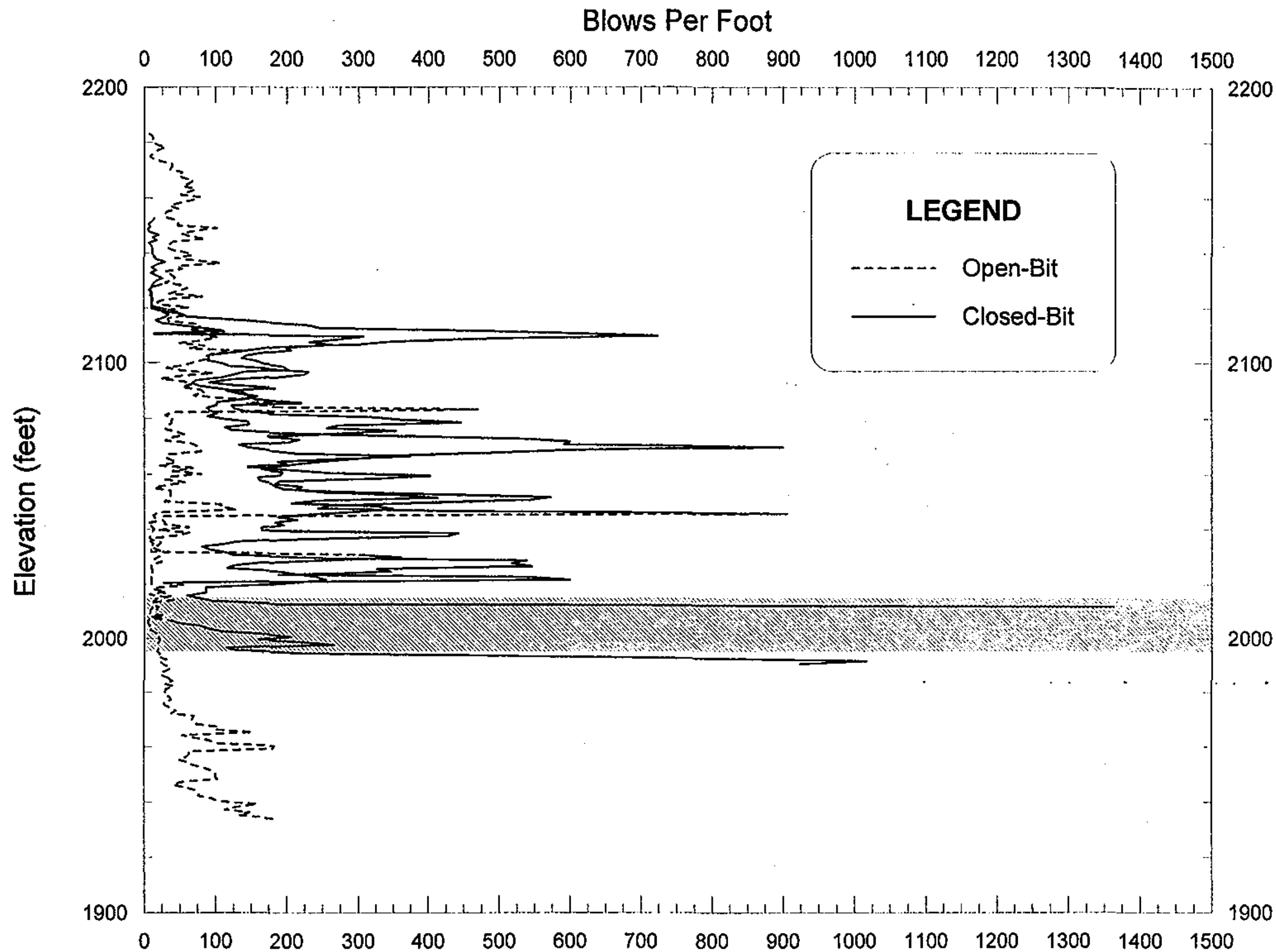
AREA WHERE LOWER OPEN-BIT BLOW COUNTS WERE RECORDED

NOTES

1. GRAPHIC LOGS ARE BASED ON SAMPLING, DRILLING RESISTANCE, AND KNOWLEDGE OF DAM CONSTRUCTION.
2. BECKER PENETRATION AND SAMPLE TESTS WERE DRILLED IN NOVEMBER OF 1998 BY LAYNE CHRISTENSEN OF TACOMA, WASHINGTON.
3. PRACTICAL RIG REFUSAL WAS DEFINED BY 400 BLOWS FOR 3 INCHES OR LESS PENETRATION.
4. LOWER SHEAR WAVE VELOCITY LAYERS WERE IDENTIFIED DURING THE 1992-93 CROSSHOLE SHEAR WAVE TESTS.
5. APPROXIMATE LOCATIONS OF BECKER TEST HOLES ARE SHOWN ON FIGURE B-2.

LEGEND.GRF / 12/10/98 / KAF

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	LEGEND AND NOTES	Figure B-9
Woodward-Clyde			



NOTES:
1. Closed-bit penetration resistances from BDH98-2 and BDH98-3.
2. Open-bit penetration resistance from BSH98-1.
3. Legend and additional notes on Figure B-9.

BH981.GRF with bdh982.xls, bdh983.xls, bsh98-1.xls / 1/6/98 / KAF

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	COMPARISON OF OPEN AND CLOSED-BIT PENETRATION	Figure B-10
Woodward-Clyde			

Attachment A
Daily Reports

DAILY REPORT

REPORT NO. 1

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke, Jim Scott
(Dick Link & Dave Curan USBR)

DATE	11/11/98			
DAY	SUN	MON	TUE	(WED)
DAY	THU	FRI	SAT	
WEATHER	Clear	P.Cloudy	(Cloudy)	Fog
TEMP.	0-32°F	(32-50°F)	50-75°F	75-100°F
WIND	Calm	(Breeze)	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain	(Light)	Moderate	Heavy
PRECIP.	Snow	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker rig (Norm, Ed, Tony)
GRL: PDA/CAPWAPP (Steve Abe)

DOWNTIME/PROBLEMS ENCOUNTERED

Data logger from USBR failed to work properly.

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. - Arrived on site. Met drillers.
7:30 - 9:00 a.m. - Set up drill rig at BDH-98-1 location, downstream of dam near the crest at break in slope.
9:00 - 10:00 a.m. - Hauled water to rig.
10:00 a.m. - Began becker penetration testing at BDH-98-1 location.
3:30 p.m. - Hit refusal at 68.5 feet. Decided to pull up closed-bit and attempt to drill through refusal zone with an open-bit.
3:30 - 4:00 p.m. - Pulled up closed-bit drill pipe.
4:00 - 5:00 p.m. - Drilled to 70' with open-bit, ~~and pulled pipe~~
~~[illegible] p.m. - Re-drilled with closed bit. Hit refusal again~~
5:00 p.m. - Cleaned up and left the site for the day.

8:00 - 9:00 p.m. - Attempted to download data from data logger. There was no electronic data for this hole. Must rely on hand-recorded data.

Total Depth 11/11/98: 70'
Total Depth to Date: 70'

Completed By: Kimberly A. Finke (Signature) 11/15/98 (Date) Checked By: [signature] (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 2

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke, Jim Scott
(Dave Curran & Dick Link - USBR)

DATE	11/12/98			
DAY	SUN	MON	TUE	WED
DAY	(THU) circled	FRI	SAT	
WEATHER	Clear	P.Cloudy	(Cloudy) circled	Fog
TEMP.	0-32°F	(32-50°F) circled	50-75°F	75-100°F
WIND	Calm	(Breeze) circled	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain	(Light) circled	Moderate	Heavy
PRECIP.	Snow	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker rig (Norm, Ed, Tony)
GRL: PDA/CAPWAPP (Steve Abe)

DOWNTIME/PROBLEMS ENCOUNTERED

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. - Arrived on site. Drillers performed routine maintenance on rig. Set up rig at BDH-98-1 location to continue same hole.
7:30-8:00 a.m. - Drilled with open bit pipe from 70 to 72 ft. in an attempt to get past very dense material.
8:00-8:30 a.m. - Pulled pipe.
8:20-10:30 a.m. - Redrilled with closed bit pipe. Hit refusal at 69 feet. Decided to abandon hole.
10:30-12:00 noon - Drillers pulled pipe and grouted hole.
12:00-12:30 p.m. - Moved rig ~12 feet downslope. Decided to perform Becker sample hole in this location, BSH-98-1.
12:30-1:30 p.m. - Drilled to 57' with open bit.
1:30 pm. - Installed PDA equipment at 57'.
2:00-3:00 p.m. - Drilled from 57 to 97 ft. Removed PDA due to air leak in the o-rings. Collected samples in 5' intervals.
3:00-4:30 p.m. - Drilled to 126 ft.
4:30 p.m. - Cleaned up and left for the day.

Total Depth 11/12/98: 128'
Total Depth to Date: 198'

Completed By: Kimberly A. Finke (Signature) 11/15/98 (Date)   Checked By: John W. [signature] (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 3

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke, Jim Scott (Dave Curran; Dick Link - USBR)

DATE	11/13/98			
DAY	SUN	MON	TUE	WED
DAY	THU	(FRI)	SAT	
WEATHER	Clear	P.Cloudy	(Cloudy)	Fog
TEMP.	0-32°F	(32-50°F)	50-75°F	75-100°F
WIND	Calm	(Breeze)	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain	(Light)	Moderate	Heavy
PRECIP.	Snow	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker rig (Norm, Ed, Tony)
GRL: PDA/CAPWAPP (Steve Abe)

DOWNTIME/PROBLEMS ENCOUNTERED

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. - Arrived on site.
7:00-8:00 a.m. - Rig needed jump started.
8:00-12:00 noon - Drilling continued at BSH-98-1. Drilled from 126' to 250', collecting samples every 5 feet.
12:00 noon - 2:00 p.m. - Woodward Clyde, USBR, GRL, and Jerry from Lane conferenced at a local restaurant to discuss options and scheduling. Decided to have Lane haul up ~30' of casing to attempt to case top of holes where materials were too dense for closed-bit penetration.
12:00 noon - 5:30 p.m. - Drillers abandoned (grouted) BSH-98-1 holes.

Total Depth 11/13/98: 124'
Total Depth to Date: 322'

Completed By: Kimberly A. Finke (Signature) 11/15/98 (Date) Checked By: John W. [illegible] (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 4

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke
(Dick Link - USBR)

DATE	11/14/98			
DAY	SUN	MON	TUE	WED
DAY	THU	FRI	(SAT)	
WEATHER	Clear	P.Cloudy	Cloudy	Fog
TEMP.	0-32°F	32-50°F	(50-75°F)	75-100°F
WIND	Calm	(Breeze)	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain N/A	Light	Moderate	Heavy
PRECIP.	Snow N/A	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker rig
GRL: CAPWAPP/PDA (Bert Mirier)

DOWNTIME/PROBLEMS ENCOUNTERED

11:30-1:30 p.m. - False alarm by GRL with PDA equipment.

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. - Arrived on site.
7:00 - 9:30 a.m. - Finished grouting BSH-98-1 hole and hauling water.
9:30 - 10:00 a.m. - Moved rig ~10' further downslope to attempt another penetration test in same location.
10:00 - 11:30 a.m. - Drilled with closed-bit to 26.5 feet (BSH-98-1B) PDA indicated pipe damage.
11:30 - 1:30 p.m. - Pulled pipe to check for break. It was a false alarm. Redrilled to 26.5 feet.
1:30 - 4:30 p.m. - Drilled from 26.5 to 52 feet.
4:30 p.m. - Left for the day.

Total Depth 11/14/98: 52'
Total Depth to Date: 374'

Completed By: Kimberly Finke (Signature) 11/15/98 (Date)   Checked By: Jon W Mm (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 5

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke
(Dick Link - USBR)

DATE	11/15/98			
DAY	(SUN)	MON	TUE	WED
DAY	THU	FRI	SAT	
WEATHER	Clear	P.Cloudy	(Cloudy)	Fog
TEMP.	0-32°F	(32-50°F)	50-75°F	75-100°F
WIND	Calm	(Breeze)	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain	(Light)	Moderate	Heavy
PRECIP.	Snow	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensen: Becker rig (Norm, Ed, Tony)
GRL: PDA/CAPWAPP (Bert Miner)

DOWNTIME/PROBLEMS ENCOUNTERED

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. – Arrived on site.
7:00–7:45 a.m. – Performed routine rig maintenance and set-up rig to continue on hole BDH-98-1B near damcrest on downstream side.
7:45–11:00 a.m. – Drilled from 52 feet to 69.5 feet with closed bit. The blow counts were greater than 1000 for depths from 63 feet to refusal at 69.5 feet.
11:00 a.m. – Decided to abandon hole at least until we could acquire 70' of casing in order to case through embankment fill. Will begin next hole downslope at next location along maximum section.
11:30 a.m. – Left site.
12:00–1:00 p.m. – Looked over downloaded data from data logger. The new data logger appears to be working well as long as the pressure lines are clear.
11:30 a.m. – Drillers abandoned BDH-98-1B Hole.

Total Depth 11/15/98: 17.5'
Total Depth to Date: 391.5'

Completed By: Kimberly O Finke (Signature) 11/15/98 (Date)   Checked By: [signature] (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 6

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke
(Dick Link - USBR)

DATE	11/16/98			
DAY	SUN	**MON** (circled)	TUE	WED
DAY	THU	FRI	SAT	
WEATHER	Clear	**P.Cloudy** (circled)	Cloudy	Fog
TEMP.	0-32°F	**32-50°F** (circled)	50-75°F	75-100°F
WIND	Calm	Breeze	**Moderate** (circled)	High
WIND DIR.	North	South	East	West
PRECIP.	Rain N/A	Light	Moderate	Heavy
PRECIP.	Snow N/A	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker rig (Norm, Ed, Tony)
GRL: PDA/CAPWAPP (Bert Miner)

DOWNTIME/PROBLEMS ENCOUNTERED

3:00 p.m. - Becker hammer broke, but the drillers were able to get it repaired by the end of the day.

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. - Arrived on site. Set up rig at BDH-98-2 location, downstream side of dam along maximum section near 1992 crosshole shear wave couplet.
8:00 a.m. - 1:45 p.m. - Drilled from 0 to 108.7 feet with closed bit at BDH-98-2. Refusal was indicated by 845 blows for 0.7 feet at 108.7 feet depth.
1:45 - 2:30 p.m. - Pulled up closed bit pipe. Decided to drill with open bit through the refusal zone and grout hole. Then, attempt closed bit penetration to depth.
2:30 - 3:00 p.m. - Began redrilling with open bit casing from 0 to ~38 feet.
3:00 p.m. - Becker hammer broke, requiring welding. Decided to call it a day while the drillers get the hammer repaired. Other USBR people on site had a welder and the drillers were able to repair the hammer.
4:30 - 5:30 p.m. - Analyzed data from data logger.

Total Depth 11/16/98: 108.5'
Total Depth to Date: 500'

Completed By: Kimberly A. Finke (Signature) 11/16/98 (Date)   Checked By: John W. Kramer (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 7

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke
(Dick Link - USBR)

DATE	11/17/98			
DAY	SUN	MON	(TUE)	WED
DAY	THU	FRI	SAT	
WEATHER	Clear	P.Cloudy	Cloudy	Fog
TEMP.	0-32°F	(32-50°F)	50-75°F	75-100°F
WIND	Calm	Breeze	(Moderate)	High
WIND DIR.	North	South	East	West
PRECIP.	Rain N/A	Light	Moderate	Heavy
PRECIP.	Snow N/A	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker rig
GRL: PDA/CAPWAPP (Jay Berger)

DOWNTIME/PROBLEMS ENCOUNTERED

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00-7:30 a.m. - Arrived on site. Set up rig at BDH98-2 location.
7:30-8:30 a.m. - Redrilled from 50 to 108 feet at BDH98-2 using open bit.
8:30-9:00 a.m. - Drilled from 108 to 122 feet with open bit in an attempt to penetrate refusal zone.
9:00-12:00 noon - Pulled up open bit casing and grouted hole.
12:00-1:30 p.m. - Redrilled BDH98-2 using closed bit through the grouted hole.
1:30-3:00 pm. - Drilled from 122 to 142.8 feet (refusal) with closed bit. Decided that the drill hole did not need to go deeper because good information on the foundation density was attained, and that a second redrilling with open bit and grouting the hole would be excessive.
3:00-4:00 pm. - Pulled casing and grouted the hole.
4:00-4:30 pm. - Drillers moved the rig downslope to the BDH98-3 location.
4:30 pm. - Left the site.

Total Depth 11/17/98: 33.3'
Total Depth to Date: 533.3'

Completed By: Kimberly A. Finke (Signature) 11/19/98 (Date) Checked By: John W. Rinn (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 8

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke

(Dick Link - USBR)

DATE	11/18/98			
DAY	SUN	MON	TUE	(WED)
DAY	THU	FRI	SAT	
WEATHER	Clear	(P.Cloudy)	Cloudy	Fog
TEMP.	0-32°F	(32-50°F)	50-75°F	75-100°F
WIND	Calm	(Breeze)	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain	(Light)	Moderate	Heavy
PRECIP.	Snow	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker rig

GRL: PDA/CAPWAPP (Jay Berger)

DOWNTIME/PROBLEMS ENCOUNTERED

After 8' of initial penetration, hole was going crooked. Drillers pulled up pipe, moved over ~3' and began a new hole.

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 - 8:00 a.m. - Arrived on site. Set up the rig at the BDH98-3 location which is along the maximum section of the dam, at the downstream edge.

8:00 - 3:30 p.m. - Drilled BDH98-3 using closed bit, from 0 to 108.1 feet. Refusal was met at 108.1 ft., indicated by 444 blows/0.1 feet. Decided to repeat method used at BDH98-2 to get deeper penetration (redrill with open bit, grout hole, then drill again with closed bit).

3:30 - 5: p.m. - Pulled up closed bit pipe.

Total Depth 11/18/98 : 108.1'

Total Depth to Date : 641.4'

Completed By: Kimberly A. Finke (Signature) 11/19/98 (Date)

Checked By: [signature] (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 9

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke

(Dick Link - USBR)

DATE	11/19/98			
DAY	SUN	MON	TUE	WED
DAY	(THU)	FRI	SAT	
WEATHER	Clear	(P.Cloudy)	Cloudy	Fog
TEMP.	0-32°F	(32-50°F)	50-75°F	75-100°F
WIND	Calm	(Breeze)	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain	(Light)	Moderate	Heavy
PRECIP.	Snow	(Light)	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker rig
GRL: PDA/CAPWAPP (Jay Berger)

DOWNTIME/PROBLEMS ENCOUNTERED

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. - Arrived on site and drillers performed daily maintenance on rig.
7:30-8:00 a.m. - Continued to pull up casing (closed-bit) from BDH98-3.
8:00-11:00 a.m. - Redrilled from 0 to 108 feet with open bit.
11:00-11:30 a.m. - Drilled in BDH98-3 from 108 to 122 feet.
11:30 a.m. - 1:00 p.m. - Pulled up open bit casing and grouted hole.
1:00-2:30 p.m. - Redrilled BDH98-3 from 0 to 122 feet.
2:30-3:45 p.m. - Drilled from 122 to refusal at 138.8 feet. Decided to abandon hole and move to BDH98-4 location on downstream midslope of dam near spillway.
3:45 p.m. - Hauled water for grouting.
4:30 p.m. - Left for the day.

Total Depth 11/19/98: 30.8'
Total Depth to Date: 672.2'

Completed By: Kimberly O. Finke (Signature) 11/19/98 (Date)   Checked By: [signature] (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 10

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke
(Dick Link - USBR)

DATE	11/20/98			
DAY	SUN	MON	TUE	WED
DAY	THU	(FRI)	SAT	
WEATHER	Clear	P.Cloudy	(Cloudy)	Fog
TEMP.	0-32°F	(32-50°F)	50-75°F	75-100°F
WIND	Calm	(Breeze)	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain	Light	(Moderate)	Heavy
PRECIP.	Snow N/A	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker drill rig.

DOWNTIME/PROBLEMS ENCOUNTERED

Data logger broke.

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. - Arrived on site. Drillers fueled rig.

7:30-9:00 a.m. - Drillers finished abandoning (pulling casing and grouting) drill hole BDH98-3.

9:00-9:30 a.m. - Moved rig to BDH98-4 location on downstream slope of dam near the spillway, and set up the rig.

9:30 a.m.-2:15 p.m. - Drilled hole BDH98-4 from 0' to 145' with open bit casing. The goals of this hole are to determine the density of the "low velocity" zone recorded on 1992 geophysical crosshole tests which began at a depth of ~60' and determine density of the sand layer which began at a depth of ~138'. The densities (blow counts) did not begin to drop until about 138' deep. After about 8' of lower blow counts (18 to 22), decided to pull up open bit casing and attempt closed bit drilling through this zone.

2:15-3:45 p.m. - Pulled up open bit casing and grouted hole.

3:45-4:15 p.m. - Began to redrill with ~~open~~ closed bit from 0' to 30'

4:30 p.m. - Left the site.

Total Depth 11/20/98: 145'

Total Depth to Date: 817.2'

Completed By: Kimberly A. Finke (Signature) 11/20/98 (Date) Checked By: John W. Mm (Signature) 02/02/00 (Date)

DAILY REPORT

REPORT NO. 11

PROJECT Cle Elum Dam

LOCATION Cle Elum, WA

PERSONNEL Kim Finke
(Dick Link - USBR)

DATE	11/21/98			
DAY	SUN	MON	TUE	WED
DAY	THU	FRI	(SAT)	
WEATHER	Clear	P.Cloudy	(Cloudy)	Fog
TEMP.	0-32°F	(32-50°F)	50-75°F	75-100°F
WIND	Calm	(Breeze)	Moderate	High
WIND DIR.	North	South	East	West
PRECIP.	Rain	Light	(Moderate)	Heavy
PRECIP.	Snow N/A	Light	Moderate	Heavy

SUBCONTRACTORS ON SITE AND EQUIPMENT

Lane-Christensian: Becker drill rig.

DOWNTIME/PROBLEMS ENCOUNTERED

SUMMARY OF ACTIVITIES/DISCUSSIONS/DECISIONS

7:00 a.m. - Arrived on site
7:30 - 9:30 a.m. - Continued redrilling BDH98-4 with closed bit from 30' to 145'.
9:30 - 10:00 a.m. - Attempted to drill with closed bit beyond 145 feet. Hit refusal at 145.4' with 1000 blows per 0.4'. Attempted pulling up casing approximately one foot and drilling again. Cave-in material at base of the hole resulted again in refusal at ~146' with greater than 1900 blows per foot. Decided to pull up closed bit casing and go down to depth with open bit to get atleast some idea of the density of subsequent layers.
10:00 - 11:00 am - Pulled up closed bit casing.
11:00 - 1:30 p.m. - Hauled water. Redrilled to 146' with open bit.
1:30 - 3:00 p.m. - Drilled from 146' to 207' with open bit.
3:00 - 3:30 pm - Began pulling up casing. Drillers will return following day to abandon hole and surface cement all Becker drill holes.

Total Depth 11/21/98: 62'
Total Depth to Date: 879.2'

Completed By: Kimberly A. Finke (Signature) 11/21/98 (Date)   Checked By: [signature] (Signature) 02/02/00 (Date)

Attachment B

Raw Becker Test Data

BDH98-1

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
1	2183.94	7		Closed
2	2182.94	7		Closed
3	2181.94	8		Closed
4	2180.94	6		Closed
5	2179.94	10		Closed
6	2178.94	15		Closed
7	2177.94	16		Closed
8	2176.94	13	15	Closed
9	2175.94	19	16	Closed
10	2174.94	37	17	Closed
11	2173.94	55	18	Closed
12	2172.94	80		Closed
13	2171.94	89		Closed
14	2170.94	97		Closed
15	2169.94			Closed
16	2168.94	210	16	Closed
17	2167.94	415	18	Closed
18	2166.94	400	18	Closed
19	2165.94	497	19	Closed
20	2164.94	572	18	Closed
21	2163.94	410		Closed
22	2162.94	300		Closed
23	2161.94	182		Closed
24	2160.94	235	19	Closed
25	2159.94	237	19	Closed
26	2158.94	260	19	Closed
27	2157.94	282	15	Closed
28	2156.94	361	15	Closed
29	2155.94	404	17	Closed
30	2154.94	280	15	Closed
31	2153.94	333	14	Closed
32	2152.94	271	15	Closed
33	2151.94	182	18	Closed
34	2150.94	245	16	Closed
35	2149.94	251	14	Closed
36	2148.94	256	14	Closed
37	2147.94	227	14	Closed
38	2146.94	206	15	Closed
39	2145.94	261	15	Closed
40	2144.94	238	18	Closed
41	2143.94	144	18	Closed
42	2142.94	107	18	Closed
43	2141.94	108	18	Closed
44	2140.94	117	18	Closed
45	2139.94	177	18	Closed
46	2138.94	166	16	Closed
47	2137.94	290	15	Closed
48	2136.94	260	18	Closed
49	2135.94	360	17	Closed
50	2134.94	473	19	Closed

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
51	2133.94	400	20	Closed
52	2132.94	338	20	Closed
53	2131.94	223	21	Closed
54	2130.94	165	21	Closed
55	2129.94	155	20	Closed
56	2128.94	160	21	Closed
57	2127.94	134	21	Closed
58	2126.94	72	20	Closed
59	2125.94	42	20	Closed
60	2124.94	61	13	Closed
61	2123.94	30	15	Closed
62	2122.94	38	18	Closed
63	2121.94	45	20	Closed
64	2120.94	63	21	Closed
65	2119.94	128	21	Closed
66	2118.94	320	21	Closed
67	2117.94	500	21	Closed
68	2116.94	960	21	Closed
69	2115.94	960	21	Open
70	2114.94	116		Open
71	2113.94	150		Open
72	2112.94	93		Open

BSH98-1

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
1	2183.14	7	8	Open
2	2182.14	12	8	Open
3	2181.14	12	8	Open
4	2180.14	12	8	Open
5	2179.14	18	8	Open
6	2178.14	30	8	Open
7	2177.14	19	8	Open
8	2176.14	15	8	Open
9	2175.14	8	10	Open
10	2174.14	12	13	Open
11	2173.14	23	13	Open
12	2172.14	39	15	Open
13	2171.14	39	15	Open
14	2170.14	36	15	Open
15	2169.14	53	17	Open
16	2168.14	48	17	Open
17	2167.14	54	18	Open
18	2166.14	68	18	Open
19	2165.14	63	18	Open
20	2164.14	54	18	Open
21	2163.14	72	18	Open
22	2162.14	63	16	Open
23	2161.14	51	16	Open
24	2160.14	78	18	Open
25	2159.14	66	18	Open
26	2158.14	49	18	Open
27	2157.14	36	18	Open
28	2156.14	47	18	Open
29	2155.14	32	17	Open
30	2154.14	28	18	Open
31	2153.14	30	20	Open
32	2152.14	42	22	Open
33	2151.14	48	20	Open
34	2150.14	46	22	Open
35	2149.14	102	22	Open
36	2148.14	74	15	Open
37	2147.14	52	15	Open
38	2146.14	62	15	Open
39	2145.14	85	18	Open
40	2144.14	40	20	Open
41	2143.14	34	17	Open
42	2142.14	32	16	Open
43	2141.14	38	16	Open
44	2140.14	57	17	Open
45	2139.14	67	17	Open
46	2138.14	44	16	Open
47	2137.14	73	15	Open
48	2136.14	107	16	Open
49	2135.14	47	15	Open
50	2134.14	54	15	Open

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
51	2133.14	30	15	Open
52	2132.14	38	17	Open
53	2131.14	43	16	Open
54	2130.14	42	23	Open
55	2129.14	30	23	Open
56	2128.14	53	25	Open
57	2127.14	61	25	Open
58	2126.14	48	17	Open
59	2125.14	36	18	Open
60	2124.14	82	13	Open
61	2123.14	34	17	Open
62	2122.14	19	18	Open
63	2121.14	22	24	Open
64	2120.14	63	25	Open
65	2119.14	32	22	Open
66	2118.14	50	23	Open
67	2117.14	56	23	Open
68	2116.14	34	23	Open
69	2115.14	34	25	Open
70	2114.14	72	25	Open
71	2113.14	80	25	Open
72	2112.14	64	25	Open
73	2111.14	113	25	Open
74	2110.14	80	25	Open
75	2109.14	103	24	Open
76	2108.14	84	20	Open
77	2107.14	50	19	Open
78	2106.14	85	25	Open
79	2105.14	64	25	Open
80	2104.14	140	25	Open
81	2103.14	96	25	Open
82	2102.14	85	25	Open
83	2101.14	88	24	Open
84	2100.14	70	25	Open
85	2099.14	59	20	Open
86	2098.14	32	20	Open
87	2097.14	53	20	Open
88	2096.14	97	21	Open
89	2095.14	51	25	Open
90	2094.14	24	21	Open
91	2093.14	56	19	Open
92	2092.14	67	18	Open
93	2091.14	53	22	Open
94	2090.14	80	21	Open
95	2089.14	84	18	Open
96	2088.14	70	20	Open
97	2087.14	108	18	Open
98	2086.14	195	14	Open
99	2085.14	143	13	Open
100	2084.14	185	13	Open
101	2083.14	470	13	Open

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
102	2082.14	41	15	Open
103	2081.14	30	18	Open
104	2080.14	40	20	Open
105	2079.14	38	20	Open
106	2078.14	38	20	Open
107	2077.14	30	13	Open
108	2076.14	30	13	Open
109	2075.14	45	13	Open
110	2074.14	57	13	Open
111	2073.14	38	14	Open
112	2072.14	30	14	Open
113	2071.14	64	15	Open
114	2070.14	74	15	Open
115	2069.14	77	15	Open
116	2068.14	80	13	Open
117	2067.14	35	13	Open
118	2066.14	30	15	Open
119	2065.14	38	13	Open
120	2064.14	45	13	Open
121	2063.14	22	8	Open
122	2062.14	68	10	Open
123	2061.14	40	12	Open
124	2060.14	80	12	Open
125	2059.14	37	10	Open
126	2058.14	30	10	Open
127	2057.14	57	17	Open
128	2056.14	34	16	Open
129	2055.14	14	15	Open
130	2054.14	37	15	Open
131	2053.14	37	15	Open
132	2052.14	37	15	Open
133	2051.14	35	16	Open
134	2050.14	29	16	Open
135	2049.14	108	16	Open
136	2048.14	108	16	Open
137	2047.14	130	15	Open
138	2046.14	20	12	Open
139	2045.14	13	12	Open
140	2044.14	15	12	Open
141	2043.14	20	13	Open
142	2042.14	5	12	Open
143	2041.14	10	12	Open
144	2040.14	14	13	Open
145	2039.14	12	13	Open
146	2038.14	12	13	Open
147	2037.14	7	13	Open
148	2036.14	11	13	Open
149	2035.14	24	13	Open
150	2034.14	20	14	Open
151	2033.14	12	13	Open
152	2032.14	22	13	Open

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
153	2031.14	20	12	Open
154	2030.14	22	13	Open
155	2029.14	14	13	Open
156	2028.14	25	14	Open
157	2027.14	10	14	Open
158	2026.14	10	13	Open
159	2025.14	11	13	Open
160	2024.14	11	14	Open
161	2023.14	8	14	Open
162	2022.14	11	14	Open
163	2021.14	10	14	Open
164	2020.14	10	13	Open
165	2019.14	12	14	Open
166	2018.14	13	14	Open
167	2017.14	30	14	Open
168	2016.14	7	15	Open
169	2015.14	31	14	Open
170	2014.14	41	14	Open
171	2013.14	11	14	Open
172	2012.14	11	14	Open
173	2011.14	12	14	Open
174	2010.14	8	15	Open
175	2009.14	9	15	Open
176	2008.14	29	14	Open
177	2007.14	7	14	Open
178	2006.14	5	14	Open
179	2005.14	6	14	Open
180	2004.14	11	14	Open
181	2003.14	8	14	Open
182	2002.14	15	14	Open
183	2001.14	22	13	Open
184	2000.14	20	14	Open
185	1999.14	22	14	Open
186	1998.14	19	14	Open
187	1997.14	19	14	Open
188	1996.14	20	14	Open
189	1995.14	18	14	Open
190	1994.14	23	14	Open
191	1993.14	20	14	Open
192	1992.14	31	14	Open
193	1991.14	23	14	Open
194	1990.14	28	14	Open
195	1989.14	37	14	Open
196	1988.14	31	14	Open
197	1987.14	22	14	Open
198	1986.14	25	14	Open
199	1985.14	34	14	Open
200	1984.14	39	14	Open
201	1983.14	29	14	Open
202	1982.14	42	14	Open
203	1981.14	31	14	Open

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
204	1980.14	30	14	Open
205	1979.14	29	14	Open
206	1978.14	36	14	Open
207	1977.14	38	14	Open
208	1976.14	28	14	Open
209	1975.14	29	14	Open
210	1974.14	38	15	Open
211	1973.14	45	15	Open
212	1972.14	39	15	Open
213	1971.14	70	15	Open
214	1970.14	67	15	Open
215	1969.14	70	14	Open
216	1968.14	74	12	Open
217	1967.14	105	14	Open
218	1966.14	102	13	Open
219	1965.14	153	14	Open
220	1964.14	53	15	Open
221	1963.14	70	15	Open
222	1962.14	92	15	Open
223	1961.14	100	15	Open
224	1960.14	183	15	Open
225	1959.14	180	14	Open
226	1958.14	63	13	Open
227	1957.14	63	13	Open
228	1956.14	59	15	Open
229	1955.14	49	15	Open
230	1954.14	62	15	Open
231	1953.14	69	15	Open
232	1952.14	85	15	Open
233	1951.14	95	15	Open
234	1950.14	100	15	Open
235	1949.14	100	15	Open
236	1948.14	103	15	Open
237	1947.14	53	15	Open
238	1946.14	41	15	Open
239	1945.14	57	15	Open
240	1944.14	72	15	Open
241	1943.14	77	14	Open
242	1942.14	76	15	Open
243	1941.14	96	15	Open
244	1940.14	104	14	Open
245	1939.14	159	14	Open
246	1938.14	132	14	Open
247	1937.14	113	15	Open
248	1936.14	148	15	Open
249	1935.14	133	14	Open
250	1934.14	180	14	Open

BDH98-1B

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
1	2182.16	13	10.63	Closed
2	2181.16	7	11.69	Closed
3	2180.16	8	11.69	Closed
4	2179.16	8	10.96	Closed
5	2178.16	11	12.12	Closed
6	2177.16	10	12.58	Closed
7	2176.16	10	11.37	Closed
8	2175.16	8	11.21	Closed
9	2174.16	15	9.3	Closed
10	2173.16	6	9.74	Closed
11	2172.16	7	9.24	Closed
12	2171.16	6	9.53	Closed
13	2170.16	9	12.9	Closed
14	2169.16	26	16.77	Closed
15	2168.16	37	20.02	Closed
16	2167.16	57	22.85	Closed
17	2166.16	155	23.66	Closed
18	2165.16	246	22.69	Closed
19	2164.16	324	22.73	Closed
20	2163.16	304	20.43	Closed
21	2162.16	462	19	Closed
22	2161.16	673	16.92	Closed
23	2160.16	522	17.58	Closed
24	2159.16	364	19.41	Closed
25	2158.16	299	18.09	Closed
26	2157.16	294	21.85	Closed
27	2156.16	594	22.89	Closed
28	2155.16	516	24.19	Closed
29	2154.16	494	23.75	Closed
30	2153.16	499	23.54	Closed
31	2152.16	497	23.67	Closed
32	2151.16	433	23.35	Closed
33	2150.16	447	21.98	Closed
34	2149.16	290	23.32	Closed
35	2148.16	277	22.46	Closed
36	2147.16	262	23.92	Closed
37	2146.16	346	24.16	Closed
38	2145.16	331	24.84	Closed
39	2144.16	306	24.65	Closed
40	2143.16	307	24.08	Closed
41	2142.16	220	24.51	Closed
42	2141.16	310	23.39	Closed
43	2140.16	203	24.45	Closed
44	2139.16	211	24.84	Closed
45	2138.16	272	24.67	Closed
46	2137.16	368	24.93	Closed
47	2136.16	590	24.08	Closed
48	2135.16	554	24.55	Closed
49	2134.16	325	24.91	Closed
50	2133.16	358	22.49	Closed

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
51	2132.16	431	21.59	Closed
52	2131.16	245	23.89	Closed
53	2130.16	231	21.67	Closed
54	2129.16	120	22.9	Closed
55	2128.16	100	23.93	Closed
56	2127.16	93	21	Closed
57	2126.16	81	21.96	Closed
58	2125.16	86	20.33	Closed
59	2124.16	135	23.74	Closed
60	2123.16	163	25.08	Closed
61	2122.16	161	24.79	Closed
62	2121.16	161	24.97	Closed
63	2120.16	514	26.06	Closed
64	2119.16	1243	26.25	Closed
65	2118.16	1368	26	Closed
66	2117.16	1524	24.6	Closed
67	2116.16	1199	24.5	Closed
68	2115.16	1284	24.33	Closed
69	2114.16	1405	24.88	Closed

BDH98-2

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
1	2152.72	14	10.46	Closed
2	2151.72	11	12.28	Closed
3	2150.72	6	11.98	Closed
4	2149.72	8	12.54	Closed
5	2148.72	4	12.75	Closed
6	2147.72	8	12.37	Closed
7	2146.72	20	15.38	Closed
8	2145.72	12	12.08	Closed
9	2144.72	17	8.5	Closed
10	2143.72	6	11.11	Closed
11	2142.72	10	12.69	Closed
12	2141.72	11	12.59	Closed
13	2140.72	11	12.8	Closed
14	2139.72	11	13.23	Closed
15	2138.72	14	14.36	Closed
16	2137.72	18	17.28	Closed
17	2136.72	30	18.66	Closed
18	2135.72	18	15.79	Closed
19	2134.72	11	14.33	Closed
20	2133.72	18	10.48	Closed
21	2132.72	10	12.78	Closed
22	2131.72	18	18.1	Closed
23	2130.72	26	18.92	Closed
24	2129.72	17	17.11	Closed
25	2128.72	13	15.89	Closed
26	2127.72	11	14.43	Closed
27	2126.72	9	13.63	Closed
28	2125.72	11	14.58	Closed
29	2124.72	9	15	Closed
30	2123.72	12	13.05	Closed
31	2122.72	11	13	Closed
32	2121.72	11	13.7	Closed
33	2120.72	10	13.66	Closed
34	2119.72	11	15.18	Closed
35	2118.72	27	19.31	Closed
36	2117.72	52	25.05	Closed
37	2116.72	61	26.26	Closed
38	2115.72	118	25.68	Closed
39	2114.72	172	25.39	Closed
40	2113.72	232	22.95	Closed
41	2112.72	246	25.42	Closed
42	2111.72	440	25.99	Closed
43	2110.72	595	25.59	Closed
44	2109.72	724	26.16	Closed
45	2108.72	483	26.37	Closed
46	2107.72	347	26.65	Closed
47	2106.72	303	26.6	Closed
48	2105.72	187	26.52	Closed
49	2104.72	158	25.24	Closed
50	2103.72	127	21.74	Closed

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
51	2102.72	91	26.66	Closed
52	2101.72	91	26.43	Closed
53	2100.72	90	25.41	Closed
54	2099.72	109	25.97	Closed
55	2098.72	119	25.31	Closed
56	2097.72	173	25.91	Closed
57	2096.72	231	26.85	Closed
58	2095.72	225	26.55	Closed
59	2094.72	188	26.9	Closed
60	2093.72	119	22.04	Closed
61	2092.72	92	26.9	Closed
62	2091.72	126	27.18	Closed
63	2090.72	184	26.84	Closed
64	2089.72	116	25.52	Closed
65	2088.72	133	26.16	Closed
66	2087.72	159	26.65	Closed
67	2086.72	140	24.64	Closed
68	2085.72	103	24.97	Closed
69	2084.72	102	25.22	Closed
70	2083.72	88	24.43	Closed
71	2082.72	93	25.44	Closed
72	2081.72	103	24.56	Closed
73	2080.72	89	24.63	Closed
74	2079.72	114	25.01	Closed
75	2078.72	146	25.24	Closed
76	2077.72	147	26.04	Closed
77	2076.72	114	26.28	Closed
78	2075.72	123	25.95	Closed
79	2074.72	186	25.44	Closed
80	2073.72	356	25.48	Closed
81	2072.72	536	26.11	Closed
82	2071.72	600	26	Closed
83	2070.72	591	25.01	Closed
84	2069.72	900	24.18	Closed
85	2068.72	608	26.8	Closed
86	2067.72	489	26.25	Closed
87	2066.72	353	25.23	Closed
88	2065.72	302	25.05	Closed
89	2064.72	255	24.27	Closed
90	2063.72	216	24.7	Closed
91	2062.72	185	24.66	Closed
92	2061.72	165	25.33	Closed
93	2060.72	194	25.82	Closed
94	2059.72	191	25.6	Closed
95	2058.72	160	25.28	Closed
96	2057.72	162	25.16	Closed
97	2056.72	178	25.11	Closed
98	2055.72	184	24.84	Closed
99	2054.72	196	24.67	Closed
100	2053.72	273	25.45	Closed
101	2052.72	414	25.54	Closed

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
102	2051.72	573	25.92	Closed
103	2050.72	544	25.57	Closed
104	2049.72	397	24.36	Closed
105	2048.72	260	23.27	Closed
106	2047.72	244	23.79	Closed
107	2046.72	420	23.34	Closed
108	2045.72	905	23.9	Closed
109	2044.72	26	16.37	Open
110	2043.72	24	21.21	Open
111	2042.72	29	23.6	Open
112	2041.72	29	23.31	Open
113	2040.72	63	24.27	Open
114	2039.72	19	13.39	Open
115	2038.72	63	18.07	Open
116	2037.72	45	16.79	Open
117	2036.72	11	13.41	Open
118	2035.72	9	13.67	Open
119	2034.72	13	9.71	Open
120	2033.72	9	14.56	Open
121	2032.72	10	15.55	Open
122	2031.72	10	16	Open
123	2030.72	301	22.7	Closed
124	2029.72	362	22.74	Closed
125	2028.72	262	23.42	Closed
126	2027.72	160	22.23	Closed
127	2026.72	125	20.94	Closed
128	2025.72	116	23.24	Closed
129	2024.72	189	23.48	Closed
130	2023.72	213	23.64	Closed
131	2022.72	239	23.38	Closed
132	2021.72	255	22.82	Closed
133	2020.72	217	22.55	Closed
134	2019.72	173	22.94	Closed
135	2018.72	86	22.11	Closed
136	2017.72	87	21.71	Closed
137	2016.72	87	22.25	Closed
138	2015.72	60	22.93	Closed
139	2014.72	79	23.17	Closed
140	2013.72	95	22.72	Closed
141	2012.72	186	23	Closed
142	2011.72	1363	22.82	Closed

BDH98-3

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
1	2128.53	25	6.299	Closed
2	2127.53	11	7.01	Closed
3	2126.53	7	9.71	Closed
4	2125.53	10	12.01	Closed
5	2124.53	11	12.71	Closed
6	2123.53	11	11.89	Closed
7	2122.53	12	12.85	Closed
8	2121.53	11	13.2	Closed
9	2120.53	12	12.17	Closed
10	2119.53	31	17.38	Closed
11	2118.53	26	17.79	Closed
12	2117.53	35	18.8	Closed
13	2116.53	29	16.75	Closed
14	2115.53	17	14.31	Closed
15	2114.53	25	16.92	Closed
16	2113.53	55	20.68	Closed
17	2112.53	85	19.81	Closed
18	2111.53	111	20.86	Closed
19	2110.53	14	21.12	Closed
20	2109.53	308	23.16	Closed
21	2108.53	272	24.69	Closed
22	2107.53	232	25.16	Closed
23	2106.53	265	25.04	Closed
24	2105.53	199	24.95	Closed
25	2104.53	207	24.68	Closed
26	2103.53	167	25.01	Closed
27	2102.53	144	25.03	Closed
28	2101.53	137	25.01	Closed
29	2100.53	157	25.01	Closed
30	2099.53	168	24.78	Closed
31	2098.53	196	26.23	Closed
32	2097.53	202	25.8	Closed
33	2096.53	140	25.04	Closed
34	2095.53	125	24.73	Closed
35	2094.53	109	24.47	Closed
36	2093.53	73	23.13	Closed
37	2092.53	67	22.25	Closed
38	2091.53	78	22.86	Closed
39	2090.53	106	23.72	Closed
40	2089.53	137	24.59	Closed
41	2088.53	144	25.69	Closed
42	2087.53	146	25.64	Closed
43	2086.53	159	26.14	Closed
44	2085.53	221	26.12	Closed
45	2084.53	123	24	Closed
46	2083.53	126	24.01	Closed
47	2082.53	140	24.8	Closed
48	2081.53	183	25.28	Closed
49	2080.53	319	26.03	Closed
50	2079.53	361	24.38	Closed

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
51	2078.53	446	24.53	Closed
52	2077.53	271	24.86	Closed
53	2076.53	256	24.95	Closed
54	2075.53	354	25.49	Closed
55	2074.53	267	25.37	Closed
56	2073.53	174	24.52	Closed
57	2072.53	218	25.51	Closed
58	2071.53	202	26.11	Closed
59	2070.53	133	24.67	Closed
60	2069.53	146	23.72	Closed
61	2068.53	176	24.11	Closed
62	2067.53	212	22.98	Closed
63	2066.53	375	22.84	Closed
64	2065.53	269	26.42	Closed
65	2064.53	188	26.78	Closed
66	2063.53	201	25.93	Closed
67	2062.53	145	25.37	Closed
68	2061.53	208	25.88	Closed
69	2060.53	260	24.75	Closed
70	2059.53	403	25.26	Closed
71	2058.53	332	24.59	Closed
72	2057.53	190	23.65	Closed
73	2056.53	184	22.67	Closed
74	2055.53	221	23.33	Closed
75	2054.53	212	23.38	Closed
76	2053.53	254	23.27	Closed
77	2052.53	360	23.02	Closed
78	2051.53	414	25.36	Closed
79	2050.53	246	25.17	Closed
80	2049.53	207	24.66	Closed
81	2048.53	324	23.07	Closed
82	2047.53	350	22.89	Closed
83	2046.53	301	23.65	Closed
84	2045.53	238	23.87	Closed
85	2044.53	188	23.75	Closed
86	2043.53	215	24.2	Closed
87	2042.53	184	24.96	Closed
88	2041.53	196	25.12	Closed
89	2040.53	165	24.34	Closed
90	2039.53	165	24.51	Closed
91	2038.53	442	23.06	Closed
92	2037.53	428	22.8	Closed
93	2036.53	229	22.72	Closed
94	2035.53	133	22.66	Closed
95	2034.53	113	23.15	Closed
96	2033.53	81	24.17	Closed
97	2032.53	93	24	Closed
98	2031.53	113	24.47	Closed
99	2030.53	124	24.67	Closed
100	2029.53	255	24.8	Closed
101	2028.53	539	23.87	Closed

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
102	2027.53	517	24.17	Closed
103	2026.53	546	23.33	Closed
104	2025.53	326	24.14	Closed
105	2024.53	346	23.92	Closed
106	2023.53	188	24.08	Closed
107	2022.53	539	24.24	Closed
108	2021.53	600	24.32	Closed
109	2020.53	28	11.1	Open
110	2019.53	55	9.96	Open
111	2018.53	15	14.6	Open
112	2017.53	21	14.53	Open
113	2016.53	28	14.89	Open
114	2015.53	37	15.1	Open
115	2014.53	16	15.3	Open
116	2013.53	13	16.75	Open
117	2012.53	11	15.78	Open
118	2011.53	20	15.32	Open
119	2010.53	17	15.79	Open
120	2009.53	22	17.38	Open
121	2008.53	19	15.96	Open
122	2007.53	9	15.06	Open
123	2006.53	37	20.71	Closed
124	2005.53	51	21.8	Closed
125	2004.53	78	22.39	Closed
126	2003.53	89.	23.11	Closed
127	2002.53	108	23.28	Closed
128	2001.53	166	23.04	Closed
129	2000.53	206	23.04	Closed
130	1999.53	160	23.08	Closed
131	1998.53	224	23.81	Closed
132	1997.53	267	23.48	Closed
133	1996.53	115	22.97	Closed
134	1995.53	127	23.53	Closed
135	1994.53	219	23.99	Closed
136	1993.53	527	23.5	Closed
137	1992.53	791	23.4	Closed
138	1991.53	1017	23.55	Closed
139	1990.53	924	23.66	Closed

BDH98-4

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
1	2176.97	9	8.82	Open
2	2175.97	12	10	Open
3	2174.97	22	15.05	Open
4	2173.97	50	20.23	Open
5	2172.97	56	20.75	Open
6	2171.97	82	18.07	Open
7	2170.97	84	21.16	Open
8	2169.97	73	23.52	Open
9	2168.97	93	22.41	Open
10	2167.97	164	20.51	Open
11	2166.97	158	23.93	Open
12	2165.97	136	24.62	Open
13	2164.97	83	23.86	Open
14	2163.97	83	23.91	Open
15	2162.97	80	15.84	Open
16	2161.97	60	21.66	Open
17	2160.97	22	20.92	Open
18	2159.97	65	24.16	Open
19	2158.97	64	22.24	Open
20	2157.97	78	25.03	Open
21	2156.97	97	25.88	Open
22	2155.97	50	23.07	Open
23	2154.97	50	23.31	Open
24	2153.97	65	24.86	Open
25	2152.97	33	19.75	Open
26	2151.97	51	22.06	Open
27	2150.97	48	22.02	Open
28	2149.97	30	18.62	Open
29	2148.97	58	19.33	Open
30	2147.97	159	23.77	Open
31	2146.97	65	23.17	Open
32	2145.97	72	24.52	Open
33	2144.97	38	21.17	Open
34	2143.97	28	21.29	Open
35	2142.97	144	26.08	Open
36	2141.97	54	22.46	Open
37	2140.97	55	23.26	Open
38	2139.97	63	23.54	Open
39	2138.97	93	22.97	Open
40	2137.97	57	25.42	Open
41	2136.97	98	24.58	Open
42	2135.97	100	24.07	Open
43	2134.97	113	23.15	Open
44	2133.97	55	21.25	Open
45	2132.97	57	20.91	Open
46	2131.97	88	21.67	Open
47	2130.97	97	23.03	Open
48	2129.97	61	22.87	Open
49	2128.97	52	17.63	Open
50	2127.97	75	22.65	Open

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
51	2126.97	5	13.91	Open
52	2125.97	193	19.36	Open
53	2124.97	121	25.03	Open
54	2123.97	67	23.22	Open
55	2122.97	101	25.13	Open
56	2121.97	141	25.83	Open
57	2120.97	82	25.17	Open
58	2119.97	65	24.52	Open
59	2118.97	132	25.26	Open
60	2117.97	127	25.45	Open
61	2116.97	111	24.28	Open
62	2115.97	99	24.13	Open
63	2114.97	84	24.08	Open
64	2113.97	78	23.82	Open
65	2112.97	44	22.73	Open
66	2111.97	41	22.23	Open
67	2110.97	88	24.28	Open
68	2109.97	96	24.57	Open
69	2108.97	62	21.56	Open
70	2107.97	145	23.91	Open
71	2106.97	204	24.28	Open
72	2105.97	89	22.74	Open
73	2104.97	52	21.69	Open
74	2103.97	33	20.59	Open
75	2102.97	66	22.37	Open
76	2101.97	102	22.65	Open
77	2100.97	23	18.29	Open
78	2099.97	72	22.28	Open
79	2098.97	57	17.72	Open
80	2097.97	66	22.25	Open
81	2096.97	42	20.88	Open
82	2095.97	49	21.45	Open
83	2094.97	83	22.52	Open
84	2093.97	38	19.94	Open
85	2092.97	23	18.29	Open
86	2091.97	27	18.31	Open
87	2090.97	88	21.38	Open
88	2089.97	36	19.44	Open
89	2088.97	28	13.32	Open
90	2087.97	91	15.25	Open
91	2086.97	89	18.29	Open
92	2085.97	81	18.43	Open
93	2084.97	77	18.93	Open
94	2083.97	93	18.99	Open
95	2082.97	182	19.8	Open
96	2081.97	153	19.58	Open
97	2080.97	95	19.69	Open
98	2079.97	87	20.79	Open
99	2078.97	66	22.58	Open
100	2077.97	108	23.84	Open
101	2076.97	30	20.79	Open

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
102	2075.97	39	21.24	Open
103	2074.97	47	21.9	Open
104	2073.97	46	21.63	Open
105	2072.97	66	22.39	Open
106	2071.97	35	20.94	Open
107	2070.97	70	22.26	Open
108	2069.97	57	22.01	Open
109	2068.97	39	15.71	Open
110	2067.97	84	19.17	Open
111	2066.97	155	19.48	Open
112	2065.97	66	18.88	Open
113	2064.97	18	17.42	Open
114	2063.97	30	16.91	Open
115	2062.97	31	17.7	Open
116	2061.97	56	21.36	Open
117	2060.97	38	20.65	Open
118	2059.97	65	22.98	Open
119	2058.97	34	15.74	Open
120	2057.97	23	19.56	Open
121	2056.97	17	18.11	Open
122	2055.97	20	18.69	Open
123	2054.97	38	20.28	Open
124	2053.97	61	21.85	Open
125	2052.97	87	21.79	Open
126	2051.97	146	21.55	Open
127	2050.97	203	23.17	Open
128	2049.97	132	22.67	Open
129	2048.97	73	19.96	Open
130	2047.97	35	20.65	Open
131	2046.97	67	21.27	Open
132	2045.97	98	21.27	Open
133	2044.97	116	20.72	Open
134	2043.97	28	19.35	Open
135	2042.97	72	20.52	Open
136	2041.97	108	20.86	Open
137	2040.97	51	20.54	Open
138	2039.97	17	18.42	Open
139	2038.97	21	13.59	Open
140	2037.97	22	14.92	Open
141	2036.97	17	15.6	Open
142	2035.97	20	15.8	Open
143	2034.97	19	15.34	Open
144	2033.97	23	15.21	Open
145	2032.97	23	14.64	Open
146	2031.97	1000	20	Closed
147	2030.97	68	14	Open
148	2029.97	8	12	Open
149	2028.97	9	12	Open
150	2027.97	10	12	Open
151	2026.97	8	12	Open
152	2025.97	8	12	Open

Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
153	2024.97	7	12	Open
154	2023.97	6	12	Open
155	2022.97	4	12	Open
156	2021.97	7	12	Open
157	2020.97	7	12	Open
158	2019.97	5	10	Open
159	2018.97	17	11	Open
160	2017.97	18	12	Open
161	2016.97	34	13	Open
162	2015.97	45	13	Open
163	2014.97	10	12	Open
164	2013.97	11	12	Open
165	2012.97	12	13	Open
166	2011.97	30	13	Open
167	2010.97	49	13	Open
168	2009.97	46	13	Open
169	2008.97	51	13	Open
170	2007.97	8	19	Open
171	2006.97	13	18	Open
172	2005.97	8	18	Open
173	2004.97	13	19	Open
174	2003.97	19	19	Open
175	2002.97	21	18	Open
176	2001.97	21	19	Open
177	2000.97	21	19	Open
178	1999.97	20	14	Open
179	1998.97	23	19	Open
180	1997.97	24	19	Open
181	1996.97	26	19	Open
182	1995.97	32	20	Open
183	1994.97	29	19	Open
184	1993.97	35	19	Open
185	1992.97	34	18	Open
186	1991.97	56	10	Open
187	1990.97	17	18	Open
188	1989.97	29	18	Open
189	1988.97	28	19	Open
190	1987.97	28	19	Open
191	1986.97	31	19	Open
192	1985.97	37	18	Open
193	1984.97	24	19	Open
194	1983.97	33	19	Open
195	1982.97	36	19	Open
196	1981.97	36	19	Open
197	1980.97	46	19	Open
198	1979.97	47	13	Open
199	1978.97	63	13	Open
200	1977.97	62	14	Open
201	1976.97	62	14	Open
202	1975.97	62	13	Open
203	1974.97	91	13	Open

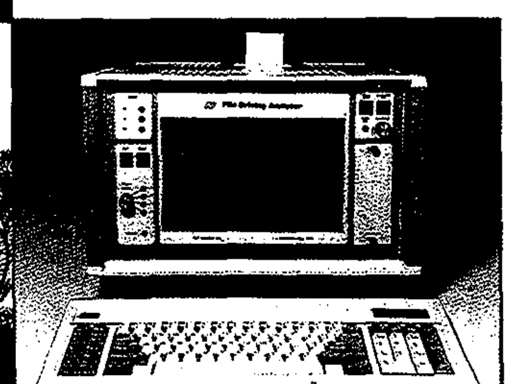
Depth (ft)	Elevation (ft)	Blows per Foot	Chamber Pressure (psi)	Bit Type
204	1973.97	91	13	Open
205	1972.97	73	13	Open
206	1971.97	58	13	Open
207	1970.97	68	13	Open

Attachment C

PDA Data

GRL

dynamic testing
services and analyses



GRL

Goble Rausche Likins and Associates, Inc.

December 9, 1998

Layne Christensen Company
1401 E. 26 th Street
Tacoma, Washington 98421

Attention: Ms. Janine LaMaie

Re: Dynamic Measurements and Analyses, Becker Hammer Drill
Cle Elum Dam, Yakama Project, November 11-19, 1998 GRL Job No. 986043

Dear Sir:

This report presents results from dynamic measurements made during operation of a Becker hammer drill for the project referenced above. The dynamic measurements were made by Goble Rausche Likins and Associates, Inc. (GRL), at the request of Layne Christensen Company. Measurements were made on five holes (BDH 98-1, 1b, 2, 3 and BSH 98-1during the period of November 11 to 19, 1998.

Results from GRL's monitoring and analysis include data on energy transfer from the hammer to the drill casing. Also, the field results from three test holes include estimates of the shaft friction acting on the casing during testing. All results are based on Case Method calculations. The Case Method, our measurement techniques and our test equipment are described in Appendix A. Appendix B contains a summary of the field results. Appendix C contains measured force and velocity records for representative hammer blows from various penetrations in BDH 98-1b and BDH 98-2.

The Becker hammer drills use an ICE 180 double acting diesel hammer with a maximum energy rating of 8.1 kip-ft and a 1.73 kip ram. Transfer energy measured with the PDA, EMX, can be divided by the 8.1 kip nominal maximum energy to obtain a rated transfer efficiency, ETR. Attached figures provide a graphical summary of ETR or EMX for each test hole. These figures, and the numerical summaries in Appendix B, indicate that transfer efficiency varied over the test holes and depths monitored, but was typically between 40 and 50 percent. Discussion regarding the causes and significance of the measured energy transfer variations is beyond the scope of this report.

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925-944-6363	303-666-6127	407-826-9539	847-670-7720	704-593-0992	610-459-0278	360-871-5480

December 9, 1998

It is our understanding that the transfer energy data measured on this project may be used to normalize the observed penetration resistance to the N_{b30} values proposed by Sy and Campanella (1992). The numerical summaries given in Appendix B contain average values of ETR for each ft of PDA monitored drilling. The N_{b30} value is computed as $N_{b30} = N_b*ETR/30$, where N_b is the observed penetration resistance in blows per ft, and ETR is the measured transfer efficiency in percent.

The effects on N_{b30} of shaft friction acting on the Becker casing have been discussed by Sy and Campanella (1993). Estimates of the shaft fiction can be obtained by CAPWAP analysis of the measured PDA data. To date CAPWAP analyses have not been requested for this project. However, the Case Method SFT calculation is an estimate of the total shaft friction acting during driving, including the so-called dynamic (damping) and static components of the friction. For BDH 98-1b, 98-2 and 98-3 the plotted and numerical summaries contain the computed SFT values. Because these SFT values are effected by the presence of any loose joints or other reflectors in the drill string and include the dynamic resistance component they must be considered as indications of relative changes in friction rather than estimates of the static shaft friction.

It was a pleasure to work with you on this project. Please do not hesitate to contact us if you have any questions regarding this report or our participation on the project.

Sincerely,

GOBLE RAUSCHE LIKINS
AND ASSOCIATES, INC.

Robert F. Miner, P.E.

Jay Berger

RFM:cp
grlwa12/98

December 9, 1998

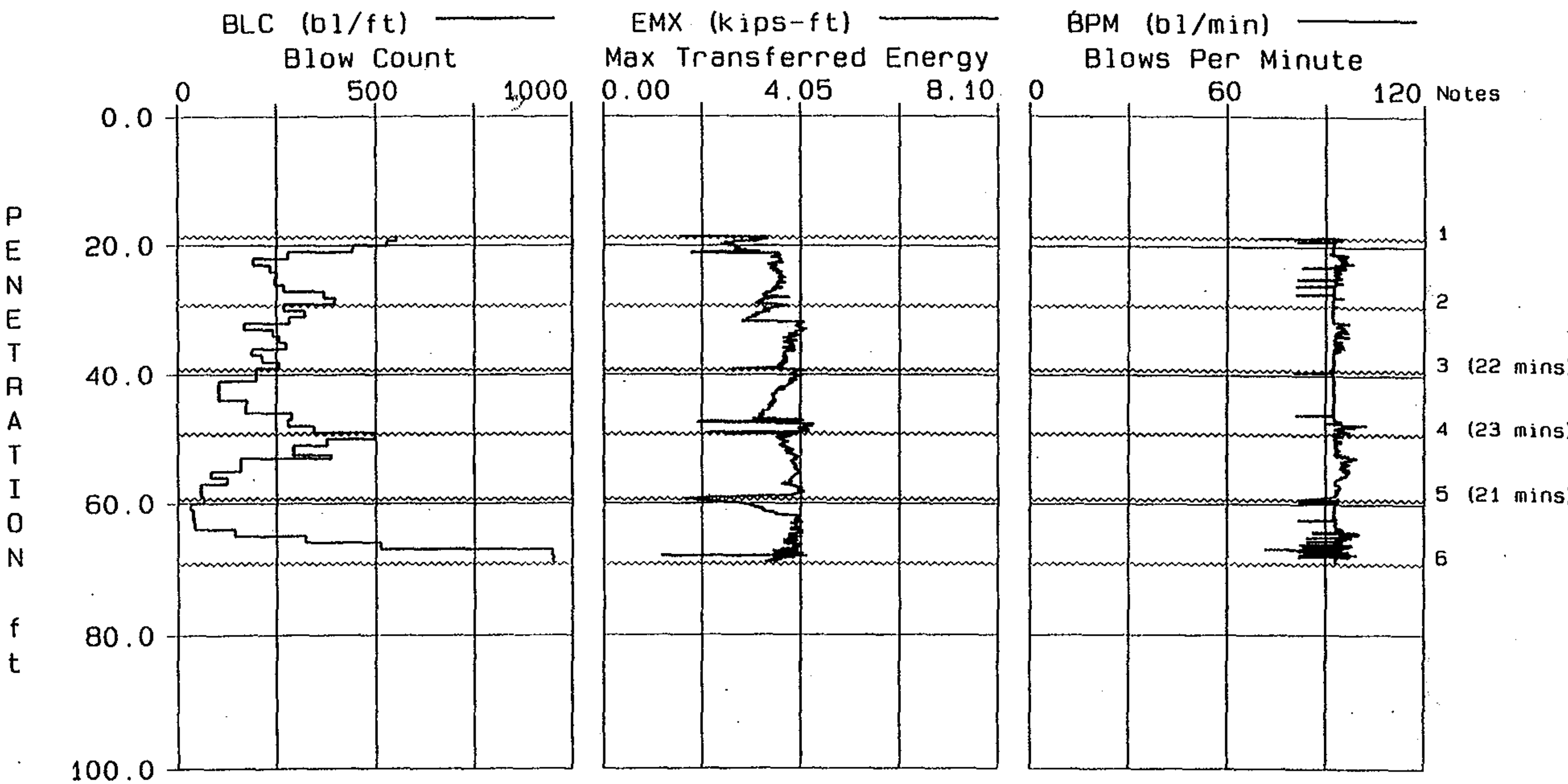
References

SY, A. and CAMPANELLA, R.G. 1992.
Dynamic Performance of the Becker Hammer Drill and Penetration Test. 45th Canadian Geotechnical Conference, Toronto, Ontario, Paper 24:1-10.

SY, A. and CAMPANELLA, R.G. 1993.
BPT-SPT Correlations with Consideration of Casing Friction. Proceeding of the 46th Geotechnical Conference, Saskatoon, Saskatchewan, September 27-29, 1993

GRL & Ass… …ates, Inc. 11-Nov-9…

Cle Elum Dam, BDH 98-1, 6-5/8" OD, Closed End

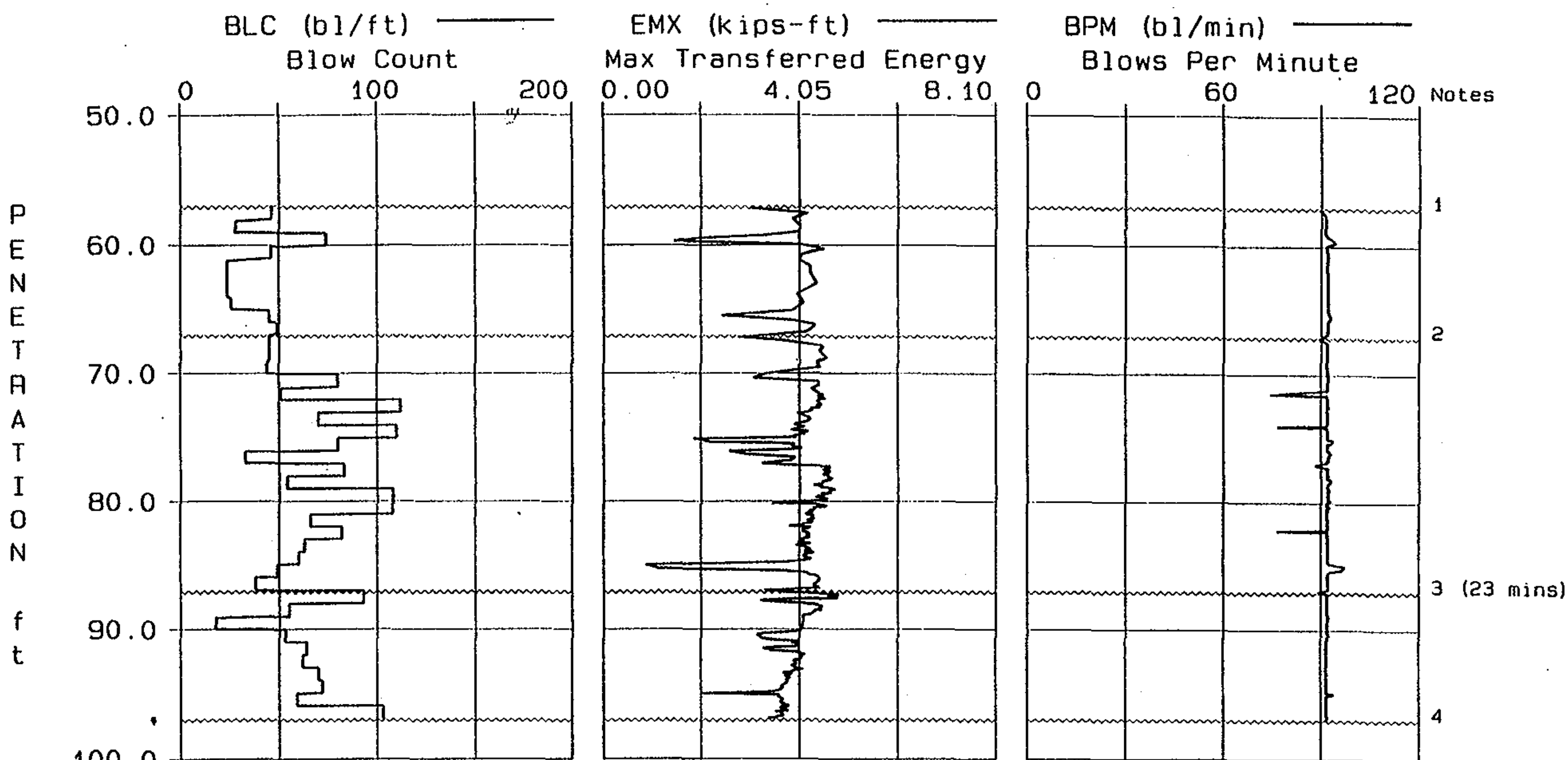


GRL Goble Rausche Likins and Associates, Inc.

Notes

1. BEGIN TESTING ON THIRD SECTION, PENETRATION 18.5 Notes
2. STOP AT 29 FT, ADD 10 FT ROD, CONTINUE.
3. STOP AT 39 FT, ADD 10 FT ROD, CONTINUE.
4. STOP AT 49 FT, ADD 10 FT ROD, CONTINUE.
5. STOP AT 59 FT, ADD 10 FT ROD, CONTINUE.
6. STOP, PULL OUT CASING AND THEN DRILL WITH OPEN BIT&AIRLI

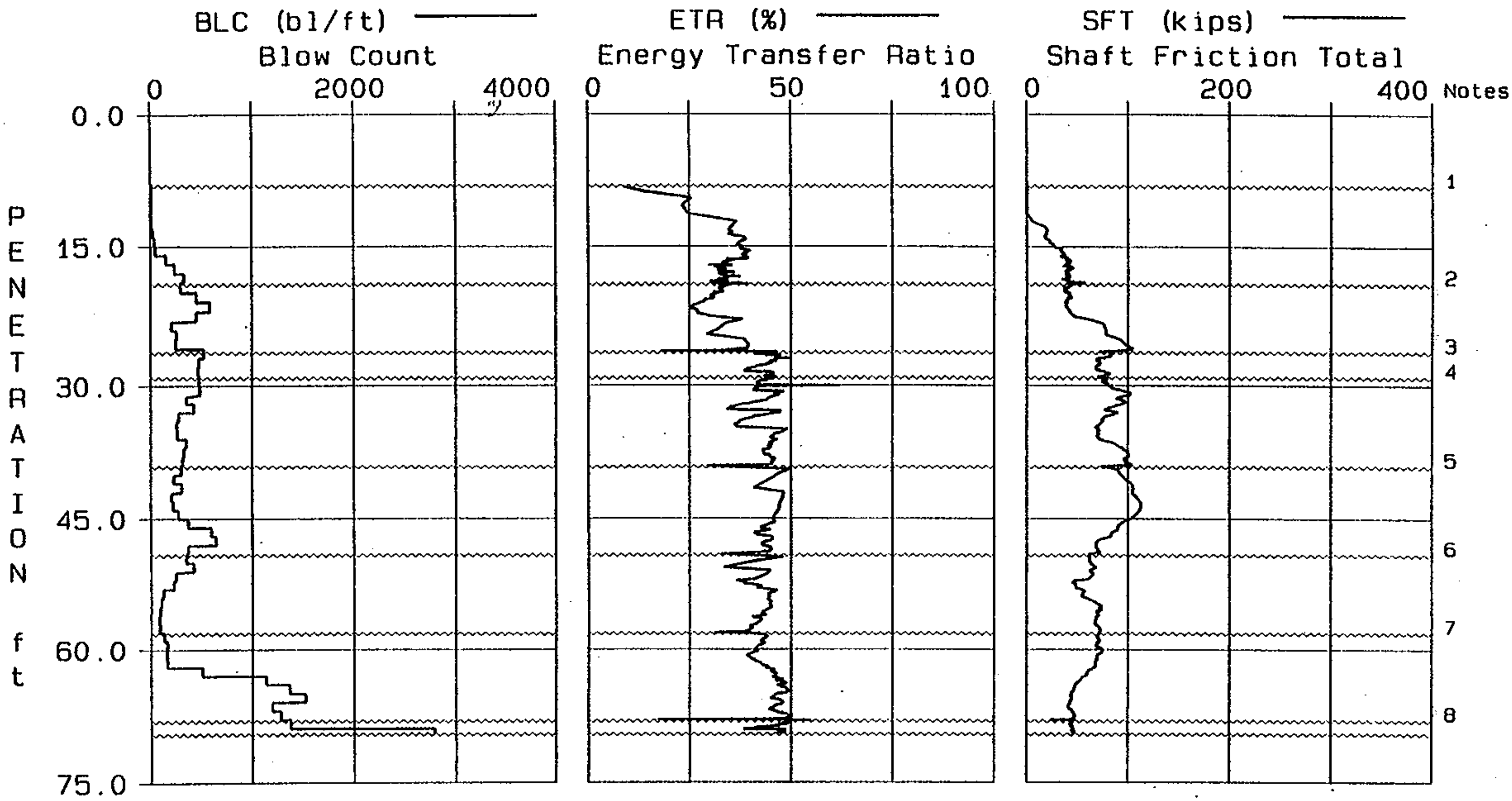
Cle Elum Dam, BSH 98-1, Open Bit



Notes
1. BEGIN TESTING AT 57 FT.
2. STOP AT 67 FT, ADD 10 FT ROD, CONTINUE.
3. LP87, EOD S9
4. STOP AT 97 FT.

GRL & Ass ıates, Inc. 15-Nov-9

CLE ELUM DAM, BDH 98-1B, 6-5/8" OD

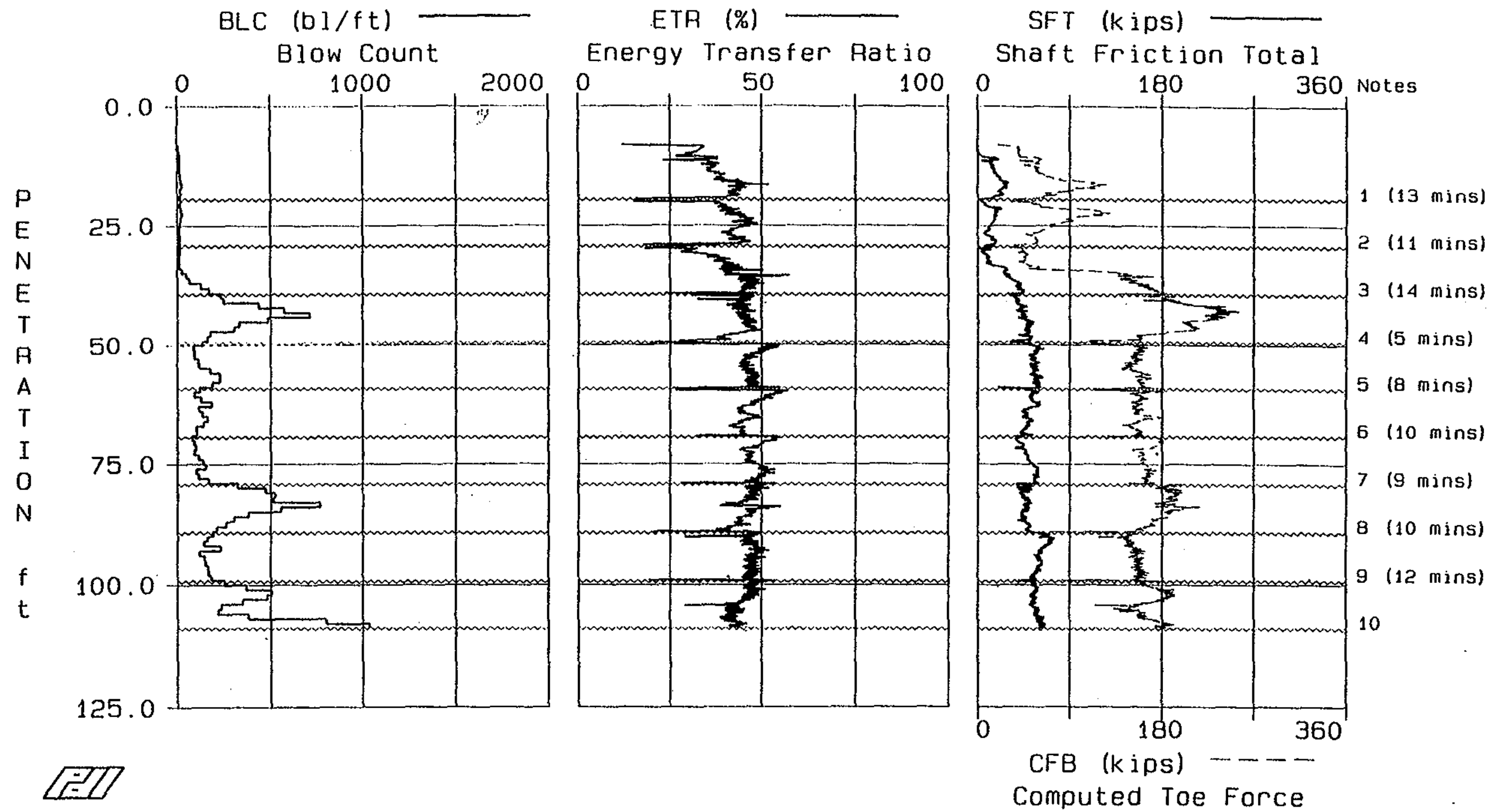


Notes 1. START PDA MONITORING AT 8 FT 14-NOV-98.
2. STOP AT 19 FT, ADD 10 FT ROD.
3. 26.5 FT: PULL OUT & INSPECT ROD, CONTINUE.
4. STOP AT 29 FT, ADD ROD, DRIVE
5. STOP AT 39 FT, ADD 10 FT ROD.

Notes 6. STOP AT 49 FT, ADD ROD, DRIVE.
7. STOP AT 58 FT, ADD 10 FT ROD, DRIVE.
8. STOP AT 68 FT, ADD 10 FT ROD, DRIVE.
9. (70ft), TERMINATE BDH 98-1B AT 69.6 FT, 15-NOV-98.

GRL & As[illegible]ciates, Inc. 16-Nov-

CLE ELUM DAM, BDH 98-2, 6-5/8", CLOSED END

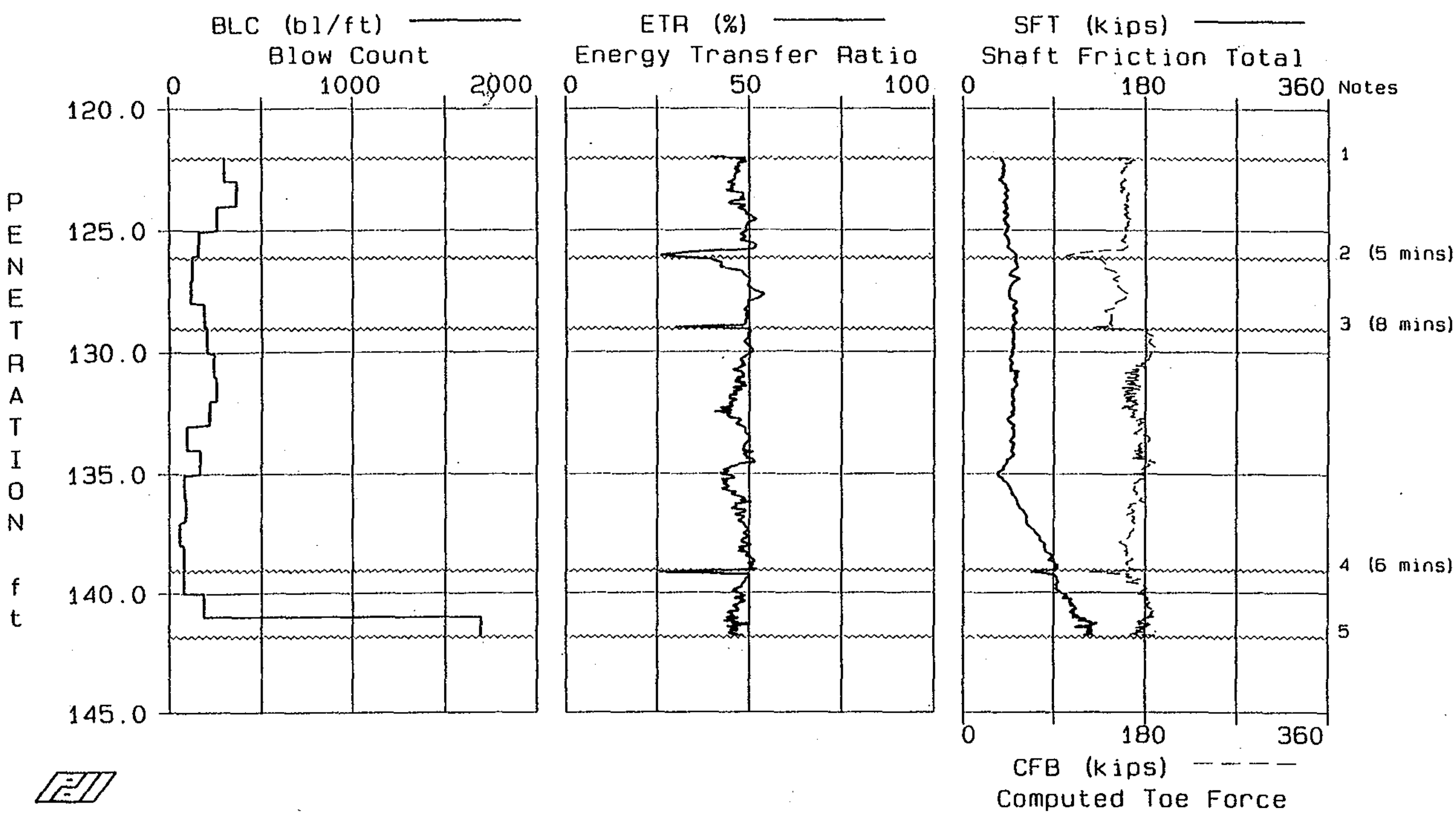


Notes

1. STOP AT 19 FT, ADD ROD, DRIVE.
2. STOP AT 19 FT, ADD ROD, DRIVE.
3. STOP AT 39 FT, ADD ROD, DRIVE.
4. STOP AT 49 FT, ADD ROD, DRIVE.
5. STOP AT 59 FT, ADD ROD, DRIVE.
6. STOP AT 69 FT, ADD ROD, DRIVE.
7. STOP AT 79 FT, ADD ROD, DRIVE.
8. STOP AT 89 FT, ADD ROD, DRIVE.
9. STOP AT 99 FT, ADD ROD, DRIVE.
10. STOP AT 108.7 FT 16-NOV-98.

GRL & Ass. .ates, Inc. 17-Nov-9

CLE ELUM DAM, BDH 98-2, 6-5/8", CLOSED END

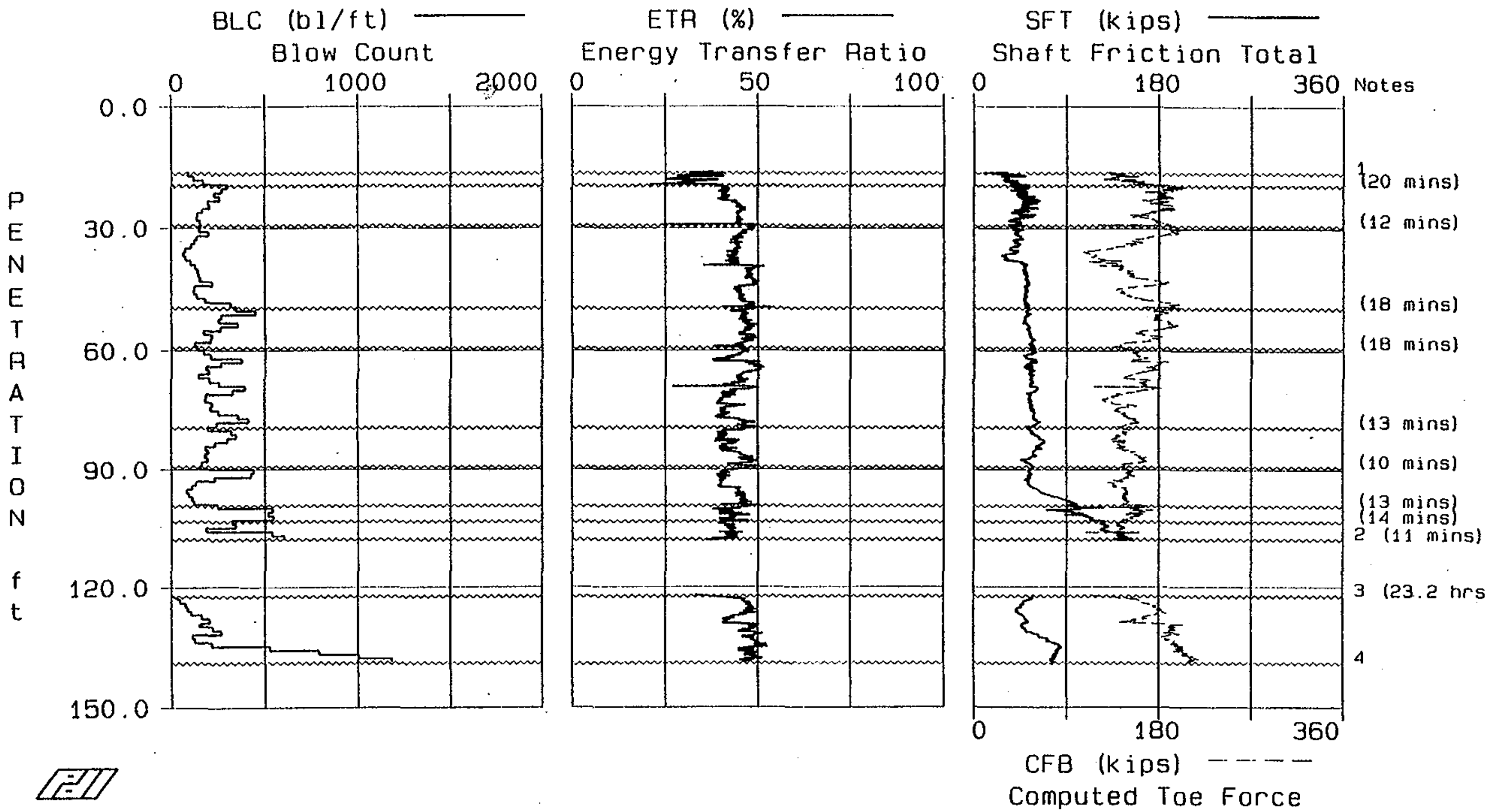


Notes
1. BEGIN 17-NOV-98 AT 13:23 AFTER DRILLING WITH OPEN BIT TO 122 FT.
2. Stop to fuel hammer.
3. Stop at 129 ft, add rod, drive.
4. Stop at 139 ft, add rod, drive.
5. Terminate BDH 98-2 at 141.8 ft, 17-NOV-98 at 14:35.

GRL Goble Rausche Likins and Associates, Inc.

GRL & Ass..iates, Inc. 19-Nov-9.

CLE ELUM DAM, BDH 98-3, 6-5/8", CLOSED END



Notes
1. Begin PDA monitoring of BDH 98-3 at 16 ft, 08:51 18-NOV-98.
2. Stop to work on hammer.
3. Stop at 108.1 ft 15:26 18-NOV-98.
4. Terminate BDH 98-3 at 138.8 ft, 15:42 19-NOV-98.

GRL Goble Rausche Likins and Associates, Inc.

APPENDIX A:

AN INTRODUCTION INTO DYNAMIC PILE TESTING METHODS

BACKGROUND

Between 1964 and 1977 research was conducted at Case Institute of Technology in Cleveland, Ohio with the objective of improving pile installation and construction control methods using electronic measurement and modern analysis methods. This work was supported by the Ohio Department of Transportation and the Federal Highway Administration.

In 1972, the research results were introduced into practice. Professor G. G. Goble, who had been the principal investigator at Case, founded Pile Dynamics, Inc. a company which manufactures - among other devices - the Pile Driving Analyzer® (PDA). Together with his former research assistants he also founded Goble Rausche Likins and Associates, Inc. (GRL) a consulting engineering firm specialized in the dynamic measurement and analysis methods of piles.

[illegible] Dynamics gradually improved the PDA technology, always searching for and utilizing advances in electronic and computer technology. In addition, new devices were built and introduced into the market. GRL, on the other hand, developed methods and software for the analysis of the measured quantities. It is the intent of this paper to summarize both analytical and measurement tools available to the civil engineer.

RESULTS FROM DYNAMIC TESTING

The following are the main objectives of dynamic pile testing (or monitoring).

- Bearing Capacity at the time of testing. For the prediction of a pile's long term bearing capacity, measurements are taken during restriking.
- Dynamic Pile Stresses during pile driving. In order to limit the possibility of pile damage, stresses must be kept within certain bounds.
- For concrete piles, both tension and compression stresses are important.
- Pile Integrity often must be checked both during and after pile installation.
- Hammer Performance must be checked for productivity and construction control.

MEASUREMENTS

The basis for the results calculated by the PDA are pile top force and velocity signals, obtained using accelerometers and bolt-on strain transducers attached to the pile near its top. The PDA conditions and calibrates these signals and immediately computes average pile force and velocity. Using Case Method solutions, the PDA calculates the results described in the following section.

Other measurements are sometimes also required. The ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™ (HPA). For open end diesel hammers, the time between two impacts indicates the magnitude of the fall height. This information is measured and calculated by the Saximeter™. Furthermore, the combustion pressure may be measured in diesels for proper wave equation modeling. Acceleration measurements taken on a helmet in addition to standard pile top force and velocity measurements yield pile top cushion stiffness information.

The Pile Integrity Tester™ (P.I.T.) can be used to evaluate damage to piles which may have occurred during driving or casting. It should also be mentioned that this so-called "Low Strain Method" of integrity testing requires only the measurement of acceleration at a pile top. The stress wave producing impact is then generated by a small hand-held hammer.

ANALYTICAL SOLUTIONS

RING CAPACITY

Wave Equation

GRL has prepared a program, GRLWEAP™, which provides for a truly analytical solution, *i.e.* it does not require measurements and provides the user with a functional relationship between both bearing capacity and pile stress and the blow count. These esults can be adjusted or calibrated if measurements of pile top quantities are available. However, the real strength of the traditional wave equation approach lies in a prediction of driving behavior and in the selection of an optimal driving system.

Case Method

The Case Method is a closed form solution based on a few simplifying assumptions such as ideal plastic soil behavior and an ideally elastic and uniform pile. Given the measured pile top force F(t) and pile top velocity v(t), the total soil esistance is

$$) = \tfrac{1}{2}\{[F(t) + F(t_2)] + Z[v(t) - v(t_2)]\} \qquad (1)$$

where

- Z EA/c is the pile impedance (EA/c)
- t_2 time t + 2L/c
- L pile length below gages
- c $(E/\rho)^{1/2}$ is the speed of the stress wave
- E elastic modulus of the pile (ρc^2)
- ρ pile mass density
- A pile cross sectional area

The total resistance consists of a dynamic and a static component. Thus

$$R_s(t) = R(t) - R_d(t) \qquad (2)$$

The static resistance component is, of course, the desired pile bearing capacity. The dynamic component may be computed from a soil damping factor, J, and a pile toe velocity, $v_t(t)$ which is conveniently calculated for the pile toe. Using wave considerations, this approach leads immediately to the dynamic resistance

$$R_d(t) = J[F(t) + Zv(t) - R(t)] \qquad (3)$$

and finally to the static resistance by means of Equation 2. This solution is simple enough to be evaluated "in real time", *i.e.* between hammer blows, using the PDA. However, the assumption of a soil damping constant must be made and the time, t, has to be selected. Often, t is selected such that the maximum static resistance, RMX, is calculated. The damping constant, J, may not be needed if the time, t, is chosen such that the $R_d(t)$ term vanishes. One calls the resulting capacity value RA2.

CAPWAP®

This method (Case Pile Wave Analysis Program) combines the wave equation pile and soil model with the Case Method measurements. Thus, the solution includes not only the total and static bearing capacity values but also the skin friction, end bearing, damping factors and soil stiffness. The method iteratively determines a number of unknowns by signal matching. While it is necessary to make hammer performance assumptions for a GRLWEAP analysis, the CAPWAP program works with the pile top measurements. Furthermore, while GRLWEAP and Case Method require certain assumptions regarding the soil behavior, CAPWAP calculates these soil parameters.

STRESSES

The wave equation and CAPWAP solutions include stresses along the pile. For the PDA, field results include the pile top stress directly from the measurement and, for concentrated end bearing, the stress at the pile toe from Equation 1.

For concrete piles the maximum tension stress is also of great importance. It occurs at some point below the pile top. The maximum tension stress can be computed from the pile top measurements by considering the magnitude of both upward and downward traveling waves, W_u and W_d.

$$W_u = \tfrac{1}{2}[F(t) - Zv(t)] \qquad (4)$$

$$W_d = \tfrac{1}{2}[F(t) + Zv(t)] \qquad (5)$$

any one of these waves is negative, a tension ·ave exists. It must be checked whether the wave 'ing in the opposite direction is sufficiently .pressive to reduce the net tension to allowable :vels. The PDA also performs this calculation.

ILE INTEGRITY

'igh Strain Tests

tress waves in a pile are reflected wherever the npedance (Z=EA/c) changes. The reflected 'aves arrive at the pile top at a time which epends on the location of the change. The eflected waves cause changes in both pile top orce and velocity. The magnitude relative change f the pile top variables allows to determine the xtent of the cross sectional change. Thus, with β_i eing a relative integrity factor which is unity for no npedance change and zero for the pile end, the ollowing can be calculated by the PDA.

$$\beta_i = (1 - \alpha_i)/(1 + \alpha_i) \qquad (6)$$

'ith

$$\alpha_i = ½(W_{ur} - W_{ud})/(W_{di} - W_{ur}) \qquad (7)$$

.e

- W_{ur} is the upward traveling wave at the onset of the reflected wave. It is caused by resistance.
- W_{ud} is the upwards traveling wave due to the damage reflection.
- W_{di} is the maximum downward traveling wave due to impact.

.ow Strain Tests (P.I.T.)

'he pile top is struck with a held hand hammer and ne resulting pile top velocity is measured, lisplayed and interpreted for signs of wave eflections. In general, a comparison of the eflected acceleration leads to a relative measure of extent of damage, again the location of the problem is indicated by the arrival time of the eflection. An approximate pile profile can be calculated from low strain records using the PIT.WAP.

HAMMER PERFORMANCE

The PDA can very simply calculate the energy transferred to the pile top.

$$E(t) = \int_0^t F(t)v(t)\,dt \qquad (8a)$$

The maximum of the E_t curve is the most important information for an overall evaluation of the performance of a driving system. This EMX or ENTHRU value allows for a classification of the hammer's performance, using:

$$e_t = EMX/E_r \qquad (8b)$$

where E_r is the hammer's rated energy.

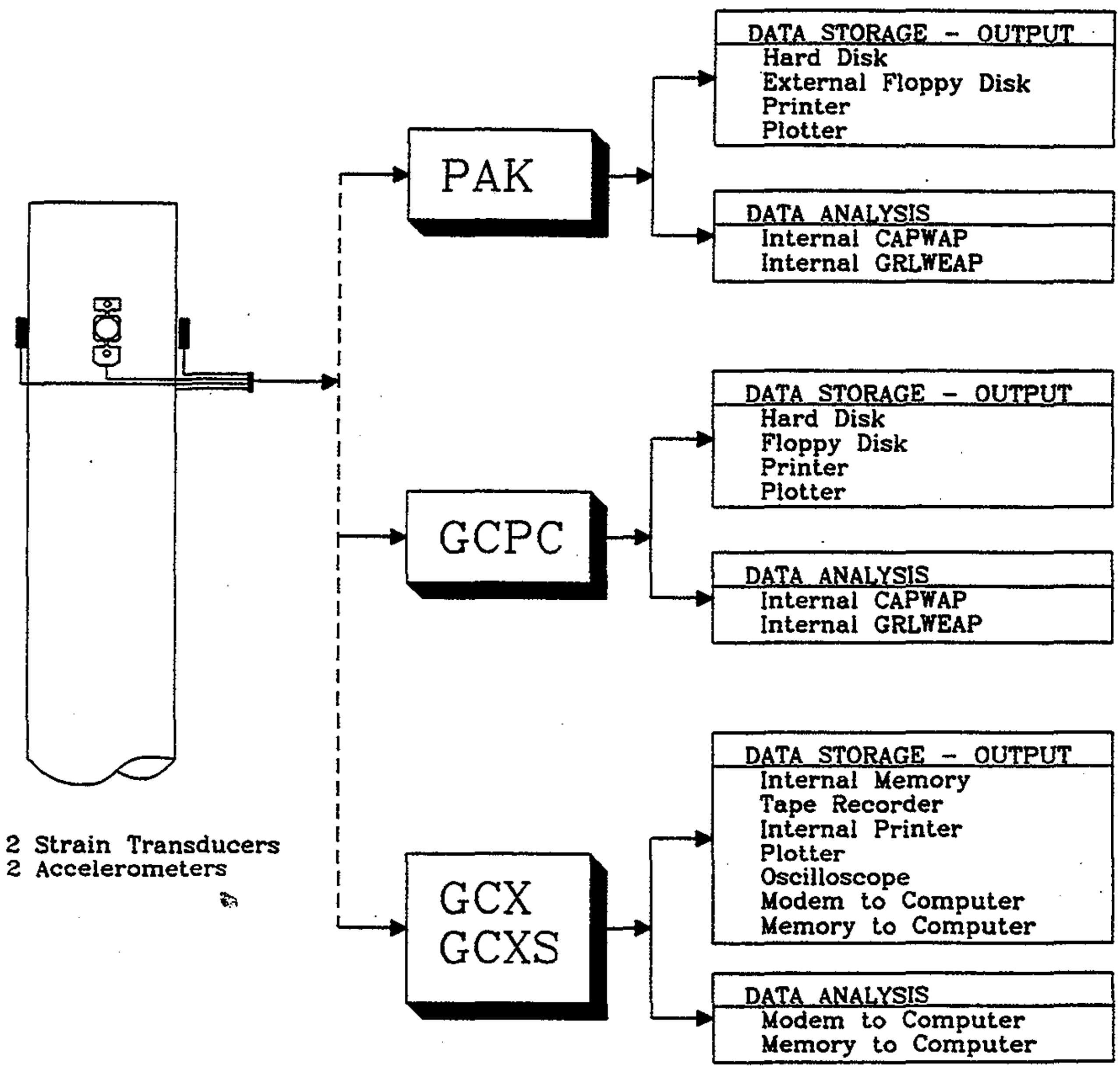
The Saximeter™ calculates the stroke from an open end diesel using

$$h = (g/8)\,T^2 - h_l \qquad (9)$$

where

- g earth gravitational acceleration,
- T time between two blows,
- h_l a stroke loss value due to gas compression and time losses during impact (usually 0.3 ft or 0.1 m).

Pile Driving Analyzer System



APPENDIX B

Case Method Results

: BDH 98-1
6-5/8" OD, Closed End
11.8 in^2
32.0 ft

Proj: Cle Elum Dam
SP: 0.492 k/ft^3
WS: 16810 ft/s
EM: 30000 KSI

x Transferred Energy
Capacity - RSU
Capacity - RAU
Capacity - RMX
Total Capacity (J=0)

BPM: Blows Per Minute
FMX: Max Measured Force
VMX: Max Measured Velocity
CFB: Computed Toe Force

bl/ft	depth ft	TY	EMX kips-ft	RSU kips	RAU kips	RMX kips	RTL kips	BPM bl/min	FMX kips	VMX ft/sec	CFB kips
551	18.50	AV	1.4	124	144	165	170	84.7	137	5.9	131
551	19.30	AV	3.0	141	205	219	250	91.2	228	11.4	203
527	20.00	AV	2.6	136	197	204	238	92.3	215	10.9	190
441	20.99	AV	2.8	137	181	212	245	92.2	224	11.3	196
280	22.00	AV	3.3	128	170	209	250	94.6	240	12.1	192
192	23.00	AV	3.6	116	167	219	249	95.4	249	12.7	190
234	24.00	AV	3.5	128	168	219	253	93.4	243	12.4	189
250	25.00	AV	3.6	119	168	214	250	92.7	246	12.6	182
246	26.00	AV	3.6	112	168	215	244	92.3	243	12.5	169
268	27.00	AV	3.5	111	165	215	240	92.4	238	12.3	154
368	28.00	AV	3.4	135	163	212	250	92.0	229	11.8	146
396	29.00	AV	3.3	117	161	207	234	92.3	225	11.5	148
269	30.00	AV	3.5	95	154	206	227	92.3	234	12.2	165
321	31.00	AV	3.2	92	150	200	216	92.1	222	11.5	150
282	32.00	AV	3.3	85	151	196	214	93.3	227	11.7	155
168	33.00	AV	4.0	85	158	205	234	94.7	254	13.1	173
41	34.00	AV	4.0	106	159	219	244	94.0	250	12.8	169
6	35.00	AV	3.8	100	158	214	236	92.8	246	12.5	166
72	36.00	AV	3.8	113	159	216	244	93.4	245	12.4	163
187	37.00	AV	3.8	115	161	210	244	92.8	244	12.2	171
214	38.00	AV	3.7	109	158	201	237	92.4	240	12.0	173
256	39.00	AV	3.6	127	151	207	246	92.4	237	11.8	181
199	41.00	AV	3.9	82	146	173	222	91.3	239	12.5	172
104	44.00	AV	3.6	97	133	150	230	92.4	237	12.2	155
175	45.00	AV	3.5	127	135	177	240	92.5	234	12.0	149
173	46.00	AV	3.4	115	134	173	236	92.5	230	11.8	153
289	47.00	AV	3.3	126	143	191	241	92.0	227	11.7	163
280	48.00	AV	3.6	123	146	202	248	95.5	242	12.5	177
344	49.00	AV	4.1	121	163	220	258	95.0	255	13.2	191
498	50.00	AV	3.6	110	150	207	233	93.0	228	11.9	172
376	51.00	AV	3.7	113	154	211	239	93.3	236	12.0	177
292	52.50	AV	3.8	109	150	203	237	93.4	238	12.1	176
388	53.00	AV	4.0	99	143	188	237	97.0	246	12.6	180
160	55.00	AV	3.9	105	137	185	241	96.1	247	12.6	179
84	56.00	AV	4.0	104	133	179	242	95.8	251	12.6	176
125	57.00	AV	3.8	103	111	158	238	93.1	248	12.4	166
58	58.93	AV	4.0	82	96	115	224	93.5	249	12.3	152
65	60.00	AV	2.1	125	57	107	183	89.5	166	8.1	110
32	61.00	AV	3.1	113	54	108	203	92.8	195	9.5	126
40	63.00	AV	3.8	110	62	109	228	92.2	229	11.3	147
43	64.00	AV	3.9	114	59	115	240	93.3	241	11.9	161
144	65.00	AV	4.0	129	102	160	253	96.4	246	12.1	176
2	66.00	AV	3.9	149	143	201	259	94.1	240	11.9	186
1	67.00	AV	3.9	140	153	212	257	93.6	237	12.1	183
949	68.00	AV	3.8	150	155	225	257	93.5	234	12.0	180

-# bl/ft	depth ft	TY	EMX kips-ft	RSU kips	RAU kips	RMX kips	RTL kips	BPM bl/min	FMX kips	VMX ft/sec	CFB kips
953	69.00	AV	3.5	157	149	216	250	93.0	224	11.6	172

#	COMMENTS
2	BEGIN TESTING ON THIRD SECTION, PENETRATION 18.5 FT.
7	STOP AT 29 FT, ADD 10 FT ROD, CONTINUE.
9	STOP AT 39 FT, ADD 10 FT ROD, CONTINUE.
)	STOP AND FUEL HAMMER.
2	STOP AT 49 FT, ADD 10 FT ROD, CONTINUE.
78	STOP AT 59 FT, ADD 10 FT ROD, CONTINUE.
52	pull back
77	STOP, PULL OUT CASING AND THEN DRILL WITH OPEN BIT&AIRLIFT.

IVE TIME SUMMARY (11-Nov-98 : BDH98-1.MDF)

Blows	Start	Stop	DRIVE (minutes)	WAIT (minutes)
2 -> 5949	START 11:09:48	-> 12:29:05 STOP	79.28	
				22.73
5953 -> 7922	START 12:51:49	-> 13:24:26 STOP	32.62	
				23.93
7926 -> 10078	START 13:48:22	-> 14:11:21 STOP	22.98	
				21.57
10083 -> 13177	START 14:32:55	-> 15:07:59 STOP	35.07	

Total Elapsed time 238.18 minutes Total Time 169.95 minutes 68.23

: BSH 98-1
Open Bit
11.8 in^2
[illegible]2.0 ft

Proj: Cle Elum Dam
SP: 0.492 k/ft^3
WS: 16810 ft/s
EM: 30000 KSI

Max Transferred Energy
Capacity - RSU
Capacity - RAU
Capacity - RMX
Total Capacity (J=0)

BPM: Blows Per Minute
FMX: Max Measured Force
VMX: Max Measured Velocity
CFB: Computed Toe Force

---

bl/ft	depth ft	TY	EMX kips-ft	RSU kips	RAU kips	RMX kips	RTL kips	BPM bl/min	FMX kips	VMX ft/sec	CFB kips
46	57.00	AV	1.4	49	76	78	112	85.8	115	6.0	85
46	58.00	AV	3.9	58	96	107	178	91.1	193	10.8	148
28	59.00	AV	4.0	55	112	118	180	91.4	199	11.1	148
74	60.00	AV	2.8	55	115	119	153	92.9	163	8.9	114
46	61.00	AV	4.3	48	69	99	178	92.0	202	11.2	140
24	64.00	AV	4.2	60	108	125	193	91.9	211	11.8	150
26	65.00	AV	4.0	55	70	95	178	92.2	193	10.9	128
45	66.00	AV	3.4	58	110	118	171	92.4	181	10.1	114
49	66.90	AV	4.3	63	128	136	196	92.0	212	11.9	145
45	68.00	AV	3.7	89	118	130	201	90.9	205	10.7	144
45	69.00	AV	4.5	95	117	137	225	91.8	232	12.1	159
44	70.00	AV	4.3	97	110	138	222	91.9	227	11.8	156
80	71.00	AV	3.8	108	126	154	223	92.2	216	11.2	160
51	72.00	AV	4.5	114	127	150	237	88.5	227	12.1	183
112	73.00	AV	4.4	114	139	163	235	92.0	226	12.0	178
70	74.00	AV	4.1	113	132	160	230	92.0	220	11.6	181
[illegible]	75.00	AV	4.0	122	127	160	233	91.0	216	11.4	183
[illegible]	76.00	AV	3.2	114	95	125	203	92.5	183	9.6	156
33	76.97	AV	3.4	107	84	115	199	92.4	182	9.5	156
83	78.00	AV	4.5	139	122	148	251	91.5	227	11.8	203
54	79.00	AV	4.6	144	121	152	258	92.4	232	12.2	213
108	80.00	AV	4.6	144	141	167	260	92.1	234	12.3	217
108	81.00	AV	4.2	139	126	151	248	92.0	222	11.7	201
66	82.00	AV	4.2	137	117	147	246	92.0	221	11.6	197
82	83.00	AV	4.2	135	120	144	244	90.7	220	11.6	197
63	84.00	AV	4.2	133	111	141	241	92.0	218	11.5	196
60	85.00	AV	3.8	126	107	134	227	92.6	204	10.7	182
49	86.00	AV	2.9	108	74	107	185	93.9	165	8.4	126
38	87.00	AV	4.3	127	94	129	237	92.2	219	11.5	190
93	88.00	AV	4.1	137	122	137	241	91.4	214	11.3	212
55	89.00	AV	4.4	142	81	142	246	91.9	216	11.4	210
18	90.00	AV	4.1	139	64	139	239	91.9	210	11.0	197
53	91.00	AV	3.6	130	81	130	221	92.0	191	10.1	174
64	92.00	AV	3.8	130	96	131	228	91.7	199	10.6	178
62	93.00	AV	4.0	131	115	133	233	91.7	205	11.0	187
70	94.00	AV	3.9	131	109	131	230	91.7	199	10.8	180
72	95.00	AV	3.7	110	110	127	212	91.7	194	10.5	175
59	96.00	AV	3.5	96	99	118	194	92.0	182	9.9	159
103	97.00	AV	3.7	103	124	134	206	91.7	191	10.6	179

COMMENTS
EGIN TESTING AT 57 FT.
STOP AT 67 FT, ADD 10 FT ROD, CONTINUE.
DATA MERGE: C:/PDAPLOT/B98-2.MDF
OPEN BIT

` EOD S8, LP77
LP87, EOD S9
_ STOP AT 97 FT.

IVE TIME SUMMARY (12-Nov-98 : BSH98-1.MDF)	DRIVE	minutes	WAIT
1064 -> 1705, START 14:09:14 -> 14:17:02 STOP,	7.80		
			0.10
1707 -> 1773, START 14:17:08 -> 14:17:56 STOP,	0.80		
			23.77
1775 -> 2266, START 14:41:42 -> 14:47:34 STOP,	5.87		
			0.22
2268 -> 2422, START 14:47:47 -> 14:49:32 STOP,	1.75		
Total Elapsed time 40.30 minutes Total Time	16.22	minutes	24.08

e: BDH 98-1B
o: 6-5/8" OD
11.8 in^2
80.5 ft

Proj: CLE ELUM DAM
SP: 0.489 k/ft^3
WS: 16808 ft/s
EM: 29810 KSI

UNDEFINED
: Energy Transfer Ratio
: Max Measured Force

SFT: Shaft Friction Total
DMX: Max Meas'd Displacement
BPM: Blows Per Minute

#		depth	TYPE	#Bls	EFV	ETR	FMX	SFT	DMX	BPM
d	bl/ft	ft				%	kips	kips	inch	bl/min
1	14	8.00	AVG	1	50	6	13	0	0.54	0.0
5	14	9.00	AVG	11	100	12	28	0	1.02	84.9
2	7	10.00	AVG	7	211	26	44	0	1.99	96.8
9	7	11.00	AVG	7	179	22	42	0	2.03	97.3
5	6	12.00	AVG	6	245	30	64	0	1.48	95.6
5	10	13.00	AVG	10	294	36	129	15	0.77	90.3
9	24	14.00	AVG	24	293	36	156	19	0.54	90.2
7	38	15.00	AVG	38	308	37	184	23	0.42	91.2
7	50	16.00	AVG	50	316	39	210	34	0.35	91.6
0	153	17.00	AVG	153	295	36	217	40	0.28	92.3
8	238	18.00	AVG	238	271	33	208	41	0.27	91.9
0	332	19.00	AVG	332	273	33	208	42	0.27	92.0
8	298	20.00	AVG	136	274	33	214	42	0.28	90.4
0	456	20.95	AVG	94	251	30	201	41	0.27	91.7
#		depth	TYPE	#Bls	CSX	ETR	FMX	SFT	DMX	BPM
d	bl/ft	ft			ksi	%	kips	kips	inch	bl/min
4	456	21.00	AVG	13	16.15	28	191	39	0.27	91.6
2	588	22.00	AVG	32	15.65	27	185	39	0.26	91.8
	455	23.00	AVG	19	17.08	32	202	52	0.28	92.1
	204	24.00	AVG	10	17.46	33	206	77	0.29	91.9
	254	25.00	AVG	11	17.45	32	206	82	0.28	92.1
2	247	26.00	AVG	11	19.82	40	234	100	0.30	92.0
2	528	26.27	AVG	7	19.31	38	228	103	0.29	92.0
#		depth	TYPE	#Bls	EFV	ETR	FMX	SFT	DMX	BPM
d	bl/ft	ft				%	kips	kips	inch	bl/min
0	528	27.00	AVG	96	338	41	238	80	0.28	93.8
2	482	28.00	AVG	101	368	45	247	70	0.31	94.4
8	476	29.00	AVG	96	346	42	240	75	0.29	93.2
2	484	30.00	AVG	93	356	43	238	77	0.35	92.5
2	490	31.00	AVG	95	367	45	240	92	0.59	93.1
#		depth	TYPE	#Bls	CSX	ETR	FMX	SFT	EMX	BPM
d	bl/ft	ft			ksi	%	kips	kips	kips-ft	bl/min
5	355	31.32	AVG	6	20.44	45	241	92	3.7	93.0
#		depth	TYPE	#Bls	CSX	ETR	FMX	SFT	DMX	BPM
d	bl/ft	ft			ksi	%	kips	kips	inch	bl/min
7	355	32.00	AVG	50	20.02	43	236	94	0.31	92.6
27	430	33.00	AVG	86	18.85	39	223	84	0.30	93.3
3	276	34.00	AVG	56	19.49	41	230	79	0.32	92.9
0	257	35.00	AVG	52	18.99	40	224	71	0.31	94.0
3	263	36.00	AVG	54	20.12	46	237	70	0.34	99.2
6	353	37.00	AVG	74	19.54	45	231	85	0.32	99.1
6	330	38.00	AVG	66	19.54	44	231	99	0.30	95.2
3	317	39.00	AVG	64	19.97	45	236	99	0.31	96.7
25	302	40.00	AVG	20	17.82	38	210	83	0.30	93.5
	227	41.00	AVG	10	19.81	45	234	99	0.34	92.5
	308	42.00	AVG	13	19.45	43	230	105	0.32	94.3
6	206	43.00	AVG	9	20.47	48	242	108	0.35	96.8

:: BDH 98-1B Proj: CLE ELUM DAM Pg2

): 6-5/8" OD

	bl/ft	depth ft	TYPE	#Bls	CSX ksi	ETR %	FMX kips	SFT kips	DMX inch	BPM bl/min
,	221	44.00	AVG	9	20.46	47	242	113	0.34	96.2
)	273	45.00	AVG	11	20.09	46	237	107	0.34	95.9
2	372	46.00	AVG	17	19.07	45	225	94	0.35	94.8
)	598	47.00	AVG	24	18.33	42	216	86	0.34	94.2
4	644	48.00	AVG	26	18.92	44	223	72	0.35	93.3
5	371	49.00	AVG	15	19.18	45	226	71	0.36	94.1
5	351	50.00	AVG	17	17.62	40	208	61	0.36	92.7
3	427	51.00	AVG	18	17.24	38	204	65	0.35	92.5
)	247	52.00	AVG	10	18.94	44	224	67	0.38	92.6
5	226	53.00	AVG	72	17.55	39	207	48	0.39	90.3
7	121	54.00	AVG	31	19.28	45	228	56	0.42	92.3
8	101	55.00	AVG	24	19.32	45	228	68	0.41	91.9
9	91	56.00	AVG	28	19.39	44	229	71	0.39	91.8
1	82	57.00	AVG	28	18.82	42	222	68	0.39	91.6
8	87	58.00	AVG	29	18.33	40	216	71	0.38	91.6
7	129	59.00	AVG	45	18.21	42	215	71	0.39	91.3
9	162	60.00	AVG	42	18.23	42	215	71	0.39	91.5
6	157	61.00	AVG	40	17.71	40	209	72	0.38	91.3
8	162	62.00	AVG	41	17.93	42	212	68	0.40	91.3
1	513	63.00	AVG	107	18.54	45	219	62	0.41	91.9
7	1136	64.00	AVG	83	19.03	47	225	53	0.42	91.9
5	1368	65.00	AVG	69	19.48	48	230	46	0.43	92.0
8	1523	66.00	AVG	44	18.90	46	223	44	0.42	91.9
5	1197	67.00	AVG	30	18.65	46	220	42	0.42	92.1
	1280	68.00	AVG	32	19.32	49	228	47	0.43	92.3
	1377	68.10	AVG	71	17.17	39	203	35	0.39	92.9

# d	bl/ft	depth ft	TYPE	#Bls	CSX ksi	ETR %	FMX kips	SFT kips	EMX kips-ft	BPM bl/min
2	1377	69.00	AVG	227	19.19	48	227	44	3.9	91.8
8	2792	69.50	AVG	98	18.64	46	220	46	3.7	91.9

: COMMENTS
. START PDA MONITORING AT 8 FT 14-NOV-98.
' STOP AT 19 FT, ADD 10 FT ROD.
: STOP 11:20:55
: 26.5 FT: PULL OUT & INSPECT ROD, CONTINUE.
' HAMMER RACKING
) HAMMER RACKING
3 STOP AT 29 FT, ADD ROD, DRIVE
2 LOOSE MAIN PDA CABLE NEAR 30 FT.
5 HAMMER RACKING
. MISSED 35FT
3 STOP AT 39 FT, ADD 10 FT ROD.
3 DATA MERGE: RPY3952.MDF
45 STOP AT 49 FT, ADD ROD, DRIVE.
70 STOP AT 52 FT 14-NOV-98, RESTART 15-NOV-98.
)2 HAMMER RACKIMG
78 STOP AT 58 FT, ADD 10 FT ROD, DRIVE.
JC = 0.30
STOP AT 68 FT, ADD 10 FT ROD, DRIVE.
DATA MERGE: 981B068F.Q00
78 TERMINATE BDH 98-1B AT 69.6 FT, 15-NOV-98.

```
E TIME SUMMARY (15-Nov-98 : 981B.MDF)                    DRIVE           WAIT
-----------------------------------------                ----- minutes   ----
     1 ->   880, START 10:23:50 -> 10:33:58 STOP,        10.13
                                                                         13.40
   881 ->  3522, START 10:47:22 -> 11:20:53 STOP,        33.52
                                                                        138.28
  3523 ->  4868, START 13:39:10 -> 13:54:14 STOP,        15.07
                                                                         12.07
  4869 ->  5842, START 14:06:18 -> 14:16:57 STOP,        10.65
                                                                         24.67
  5935 ->  8423, START 14:41:37 -> 15:08:16 STOP,        26.65
                                                                          9.23
  8424 -> 11945, START 15:17:30 -> 15:55:25 STOP,        37.92
                                                                         20.97
 11946 -> 12970, START 16:16:23 -> 16:27:29 STOP,        11.10
                                                                        914.57
 12971 -> 13678, START  7:42:04 ->  7:49:51 STOP,         7.78
                                                                         26.70
 13679 -> 15579, START  8:16:33 ->  8:37:20 STOP,        20.78
                                                                          1.35
 15599 -> 21305, START  8:38:41 ->  9:41:36 STOP,        62.92
                                                                         19.93
 21306 -> 22933, START 10:01:32 -> 10:39:28 STOP,        37.93
                                                                         14.15
 22948 -> 24078, START 10:53:37 -> 11:06:33 STOP,        12.93
                                             ------------------------------------
 cal Elapsed time 1482.70 minutes     Total Time 287.38 minutes 1195.32
```

'ile: BDH 98-2 ıfo: 6-5/8", CLOSED END
: 11.8 in^2
113.0 ft

Proj: CLE ELUM DAM
SP: 0.489 k/ft^3
WS: 16808 ft/s
EM: 29810 KSI

: Max Measured C-Stress
'R: Energy Transfer Ratio
IX: Max Measured Force
'T: Shaft Friction Total
IX: Max Transferred Energy

BPM: Blows Per Minute
RTL: Total Capacity (J=0)
CFB: Computed Toe Force
DMX: Max Meas'd Displacement

3L# ɜnd	bl/ft	depth ft	TY	CSX ksi	ETR %	FMX kips	SFT kips	EMX K-ft	BPM bl/min	RTL kips	CFB kips	DMX inch
2	7	8.00	AV	1.61	7	19	0	0.6	0.0	15	16	0.41
9	7	9.00	AV	6.75	32	80	0	2.6	83.4	33	37	1.36
15	6	10.00	AV	7.21	32	85	0	2.6	92.1	35	39	1.54
25	10	11.00	AV	9.52	34	112	11	2.7	95.5	62	51	1.12
36	11	12.00	AV	9.44	34	112	12	2.8	94.9	67	55	1.65
46	10	13.00	AV	10.33	36	122	14	2.9	95.0	69	54	1.08
58	12	14.00	AV	11.05	36	131	16	3.0	94.7	75	60	1.02
72	14	15.00	AV	12.57	39	148	20	3.2	93.9	92	71	0.92
91	19	16.00	AV	15.33	42	181	26	3.4	92.8	125	99	0.75
.18	27	17.00	AV	16.81	45	198	27	3.7	92.4	140	113	0.77
.37	19	18.00	AV	14.84	43	175	22	3.5	93.2	106	85	0.74
.50	13	19.00	AV	13.27	42	157	19	3.4	94.2	85	68	0.93
.65	15	20.00	AV	7.75	21	91	3	1.8	55.5	37	42	0.70
.77	12	21.00	AV	10.82	39	128	9	3.2	85.6	68	59	1.16
196	19	22.00	AV	14.44	41	170	19	3.3	91.1	121	102	0.70
221	25	23.00	AV	15.54	43	183	17	3.6	92.0	135	117	0.65
	17	24.00	AV	14.45	46	171	16	3.8	92.7	108	92	0.92
	13	25.00	AV	13.25	45	156	14	3.7	93.4	92	78	1.08
262	11	26.00	AV	12.07	44	142	11	3.6	94.4	79	67	1.18
272	10	27.00	AV	10.93	41	129	7	3.4	95.1	62	55	1.25
284	12	28.00	AV	12.07	43	143	14	3.5	94.3	69	55	1.16
293	9	29.00	AV	12.39	43	146	17	3.5	94.0	70	54	1.14
304	11	30.00	AV	8.18	26	97	8	2.1	77.0	34	37	0.78
317	13	31.00	AV	9.94	31	117	6	2.5	94.6	48	45	1.01
327	10	32.00	AV	11.38	38	134	10	3.1	94.4	53	47	1.33
337	10	33.00	AV	11.74	40	139	12	3.3	94.7	52	45	1.58
348	11	34.00	AV	13.25	43	156	22	3.5	93.8	77	55	1.53
375	27	35.00	AV	16.32	42	193	27	3.5	92.1	144	117	0.82
424	49	36.00	AV	19.02	48	225	30	3.9	93.2	182	152	0.50
486	62	37.00	AV	19.35	47	228	37	3.8	93.5	187	150	0.45
610	124	38.00	AV	19.99	47	236	40	3.9	98.8	201	164	0.41
778	168	39.00	AV	20.05	45	237	43	3.7	99.6	214	175	0.38
010	232	40.00	AV	18.42	39	217	35	3.2	94.1	210	176	0.37
257	247	41.00	AV	19.59	44	231	39	3.6	96.4	216	189	0.39
693	436	42.00	AV	19.68	44	232	42	3.6	96.7	258	217	0.37
266	573	43.00	AV	19.88	46	235	42	3.7	99.7	281	239	0.38
980	714	44.00	AV	19.42	45	229	45	3.7	97.6	276	235	0.37
465	485	45.00	AV	18.96	46	224	47	3.8	98.9	261	220	0.37
793	328	46.00	AV	19.09	46	225	50	3.8	97.6	242	206	0.37
095	302	47.00	AV	19.65	48	232	48	3.9	98.3	248	209	0.38
270	175	48.00	AV	18.92	44	223	47	3.6	93.5	220	175	0.37
7	160	48.98	AV	17.96	39	212	50	3.2	92.2	200	158	0.35
	132	50.00	AV	16.28	35	192	47	2.9	92.6	168	125	0.55
648	86	51.00	AV	20.97	52	248	58	4.2	93.3	217	159	0.52
738	90	52.00	AV	20.59	50	243	57	4.1	92.2	214	157	0.44

ile: BDH 98-2 Proj: CLE ELUM DAM Pg2
ifo: 6-5/8", CLOSED END

…T#	bl/ft	depth ft	TY	CSX ksi	ETR %	FMX kips	SFT kips	EMX K-ft	BPM bl/min	RTL kips	CFB kips	DMX inch
[illegible]	91	53.00	AV	19.79	47	234	54	3.9	92.0	208	154	0.42
41	112	54.00	AV	19.39	46	229	56	3.8	92.1	209	152	0.40
58	117	55.00	AV	19.68	45	232	55	3.7	92.3	202	147	0.42
31	173	56.00	AV	19.93	46	235	55	3.8	92.3	202	153	0.41
58	227	57.00	AV	20.55	48	243	57	3.9	92.6	209	161	0.41
83	225	58.00	AV	20.29	47	239	56	3.9	92.4	208	161	0.40
70	187	59.00	AV	20.40	48	241	59	3.9	92.8	219	161	0.40
89	119	60.00	AV	19.12	43	226	50	3.5	93.8	194	147	0.41
80	91	61.00	AV	21.47	53	253	53	4.3	93.7	210	157	0.47
07	127	62.00	AV	20.99	50	248	54	4.1	93.8	212	159	0.44
91	184	63.00	AV	20.18	48	238	58	3.9	92.6	210	155	0.42
05	114	64.00	AV	19.16	44	226	47	3.6	92.3	202	155	0.42
37	132	65.00	AV	19.60	46	231	47	3.8	92.5	208	161	0.43
96	159	66.00	AV	19.89	47	235	50	3.9	92.8	216	166	0.43
36	140	67.00	AV	18.67	43	220	49	3.6	92.4	200	151	0.42
37	101	68.00	AV	18.64	44	220	46	3.6	92.4	198	153	0.44
39	103	68.99	AV	18.64	45	220	45	3.7	92.4	203	158	0.44
20	80	70.00	AV	18.25	43	215	40	3.5	90.7	190	150	0.67
12	92	71.00	AV	20.20	51	238	42	4.1	92.2	220	178	0.90
13	101	72.00	AV	19.45	47	230	43	3.9	92.3	209	166	0.75
01	88	73.00	AV	19.20	46	227	47	3.8	92.3	205	158	0.48
14	113	74.00	AV	19.30	47	228	49	3.8	92.3	209	161	0.47
50	136	75.00	AV	19.35	46	228	51	3.8	92.3	211	160	0.50
01	151	76.00	AV	20.14	50	238	57	4.1	92.4	223	166	0.53
[illegible]	100	77.00	AV	20.54	51	242	58	4.2	92.5	227	169	0.61
	113	78.00	AV	20.28	50	239	57	4.1	92.5	223	166	0.74
[illegible]	168	79.00	AV	19.21	48	227	57	3.9	92.4	214	167	0.48
04	322	80.00	AV	18.55	46	219	47	3.8	92.4	211	179	0.46
77	473	81.00	AV	19.32	48	228	48	3.9	92.4	223	190	0.45
99	522	82.00	AV	19.07	48	225	44	3.9	92.4	231	192	0.44
11	512	83.00	AV	18.70	46	221	49	3.8	92.5	223	186	0.43
77	766	84.00	AV	17.81	45	210	48	3.7	93.1	219	187	0.43
33	556	85.00	AV	18.38	48	217	47	4.0	92.6	229	193	0.45
13	380	86.00	AV	18.11	47	214	43	3.9	92.6	226	186	0.45
15	302	87.00	AV	17.31	44	204	45	3.6	92.7	219	174	0.43
75	260	88.00	AV	17.11	43	202	50	3.6	92.7	219	169	0.42
86	211	89.00	AV	16.28	40	192	49	3.3	92.8	208	160	0.41
60	190	89.92	AV	17.86	42	211	61	3.4	90.7	201	140	0.42
34	158	91.00	AV	18.84	45	222	70	3.7	92.5	213	143	0.42
74	140	92.00	AV	19.26	47	227	69	3.8	92.7	217	148	0.44
04	230	93.00	AV	19.48	49	230	63	4.0	92.7	217	154	0.47
21	117	94.00	AV	19.27	49	228	60	4.0	92.6	215	155	0.48
65	144	95.00	AV	19.10	48	226	60	3.9	92.6	214	154	0.48
16	151	96.00	AV	19.12	47	226	62	3.9	92.7	218	156	0.53
80	164	97.00	AV	19.07	47	225	59	3.9	92.7	217	157	0.47
47	167	98.00	AV	19.16	47	226	56	3.9	92.7	217	160	0.47
26	179	99.00	AV	18.65	45	220	55	3.7	92.8	208	154	0.62
77	251	100.00	AV	19.22	49	227	50	4.0	92.0	214	165	0.60
43	366	101.00	AV	18.49	47	218	56	3.8	92.6	212	171	0.47
[illegible]	504	102.00	AV	18.50	48	218	56	3.9	92.7	216	186	0.48
	480	103.00	AV	18.24	47	215	54	3.9	92.7	213	186	0.47
[illegible]	349	104.00	AV	17.49	44	206	54	3.6	92.7	205	168	0.45
12	236	105.00	AV	16.83	42	199	54	3.4	92.9	197	151	0.44

le: BDH 98-2 Proj: CLE ELUM DAM Pg3
fo: 6-5/8", CLOSED END

-# bl/ft	depth ft	TY	CSX ksi	ETR %	FMX kips	SFT kips	EMX K-ft	BPM bl/min	RTL kips	CFB kips	DMX inch
-- 219	106.00	AV	17.25	43	204	58	3.5	92.8	202	152	0.45
11 380	107.00	AV	16.83	41	199	61	3.4	92.7	200	161	0.43
11 800	108.00	AV	16.65	42	197	62	3.5	92.8	205	178	0.44
361035	108.70	AV	16.66	44	197	63	3.6	92.8	206	182	0.44

COMMENTS
0 STOP AT 19 FT, ADD ROD, DRIVE.
7 HAMMER NOT FIREING
3 STOP AT 19 FT, ADD ROD, DRIVE.
8 BLOWER ON NOW
8 STOP AT 39 FT, ADD ROD, DRIVE.
8 JC = 0.30
0 STOP AT 49 FT, ADD ROD, DRIVE.
0 MISSED FIRST 64 BLOWS, PDA CABLE NOT CONNECTED.
0 STOP AT 59 FT, ADD ROD, DRIVE.
0 DATA FROM 69 TO 79 FT BASED ON DATA REPLAY.
0 STOP AT 69 FT, ADD ROD, DRIVE.
2 STOP AT 79 FT, ADD ROD, DRIVE.
39 ADJUST THROTTLE
02 LATE ON 85
86 STOP AT 89 FT, ADD ROD, DRIVE.
09 STOP LOOSE CABLE CONNECTION.
26 STOP AT 99 FT, ADD ROD, DRIVE.
STOP AT 108.7 FT 16-NOV-98.

IVE TIME SUMMARY (16-Nov-98 : 982.MDF)

	Blows		Start		Stop		DRIVE minutes	WAIT
I	2 -> 150,	START	8:14:38	->	8:16:13	STOP,	1.58	
								13.63
I	151 -> 293,	START	8:29:51	->	8:32:54	STOP,	3.05	
								11.58
I	294 -> 778,	START	8:44:29	->	8:49:30	STOP,	5.02	
								14.67
I	779 -> 443[illegible],	START	9:04:10	->	9:43:05	STOP,	38.92	
								5.95
I	4462 -> 5870,	START	9:49:02	->	10:09:53	STOP,	20.85	
								8.72
I	5871 -> 7140,	START	10:18:36	->	10:32:19	STOP,	13.72	
								10.82
I	7141 -> 8282,	START	10:43:08	->	10:56:06	STOP,	12.97	
								9.27
I	8283 -> 12586,	START	11:05:22	->	11:59:04	STOP,	53.70	
								10.57
I	12587 -> 14226,	START	12:09:38	->	12:31:27	STOP,	21.82	
								12.83
I	14227 -> 18536,	START	12:44:17	->	13:36:36	STOP,	52.32	

Total Elapsed time 321.97 minutes Total Time 223.93 minutes 98.03

Pile: BDH 98-2
nfo: 6-5/8", CLOSED END
R: 11.8 in^2
F· 152.0 ft

Proj: CLE ELUM DAM
SP: 0.492 k/ft^3
WS: 16810 ft/s
EM: 30000 KSI

.: Max Measured C-Stress
TR: Energy Transfer Ratio
MX: Max Measured Force
FT: Shaft Friction Total
MX: Max Transferred Energy

BPM: Blows Per Minute
RTL: Total Capacity (J=0)
CFB: Computed Toe Force
DMX: Max Meas'd Displacement

L# nd	bl/ft	depth ft	TY	CSX ksi	ETR %	FMX kips	SFT kips	EMX kips-ft	BPM bl/min	RTL kips	CFB kips	DMX inch
6	295	122.00	AV	14.83	34	175	37	2.8	82.8	160	147	0.42
01	295	123.00	AV	17.66	47	208	39	3.9	91.4	182	161	0.52
64	363	124.00	AV	17.41	46	205	42	3.8	91.5	191	159	0.50
22	258	125.00	AV	18.20	50	215	42	4.1	91.6	204	162	0.51
81	159	126.00	AV	17.36	46	205	45	3.8	91.9	195	150	0.49
06	125	127.00	AV	17.39	44	205	51	3.6	91.0	193	142	0.48
22	116	128.00	AV	18.53	51	219	48	4.2	91.8	203	156	0.52
11	189	129.00	AV	17.41	48	205	51	3.9	92.0	194	143	0.51
12	201	130.00	AV	19.77	49	233	49	4.0	91.1	232	183	0.54
52	240	131.00	AV	19.13	48	226	49	3.9	91.8	224	175	0.53
06	254	132.00	AV	18.36	47	217	51	3.8	91.8	216	166	0.53
24	218	133.00	AV	18.18	45	215	48	3.7	91.8	218	169	0.52
19	95	134.00	AV	18.82	49	222	49	4.0	91.8	226	177	0.54
85	166	135.00	AV	18.72	47	221	43	3.9	92.0	221	178	0.56
66	81	136.00	AV	18.76	45	221	45	3.7	92.0	218	173	0.53
53	87	137.00	AV	19.11	48	226	58	3.9	92.0	227	169	0.52
	57	138.00	AV	19.29	49	228	74	4.0	92.0	238	164	0.52
	77	139.00	AV	19.66	50	232	87	4.1	92.0	249	163	0.52
65	78	140.00	AV	17.90	46	211	90	3.8	92.0	259	169	0.52
49	184	141.00	AV	18.06	47	213	107	3.8	91.9	290	183	0.53
98	1686	141.80	AV	17.65	46	208	122	3.8	91.9	299	178	0.53

L#	COMMENTS
6	BEGIN 17-NOV-98 AT 13:23 AFTER DRILLING WITH OPEN BIT TO 122 FT.
81	Stop to fuel hammer.
11	Stop at 129 ft, add rod, drive.
87	Stop at 139 ft, add rod, drive.
98	Terminate BDH 98-2 at 141.8 ft, 17-NOV-98 at 14:35.

RIVE TIME SUMMARY (17-Nov-98 : 982JAY.MDF)	DRIVE minutes	WAIT
N 6 -> 1081, START 13:23:24 -> 13:35:09 STOP,	11.75	
		5.85
N 1091 -> 1511, START 13:41:00 -> 13:45:35 STOP,	4.58	
		8.15
N 1512 -> 2987, START 13:53:44 -> 14:09:54 STOP,	16.17	
		6.55
N 2988 -> 4598, START 14:16:27 -> 14:33:59 STOP,	17.53	
Total Elapsed time 70.58 minutes — Total Time	50.03 minutes	20.55

ile: BDH 98-3 | Proj: CLE ELUM DAM | Pg1

nfo: 6-5/8", CLOSED END | SP: 0.492 k/ft^3

: 11.8 in^2 | WS: 16810 ft/s

: 142.0 ft | EM: 30000 KSI

. Max Measured C-Stress | BPM: Blows Per Minute
R: Energy Transfer Ratio | RTL: Total Capacity (J=0)
X: Max Measured Force | CFB: Computed Toe Force
T: Shaft Friction Total | DMX: Max Meas'd Displacement
X: Max Transferred Energy

BL# end	bl/ft	depth ft	TY	CSX ksi	ETR %	FMX kips	SFT kips	EMX K-ft	BPM bl/min	RTL kips	CFB kips	DMX inch
1	90	16.00	AV	15.42	39	182	31	3.2	92.3	138	135	0.37
91	90	17.00	AV	17.39	35	205	34	2.8	91.8	161	142	2.05
210	119	18.00	AV	16.54	31	195	32	2.6	93.3	154	140	0.34
382	172	19.00	AV	17.02	32	201	35	2.6	94.3	177	157	0.29
585	303	20.00	AV	19.74	39	233	43	3.2	100.0	225	194	0.30
958	273	21.00	AV	19.87	41	235	46	3.4	97.4	221	186	0.32
192	234	22.00	AV	19.88	41	235	47	3.4	95.2	216	184	0.32
453	261	23.00	AV	19.82	41	234	55	3.3	95.6	231	180	0.31
552	199	24.00	AV	20.51	44	242	53	3.6	97.3	225	181	0.32
359	207	25.00	AV	20.70	45	244	52	3.7	97.4	227	190	0.33
028	169	26.00	AV	20.45	45	241	46	3.7	95.3	215	180	0.35
170	142	27.00	AV	20.01	45	236	49	3.6	92.9	201	162	0.35
308	138	28.00	AV	20.19	45	238	42	3.7	92.7	196	173	0.35
464	156	29.00	AV	20.24	45	239	41	3.7	92.9	198	182	0.35
524	160	30.00	AV	21.14	47	249	38	3.8	89.6	208	188	0.37
776	152	31.00	AV	20.79	47	245	43	3.9	94.4	216	195	0.37
7	201	32.00	AV	19.90	46	235	42	3.7	92.9	210	187	0.37
	140	33.00	AV	19.31	44	228	44	3.6	92.5	194	163	0.37
242	125	34.00	AV	19.36	44	229	42	3.6	92.4	181	156	0.38
350	108	35.00	AV	19.08	45	225	39	3.7	92.3	171	142	0.40
426	76	36.00	AV	18.51	43	218	39	3.6	92.3	150	114	0.45
491	65	37.00	AV	17.92	43	211	31	3.5	92.3	132	115	0.44
570	79	38.00	AV	18.33	43	216	32	3.5	92.3	147	125	0.42
575	105	39.00	AV	19.08	43	225	48	3.5	92.3	166	132	0.40
305	130	40.00	AV	18.31	47	216	49	3.9	92.4	190	141	0.42
948	143	41.00	AV	18.56	48	219	49	3.9	92.4	193	151	0.42
096	148	42.00	AV	18.46	47	218	51	3.9	92.4	196	154	0.41
251	155	43.00	AV	18.91	49	223	51	4.0	92.8	208	174	0.41
472	221	44.00	AV	19.17	49	226	52	4.0	91.9	214	179	0.41
597	125	45.00	AV	17.92	44	212	50	3.7	92.4	192	145	0.41
719	122	46.00	AV	18.18	45	215	50	3.7	92.4	195	146	0.41
359	140	47.00	AV	18.54	45	219	50	3.7	92.5	197	155	0.41
042	183	48.00	AV	18.75	46	221	49	3.8	92.5	202	176	0.40
362	320	49.00	AV	19.33	48	228	51	3.9	92.7	217	194	0.40
710	348	50.00	AV	18.79	48	222	52	3.9	91.8	204	188	0.43
160	450	51.00	AV	18.60	45	220	52	3.7	92.4	208	182	0.41
430	270	52.00	AV	18.72	46	221	50	3.8	92.4	202	177	0.41
685	255	53.00	AV	18.63	46	220	49	3.8	92.5	197	185	0.43
039	354	54.00	AV	19.03	48	225	52	3.9	92.6	215	193	0.42
305	266	55.00	AV	19.06	48	225	53	3.9	92.7	213	180	0.42
479	174	56.00	AV	18.73	46	221	53	3.8	92.7	203	162	0.42
696	217	57.00	AV	19.24	48	227	55	3.9	91.5	211	177	0.42
	209	58.00	AV	19.34	47	228	57	3.8	92.8	206	165	0.41
[illegible]	125	59.00	AV	18.87	45	223	55	3.7	92.7	199	144	0.41
170	140	60.00	AV	19.28	45	228	57	3.7	92.0	204	147	0.43

File: BDH 98-3 Proj: CLE ELUM DAM Pg2
Info: 6-5/8", CLOSED END

BL#	bl/ft	depth ft	TY	CSX ksi	ETR %	FMX kips	SFT kips	EMX K-ft	BPM bl/min	RTL kips	CFB kips	DMX inch
	174	61.00	AV	20.09	46	237	57	3.8	92.3	214	157	0.43
56	212	62.00	AV	19.12	43	226	50	3.5	92.4	201	162	0.42
31	375	63.00	AV	18.10	42	214	57	3.4	92.8	199	165	0.41
97	266	64.00	AV	19.89	48	235	53	4.0	92.9	214	178	0.44
85	188	65.00	AV	20.69	50	244	53	4.1	93.2	219	174	0.46
86	201	66.00	AV	19.74	47	233	54	3.9	92.8	210	161	0.44
33	147	67.00	AV	19.24	45	227	55	3.7	92.7	204	149	0.43
41	208	68.00	AV	19.33	45	228	56	3.7	92.8	206	165	0.43
01	260	69.00	AV	18.44	43	218	55	3.5	92.7	199	166	0.41
96	395	70.00	AV	19.58	47	231	61	3.8	92.9	209	170	0.44
28	332	71.00	AV	18.73	42	221	56	3.5	92.8	202	152	0.42
17	189	72.00	AV	18.46	42	218	55	3.5	92.8	191	136	0.44
01	184	73.00	AV	17.90	40	211	54	3.3	92.8	177	128	0.43
22	221	74.00	AV	18.43	42	218	55	3.5	92.8	184	147	0.44
34	212	75.00	AV	18.07	41	213	56	3.4	92.7	188	141	0.43
89	255	76.00	AV	17.95	41	212	58	3.4	92.7	188	143	0.42
48	359	77.00	AV	17.71	40	209	58	3.3	92.7	187	149	0.42
62	414	78.00	AV	19.44	46	229	61	3.7	93.0	211	157	0.44
08	246	79.00	AV	19.42	47	229	60	3.8	93.0	208	151	0.44
06	198	80.00	AV	18.68	47	221	53	3.8	92.1	194	147	0.48
31	325	81.00	AV	17.53	41	207	56	3.4	92.6	189	148	0.43
80	349	82.00	AV	17.72	40	209	62	3.3	92.6	197	140	0.41
83	303	83.00	AV	18.61	42	220	67	3.4	92.8	207	141	0.39
20	237	84.00	AV	18.80	42	222	65	3.5	92.8	208	143	0.40
05	185	85.00	AV	18.64	41	220	61	3.4	92.8	206	145	0.77
	198	86.00	AV	19.07	43	225	58	3.6	92.8	211	154	0.43
	183	87.00	AV	19.53	46	231	57	3.8	92.9	218	161	0.44
82	196	88.00	AV	19.49	47	230	50	3.9	92.9	215	165	0.46
47	165	89.00	AV	18.90	45	223	54	3.7	92.9	206	152	0.46
03	156	90.00	AV	18.35	47	217	56	3.9	92.7	201	146	0.48
43	440	91.00	AV	17.14	41	202	54	3.4	92.7	200	152	0.44
58	425	92.00	AV	17.82	40	210	54	3.3	92.8	206	152	0.41
01	233	93.00	AV	18.34	40	217	52	3.3	92.9	195	144	0.42
34	133	94.00	AV	18.33	40	216	53	3.3	93.0	187	134	0.43
46	112	95.00	AV	18.57	42	219	57	3.4	93.0	199	142	0.43
28	82	96.00	AV	19.36	45	228	64	3.7	93.1	212	148	0.44
22	94	97.00	AV	19.30	45	228	74	3.7	93.1	220	146	0.42
34	112	98.00	AV	19.36	46	229	87	3.8	93.0	234	148	0.42
57	123	99.00	AV	19.30	46	228	96	3.8	93.0	244	148	0.42
07	250	100.00	AV	18.23	46	215	100	3.8	92.3	260	160	0.47
17	540	101.00	AV	16.25	41	192	93	3.4	92.5	253	160	0.46
54	517	102.00	AV	16.34	43	193	102	3.6	92.7	260	157	0.47
09	545	103.00	AV	16.94	42	200	113	3.5	92.8	265	152	0.45
35	326	104.00	AV	17.69	43	209	125	3.5	92.7	269	144	0.45
79	344	105.00	AV	17.65	42	208	129	3.5	92.8	272	143	0.44
56	187	106.00	AV	17.78	43	210	127	3.5	92.8	271	144	0.44
04	538	107.00	AV	17.78	42	210	143	3.5	92.8	285	143	0.43
05	601	108.00	AV	18.12	42	214	148	3.5	92.6	294	146	0.43
84	430	108.10	AV	17.19	38	203	146	3.1	92.8	283	137	0.40
9	1	122.00	AV	13.98	30	165	57	2.5	82.9	169	112	0.45
	38	123.00	AV	17.44	45	206	57	3.7	90.8	208	152	0.59
	47	124.00	AV	17.77	46	210	51	3.8	92.3	212	162	0.59
1	77	125.00	AV	18.47	48	218	47	3.9	92.3	219	173	0.56

le: BDH 98-3 Proj: CLE ELUM DAM Pg3

.fo: 6-5/8", CLOSED END

- #	bl/ft	depth ft	TY	CSX ksi	ETR %	FMX kips	SFT kips	EMX K-ft	BPM bl/min	RTL kips	CFB kips	DMX inch
[illegible]	89	126.00	AV	18.76	48	221	43	3.9	92.3	223	180	0.56
·06	106	127.00	AV	18.74	47	221	43	3.9	92.2	224	181	0.54
·71	165	128.00	AV	17.94	44	212	49	3.6	92.0	218	169	0.49
:78	207	129.00	AV	16.90	41	199	51	3.4	92.0	206	154	0.49
:29	151	130.00	AV	18.51	48	218	46	4.0	91.7	241	195	0.52
;53	224	131.00	AV	18.13	48	214	49	3.9	92.2	242	193	0.52
'22	269	132.00	AV	17.80	48	210	55	3.9	92.1	249	193	0.53
'36	114	133.00	AV	17.60	48	208	65	3.9	92.3	251	186	0.52
.64	128	134.00	AV	17.83	49	210	73	4.0	92.3	265	192	0.53
;82	218	135.00	AV	18.07	50	213	81	4.1	92.3	278	197	0.53
'08	526	136.00	AV	17.58	48	207	83	4.0	92.3	284	201	0.53
;99	791	137.00	AV	17.41	47	205	80	3.9	92.3	284	203	0.53
'04	1005	138.00	AV	17.71	49	209	78	4.0	92.4	289	211	0.53
;50	1182	138.80	AV	18.05	47	213	76	3.9	92.4	288	212	0.52

#	COMMENTS
1	Begin PDA monitoring of BDH 98-3 at 16 ft, 08:51 18-NOV-98.
32	DATA MERGE: 983019.Q00
32	Berger
;4	DATA MERGE: 983029.Q00
;4	Berger
75	DATA MERGE: 983039.Q00
75	Berger
	DATA MERGE: 983049.Q00
	Berger
30	DATA MERGE: 983059.Q00
30	Berger
201	DATA MERGE: 983069.Q00
201	Berger
008	DATA MERGE: 983079.Q00
008	Berger
685	a4 connector loose
347	DATA MERGE: 983089.Q00
347	Berger
257	DATA MERGE: 983099.Q00
257	Berger
848	Stop to work on hammer.
548	Stop at 108.1 ft 15:26 18-NOV-98.
548	Drilled open bit to 122 ft, begin closed bit at 122 ft 14:37 19-NOV-98.
278	DATA MERGE: 983129.Q00
278	Berger
278	Stop at 129 ft, add rod, drive.
650	Terminate BDH 98-3 at 138.8 ft, 15:42 19-NOV-98.

E TIME SUMMARY (19-Nov-98 : 983.MDF)						DRIVE (minutes)	WAIT
N	1 ->	18,	START	8:55:49 ->	8:59:53 STOP,	4.07	
							5.57
N	19 ->	382,	START	9:05:27 ->	9:09:39 STOP,	4.20	
							20.67
N	383 ->	2464,	START	9:30:19 ->	9:52:03 STOP,	21.73	
							12.50
N	2465 ->	3675,	START	10:04:33 ->	10:17:58 STOP,	13.42	
							8.58
N	3676 ->	5362,	START	10:26:33 ->	10:44:48 STOP,	18.25	
							18.55
N	5363 ->	8030,	START	11:03:21 ->	11:32:14 STOP,	28.88	
							18.23
N	8031 ->	10201,	START	11:50:28 ->	12:13:54 STOP,	23.43	
							6.77
N	10202 ->	13008,	START	12:20:40 ->	12:50:57 STOP,	30.28	
							13.67
N	13009 ->	15347,	START	13:04:37 ->	13:31:11 STOP,	26.57	
							10.18
N	15348 ->	17257,	START	13:41:22 ->	14:01:56 STOP,	20.57	
							13.02
N	17258 ->	19109,	START	14:14:57 ->	14:34:57 STOP,	20.00	
							14.05
N	19126 ->	20848,	START	14:49:00 ->	15:07:36 STOP,	18.60	
							11.22
	.0856 ->	21548,	START	15:18:49 ->	15:26:17 STOP,	7.47	
							1390.93
N	21549 ->	22278,	START	14:37:14 ->	14:45:10 STOP,	7.93	
							7.15
N	22279 ->	22323,	START	14:52:19 ->	14:52:48 STOP,	0.48	
							0.07
N	22327 ->	22335,	START	14:52:52 ->	14:52:57 STOP,	0.08	
							1.57
N	22339 ->	25716,	START	14:54:31 ->	15:31:10 STOP,	36.65	
							1.05
N	25728 ->	26650,	START	15:32:13 ->	15:42:12 STOP,	9.98	

Total Elapsed time 1846.37 minutes Total Time 292.60 minutes 1553.77

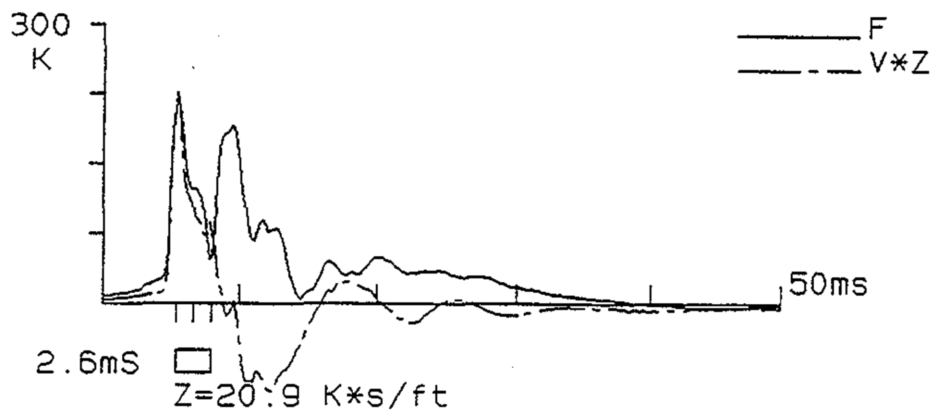
APPENDIX C

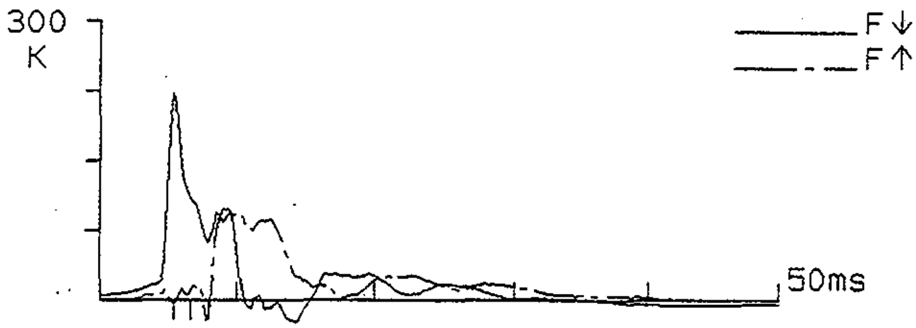
Force and Velocity Measurements

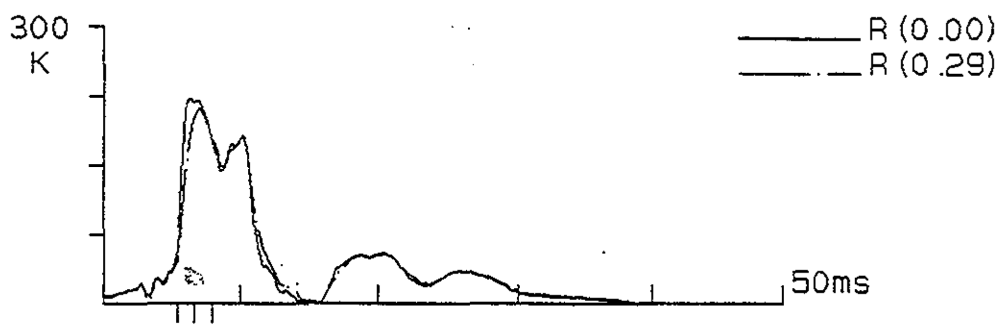
GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM 981B009F 1998-11-14

BN	510/764	
CSX	18.55	Ksi
ETR	35	%
FMX	219	Kips
SFT	47	Kips
BPM	92.0	BPM
EMX	2.90	Kip-ft
ATL	209	Kips
CFB	175	Kips
DMX	0.27	inch
LP	17.00	ft
LE	22.50	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A12	







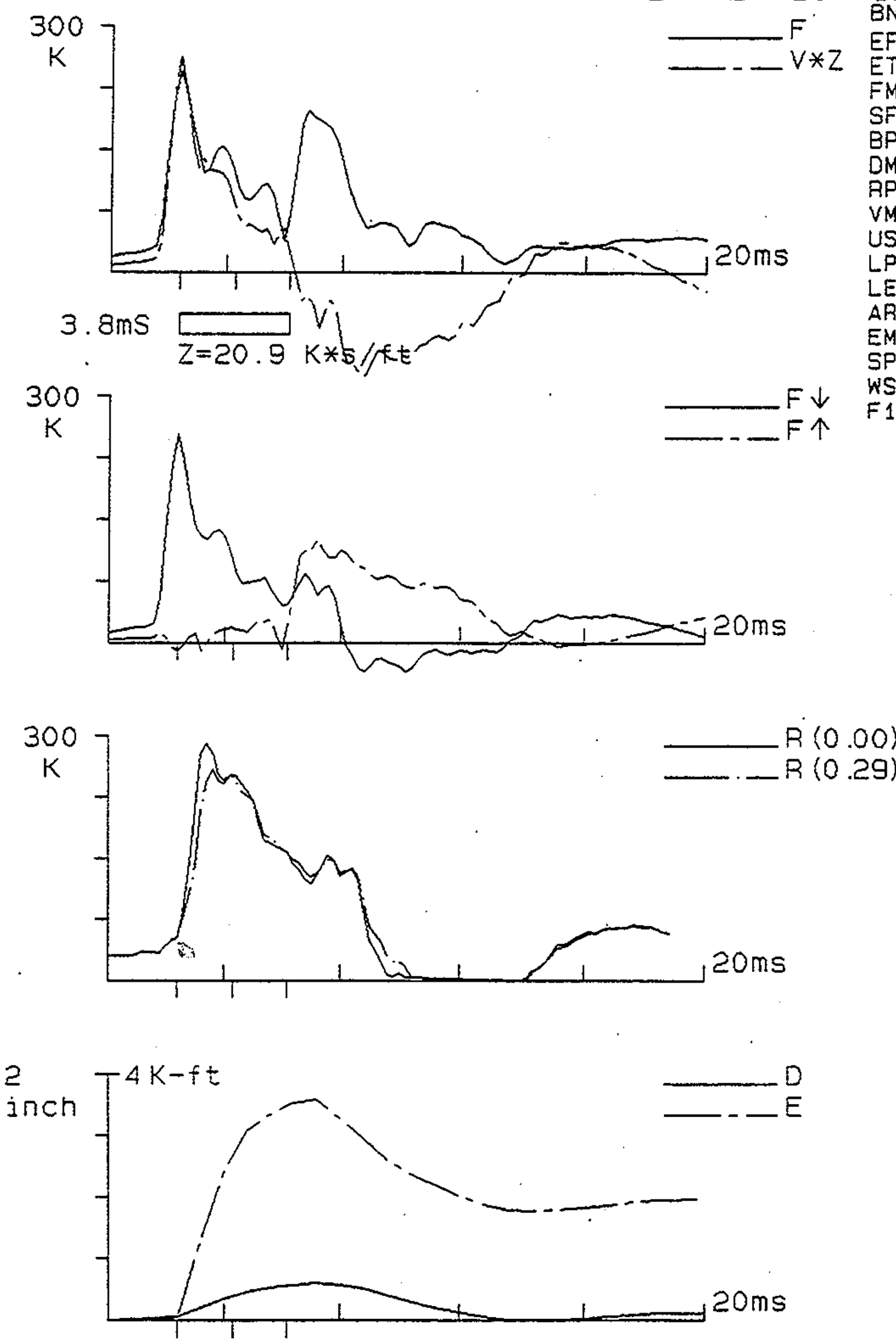
GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM

981B019F 1998-11-14

LAYNE RIG 412, ICE 180C

BN	425/4012
EFV	3.600 Kip-ft
ETR	44 %
FMX	245 Kips
SFT	76 Kips
BPM	92.5 BPM
DMX	0.30 inch
RP3	209 Kips
VMX	12.6 ft/s
USR	0
LP	28.00 ft
LE	32.50 ft
AR	11.80 in2
EM	29810 Ksi
SP	0.489 K/ft3
WS	16808 ft/s
F12	A12

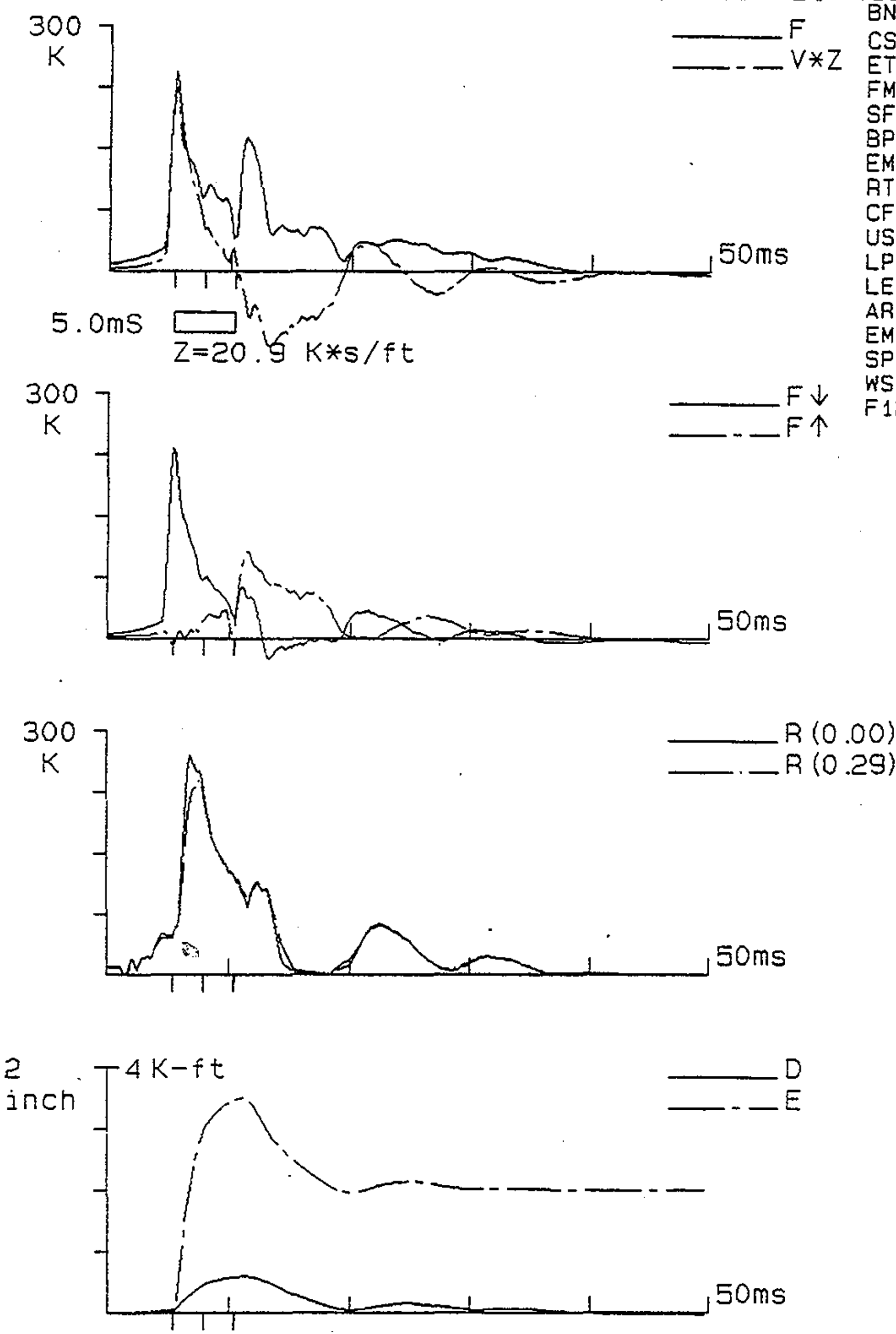


GRL & Associates, Inc. PDI PILE DRIVING ANALYZER®v5.01

CLE ELUM DAM

981B029F 1998-11-14

LAYNE RIG 412, ICE 180C



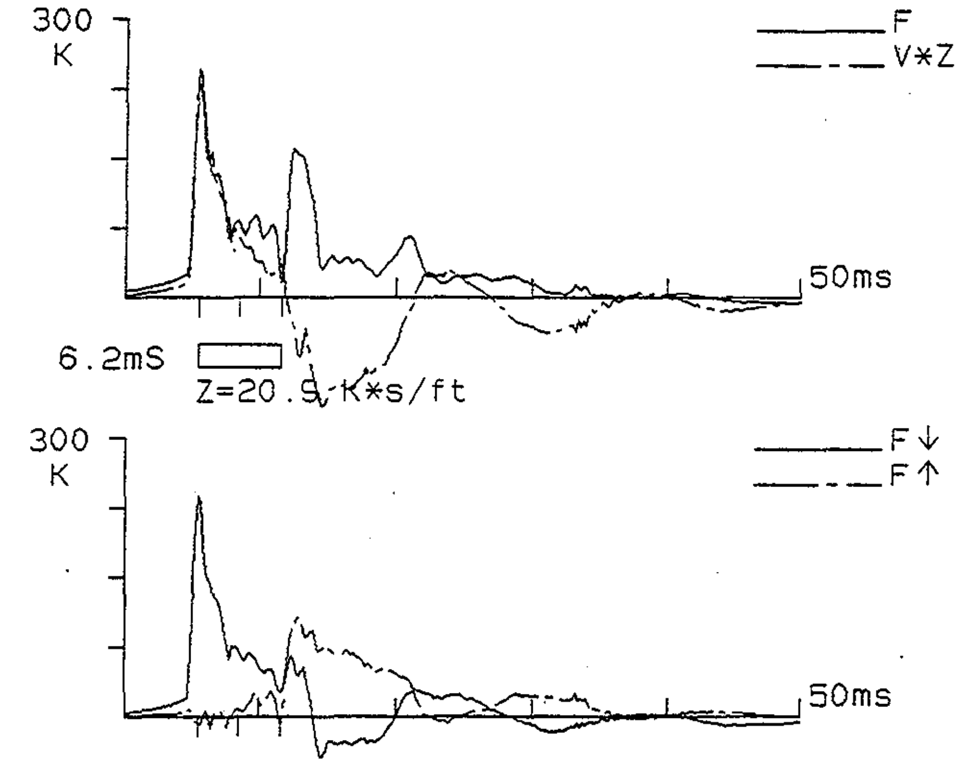
BN	125/1787	
CSX	18.89	Ksi
ETR	43	%
FMX	223	Kips
SFT	91	Kips
BPM	96.0	BPM
EMX	3.50	Kip-ft
RTL	252	Kips
CFB	172	Kips
USR	0	
LP	36.00	ft
LE	42.50	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A12	

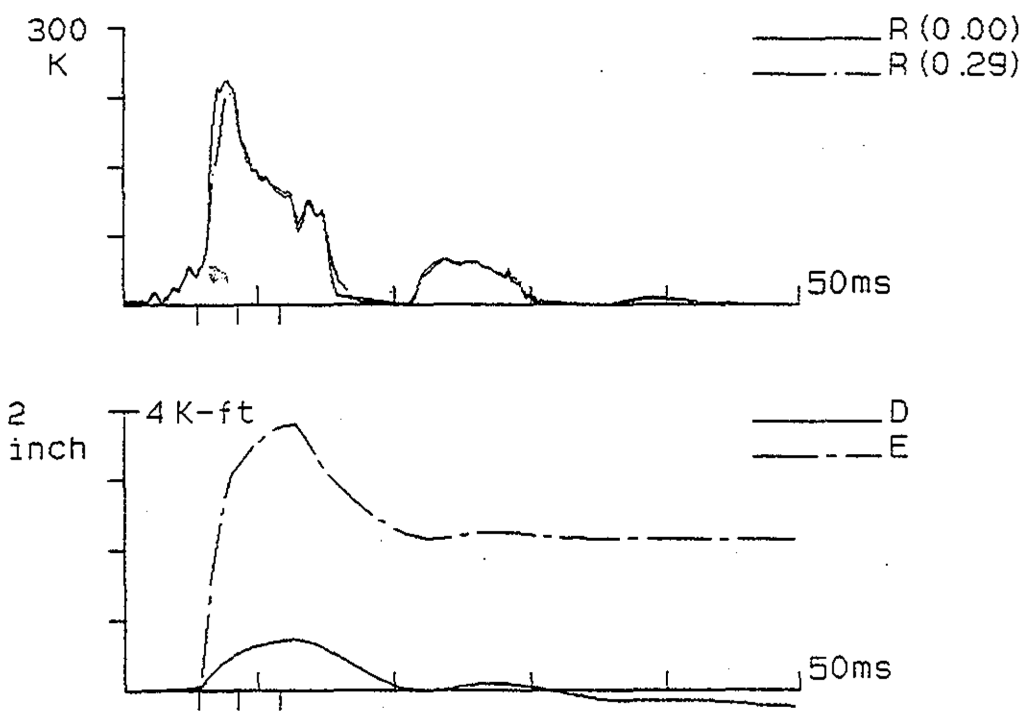
GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM 9818039F 1998-11-14

PDA OP: GRL--B. Miner LAYNE RIG 412, ICE 180C

BN	350/3500	
CSX	19.49	Ksi
ETR	46	%
FMX	230	Kips
SFT	73	Kips
BPM	96.9	BPM
EMX	3.80	Kip-ft
RTL	228	Kips
CFB	170	Kips
DMX	0.37	inch
LP	48.00	ft
LE	52.50	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A12	

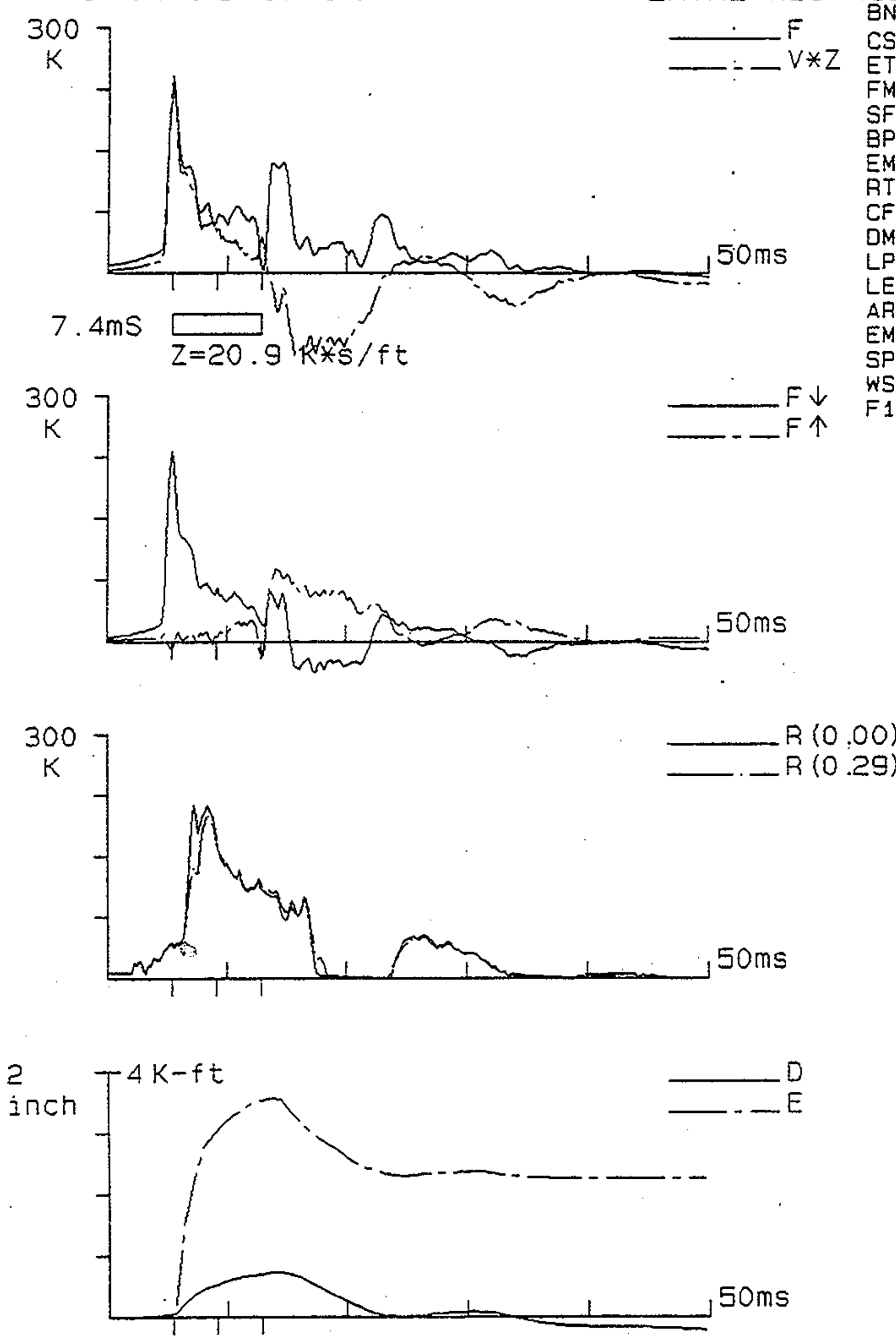




GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM 981B049F 1998-11-14

PDA OP: GRL--B. Miner LAYNE RIG 412, ICE 180C



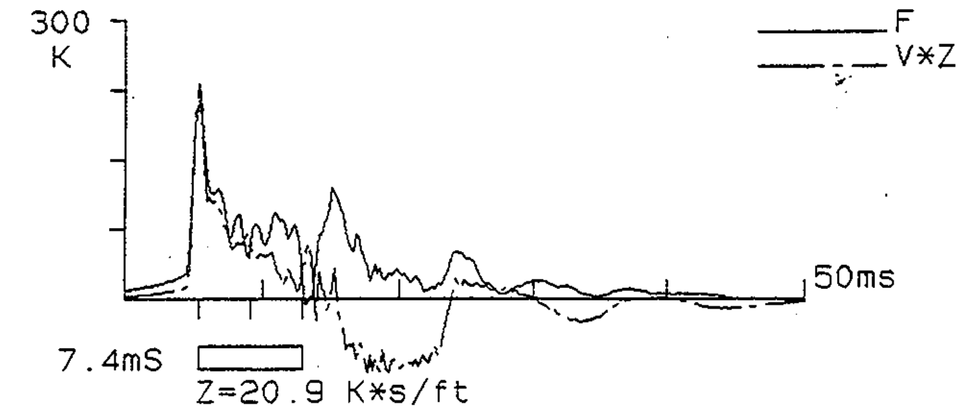
BN 225/1007
CSX 18.98 Ksi
ETR 44 %
FMX 224 Kips
SFT 66 Kips
BPM 92.7 BPM
EMX 3.60 Kip-ft
RTL 213 Kips
CFB 148 Kips
DMX 0.37 inch
LP 51.00 ft
LE 62.50 ft
AR 11.80 in2
EM 29810 Ksi
SP 0.489 K/ft3
WS 16808 ft/s
F12 A12

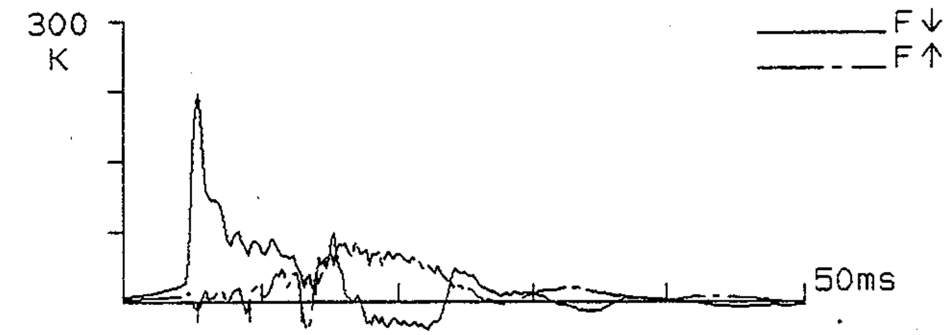
GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

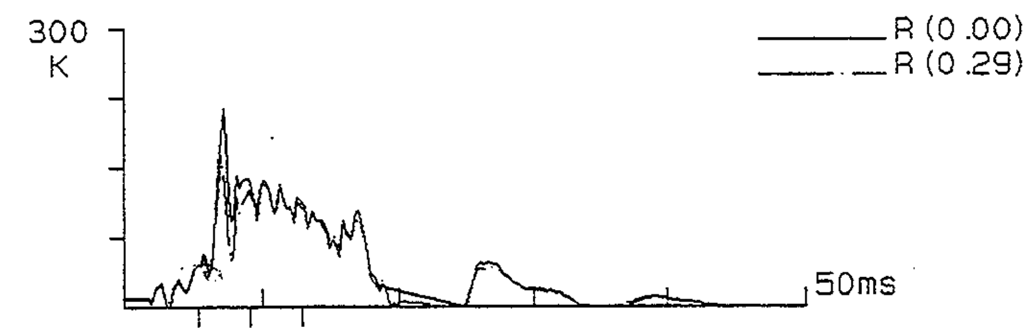
CLE ELUM DAM 981B052F 1998-11-15

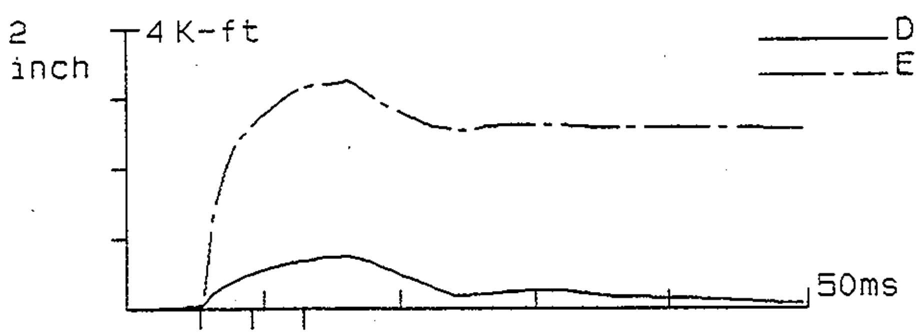
PDA OP: GRL--B. Miner LAYNE RIG 412, ICE 180C

BN	60/708	
CSX	18.13	Ksi
ETR	40	%
FMX	214	Kips
SFT	72	Kips
BPM	91.4	BPM
EMX	3.30	Kip-ft
ATL	215	Kips
CFB	143	Kips
DMX	0.37	inch
LP	57.00	ft
LE	62.50	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A12	





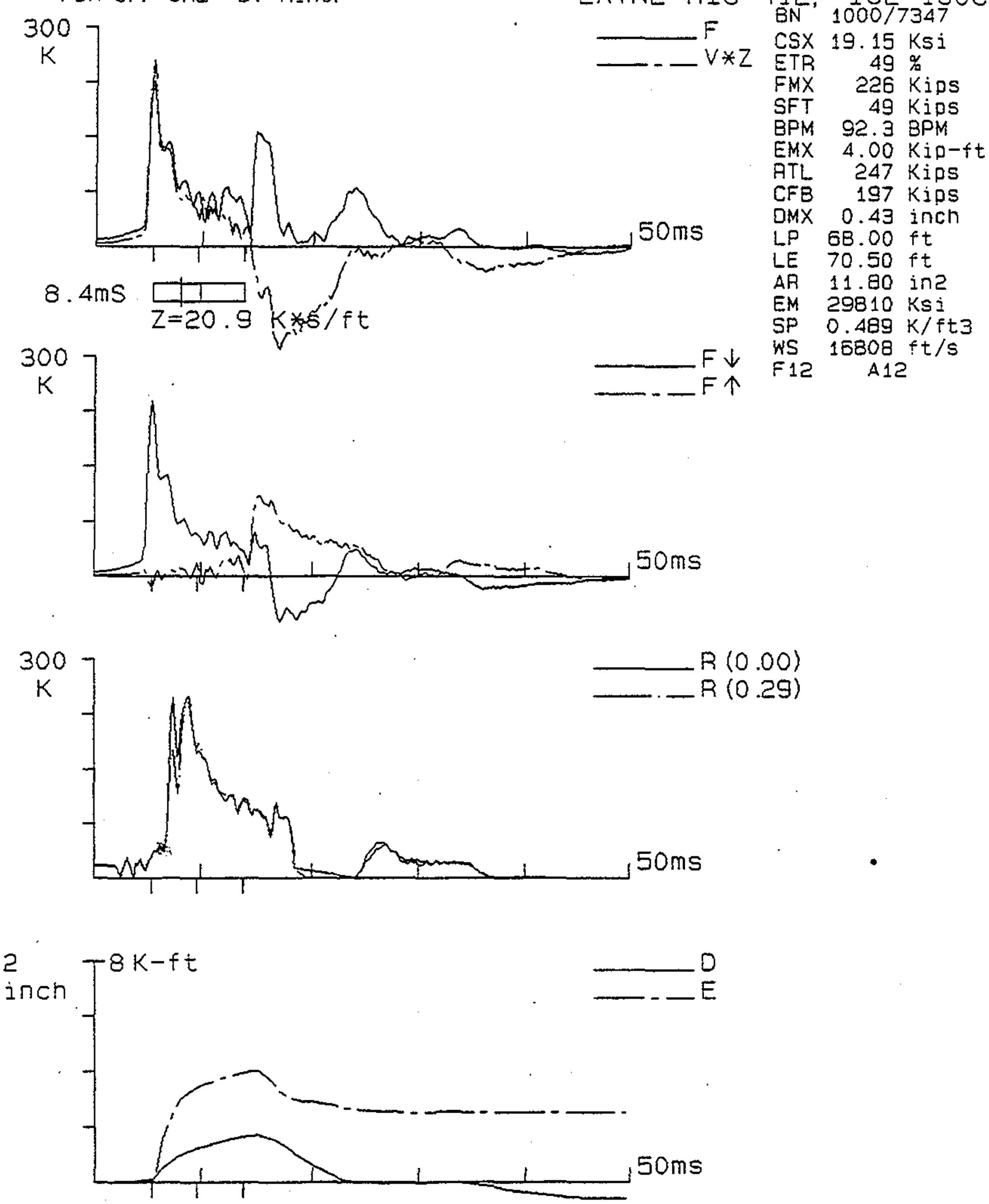




GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM 981B058 1998-11-15

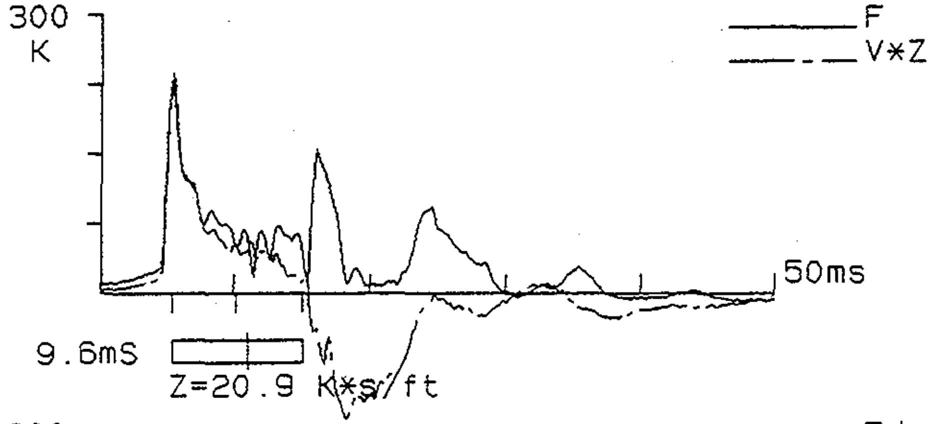
PDA OP: GRL--B. Miner LAYNE RIG 412, ICE 180C



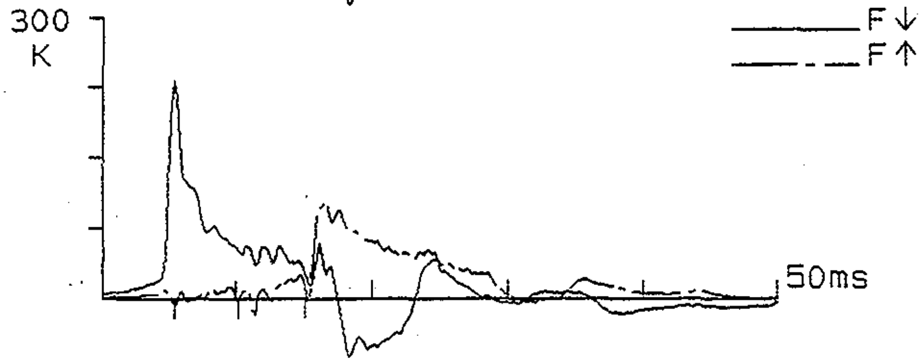
GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

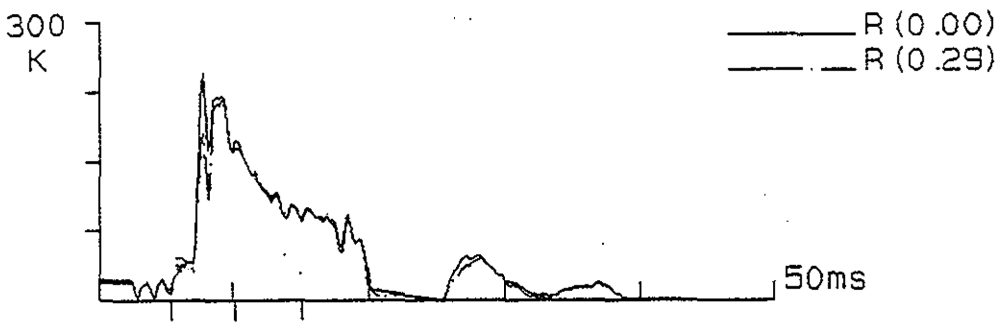
CLE ELUM DAM 981B068F 1998-11-15

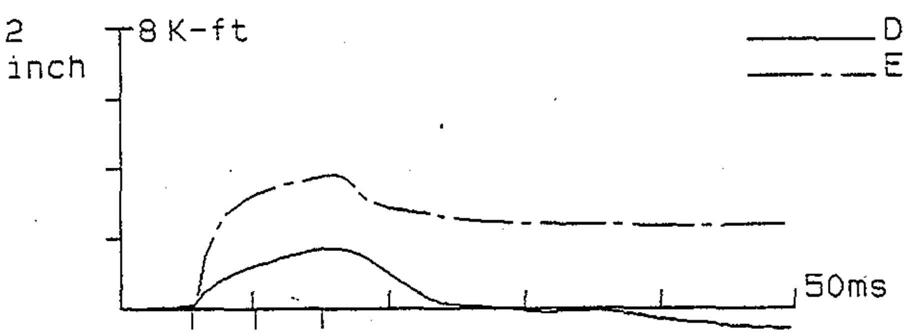
PDA OP: GRL--B. Miner LAYNE RIG 412, ICE 180C



BN	1340/2709
CSX	19.15 Ksi
ETR	46 %
FMX	226 Kips
SFT	45 Kips
BPM	91.8 BPM
EMX	3.80 Kip-ft
RTL	246 Kips
CFB	201 Kips
DMX	0.44 inch
LP	69.00 ft
LE	80.50 ft
AR	11.80 in2
EM	29810 Ksi
SP	0.489 K/ft3
WS	16808 ft/s
F12	A12







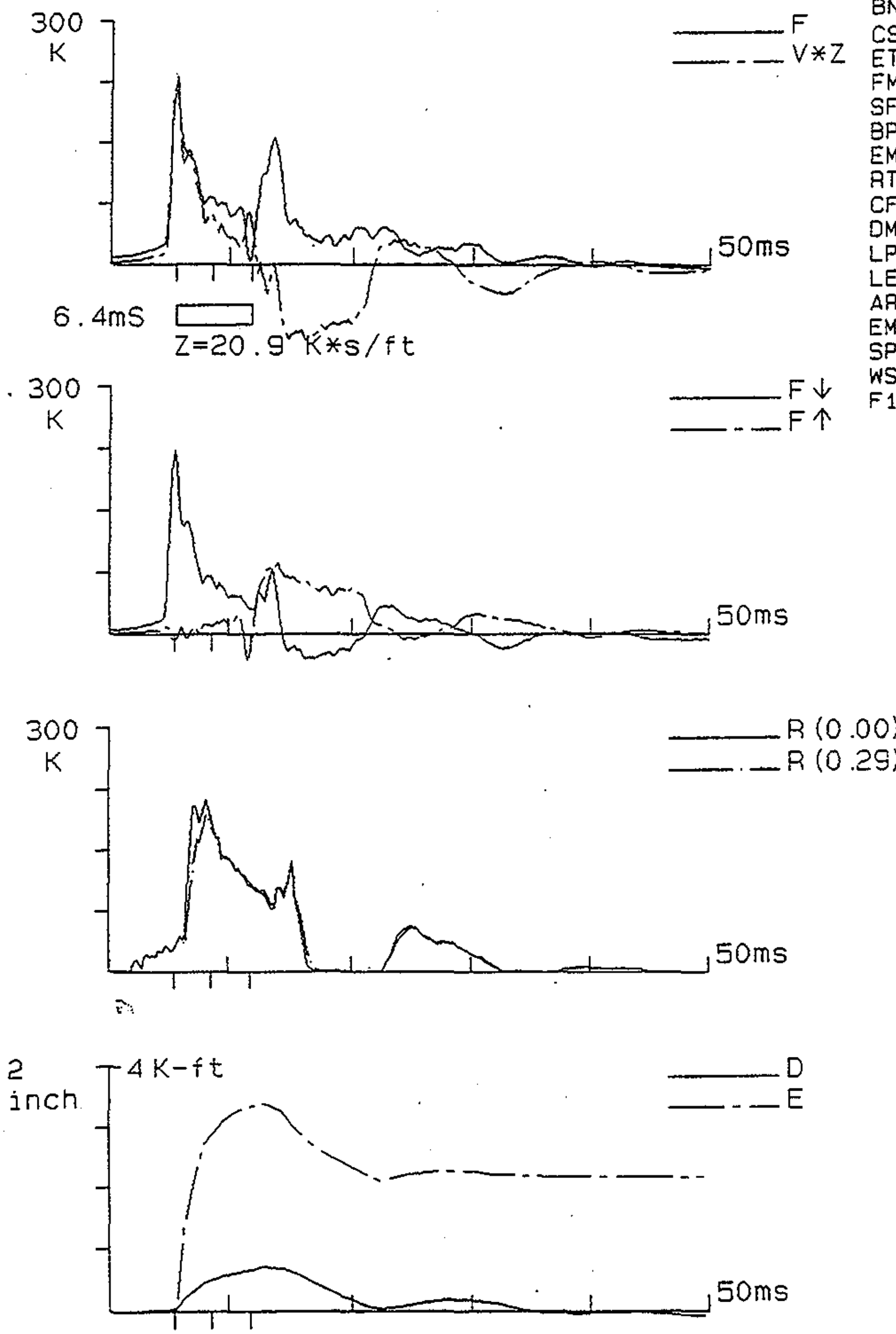
GRL & Associates, Inc. — PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM

982039F 1998-11-16

6-5/8" CLOSED END

BN	80/3551	
CSX	18.30	Ksi
ETR	41	%
FMX	216	Kips
SFT	50	Kips
BPM	92.3	BPM
EMX	3.40	Kip-ft
RTL	205	Kips
CFB	163	Kips
DMX	0.35	inch
LP	48.00	ft
LE	53.00	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A12	



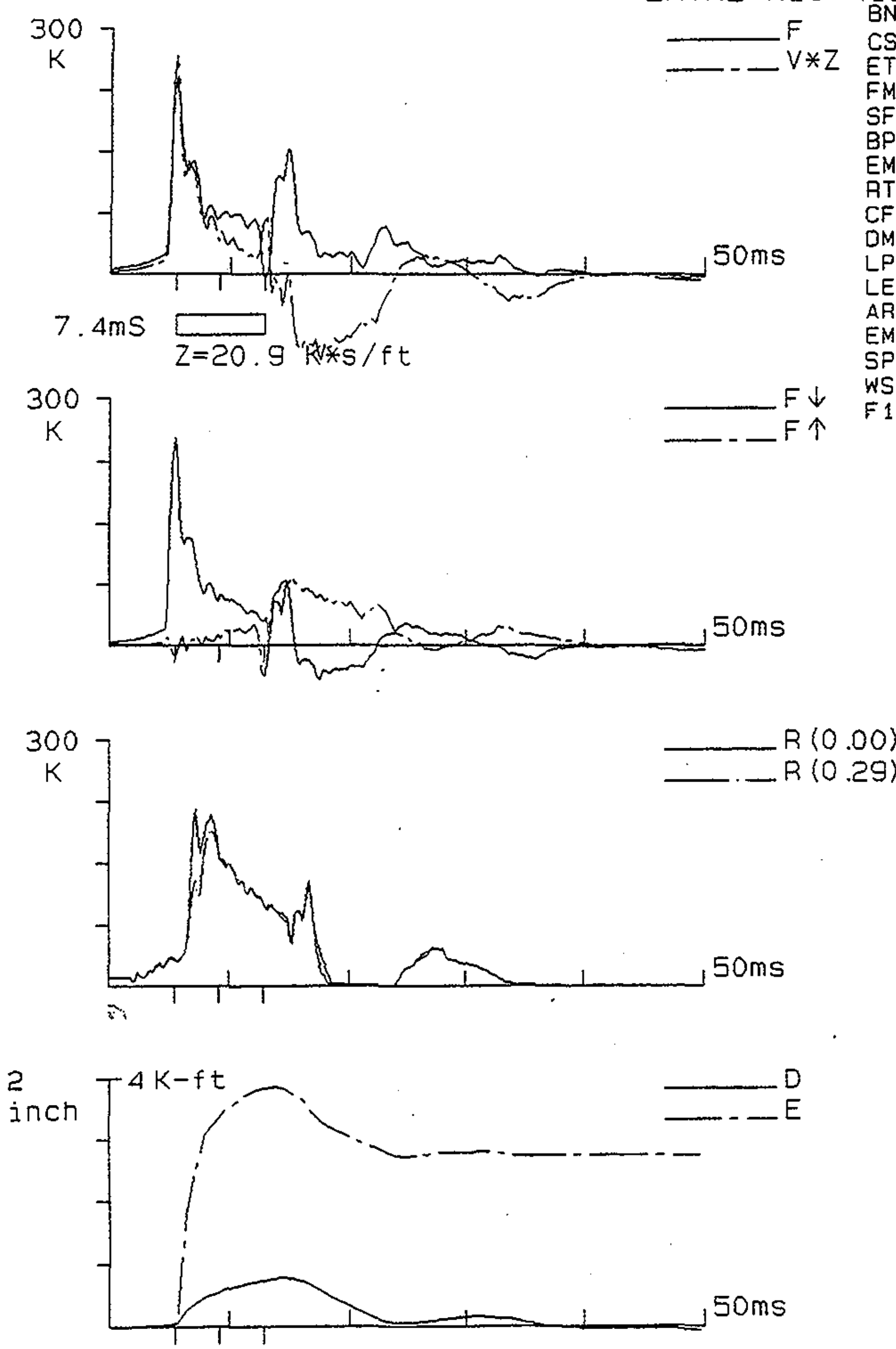
GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM

982049F 1998-11-16

LAYNE RIG 412, ICE 180C

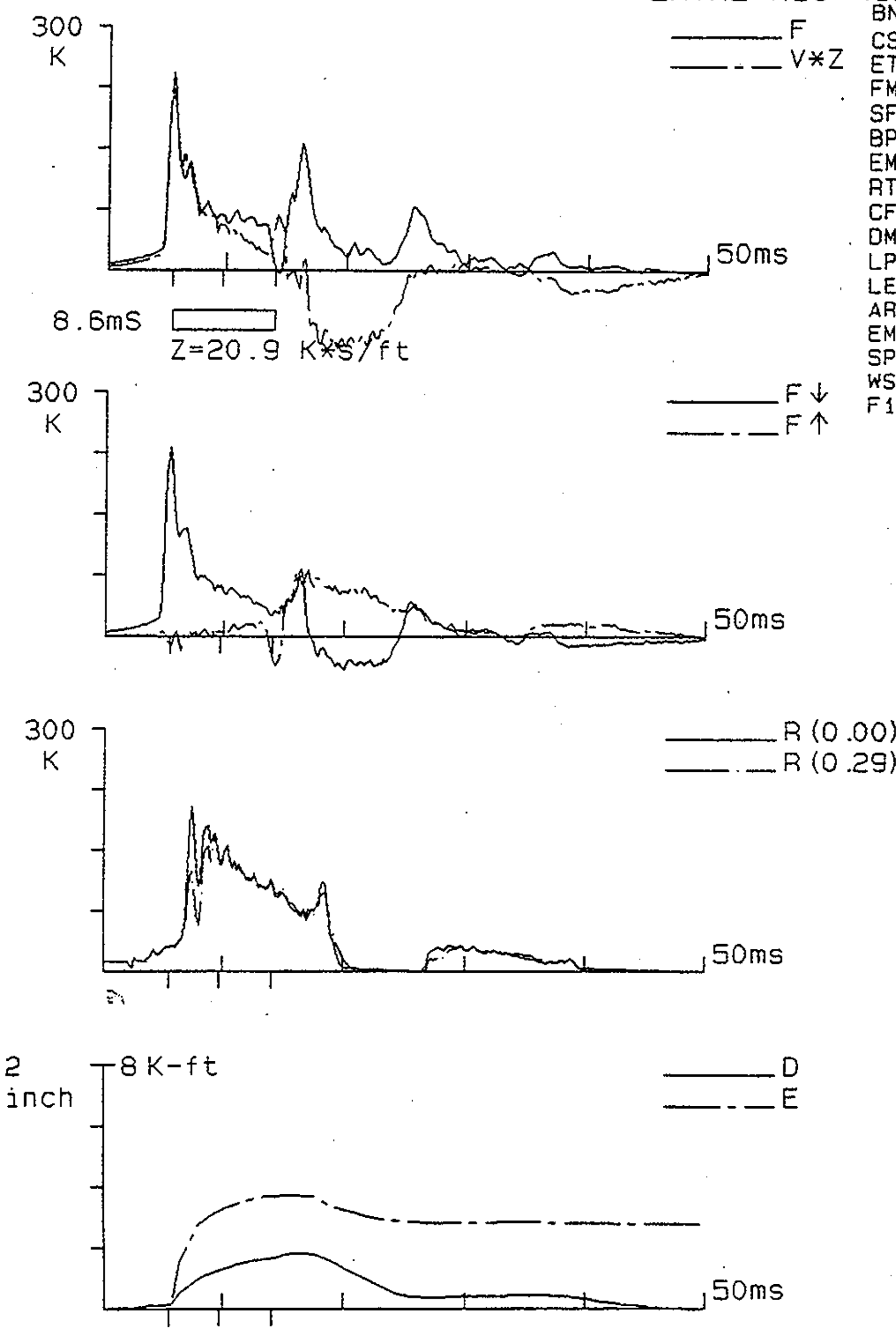
BN	183/1424	
CSX	20.25	Ksi
ETR	48	%
FMX	239	Kips
SFT	62	Kips
BPM	92.5	BPM
EMX	3.90	Kip-ft
RTL	216	Kips
CFB	154	Kips
DMX	0.39	inch
LP	58.00	ft
LE	63.00	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A12	



GRL & Associates, Inc.
CLE ELUM DAM

PDI PILE DRIVING ANALYZER® v5.01
98209F 1998-11-16
LAYNE RIG 412, ICE 180C

BN 93/1251
CSX 18.81 Ksi
ETR 46 %
FMX 222 Kips
SFT 43 Kips
BPM 92.4 BPM
EMX 3.80 Kip-ft
RTL 203 Kips
CFB 161 Kips
DMX 0.46 inch
LP 68.00 ft
LE 73.00 ft
AR 11.80 in2
EM 29810 Ksi
SP 0.489 K/ft3
WS 16808 ft/s
F12 A12



GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

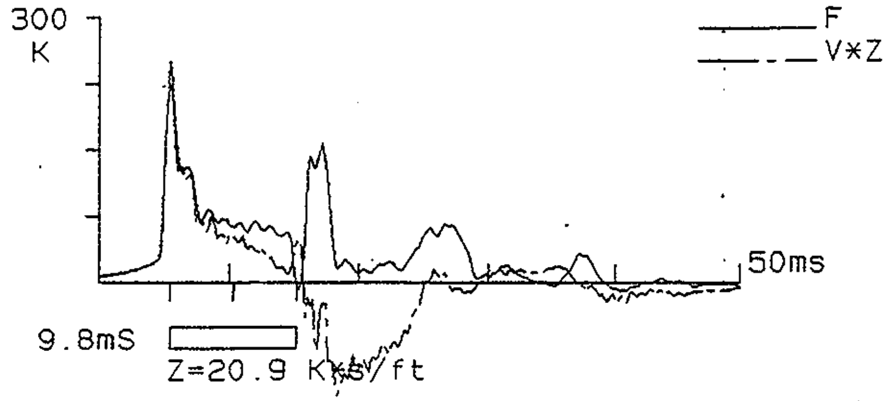
CLE ELUM DAM

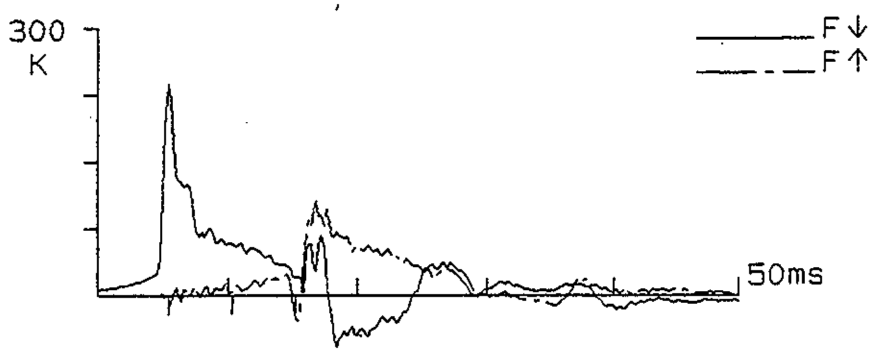
PDA OP: GRL--B. Miner

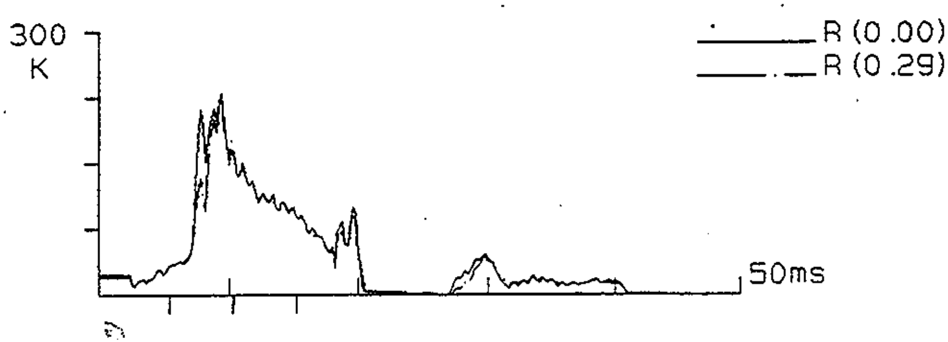
982069F 1998-11-16

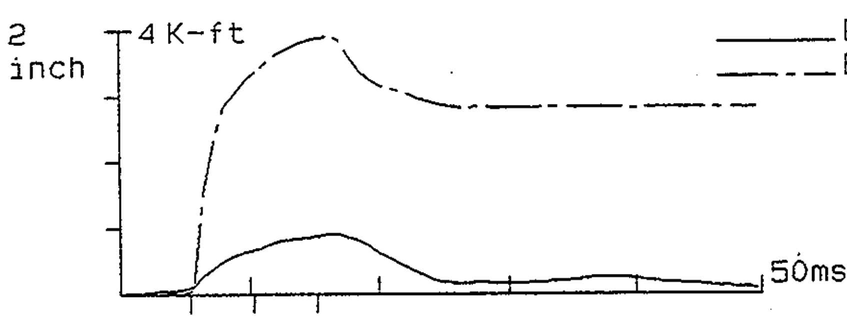
LAYNE RIG 412, ICE 180C

BN	158/1122	
CSX	18.98	Ksi
ETR	48	%
FMX	224	Kips
SFT	58	Kips
BPM	92.4	BPM
EMX	3.90	Kip-ft
RTL	211	Kips
CFB	173	Kips
DMX	0.46	inch
LP	78.00	ft
LE	83.00	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A1	









GRL & Associates, Inc.

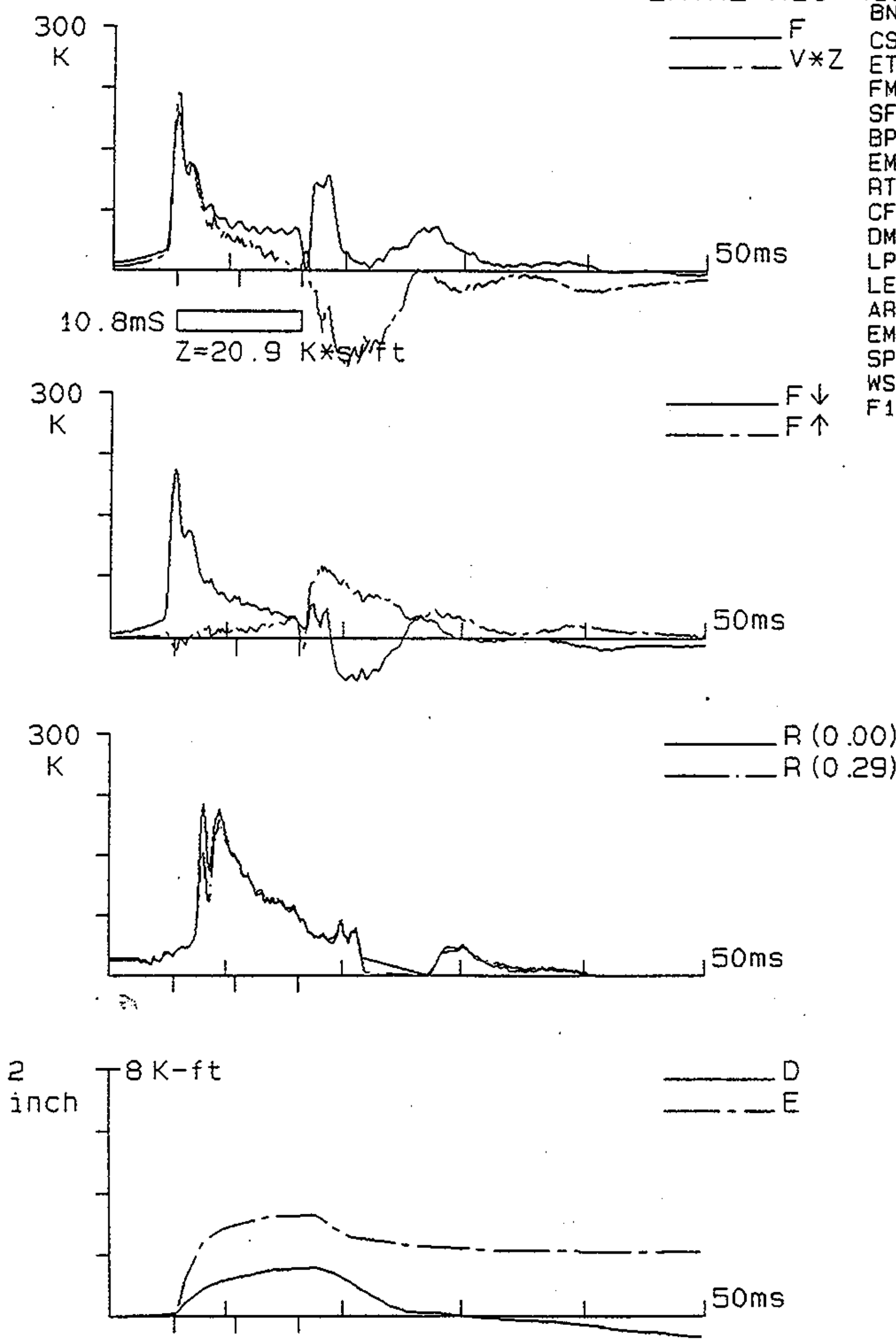
PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM

PDA OP: GRL--B. Miner

982079F 1998-11-16

LAYNE RIG 412, ICE 180C



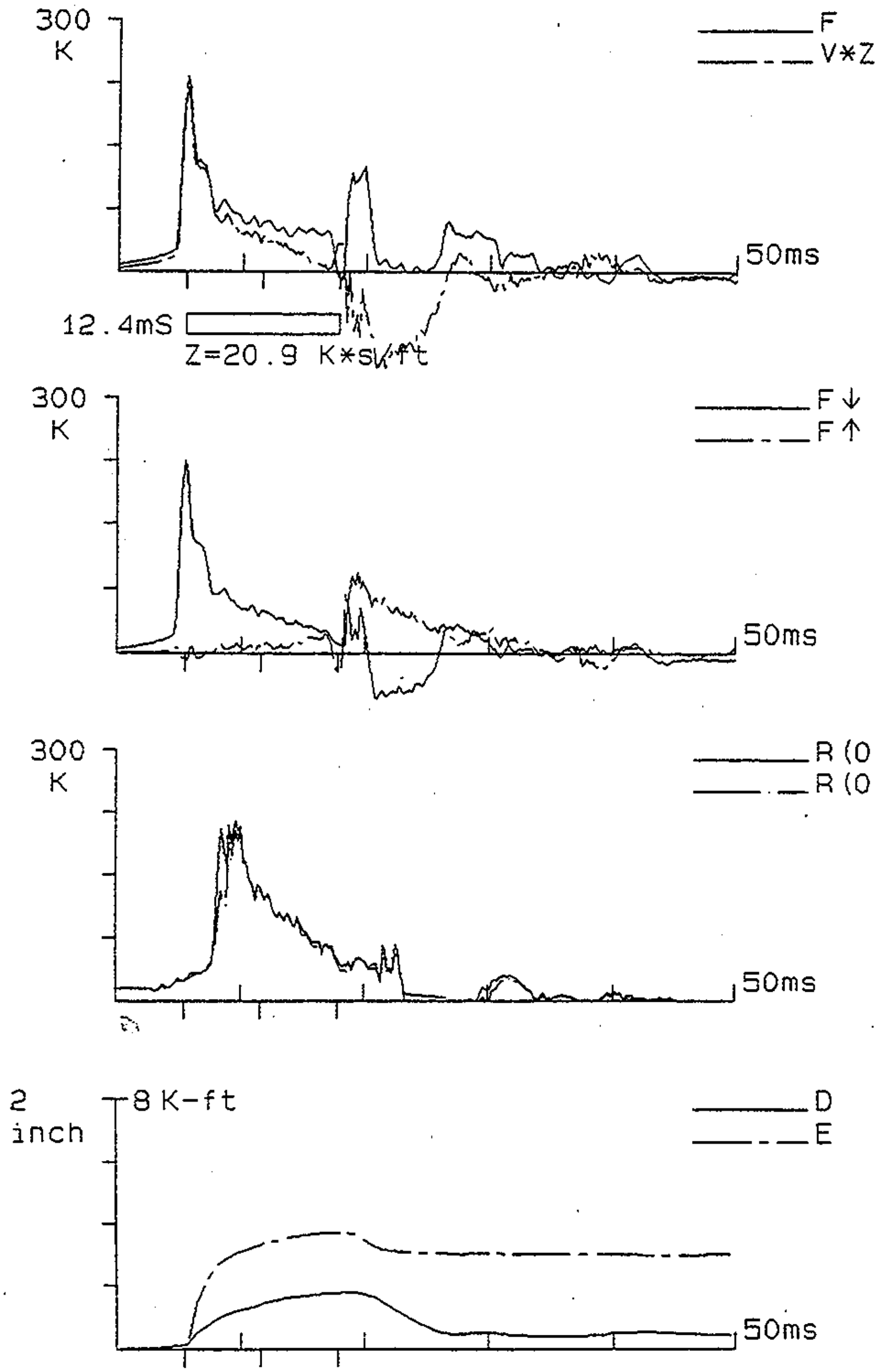
BN	219/4225	
CSX	16.52	Ksi
ETR	40	%
FMX	195	Kips
SFT	51	Kips
BPM	92.8	BPM
EMX	3.30	Kip-ft
RTL	214	Kips
CFB	163	Kips
DMX	0.40	inch
LP	88.00	ft
LE	93.00	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A12	

GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

CLE ELUM DAM 982089F 1998-11-16

PDA OP: GRL--B. Miner LAYNE RIG 412, ICE 180C

BN	156/1557	
CSX	18.64	Ksi
ETR	45	%
FMX	220	Kips
SFT	48	Kips
BPM	92.8	BPM
EMX	3.70	Kip-ft
RTL	205	Kips
CFB	168	Kips
DMX	0.46	inch
LP	98.00	ft
LE	103.00	ft
AR	11.80	in2
EM	29810	Ksi
SP	0.489	K/ft3
WS	16808	ft/s
F12	A12	



GRL & Associates, Inc. PDI PILE DRIVING ANALYZER® v5.01

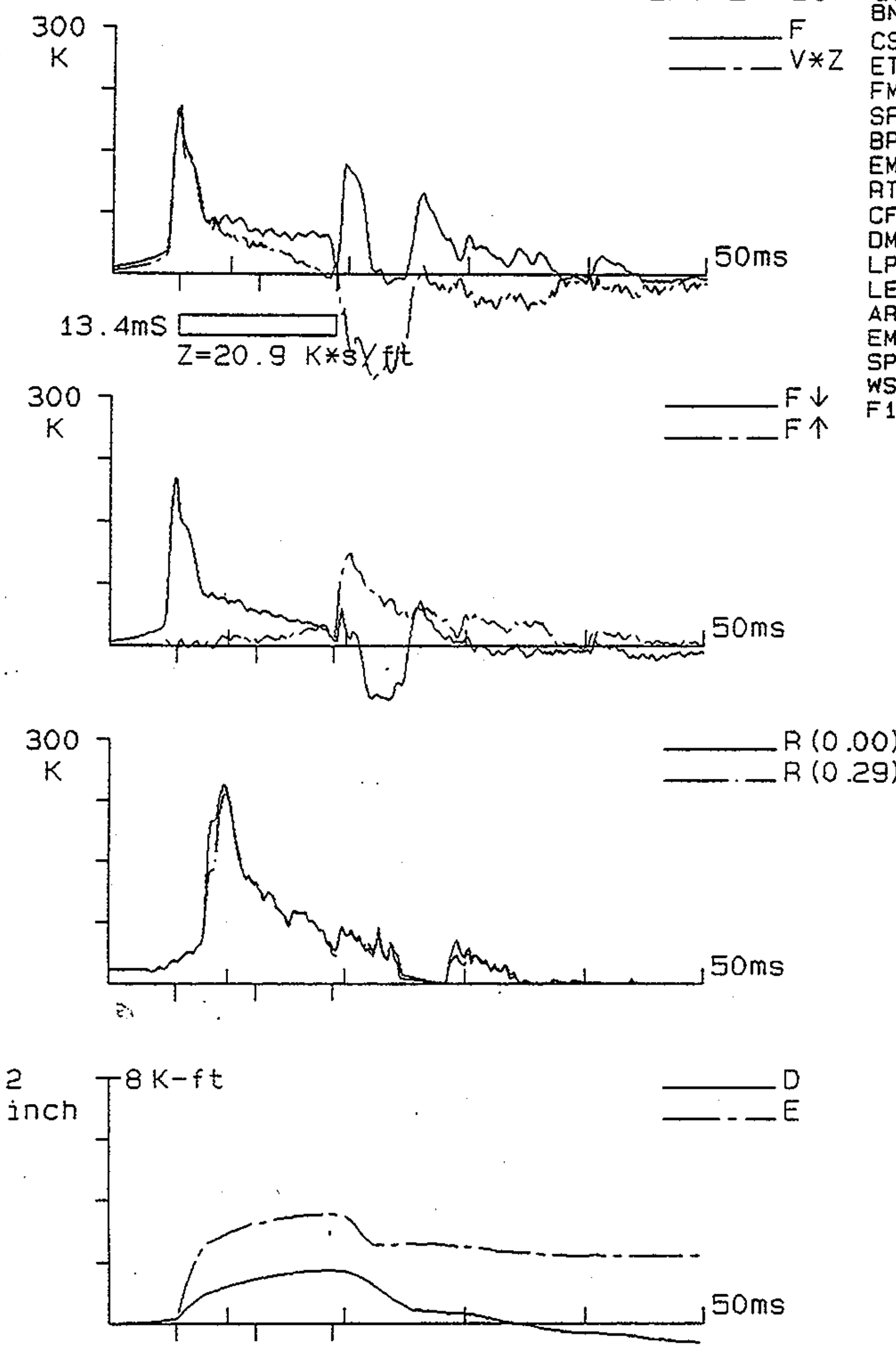
CLE ELUM DAM

PDA OP: GRL--B. Miner

982099F 1998-11-16

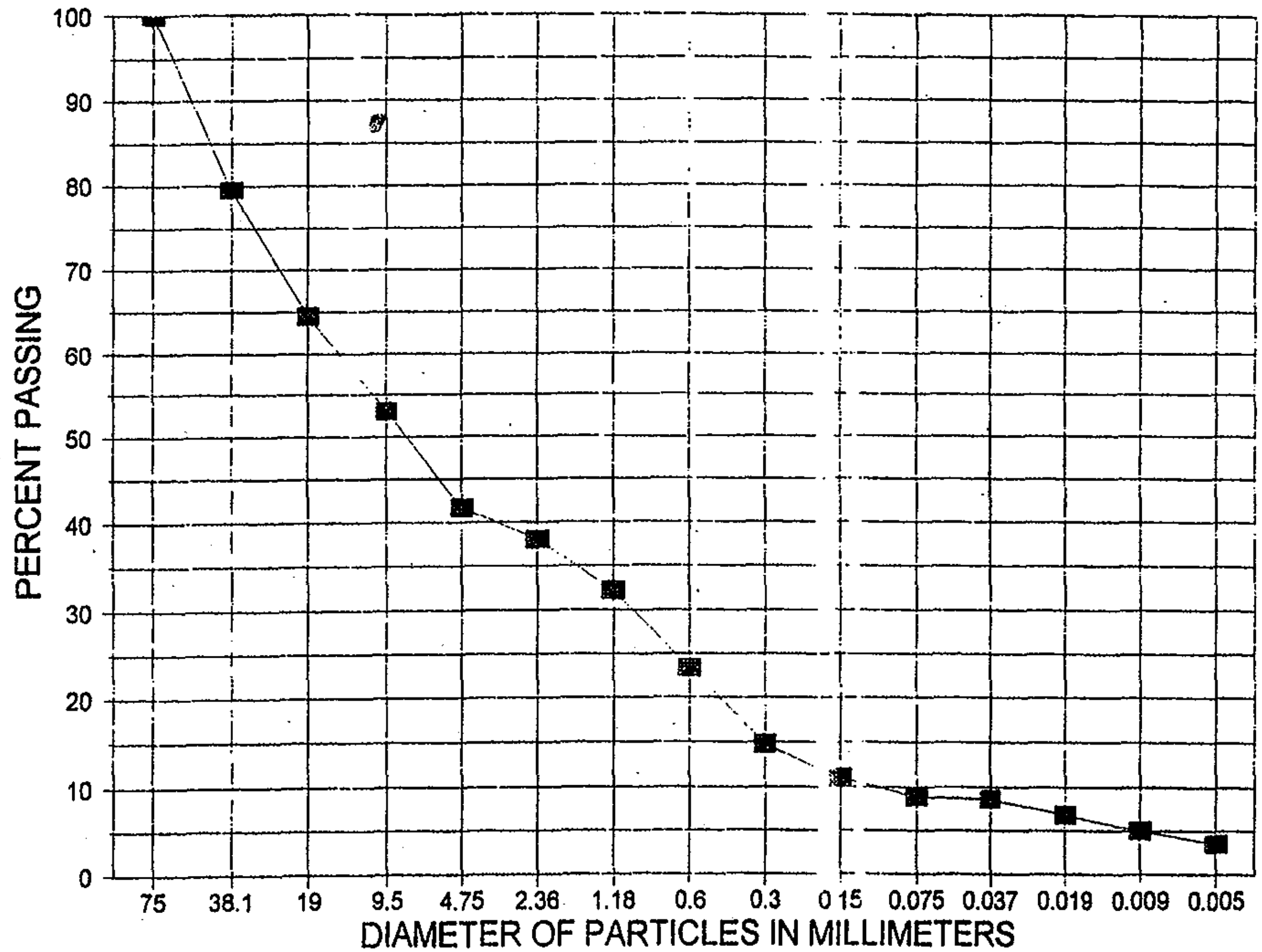
LAYNE RIG 412, ICE 180C

BN 678/4122
CSX 16.69 Ksi
ETR 44 %
FMX 197 Kips
SFT 61 Kips
BPM 92.8 BPM
EMX 3.60 Kip-ft
RTL 200 Kips
CFB 183 Kips
DMX 0.44 inch
LP 108.00 ft
LE 113.00 ft
AR 11.80 in2
EM 29810 Ksi
SP 0.489 K/ft3
WS 16808 ft/s
F12 A12



Attachment D
Laboratory Test Results

Cle Elum Dam **BSH 98-1** **60.0' to 65.0'**



Unified Soil Classification: GP-GC Poorly Graded Gravel with Silty Clay and Sand

% Gravel: 58.3 Maximum Size: 2.5" Cu: 132.34
% Sand: 32.9 Liquid Limit: 21.5 Cc: 0.63
% Fines: 8.8 Plastic Limit: 4.1

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 60' to 65'	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 23.18

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER	203						
WET MASS RETAINED							
DRY MASS RETAINED		~~0~~	4.75	3.47	2.68	2.61	
DRY MASS PASSING		23.18	18.43	14.96	12.28	9.67	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	79.5	64.5	53.0	41.7	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 82.8 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 41.7 / [illegible] = 0.5036

D.S. NO. 7 | DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	7.3	75.5		38.0	2.36 mm	Max size = 2 1/2"
16	11.5	64.0		32.2	1.18 mm	58.3% Gravel
30	17.7	46.3		23.3	600 µm	32.9 % Sand
50	17.1	29.2		14.7	300 µm	8.8% Fines
100	7.4	21.8		11.0	150 µm	GP - GC = Poorly Graded Gravel with
200	4.4	17.4		8.8	75 µm	silty Clay and Sand
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JWF			

HYDROMETER ANALYSIS

HYDROMETER NO. 87		DISPERSING AGENT Sodium Hexametaphosphate
STARTING TIME	DATE 11-23-98	AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	21.5	22.5	5.5	17		8.6	37 µm	
4 min	21.5	19	5.5	13.5		6.8	19 µm	
19 min	21.5	15.5	5.5	10		5.0	9 µm	
60 min	21	12.5	5.5	7		3.5	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
23 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JWF			

*Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______ - __

SAMPLE NO.	FEATURE	PROJECT
60.0 to 65.0	BSH 98-1	Cle Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by J Fitzsimmons Date 11-30-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	40			4	
No. of blows (N)				23	
Mass of dish + wet soil (g)	20.41			30.14	
Mass of dish + dry soil (g)	19.09			26.99	
Mass of dish (g)	11.52			12.45	
Mass of water (g)	1.32			3.15	
Mass of dry soil (g)	7.57			14.54	
Moisture %	17.4		W_n =	21.7	
Average Plastic Limit			F_n =	0.990	
			Liquid Limit	21.5	

SHRINKAGE LIMIT

1. Shrinkage Dish No.			
2. Mass of dish + wet soil	(g)		
3. Mass of dish + dry soil	(g)		
4. Mass of dish	(g)		
5. Mass of water (2 - 3)	(g)		
6. Mass of dry soil (W_o) (3 - 4)	(g)		
7. % Moisture (5/6 x 100)			
8. Vol. Shrinkage Dish (V)			
9. Vol. Dry Soil (V_o)			
10. $V - V_o$ = (8 - 9)			
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$			
12. Shrinkage Limit (7 - 11)			
13. Shrinkage Ratio (6/9)			

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PI = LL - PL

PLASTICITY INDEX:

PI = ____ - ____ = ____

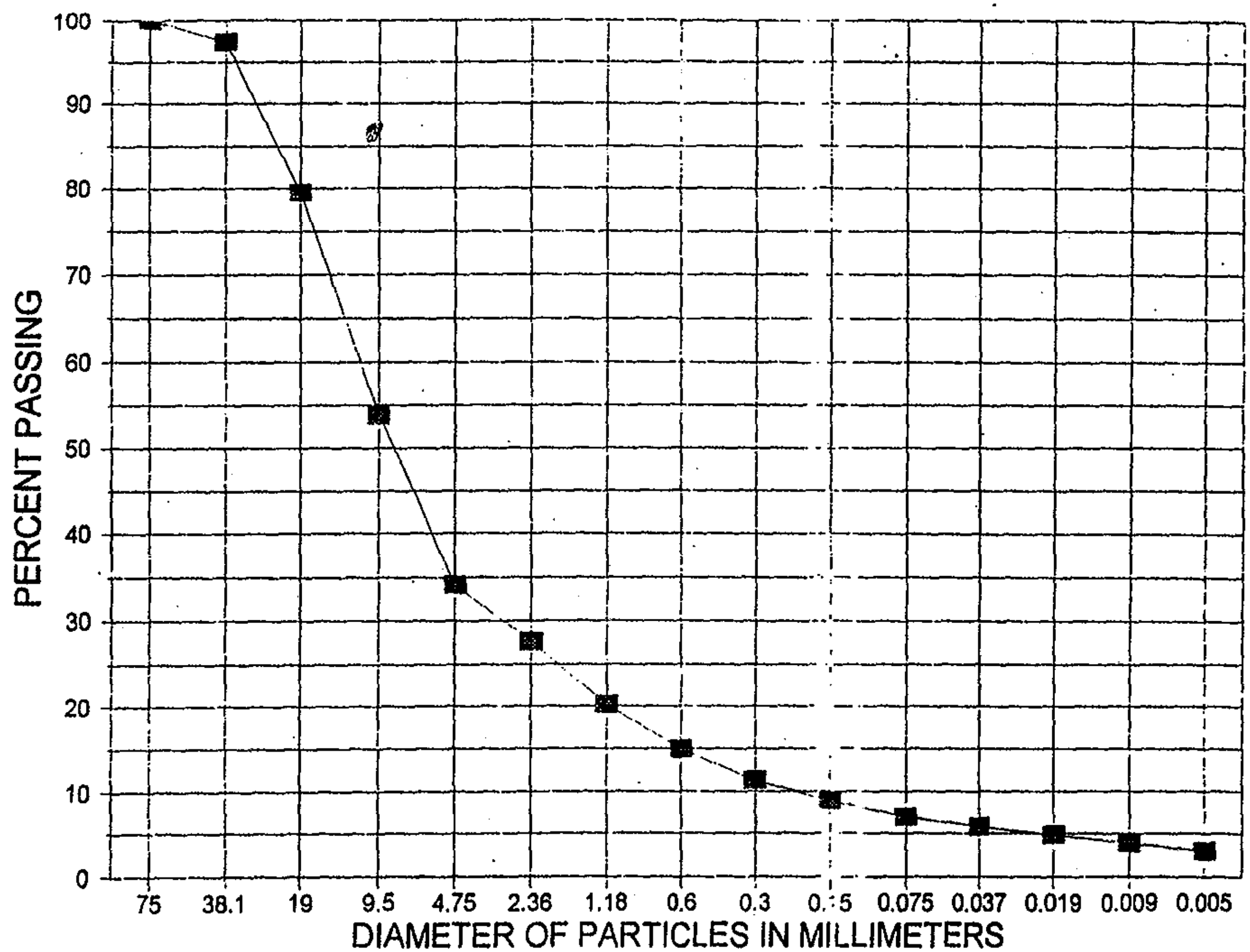
LIQUID LIMIT (LL) = 21.5
PLASTIC LIMIT (PL) = 17.4
PLASTICITY INDEX (PI) = 4.1
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: CL-ML

GPO 849-227

Cle Elum Dam **BSH 98-1** **65.0' to 70.0'**



Unified Soil Classification: GP-GC Poorly Graded Gravel with Silty Clay and Sand

% Gravel:	65.9	Maximum Size: 2"		Cu:	53.67
% Sand:	27.2	Liquid Limit:	21.9	Cc	3.97
% Fines:	6.9	Plastic Limit:	4.7		

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1	PROJECT	FEATURE CleElum Dam	
AREA	EXC. NO.	DEPTH 65.0 to 70.0	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 22.44

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER	202						
WET MASS RETAINED							
DRY MASS RETAINED		-0-	0.59	4.02	5.75	4.42	
DRY MASS PASSING		22.44	21.85	17.83	12.08	7.66	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	97.4	79.5	53.8	34.1	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 70.7 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ = [illegible]

DISH NO. 1-4 DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	13.5	57.2		27.6	2.36 mm	Max size = 2"
16	15.3	41.9		20.2	1.18 mm	Gravel = 65.9
30	11.0	30.4		14.4	600 µm	Sand = 27.2
50	7.5	23.4		11.3	300 µm	Fines = 6.9
100	5.2	18.2		8.8	150 µm	GP-GC = Poorly Graded Gravel with
200	3.8	14.4		6.9	75 µm	Silty Clay and Sand
PAN		TESTED AND COMPUTED BY		DATE	CHECKED BY	DATE
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO.		DISPERSING AGENT Sodium Hexametaphosphate
STARTING TIME	DATE 11-21-98	AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	24	17	5.0	12.0		5.8	37 µm	
4 min	24	15	5.0	10.0		4.8	19 µm	
19 min	24	13	5.0	8.0		3.9	9 µm	
60 min	24	11	5.0	6.0		2.9	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY JF	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______

SAMPLE NO. 65.0 - 70.0 | FEATURE RSH 98-1 | PROJECT C/c Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by [illegible] Date 11-21-98
Computed by ______ Date ______
Checked by ______ Date ______

Trial No.	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Dish No.	47			1	
No. of blows (N)				25	
Mass of dish + wet soil (g)	24.89			27.56	
Mass of dish + dry soil (g)	22.91			24.90	
Mass of dish (g)	11.38			12.73	
Mass of water (g)	1.98			2.66	
Mass of dry soil (g)	11.53			12.17	
Moisture %	17.2		W_n =	21.9	
Average Plastic Limit			F_n =	1.000	
			Liquid Limit	21.9	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

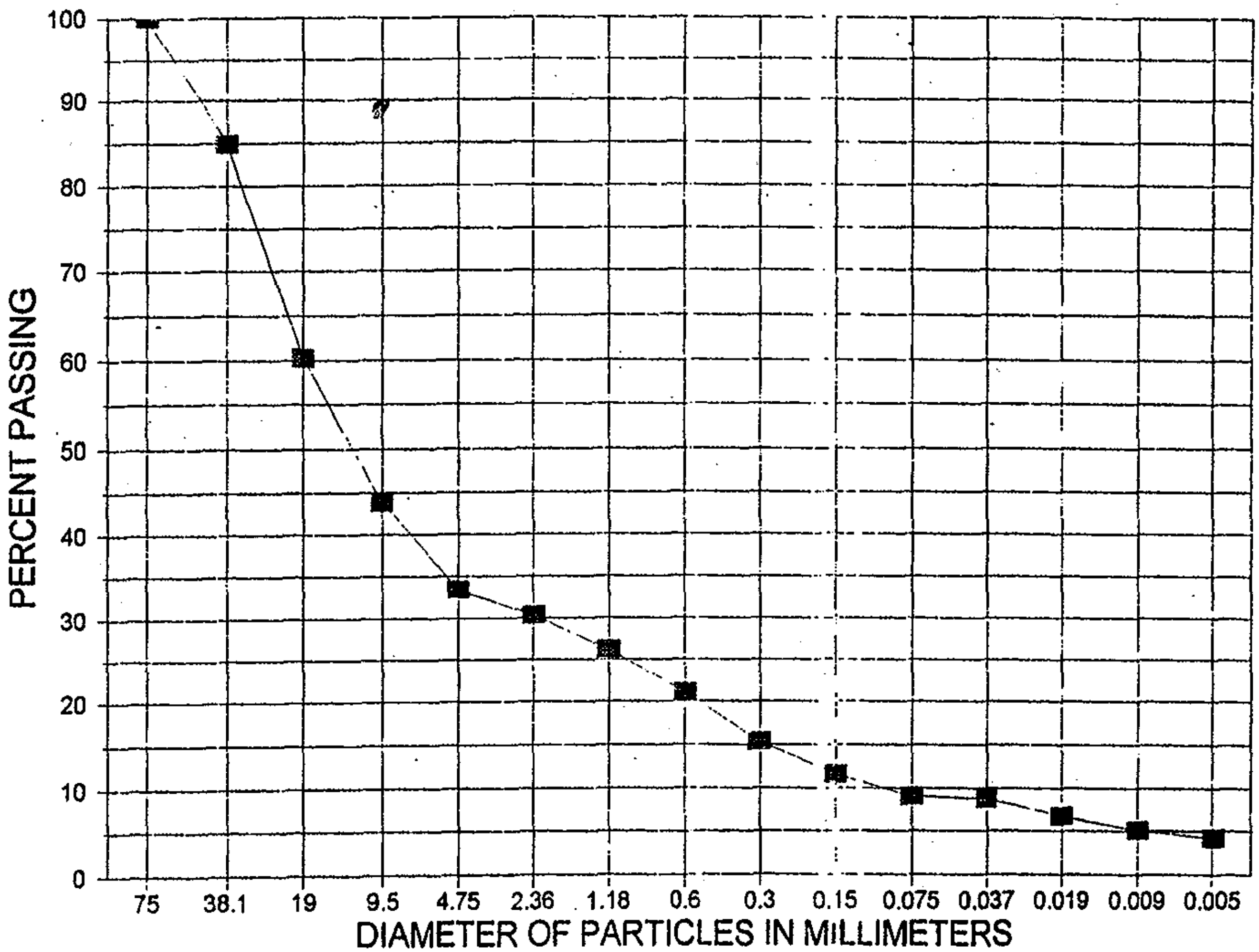
PI = ____ - ____ = ____

LIQUID LIMIT (LL) = ~~17.2~~ 21.9
PLASTIC LIMIT (PL) = 17.2
PLASTICITY INDEX (PI) = 4.7
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - ______
USBR 5300 - ______
USBR 5350 - ______
USBR 5360 - ______
USBR 5365 - ______

Remarks: CL-ML

Cle Elum Dam BSH 98-1 70.0' to 75.0'



Unified Soil Classification: GW-GM Well Graded Gravel with Silt and Sand

% Gravel: 66.6	Maximum Size: 2.75"		Cu: 190.38
% Sand: 24.4	Liquid Limit:	21.5	Cc: 2.68
% Fines: 9.0	Plastic Limit:	3.7	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 70.0 to 75.0	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 21.05

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 201							
WET MASS RETAINED							
DRY MASS RETAINED		0	3.17	5.20	3.46	2.18	
DRY MASS PASSING		21.05	17.88	12.68	9.22	7.04	[X] lbm [ ] kg [ ] g
% OF TOTAL PASSING		100	84.9	60.2	43.8	33.4	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 74.7 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 33.4 / = 0.4471

DISH NO. [illegible] DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	6.6	68.1		30.4	2.36 mm	Max size = 2 1/2"
16	9.5	58.6		26.2	1.18 mm	66.6 % Gravel
30	11.7	46.9		21.0	600 µm	24.4 % Sand
50	12.5	34.4		15.4	300 µm	9.0 % Fines
100	8.7	25.7		11.5	150 µm	GW-GM = Well Graded Gravel with
200	5.6	20.1		9.0	75 µm	Silt and Sand
PAN		TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE	
TOTAL		JF				

HYDROMETER ANALYSIS

HYDROMETER NO. 72	DISPERSING AGENT Sodium Hexametaphosphate	
STARTING TIME 8:58	DATE 11-23-98	AMOUNT [illegible] mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	20.5	25	5.5	19.5		8.7	37 µm	
4 min	20.5	20.5	5.5	15		6.7	19 µm	
19 min	20.5	17	5.5	11.5		5.1	9 µm	
60 min	21	15	5.5	9.5		4.2	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY JF	DATE	CHECKED BY	DATE

17

*Not required for standard test.

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR

SAMPLE NO.	FEATURE	PROJECT
70.0 - 75.0	BSH 98 - 1	70.0 - 75.0

Air dried ☐
Oven dried ☒
Natural ☐

Tested by Juj Tzsilimedes Date 11-21-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	3			4	
No. of blows (N)				30	
Mass of dish + wet soil (g)	23.25			27.63	
Mass of dish + dry soil (g)	21.67			25.00	
Mass of dish (g)	12.78			12.45	
Mass of water (g)	1.58			2.63	
Mass of dry soil (g)	8.89			12.55	
Moisture %	17.8		W_n =	21.0	
Average Plastic Limit			F_n =	1.022	
			Liquid Limit	21.5	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n\left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

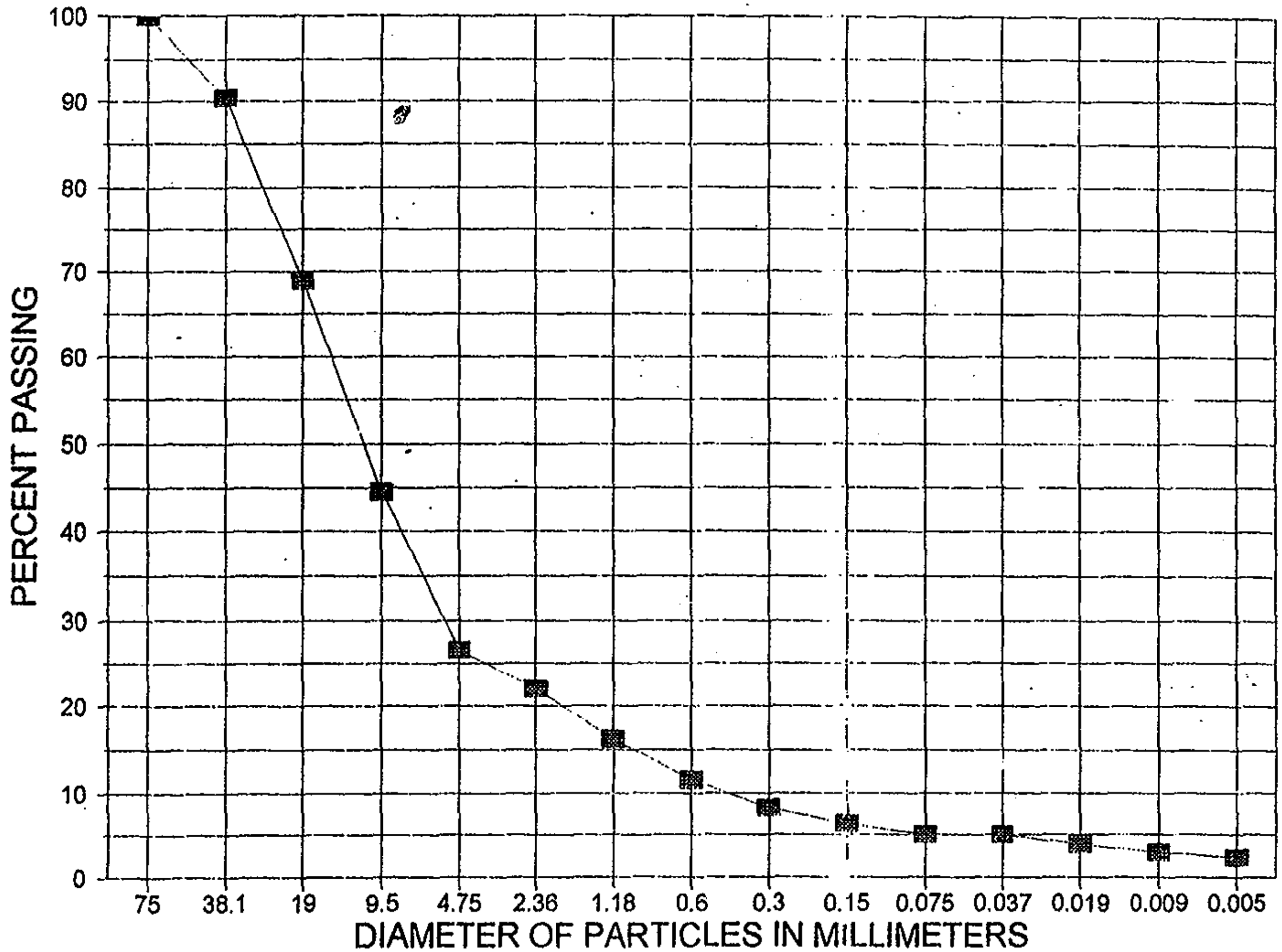
PI = ____ - ____ = ____

LIQUID LIMIT (LL) = 21.5
PLASTIC LIMIT (PL) = 17.8
PLASTICITY INDEX (PI) = 3.7
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - ____
USBR 5300 - ____
USBR 5350 - ____
USBR 5360 - ____
USBR 5365 - ____

Remarks: ML

Cle Elum Dam **BSH 98-1** **75.0' to 80.0'**



Unified Soil Classification: GP-GM Poorly Graded Gravel with Silt and Sand

% Gravel: 73.5	Maximum Size: 2.5"		Cu:	33.7
% Sand: 21.5	Liquid Limit:	21.0	Cc:	4.57
% Fines: 5.0	Plastic Limit:	2.8		

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 75' to 80'

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 25.71

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER /							
WET MASS RETAINED							
DRY MASS RETAINED		0	2.47	5.53	6.26	4.65	
DRY MASS PASSING		25.71	23.24	17.71	11.45	6.80	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	90.4	68.9	44.5	26.5	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 85.6 g | FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 26.5 / 85.6 = 0.3096

DISH NO. | DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	14.6	71.0		22.0	2.36 mm	Max size - 2 1/2
16	18.7	52.3		16.2	1.18 mm	73.5 % Gravel
30	15.0	37.3		11.5	600 µm	21.5 % Sand
50	10.9	26.4		8.2	300 µm	5.0 % Fines
100	6.1	20.3		6.3	150 µm	GP-GM = Poorly Graded Gravel with
200	4.2	16.1		5.0	75 µm	Silt and Sand
PAN						
TOTAL		TESTED AND COMPUTED BY JW	DATE	CHECKED BY		DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 76	DISPERSING AGENT Sodium Hexametaphosphate
STARTING TIME / DATE 11-23-98	AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	21	21.5	5.5	16		5.0	37 µm	
4 min	21	18	5.5	12.5		3.9	19 µm	
19 min	21	15	5.5	9.5		2.9	9 µm	
60 min	21	13	5.5	7.5		2.3	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY JW	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______

SAMPLE NO. 75.0 to 80.0 | FEATURE BSH 98-1 | PROJECT Cle Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by JF Fitzsimmons Date ______
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	47			34	
No. of blows (N)				22	
Mass of dish + wet soil (g)	20.67			28.38	
Mass of dish + dry soil (g)	19.24			25.52	
Mass of dish (g)	11.38			12.06	
Mass of water (g)	1.43			2.86	
Mass of dry soil (g)	7.86			13.46	
Moisture %	18.2		W_n =	21.3	
Average Plastic Limit			F_n =	0.985	
			Liquid Limit	21.0	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

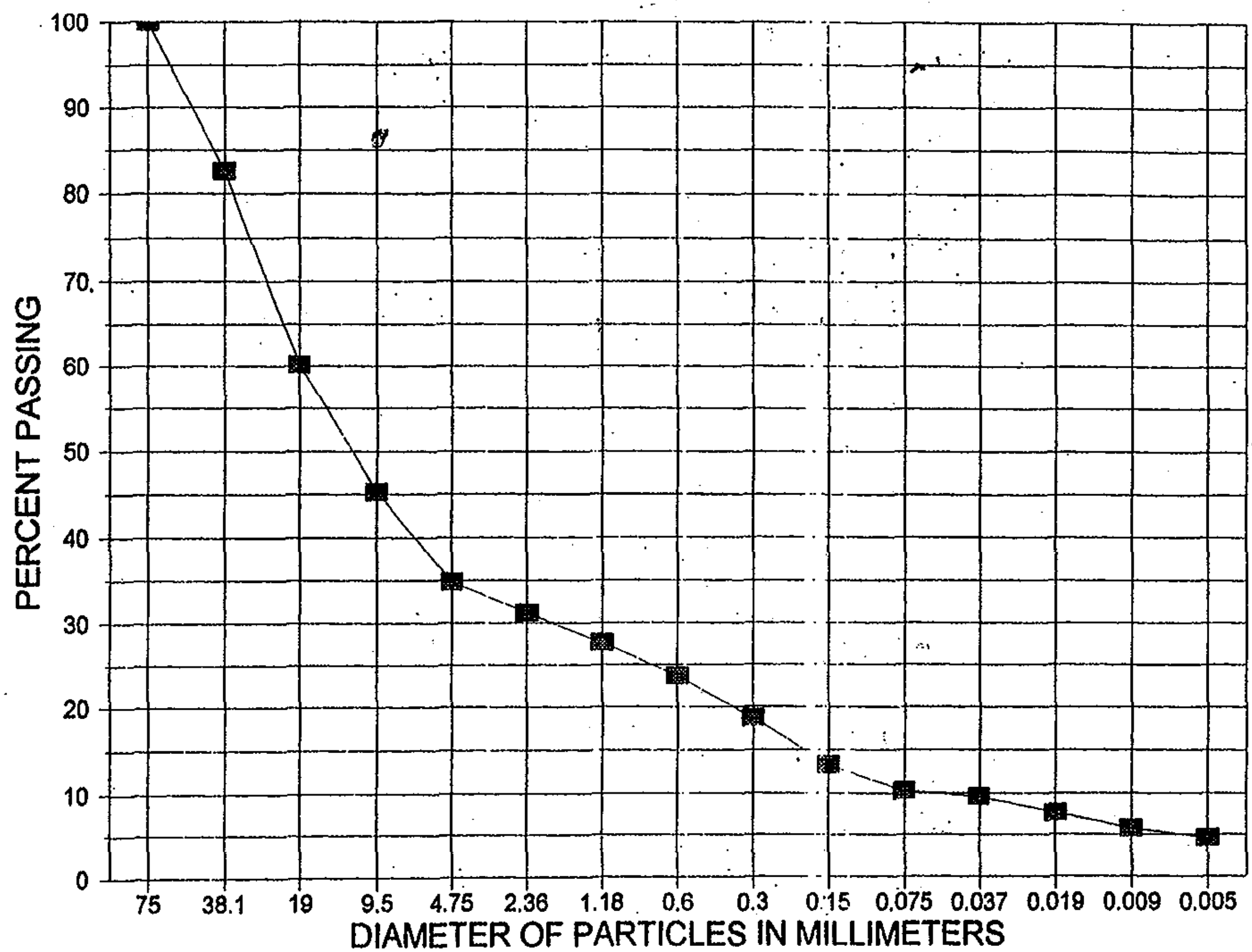
PI = ____ - ____ = ____

LIQUID LIMIT (LL) = 21.0
PLASTIC LIMIT (PL) = 18.2
PLASTICITY INDEX (PI) = 2.8
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

Cle Elum Dam **BSH 98-1** **80.0' to 85.0'**



Unified Soil Classification: GP-GC Poorly Graded Gravel with Silty Clay and Sand

% Gravel: 65.2 Maximum Size: 2.75" Cu: 328.65

% Sand: 24.5 Liquid Limit: 23.3 Cc: 3.22

% Fines: 10.3 Plastic Limit: 4.7

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 80' to 85'	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 23.31

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 5C							
WET MASS RETAINED							
DRY MASS RETAINED		0	4.08	5.22	3.45	2.46	
DRY MASS PASSING		23.31	19.23	14.01	10.56	8.10	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	82.5	60.1	45.3	34.8	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 82.4 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 34.8 / — = 0.4223

DISH NO. 8 | DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	8.6	73.8		31.2	2.36 mm	Max size 2 3/4"
16	8.5	65.3		27.6	1.18 mm	65.2% Gravel
30	9.4	55.9		23.6	600 µm	24.5% Sand
50	11.7	44.2		18.7	300 µm	10.3% Fines
100	12.8	31.4		13.3	150 µm	GP - GC = Poorly Graded Gravel with
200	7.1	24.3		10.3	75 µm	Silty Clay and Sand
PAN						
TOTAL		TESTED AND COMPUTED BY JWF		DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 76		DISPERSING AGENT Sodium Hexametaphosphate
STARTING TIME 9:01	DATE 11-23-98	AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	20.5	28	5.5	22.5		9.5	37 µm	
4 min	20.5	23.5	5.5	18		7.6	19 µm	
19 min	20.5	19	5.5	13.5		5.7	9 µm	
60 min	21	16.5	5.5	11		4.6	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY JWF	DATE	CHECKED BY	DATE

* Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______ - __ __

SAMPLE NO.	FEATURE	PROJECT
80.0 to 85.0	BSH 98-1	Cle Elum

Air dried ☐
Oven dried ☐
Natural ☐

Tested by JWFitzsimons Date 11-30-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	47			38	
No. of blows (N)				22	
Mass of dish + wet soil (g)	20.45			30.69	
Mass of dish + dry soil (g)	19.03			27.06	
Mass of dish (g)	11.38			11.73	
Mass of water (g)	1.42			3.63	
Mass of dry soil (g)	7.65			15.33	
Moisture %	18.6		W_n =	23.7	
Average Plastic Limit			F_n =	0.985	
			Liquid Limit		

SHRINKAGE LIMIT

1. Shrinkage Dish No.			
2. Mass of dish + wet soil	(g)		
3. Mass of dish + dry soil	(g)		
4. Mass of dish	(g)		
5. Mass of water (2 - 3)	(g)		
6. Mass of dry soil (W_o) (3 - 4)	(g)		
7. % Moisture (5/6 x 100)			
8. Vol. Shrinkage Dish (V)			
9. Vol. Dry Soil (V_o)			
10. $V - V_o$ = (8 - 9)			
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$			
12. Shrinkage Limit (7 - 11)			
13. Shrinkage Ratio (6/9)			

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

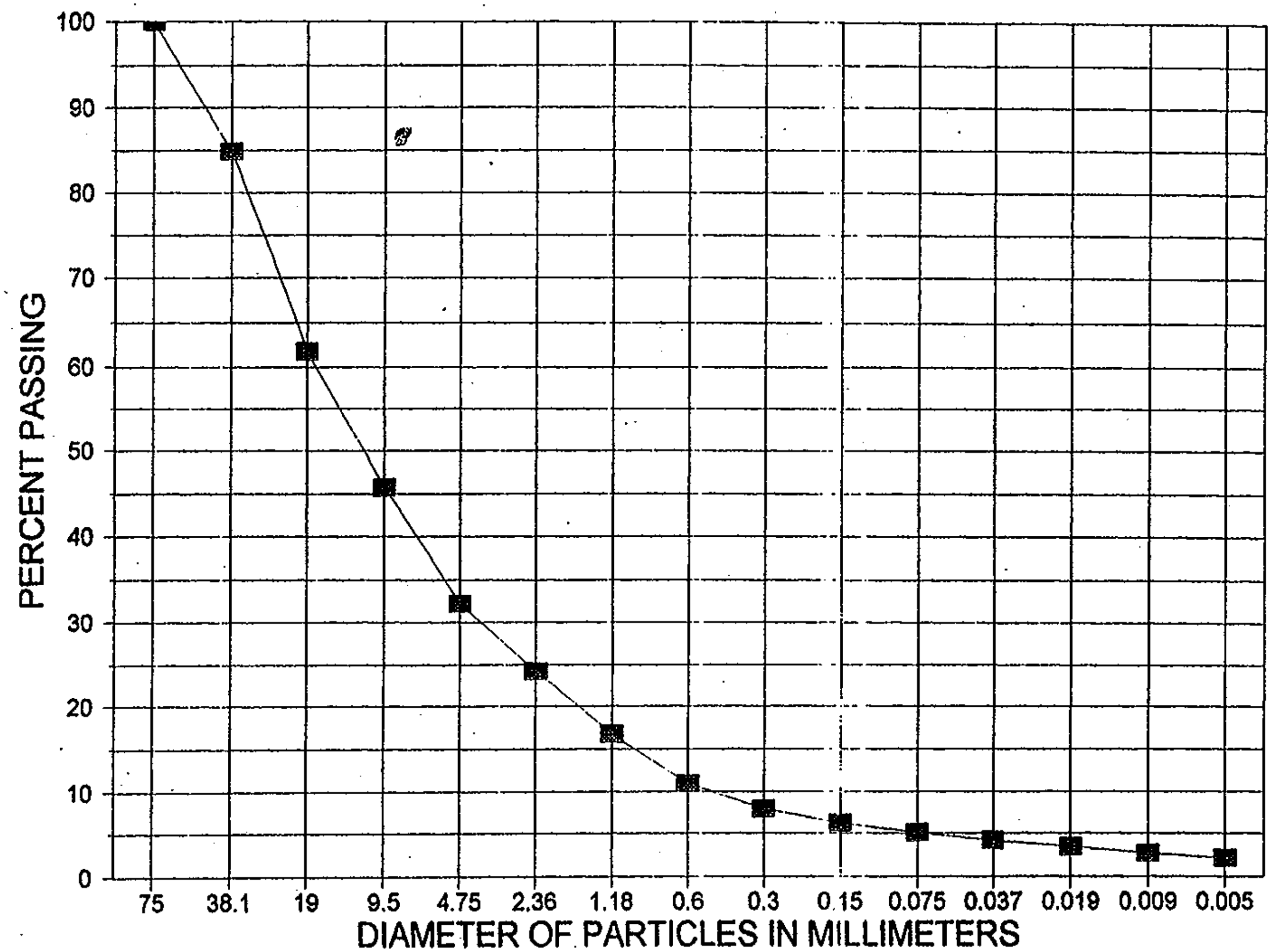
PI = ______ - ______ = ______

LIQUID LIMIT (LL) = 23.3
PLASTIC LIMIT (PL) = 18.6
PLASTICITY INDEX (PI) = 4.7
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: CL - ML

Cle Elum Dam **BSH 98-1** **85.0' to 90.0'**



Unified Soil Classification: GW-GM Well Graded Gravel with Silt and Sand

% Gravel:	67.8	Maximum Size:	3"	Cu:	36.21
% Sand:	27.1	Liquid Limit:	21.7	Cc:	1.79
% Fines:	5.1	Plastic Limit:	3.7		

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 85.0 to 90.0

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 25.39

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER	XX						
WET MASS RETAINED							
DRY MASS RETAINED		0	3.85	5.87	4.08	3.42	
DRY MASS PASSING		25.39	21.54	15.67	11.59	8.17	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	84.8	61.7	45.7	32.2	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 100.0 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 32.2 / ____ = 0.3220

DISH NO. 36 DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	24.8	75.2		24.2	2.36 mm	Max size = 3"
16	23.4	51.8		16.7	1.18 mm	67.8 % Gravel
30	17.9	33.9		10.9	600 µm	27.1 % Sand
50	9.5	24.4		7.9	300 µm	5.1 % ~~Grav Sand~~ Fines
100	5.3	19.1		6.2	150 µm	GW-GM = Well Graded Gravel with
200	3.3	15.8		5.1	75 µm	Silt and Sand
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JLP			

HYDROMETER ANALYSIS

HYDROMETER NO. 36	DISPERSING AGENT
STARTING TIME 1 30	DATE 12-1-98
AMOUNT	mL

	TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1	1 min		17.5	-4.5	13		4.2	37 µm	
54	4 min	23.0	15.0	-4.5	10.5		3.4	19 µm	
9	19 min	23.0	13.0	-4.5	8.5		2.7	9 µm	
30	60 min	23.0	11.0	-4.5	6.5		2.1	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
	7 h 15 min*							2 µm	
	25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ____ - __ __

SAMPLE NO.	FEATURE	PROJECT
85.0 to 90.0	BSH 98-1	Cle Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by J Fitzsimmons Date 11-30-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	3			23	
No. of blows (N)				22	
Mass of dish + wet soil (g)	22.66			27.74	
Mass of dish + dry soil (g)	21.15			24.92	
Mass of dish (g)	12.78			12.10	
Mass of water (g)	1.51			2.82	
Mass of dry soil (g)	8.37			12.82	
Moisture %	18.0		W_n =	22.0	
Average Plastic Limit			F_n =	0.985	
			Liquid Limit	21.7	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

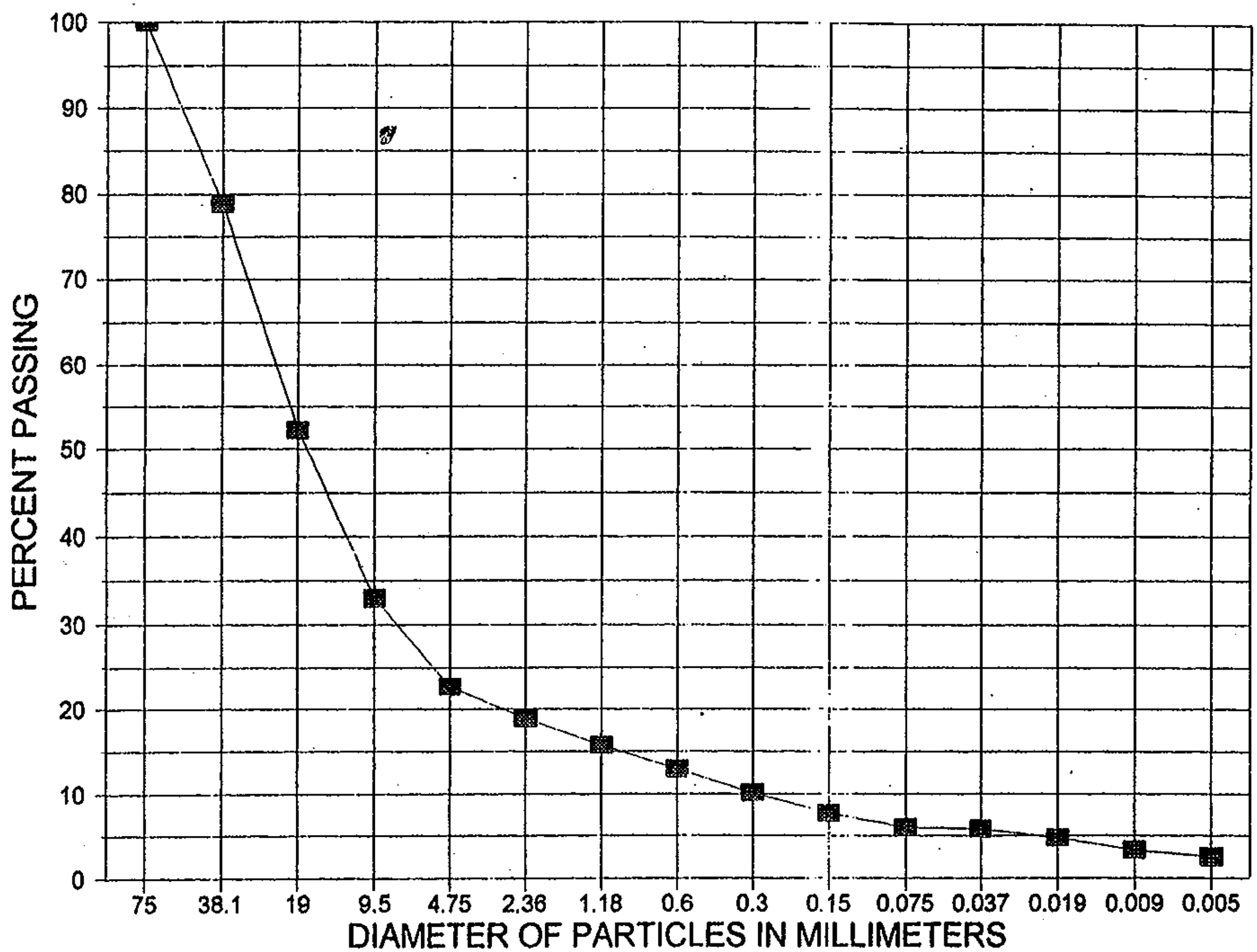
PI = ____ - ____ = ____

LIQUID LIMIT (LL) = 21.7
PLASTIC LIMIT (PL) = 18.0
PLASTICITY INDEX (PI) = 3.7
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

Cle Elum Dam **BSH 98-1** **90.0' to 95.0'**



Unified Soil Classification: GP-GC Poorly Graded Gravel with Silty Clay and Sand

% Gravel:	77.3	Maximum Size:	2.75"	Cu:	79.48
% Sand:	16.7	Liquid Limit:	22.8	Cc:	8.91
% Fines:	6.0	Plastic Limit:	5.3		

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1	PROJECT	FEATURE CleElum Dam
AREA	EXC. NO.	DEPTH 90° to 95°

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 24.34

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER	203						
WET MASS RETAINED							
DRY MASS RETAINED		0	5.16	6.48	4.66	2.52	
DRY MASS PASSING		24.34	19.18	12.70	8.04	5.52	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	78.8	52.2	33.0	22.7	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 86.4 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 0.2627
DISH NO. 1	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	14.6	71.8		18.9	2.36 mm	Max size = 3/4"
16	12.1	59.7		15.7	1.18 mm	Gravel = 77.3
30	10.5	49.2		12.9	600 µm	Sand = 16.7
50	10.7	38.5		10.1	300 µm	Fines = 6.0
100	9.5	29.0		7.6	150 µm	GP-GC = Poorly Graded Gravel with
200	6.0	23.0		6.0	75 µm	Silty Clay and Sand
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 72	DISPERSING AGENT Sodium Hexametaphosphate
STARTING TIME / DATE 11-21-98	AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	23.5	27	5.0	22.0		5.8	37 µm	
4 min	23.5	23	5.0	18.0		4.7	19 µm	
19 min	23.5	17.5	5.0	12.5		3.3	9 µm	
60 min	23.5	14.5	5.0	9.5		2.5	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY JF	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

7-1702 (11-85) Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ____ - __

SAMPLE NO. 90.0 to 95.0 | FEATURE BSH 98-1 | PROJECT Cle Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by JWFitzsimmons Date 11-30-98
Computed by ________ Date ________
Checked by ________ Date ________

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	28			34	
No. of blows (N)				28	
Mass of dish + wet soil (g)	22.66			28.22	
Mass of dish + dry soil (g)	21.14			25.25	
Mass of dish (g)	12.46			12.06	
Mass of water (g)	1.52			2.97	
Mass of dry soil (g)	8.68			13.19	
Moisture %	17.5		W_n =	22.5	
Average Plastic Limit			F_n =	1.014	
			Liquid Limit	22.8	

SHRINKAGE LIMIT

1. Shrinkage Dish No.			
2. Mass of dish + wet soil	(g)		
3. Mass of dish + dry soil	(g)		
4. Mass of dish	(g)		
5. Mass of water (2 - 3)	(g)		
6. Mass of dry soil (W_o) (3 - 4)	(g)		
7. % Moisture (5/6 x 100)			
8. Vol. Shrinkage Dish (V)			
9. Vol. Dry Soil (V_o)			
10. $V - V_o = (8 - 9)$			
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$			
12. Shrinkage Limit (7 - 11)			
13. Shrinkage Ratio (6/9)			

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

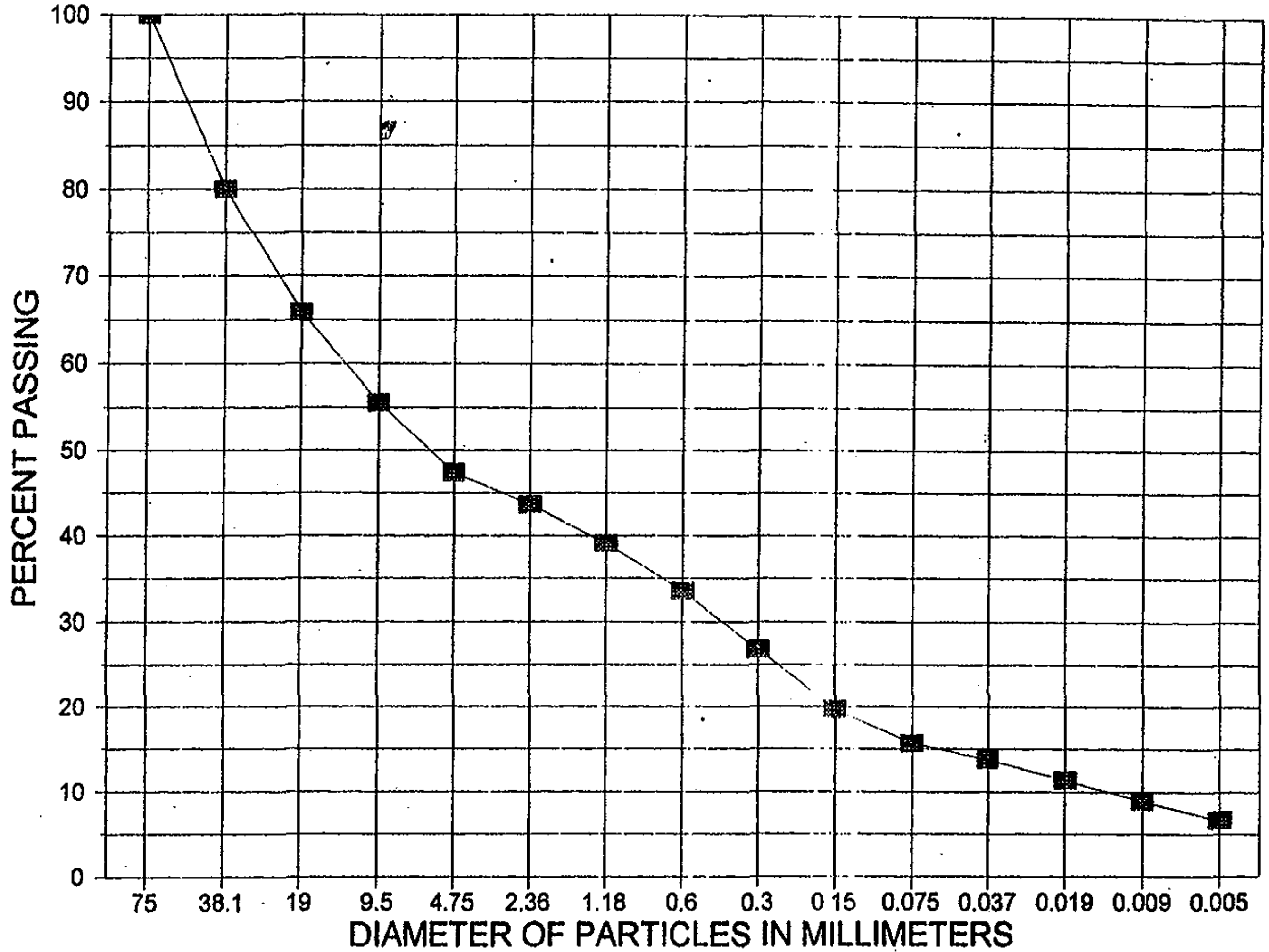
PI = ____ - ____ = ____

LIQUID LIMIT (LL) = 22.8
PLASTIC LIMIT (PL) = 17.5
PLASTICITY INDEX (PI) = 5.3
SHRINKAGE LIMIT (SL) = ________

Auxiliary tests:
USBR 5205 - __
USBR 5300 - __
USBR 5350 - __
USBR 5360 - __
USBR 5365 - __

Remarks: CL-ML

Cle Elum Dam BSH 98-1 95.0' to 100.0'



Unified Soil Classification: GW-GC Well Graded Gravel with Silty Clay and Sand

% Gravel: 52.6 Maximum Size: 2.75" Cu: 1028.52

% Sand: 31.8 Liquid Limit: 23.6 Cc: 1.09

% Fines: 15.6 Plastic Limit: 7.0

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 95.0 to 100.0	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 29.11

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER							
WET MASS RETAINED							
DRY MASS RETAINED		0	5.83	4.13	2.99	2.37	
DRY MASS PASSING		29.11	23.28	19.15	16.16	13.79	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	80.0	65.8	55.5	47.4	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 85.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 0.5576	
DISH NO.	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME	DATE	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	6.8	78.2		43.6	2.36 mm	Max size = 2 3/4"
16	8.0	70.2		39.1	1.18 mm	Gravel = 52.6
30	10.2	60.0		33.5	600 µm	Sand = 31.8
50	12.0	48.0		26.8	300 µm	Fines = 15.6
100	12.6	35.4		19.7	150 µm	GW-GC = Well Graded Gravel with
200	7.4	28.0		15.6	75 µm	Silty Clay and Sand
PAN		TESTED AND COMPUTED BY	DATE	CHECKED BY		DATE
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO. 76	DISPERSING AGENT Sodium Hexametaphosphate	
STARTING TIME	DATE 11-21-98	AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	24.5	29	4.5	24.5		13.7	37 µm	
4 min	24.5	25	4.5	20.5		11.4	19 µm	
19 min	24.5	20.5	4.5	16.0		8.9	9 µm	
60 min	24	17	5.0	12.0		6.7	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY JF	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______ - __ __

SAMPLE NO.	FEATURE	PROJECT
95.0 to 100.0	BSH 98-1	Cle Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by: [signature] Date: 11/25/98
Computed by: ______ Date: ______
Checked by: ______ Date: ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	7			25	
No. of blows (N)				22	
Mass of dish + wet soil (g)	20.55			25.28	
Mass of dish + dry soil (g)	19.38			22.76	
Mass of dish (g)	12.35			12.26	
Mass of water (g)	1.17			2.52	
Mass of dry soil (g)	7.03			10.50	
Moisture %	16.6		W_n =	24.0	
Average Plastic Limit			F_n =	0.985	
			Liquid Limit	23.6	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

PI = ____ - ____ = ____

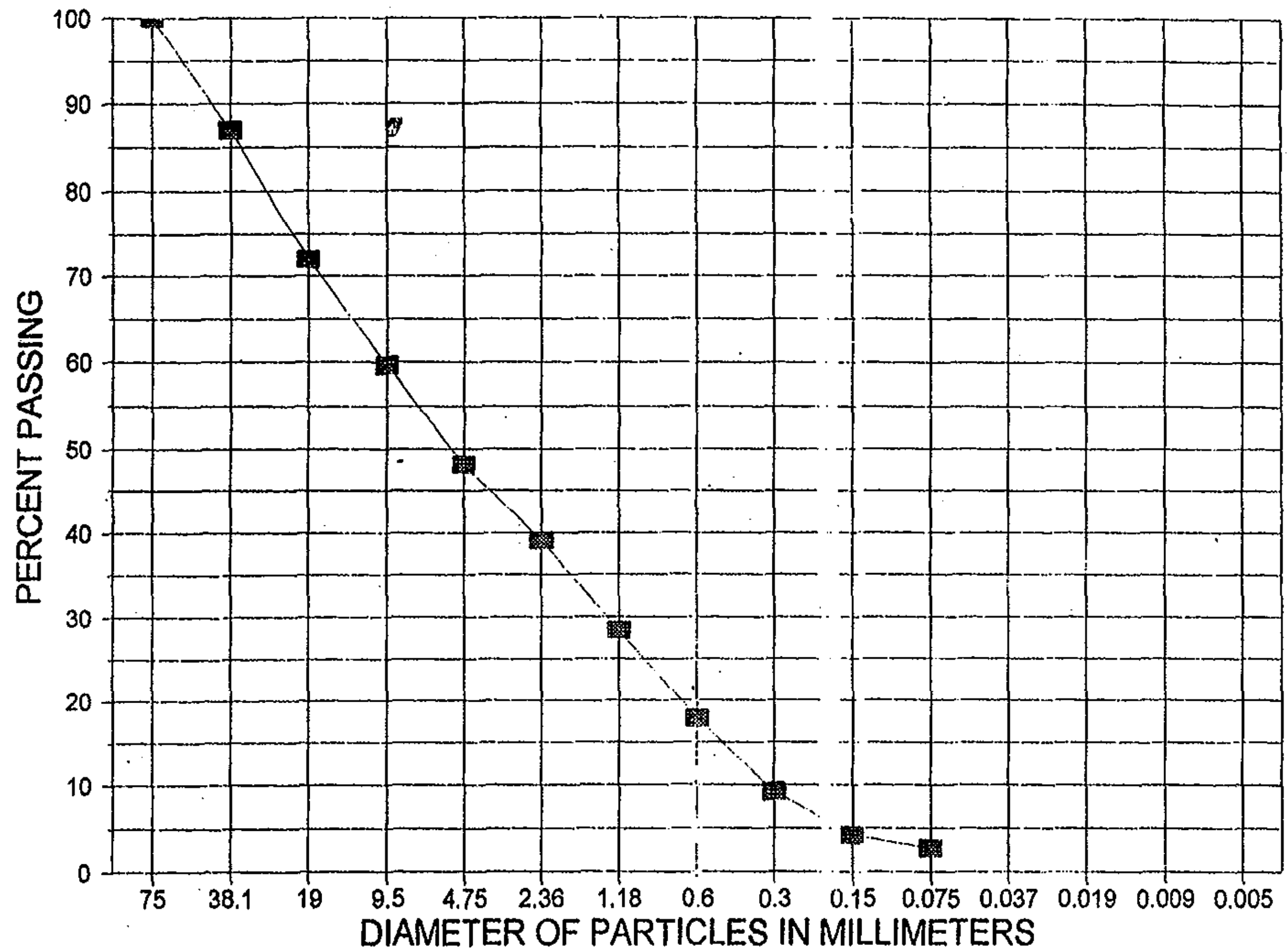
LIQUID LIMIT (LL) = 23.6
PLASTIC LIMIT (PL) = 16.6
PLASTICITY INDEX (PI) = 7.0
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: CL-ML

GPO 849-227

Cle Elum Dam **BSH 98-1** **100.0' to 105.0'**



Unified Soil Classification: GP Poorly Graded Gravel with Sand

% Gravel: 51.9	Maximum Size: 2.5"	Cu: 30.53
% Sand: 45.4	Liquid Limit:	Cc: 0.55
% Fines: 2.7	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. ESH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 100.0 to 105.0

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 35.49

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 22							
WET MASS RETAINED							
DRY MASS RETAINED		0	4.60	5.37	4.42	4.03	
DRY MASS PASSING		35.49	30.89	25.52	21.10	17.07	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	87.0	71.9	59.5	48.1	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 829.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 0.0580
DISH NO.	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE 11-21-98

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	155	674		39.1	2.36 mm	Max. size = 2 1/2"
16	184	490		28.4	1.18 mm	Gravel = 51.9
30	183	307		17.8	600 µm	Sand - 45.4
50	148	159		9.2	300 µm	Fines = 2.7
100	86	73		4.2	150 µm	GP = Poorly Graded Gravel
200	27	46		2.7	75 µm	with Sand
PAN						
TOTAL		TESTED AND COMPUTED BY	DATE	CHECKED BY		DATE

HYDROMETER ANALYSIS

HYDROMETER NO.		DISPERSING AGENT
STARTING TIME	DATE	AMOUNT mL

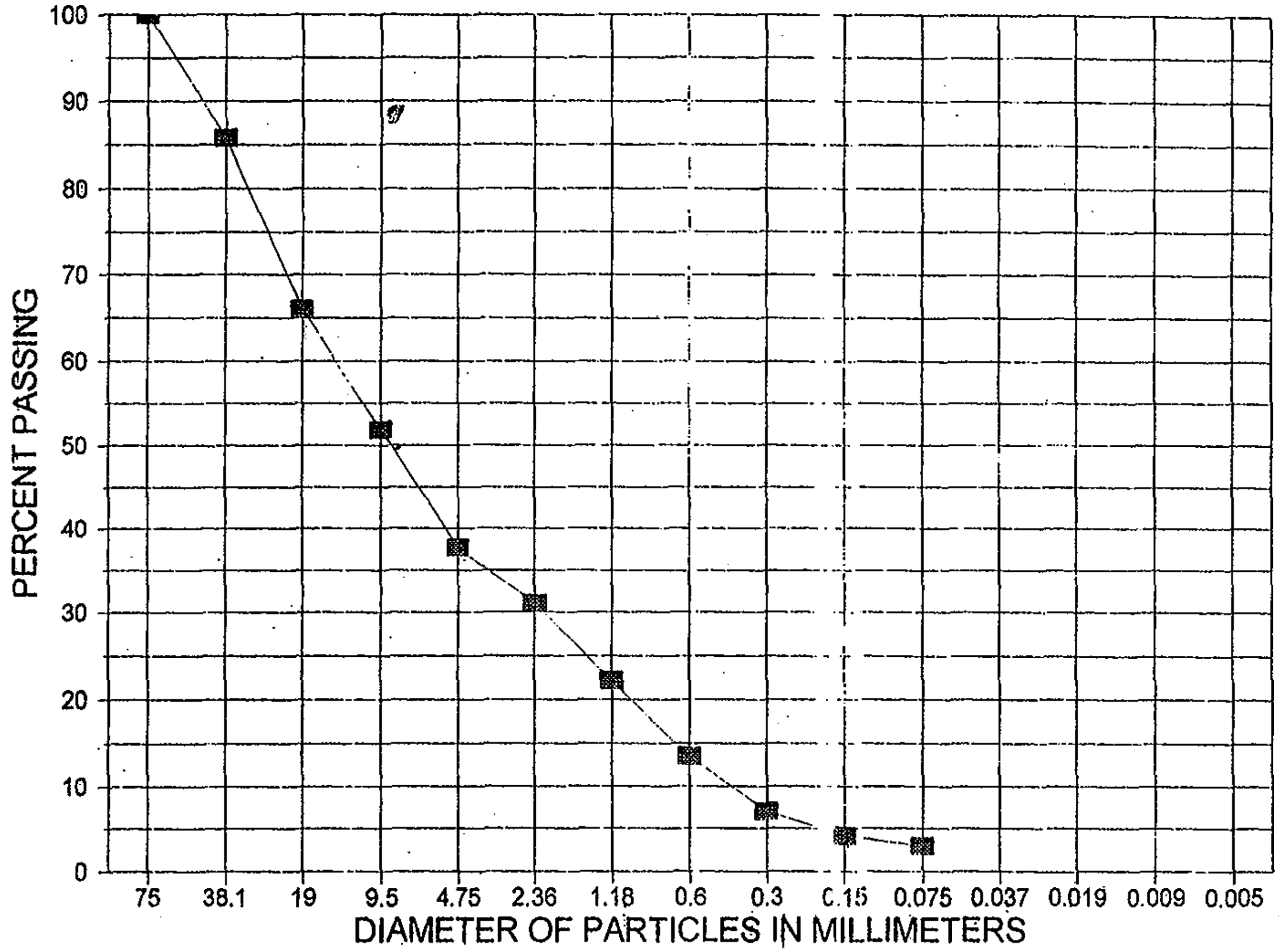
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam **BSH 98-1** **105.0' to 110.0'**



Unified Soil Classification: GP Poorly Graded Gravel with Sand

% Gravel: 62.3	Maximum Size: 2.5"	Cu: 34.32
% Sand: 34.8	Liquid Limit:	Cc: 0.81
% Fines: 2.9	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 105.0 to 110.0

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 30.05

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER XX							
WET MASS RETAINED							
DRY MASS RETAINED		0	4.28	5.94	4.26	4.24	
DRY MASS PASSING		30.05	25.77	19.83	15.57	11.33	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	85.8	66.0	51.8	37.7	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 705.0 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ = 0.0535

D.S. NO. DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	126	579		31.0	2.36 mm	Max size = 1 1/2"
16	165	414		22.1	1.18 mm	Gravel - 62.3
30	161	253		13.5	600 μm	Sand - 34.8
50	123	130		7.0	300 μm	Fines = 2.9
100	53	77		4.1	150 μm	GP = Poorly Graded Gravel with
200	23	54		2.9	75 μm	Sand
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

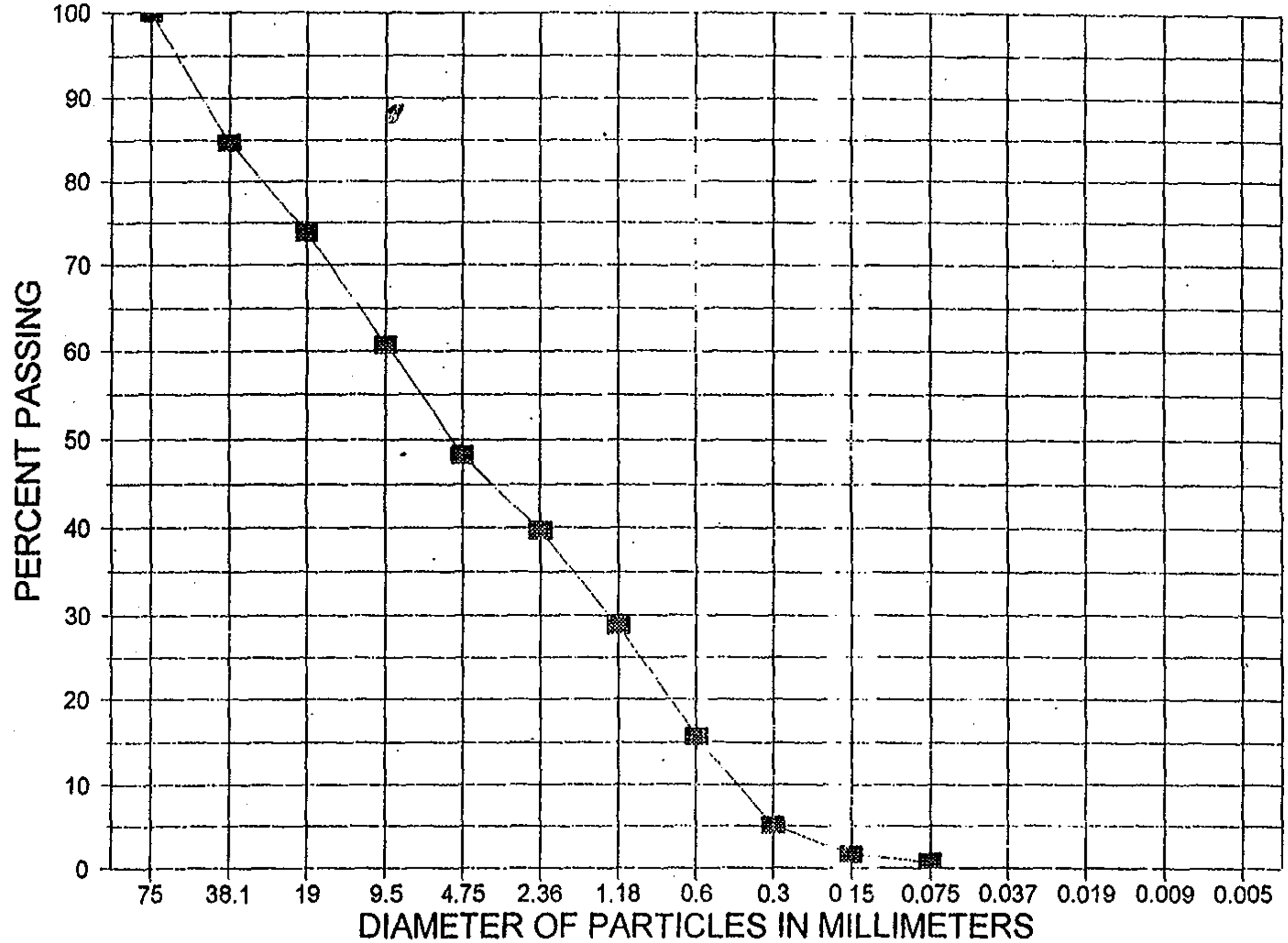
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 μm	
4 min							19 μm	
19 min							9 μm	
60 min							5 μm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 μm	
25 h 45 min*							1 μm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam **BSH 98-1** **110.0' to 115.0'**



Unified Soil Classification: GP Poorly Graded Gravel with Sand

% Gravel: 51.7	Maximum Size: 2.5"	Cu: 22.04
% Sand: 47.6	Liquid Limit:	Cc: 0.43
% Fines: 0.7	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1	PROJECT		FEATURE Cle Elum Dam
AREA	EXC. NO.		DEPTH 110° to 115°

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 30.86

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER /							
WET MASS RETAINED							
DRY MASS RETAINED		0	4.71	3.41	4.02	3.80	
DRY MASS PASSING		30.86	26.15	22.74	18.72	14.92	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	84.7	73.7	60.7	48.3	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 649.0 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 0.074

D.S. NO. / (DRY MASS OF SPECIMEN SIEVED)

SIEVING TIME

DATE 11-21-98

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	116	533		39.1	2.36 mm	Max Size = [illegible]
16	147	386		28.7	1.18 mm	Gravel : 51.7
30	176	210		15.6	600 µm	Sand : 47.6
50	141	69		5.1	300 µm	Fines = 0.7
100	47	22		1.6	150 µm	GP = Poorly Graded Gravel
200	12	10		0.7	75 µm	with Sand
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO.		DISPERSING AGENT
STARTING TIME	DATE	AMOUNT mL

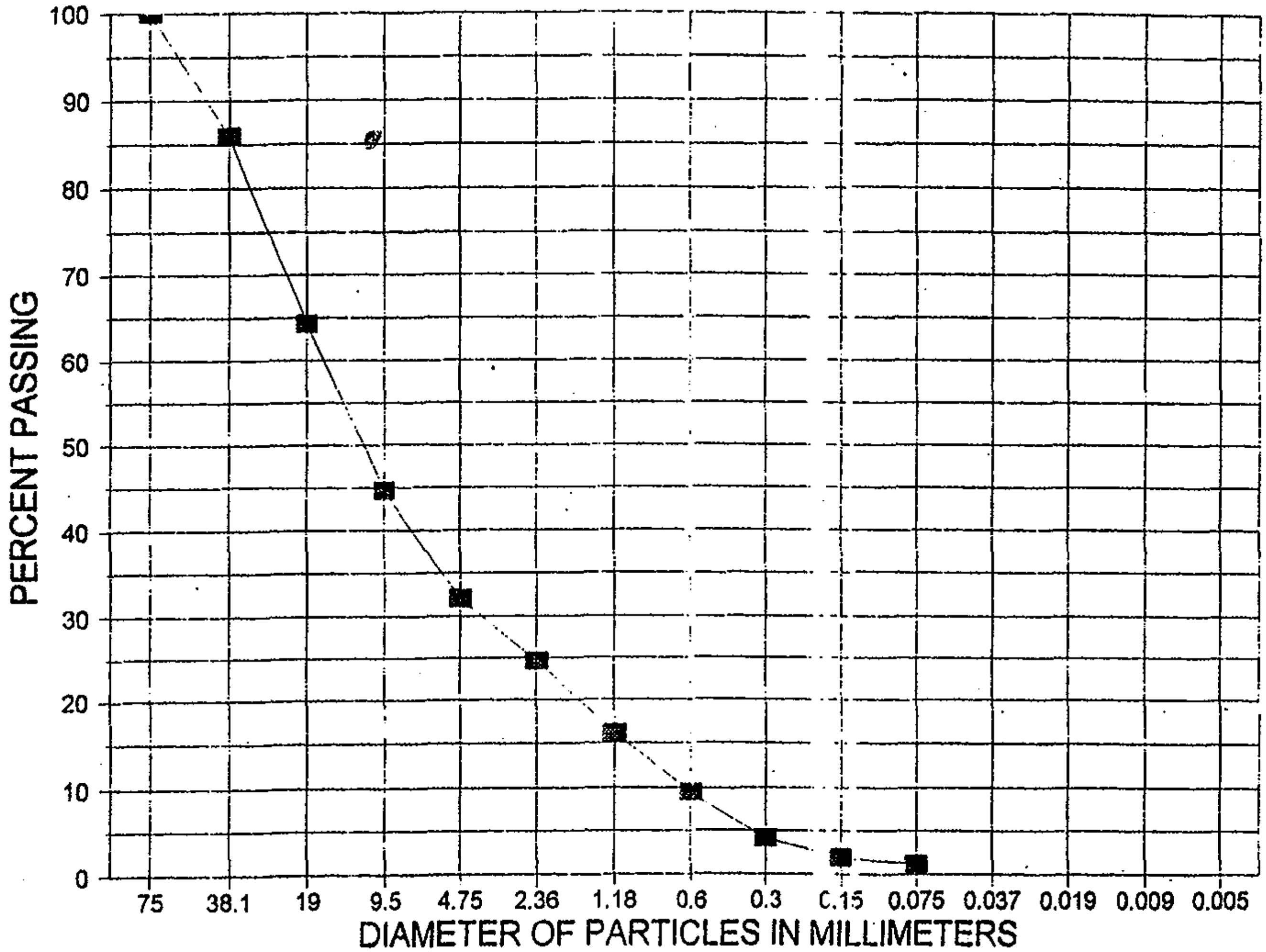
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
min*							2 µm	
5 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam BSH 98-1 115.0' to 120.0'



Unified Soil Classification: GW Well Graded Gravel with Sand

% Gravel: 68.0
% Sand: 30.8
% Fines: 1.2

Maximum Size: 2.5"
Liquid Limit:
Plastic Limit:

Cu: 25.62
Cc: 1.48

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-
Designation USBR 5330-
Designation USBR 5335-

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 115.0 to 120.0	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 33.68

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 203							
WET MASS RETAINED							
DRY MASS RETAINED		0	4.76	7.25	6.64	4.24	
DRY MASS PASSING		33.68	28.92	21.67	15.03	10.79	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	85.9	64.3	44.6	32.0	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 750.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 0.0427
DS. 1.0.	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE 11-23-98

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	174	576		24.6	2.36 mm	Max size = 2 1/2"
16	198	378		16.1	1.18 mm	Gravel - 68.0
30	157	221		9.4	600 µm	Sand - 30.8
50	126	95		4.1	300 µm	Fines = 1.2
100	51	44		1.9	150 µm	GW = Well Graded Gravel
200	17	27		1.2	75 µm	with Sand
PAN		TESTED AND COMPUTED BY	DATE	CHECKED BY		DATE
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

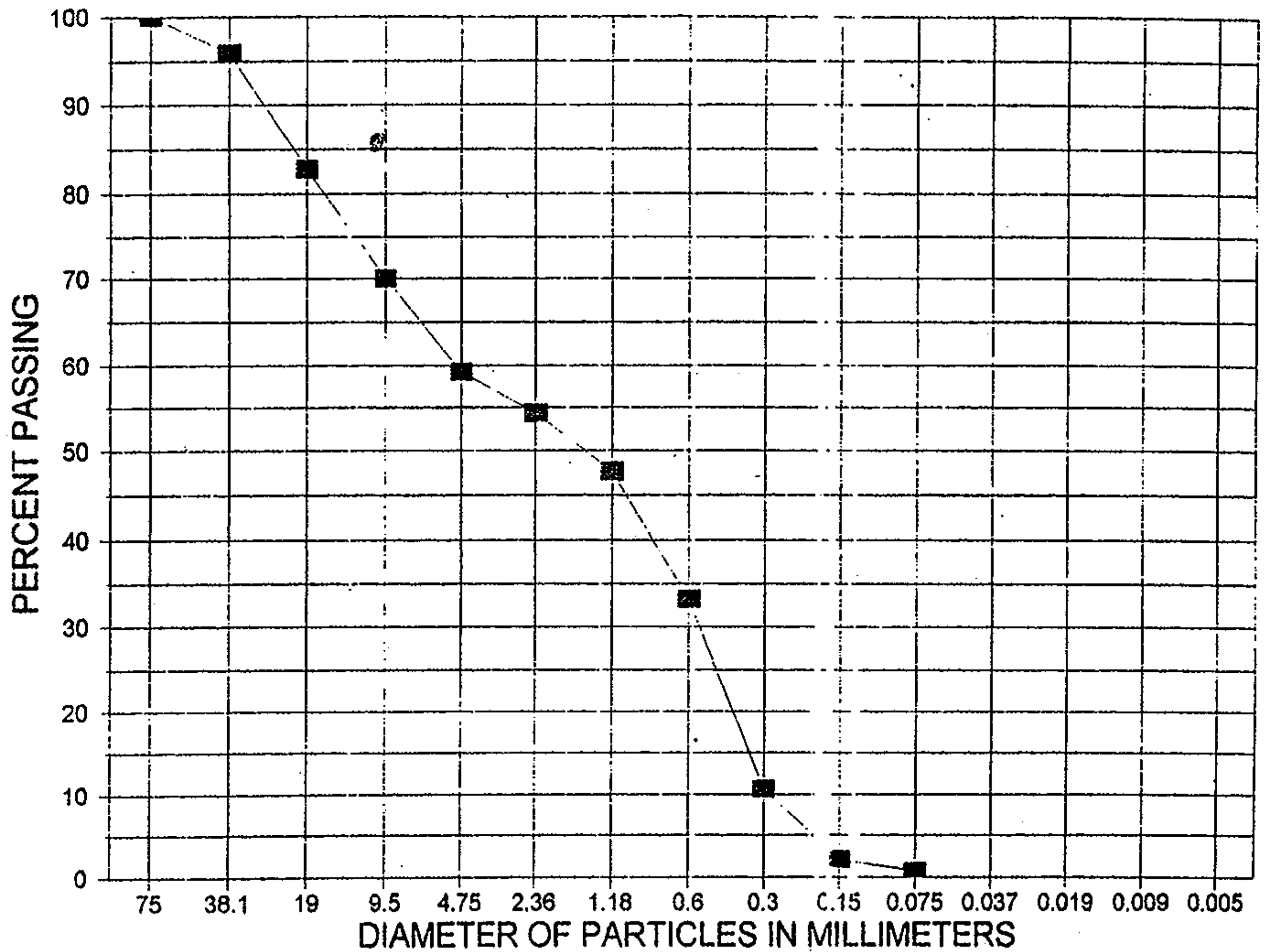
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205- USBR 5300-
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam **BSH 98-1** **120.0' to 125.0'**



Unified Soil Classification: SP Poorly Graded Sand with Gravel

% Gravel: 40.8	Maximum Size: 2.25"	Cu: 17.50
% Sand: 58.5	Liquid Limit:	Cc: 0.21
% Fines: 0.7	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 120.5 to 125.9

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 31.67

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 22							
WET MASS RETAINED							
DRY MASS RETAINED		0	1.30	4.17	4.03	3.41	
DRY MASS PASSING		31.67	30.37	26.20	22.17	18.76	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	95.9	82.7	70.0	59.2	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 664.0 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 0.0892

D.S. - 1.0. DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	54	610		54.4	2.36 mm	Max size = 2 1/2"
	76	534		47.6	1.18 mm	Gravel = 40.8
30	162	372		33.2	600 µm	Sand = 58.5
50	253	119		10.6	300 µm	Fines = 0.7
100	95	24		2.1	150 µm	SP = Poorly Graded Sand
200	16	8		0.7	75 µm	with Gravel
PAN						
TOTAL		TESTED AND COMPUTED BY		DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO.		DISPERSING AGENT
STARTING TIME	DATE	AMOUNT mL

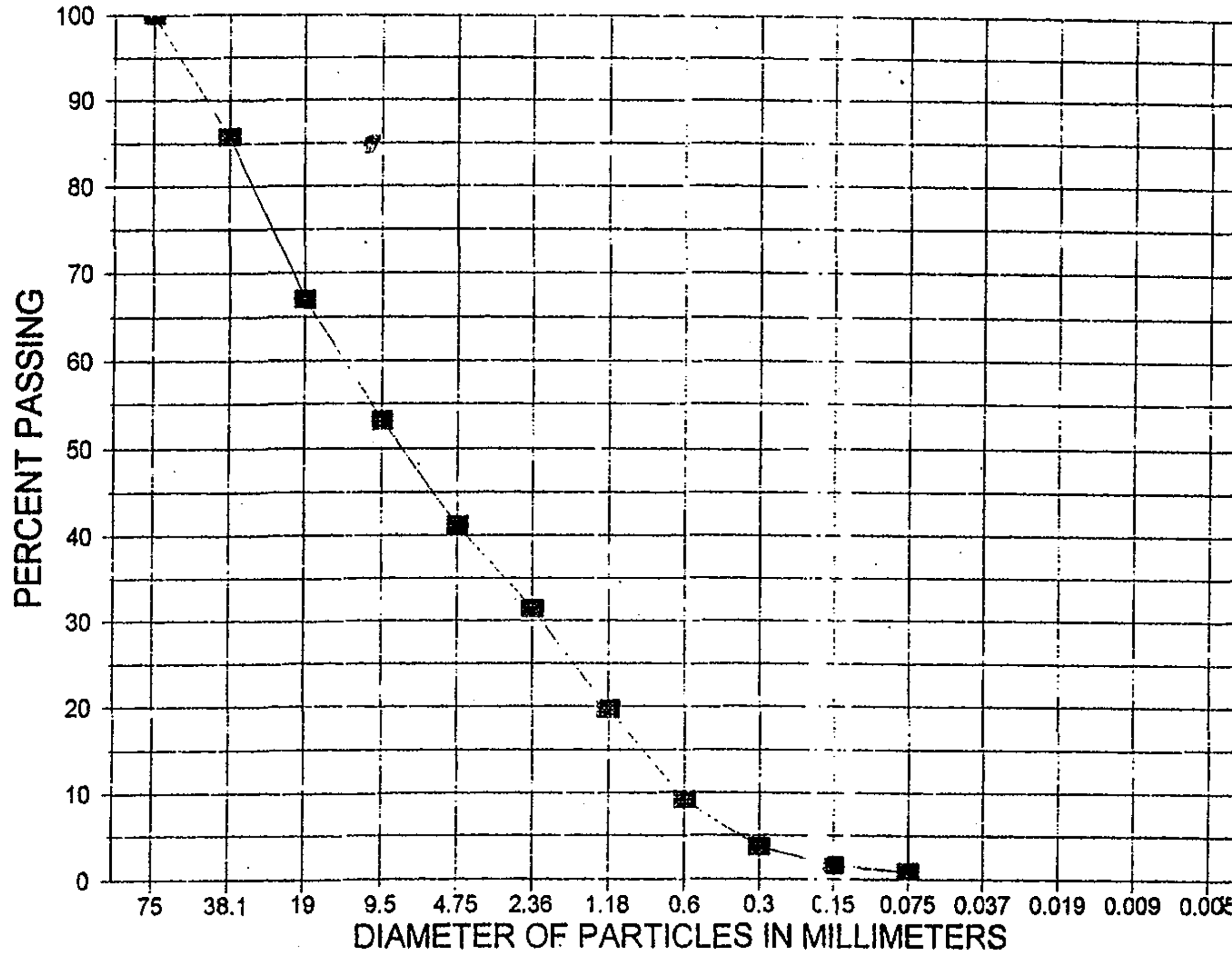
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam   BSH 98-1   125.0' to 130.0'



Unified Soil Classification: GP Poorly Graded Gravel with Sand

% Gravel: 58.8	Maximum Size: 2.5"	Cu: 21.08
% Sand: 40.4	Liquid Limit:	Cc: 0.55
% Fines: 0.8	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. FS1 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 125 to 1[illegible]	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 30.94

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 202							
WET MASS RETAINED							
DRY MASS RETAINED		-0-	4.38	5.82	4.30	3.70	
DRY MASS PASSING		30.94	26.56	20.74	16.44	12.74	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	85.8	67.0	53.1	41.2	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 750.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 0.0549	
C.S. NO.	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME	DATE	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	178	572		31.4	2.36 mm	Mix [illegible]
[illegible]	215	357		19.6	1.18 mm	Gravel = 58.8
30	191	166		9.1	600 µm	Sand = 40.4
50	99	67		3.7	300 µm	Fines = 0.8
100	40	27		1.5	150 µm	GP = Poorly Graded Gravel
200	13	14		0.8	75 µm	with Sand
PAN		TESTED AND COMPUTED BY	DATE	CHECKED BY		DATE
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

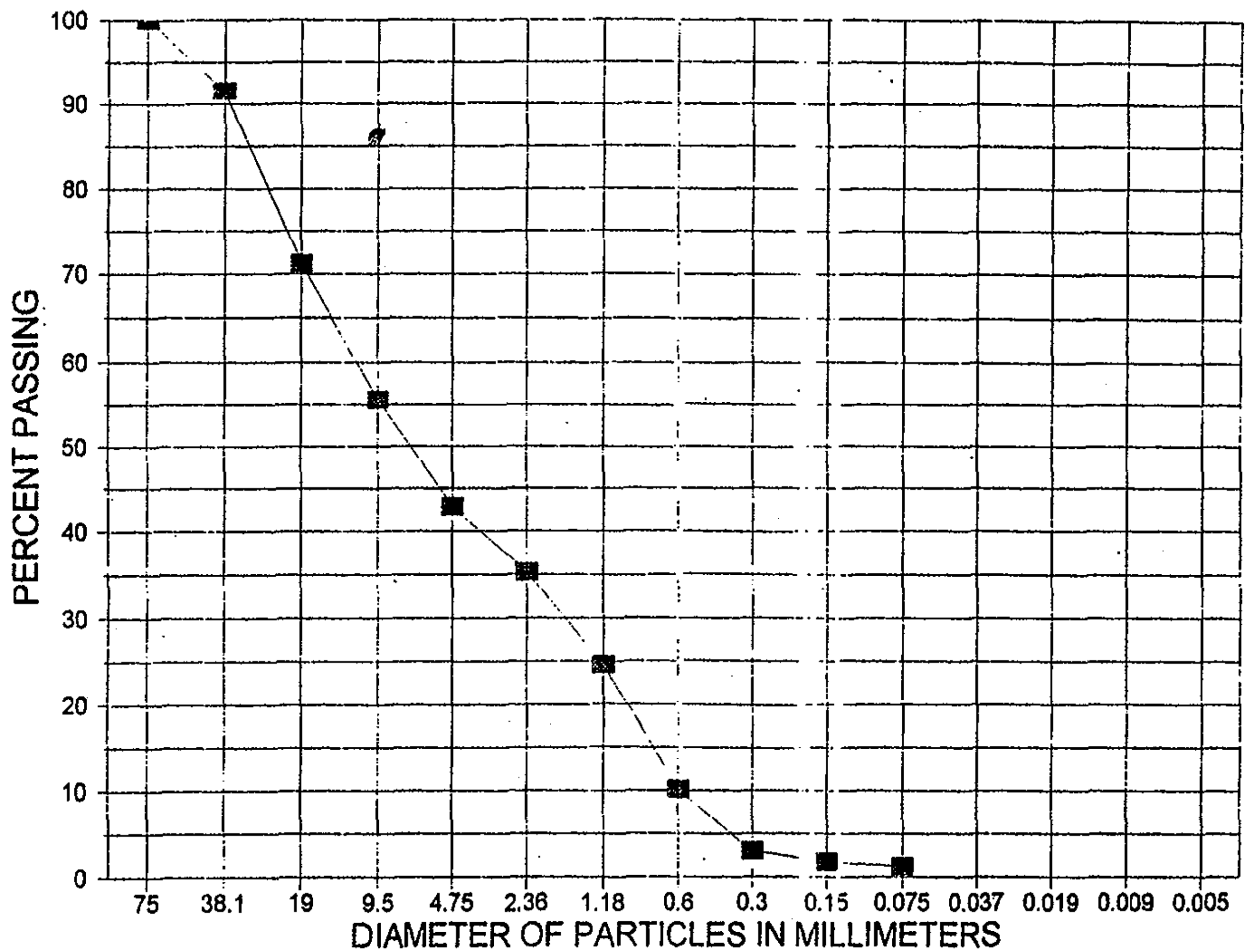
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam BSH 98-1 130.0' to 135.0'



Unified Soil Classification: GP Poorly Graded Gravel with Sand

% Gravel: 57.2	Maximum Size: 2.25"	Cu: 19.50
% Sand: 41.6	Liquid Limit:	Cc: 0.41
% Fines: 1.2	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 130' to 135'

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 30.37

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 203							
WET MASS RETAINED							
DRY MASS RETAINED		0	2.59	6.17	4.76	3.84	
DRY MASS PASSING		30.37	27.78	21.61	16.85	13.01	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	91.5	71.2	55.5	42.8	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 441.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ = 0.0[illegible]	
DISH NO. 545	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME	DATE 11-23-98	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	114	532		35.3	2.36 mm	Max. size = 2 1/4"
16	162	370		24.5	1.18 mm	Gravel = 57.2
30	217	153		10.1	600 µm	Sand = 41.6
50	108	45		3.0	300 µm	Fines = 1.2
100	20	25		1.7	150 µm	GP = Poorly Graded Gravel
200	7	18		1.2	75 µm	with Sand
PAN		TESTED AND COMPUTED BY		DATE	CHECKED BY	DATE
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

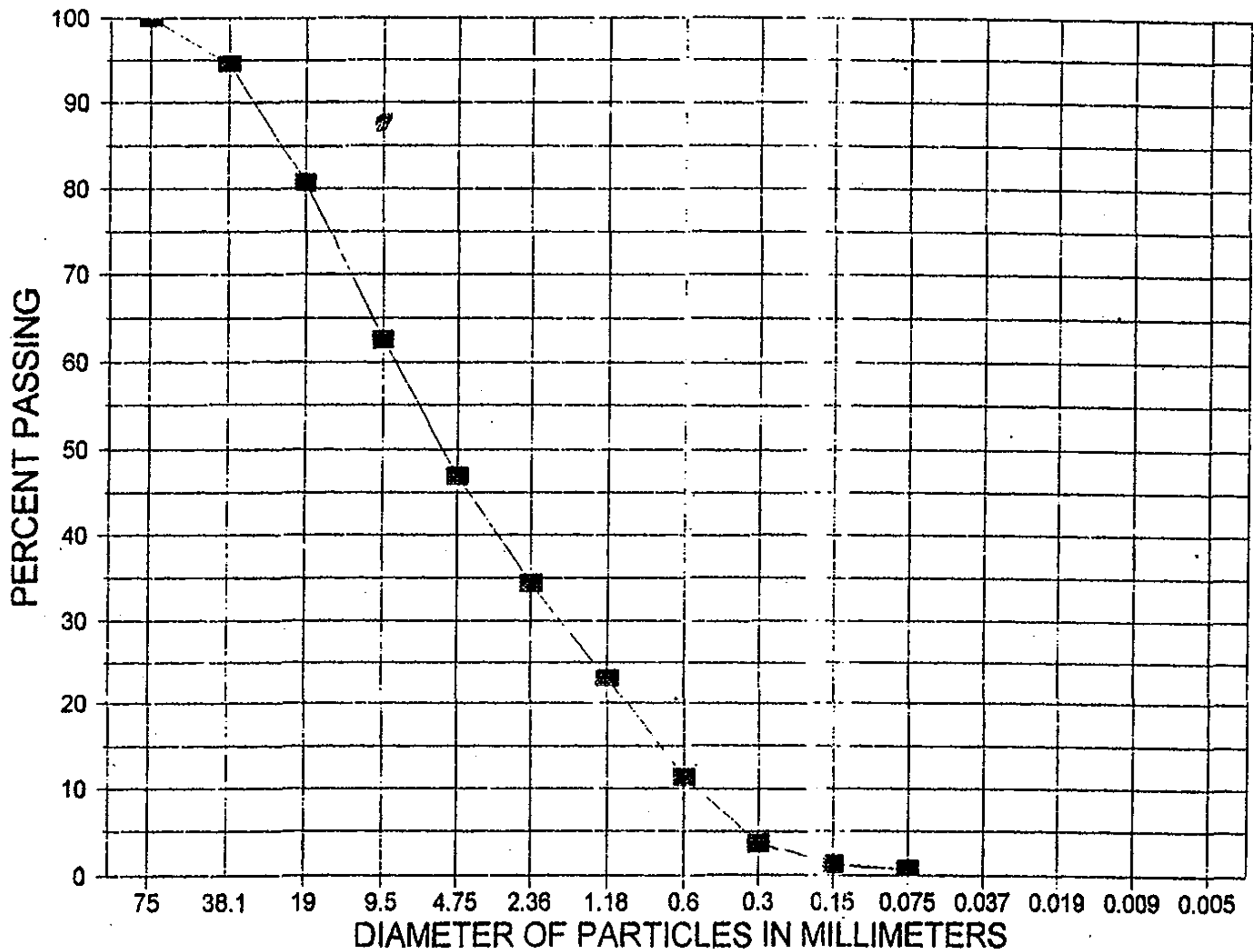
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam BSH 98-1 135.0' to 140.0'



Unified Soil Classification: GP Poorly Graded Gravel with Sand

% Gravel: 53.1	Maximum Size: 2"	Cu: 15.93
% Sand: 46.2	Liquid Limit:	Cc: 0.72
% Fines: 0.7	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 135' to 140'	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 28.37

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER #1 (1.38)							
WET MASS RETAINED							
DRY MASS RETAINED		0	1.55	3.96	5.12	4.44	
DRY MASS PASSING		28.37	26.82	22.86	17.74	13.30	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	94.5	80.6	62.5	46.9	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 6170 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = [illegible]
DISH NO. 513A	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE 11-23-98

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	171	471		34.4	2.36 mm	Max. size = 2"
16	157	314		23.0	1.18 mm	Gravel = 53.1
30	159	155		11.3	600 µm	Sand = 46.2
50	106	49		3.6	300 µm	Fines = 0.7
100	31	18		1.3	150 µm	GP = Poorly Graded Gravel
200	9	9		0.7	75 µm	with ~~Silt~~ Sand
PAN		TESTED AND COMPUTED BY		DATE	CHECKED BY	DATE
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

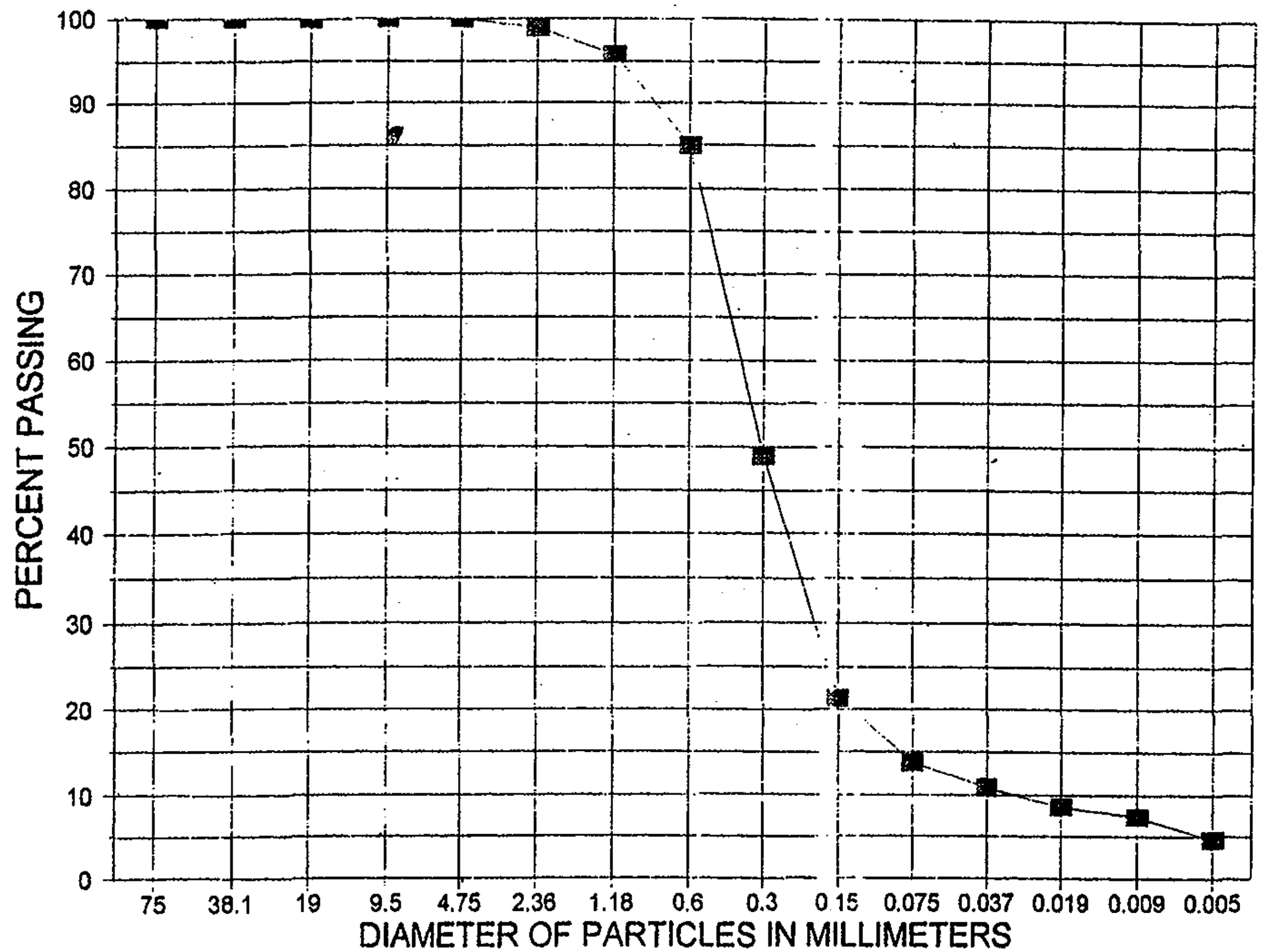
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

* Not required for standard test.

GPO 853-659

Cle Elum Dam BSH 98-1 140.0' to 145.0'



Unified Soil Classification: SM Silty Sand

% Gravel: 0.0
% Sand: 86.3
% Fines: 13.7

Maximum Size: No. 4
Liquid Limit:
Plastic Limit:

Cu:
Cc:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 140.0 to 145.0	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER D-4							
WET MASS RETAINED							
DRY MASS RETAINED						0	
DRY MASS PASSING							☐ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 87.9 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ = ______
C.S. I.D. 17	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	1.0	86.9		98.9	2.36 mm	Max Size = No. 4
	2.7	84.2		95.8	1.18 mm	0 % Gravel
30	9.5	74.7		85.0	600 µm	86.3 % Sand
50	31.7	43.0		48.9	300 µm	13.7 % Fines
100	24.3	18.7		21.3	150 µm	SM = Silty Sand
200	6.7	12.0		13.7	75 µm	
PAN		TESTED AND COMPUTED BY		DATE	CHECKED BY	DATE
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO. 36	DISPERSING AGENT	
STARTING TIME 1:34	DATE 12-2-98	AMOUNT mL

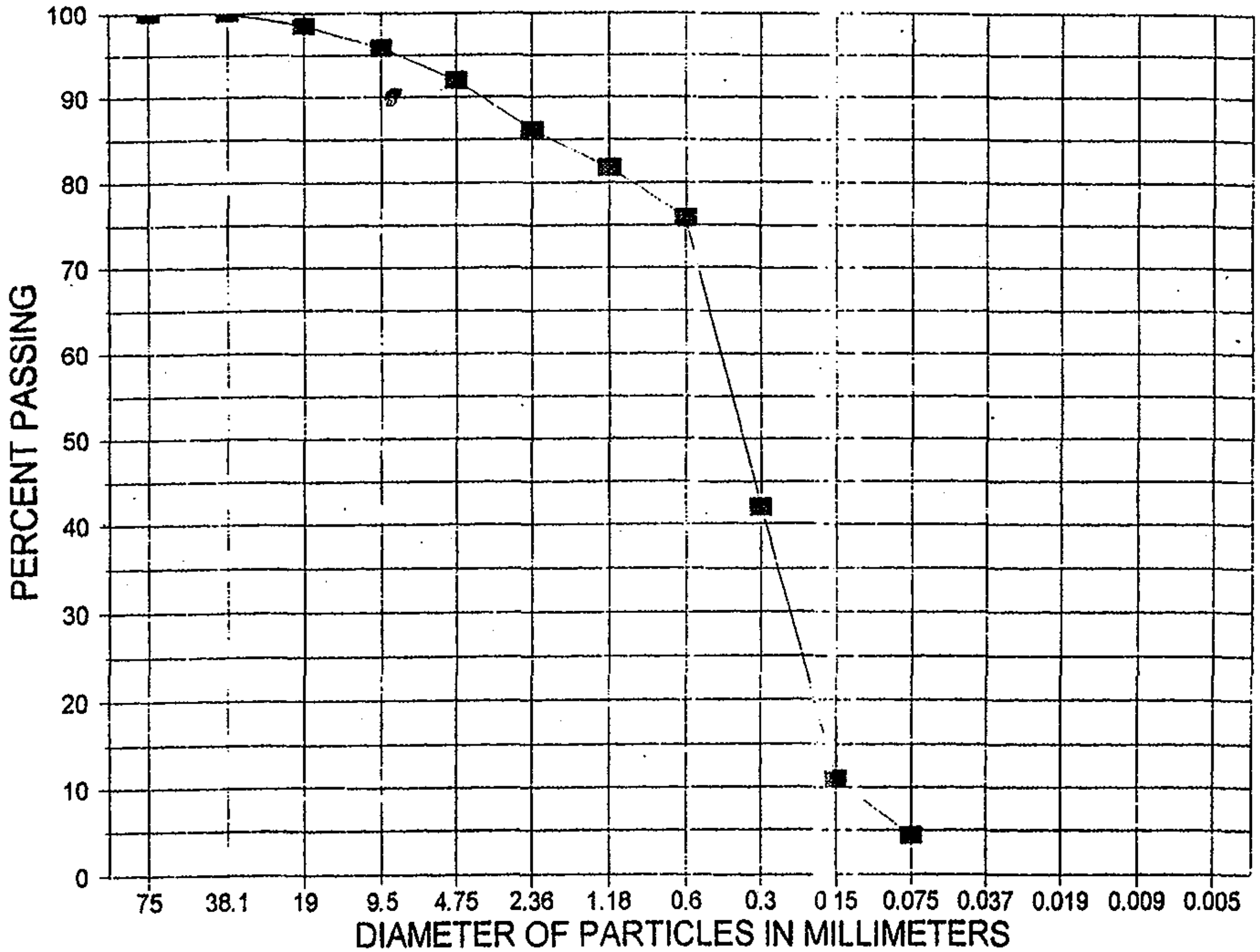
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
								One bag marked
1 min		14.0	-4.5	9.5		10.8	37 µm	1 of 3
4 min	23.0	12.0	-4.5	7.5		8.5	19 µm	
19 min	23.0	11.0	-4.5	6.5		7.4	9 µm	
60 min	23.0	8.5	-4.5	4.0		4.6	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
15 min*							2 µm	
23 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam BSH 98-1 145.0' to 150.0'



Unified Soil Classification: SP Poorly Graded Sand

% Gravel: 8.0
% Sand: 87.6
% Fines: 4.4

Maximum Size: 1.25"
Liquid Limit:
Plastic Limit:

Cu: 3.18
Cc: 0.89

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum
AREA	EXC. NO.	DEPTH 145' to 150'

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 9,80

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 38							
WET MASS RETAINED							
DRY MASS RETAINED			~~0~~	0,15	0,26	0,37	
DRY MASS PASSING			9,80	9,65	9,39	9,02	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING			100	98.5	95.8	92.0	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 482,0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ____ = [illegible]
DISH NO. [illegible]	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE 11-23-98

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	31	451		86.1	2.36 mm	Max size = 1 1/2"
16	23	428		81.7	1.18 mm	Gravel = 8.0
30	31	397		75.8	600 µm	Sand = 87.6
50	177	220		42.0	300 µm	Fines = 4.4
100	163	57		10.9	150 µm	SP = Poorly Graded Sand
200	34	23		4.4	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO.		DISPERSING AGENT
STARTING TIME	DATE	AMOUNT mL

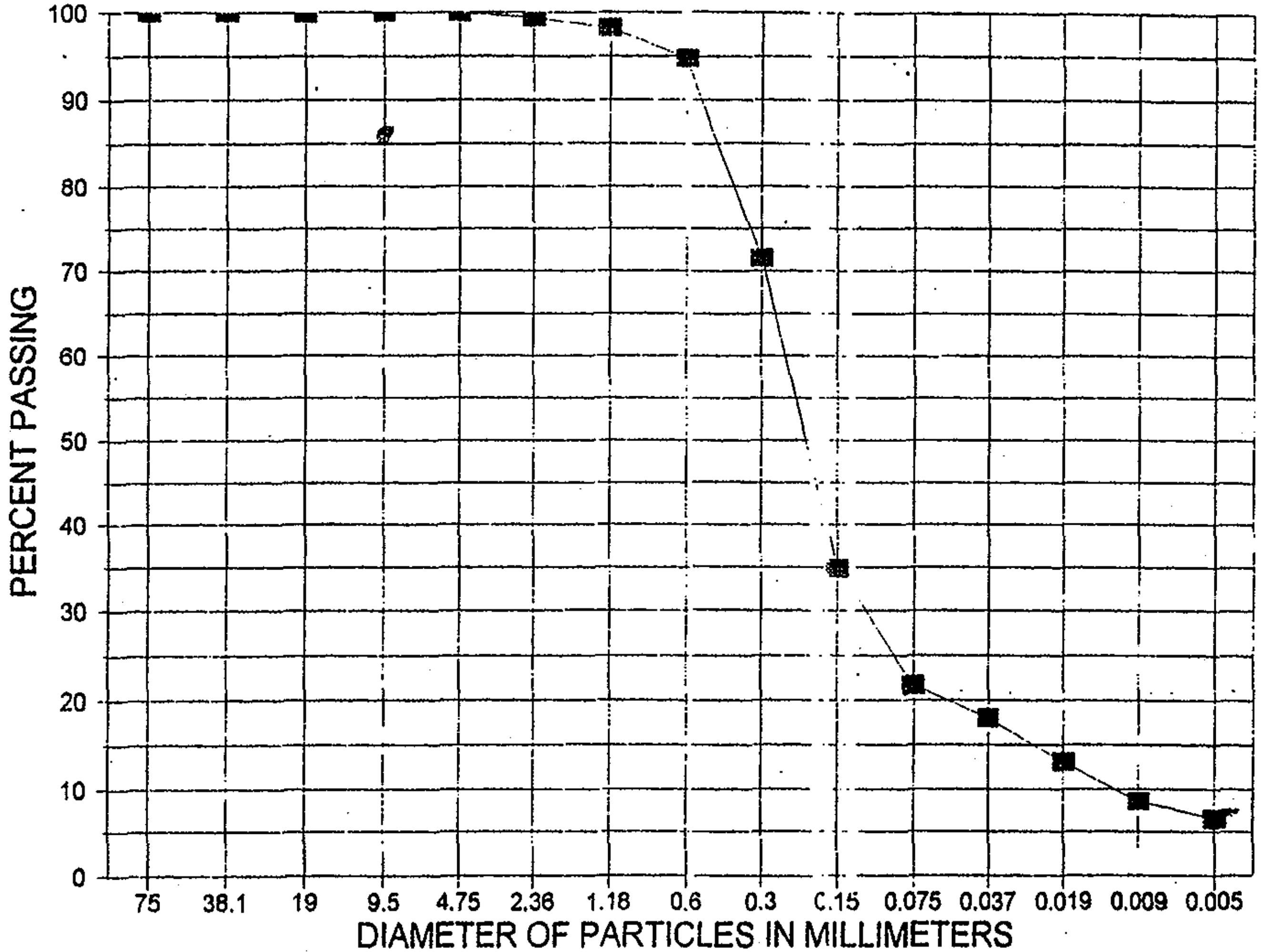
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam BSH 98-1 150.0' to 155.0'



Unified Soil Classification: SM Silty Sand

% Gravel: 0.0	Maximum Size: 3/8"	Cu:
% Sand: 78.4	Liquid Limit:	Cc:
% Fines: 21.6	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH – 98 – 1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 150' to 155'

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 5.42

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 17							
WET MASS RETAINED							
DRY MASS RETAINED						TRACE	
DRY MASS PASSING						5.42	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 100.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ =	
DISH NO. 26	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME	DATE	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	0.6	99.4		99.4	2.36 mm	Max. Size = 3/8"
16	1.1	98.3		98.3	1.18 mm	-0- % Gravel
30	3.6	94.7		94.7	600 µm	78.4 % Sand
50	23.2	71.5		71.5	300 µm	21.6 % Fines
100	36.6	34.9		34.9	150 µm	SM = Silty Sand
200	13.3	21.6		21.6	75 µm	
PAN		TESTED AND COMPUTED BY		DATE	CHECKED BY	DATE
TOTAL		SF				

HYDROMETER ANALYSIS

HYDROMETER NO. 76	DISPERSING AGENT	
STARTING TIME 8 59	DATE 12-2-98	AMOUNT mL

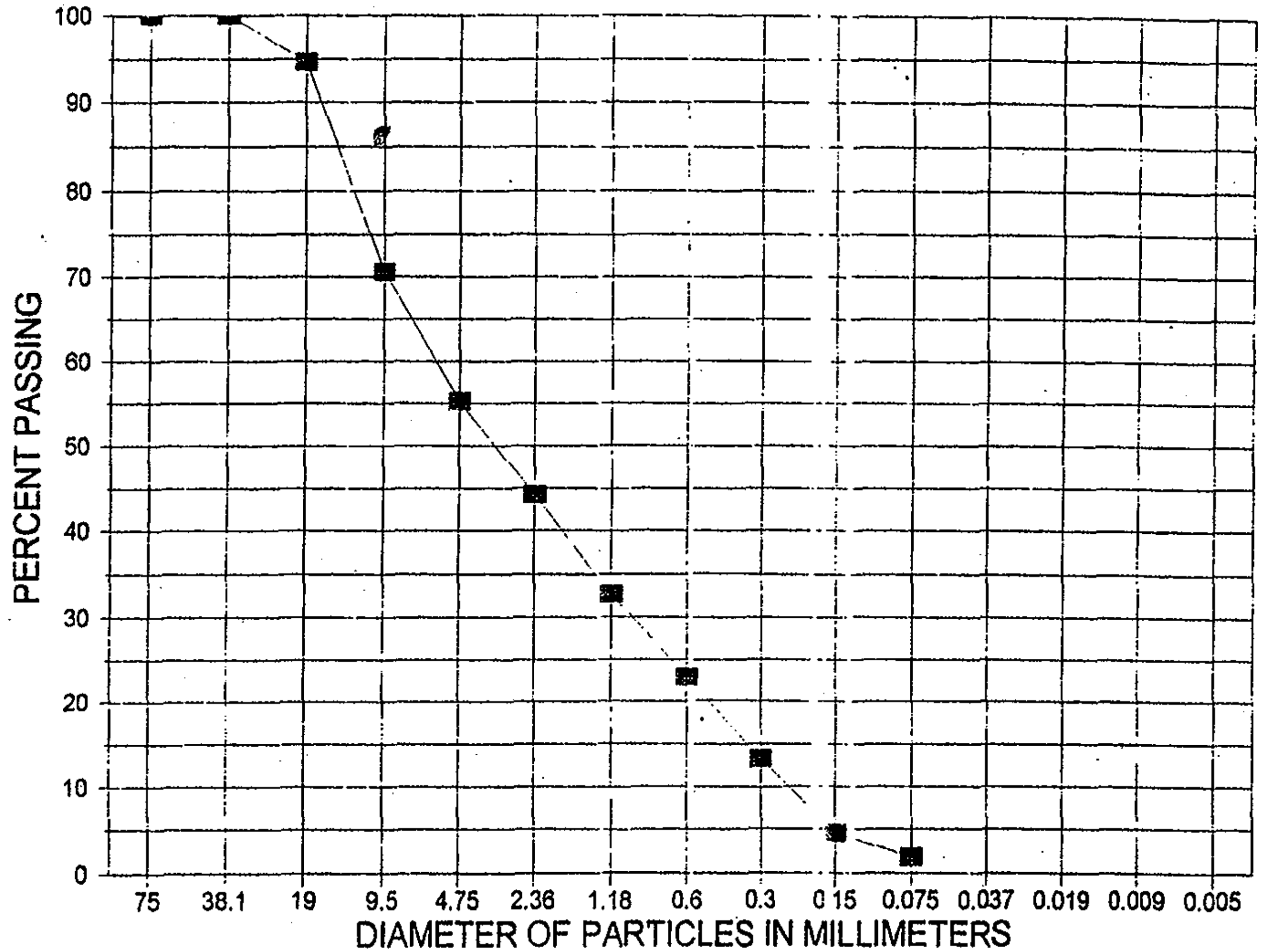
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min		23.0	-5.0	18		18	37 µm	
4 min	23.0	18.0	-5.0	13		13	19 µm	
19 min	23.0	13.5	-5.0	8.5		8.5	9 µm	
60 min	23.0	11.5	-5.0	6.5		6.5	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-859

Cle Elum Dam **BSH 98-1** **155' to 165'**



Unified Soil Classification: SP Poorly Graded Sand with Gravel

% Gravel: 44.7 Maximum Size: 1" Cu: 25.31

% Sand: 53.5 Liquid Limit: Cc: 0.70

% Fines: 1.8 Plastic Limit:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1		PROJECT		FEATURE Cle Elum Dam	
AREA		EXC. NO.		DEPTH 155' to 165'	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 22.07

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 5C							
WET MASS RETAINED							
DRY MASS RETAINED			-0-	1.20	5.31	3.36	
DRY MASS PASSING			22.07	20.87	15.56	12.20	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING			100	94.6	70.5	55.3	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 741.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ = [illegible]	
DISH NO. 513	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME	DATE	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	148	593		44.2	2.36 mm	Max. size = 1"
16	155	438		32.7	1.18 mm	Gravel = 44.7
30	131	307		22.9	600 µm	Sand = 53.5
50	130	177		13.2	300 µm	Fines = 1.8
100	117	60		4.5	150 µm	SP = Poorly Graded Sand
200	36	24		1.8	75 µm	with Gravel
PAN		TESTED AND COMPUTED BY	DATE	CHECKED BY		DATE
TOTAL						

HYDROMETER ANALYSIS

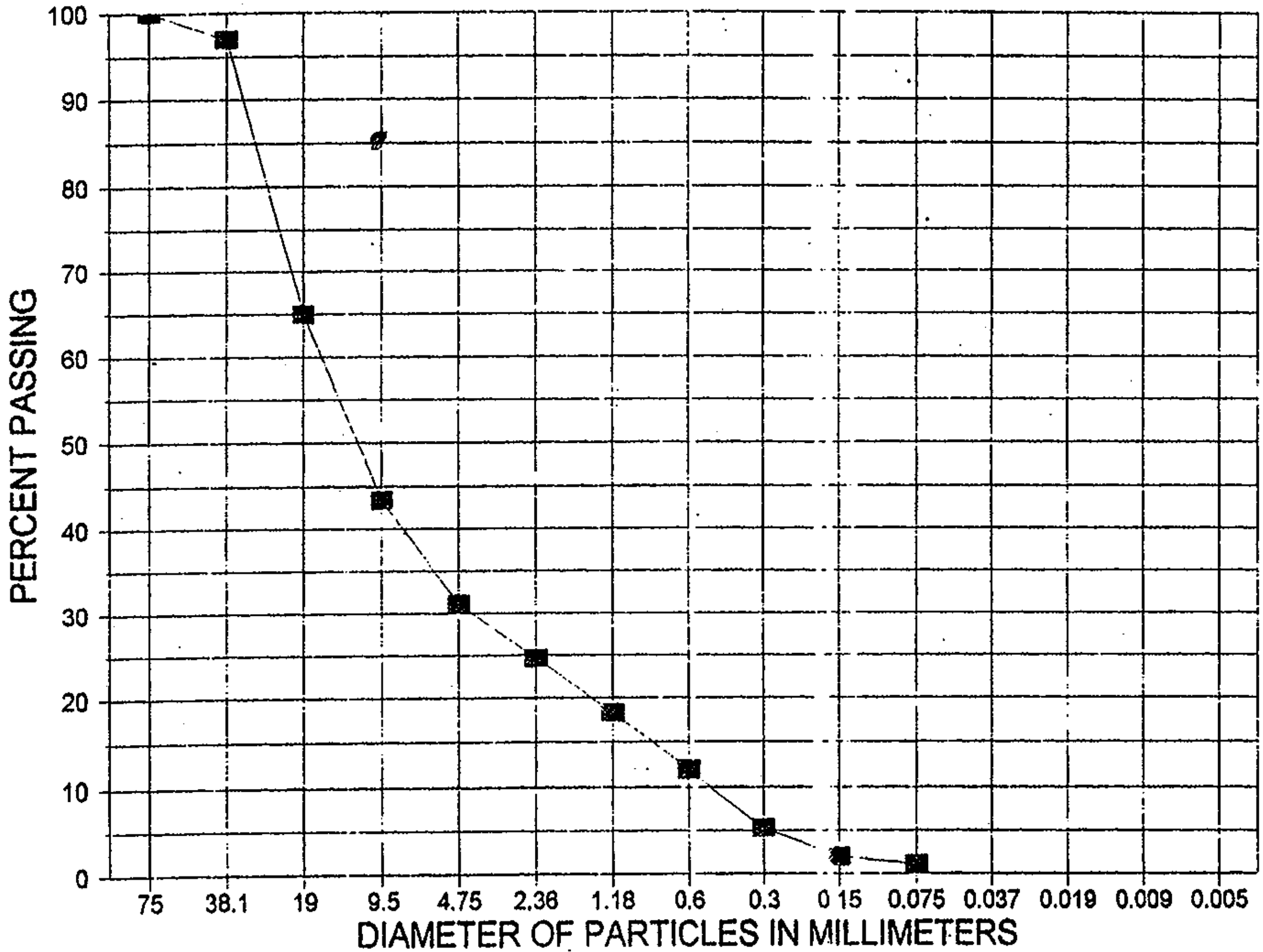
HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

Cle Elum Dam BSH ..-1 165.0' to 170.0'



Unified Soil Classification: GW Well Graded Gravel with Sand

% Gravel: 68.9 | Maximum Size: 2" | Cu: 33.01
% Sand: 30.0 | Liquid Limit: | Cc: 2.23
% Fines: 1.1 | Plastic Limit:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. RSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 165.0 to 170.0

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 27.61

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 201							
WET MASS RETAINED							
DRY MASS RETAINED		0	0.82	8.86	5.94	3.41	
DRY MASS PASSING		27.61	26.79	17.93	11.99	8.58	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	97.0	64.9	43.4	31.1	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 612.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = [illegible]	
DISH NO.	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME	DATE 11-24-98	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	128	481		24.6	2.36 mm	Max size [illegible]
16	124	360		18.3	1.18 mm	Gravel = 68.9
30	126	231		11.9	600 μm	Sand = [illegible]
50	129	105		5.3	300 μm	Fines = 1.1
100	66	39		2.0	150 μm	GW = Well Graded Gravel
200	17	22		1.1	75 μm	with Sand
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

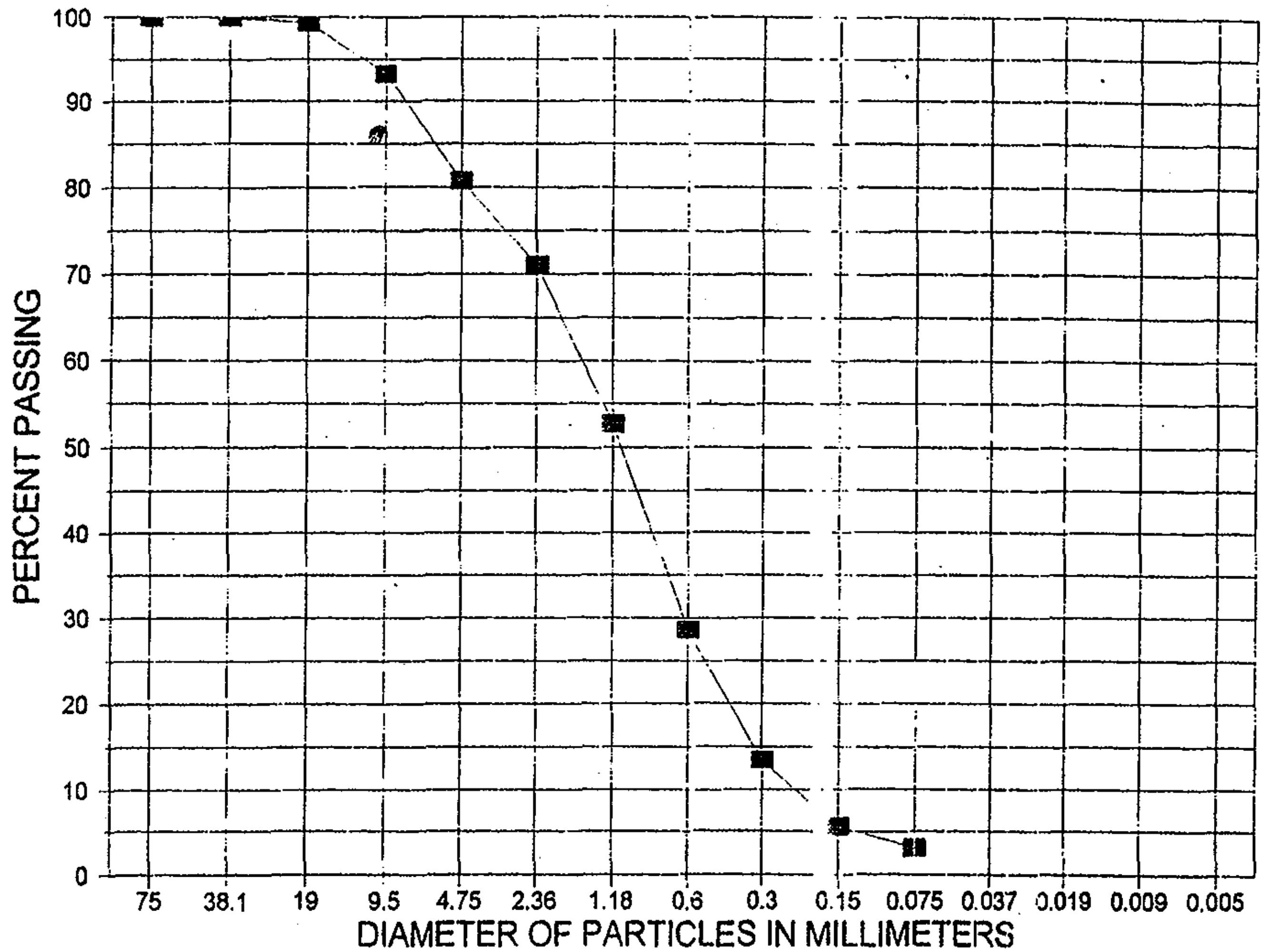
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 μm	
4 min							19 μm	
19 min							9 μm	
60 min							5 μm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
h 15 min*							2 μm	
25 h 45 min*							1 μm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam **BSH 98-1** **170.0' to 175.0'**



Unified Soil Classification: SW Well Graded Sand with Gravel

% Gravel: 19.3	Maximum Size: 1"	Cu: 6.99
% Sand: 77.5	Liquid Limit:	Cc: 1.13
% Fines: 3.2	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE CleElum Dam	
AREA	EXC. NO.	DEPTH 170' to 175'	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 1-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 19.63

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 201							
WET MASS RETAINED							
DRY MASS RETAINED			-0-	0.14	1.20	2.45	
DRY MASS PASSING			19.63	19.49	18.29	15.84	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING			100	99.3	93.2	80.7	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 749.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = [illegible]
DISH NO. 501	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	90	659		71.0	2.36 mm	Max size = 1"
16	170	489		52.7	1.18 mm	Gravel 19.3
30	224	265		20.5	600 µm	Sand = 77.5
50	141	124		13.4	300 µm	Fines = 3.2
100	73	51		5.5	150 µm	SW = Well Graded Sand
200	21	30		3.2	75 µm	with Gravel
PAN		TESTED AND COMPUTED BY		DATE	CHECKED BY	DATE
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

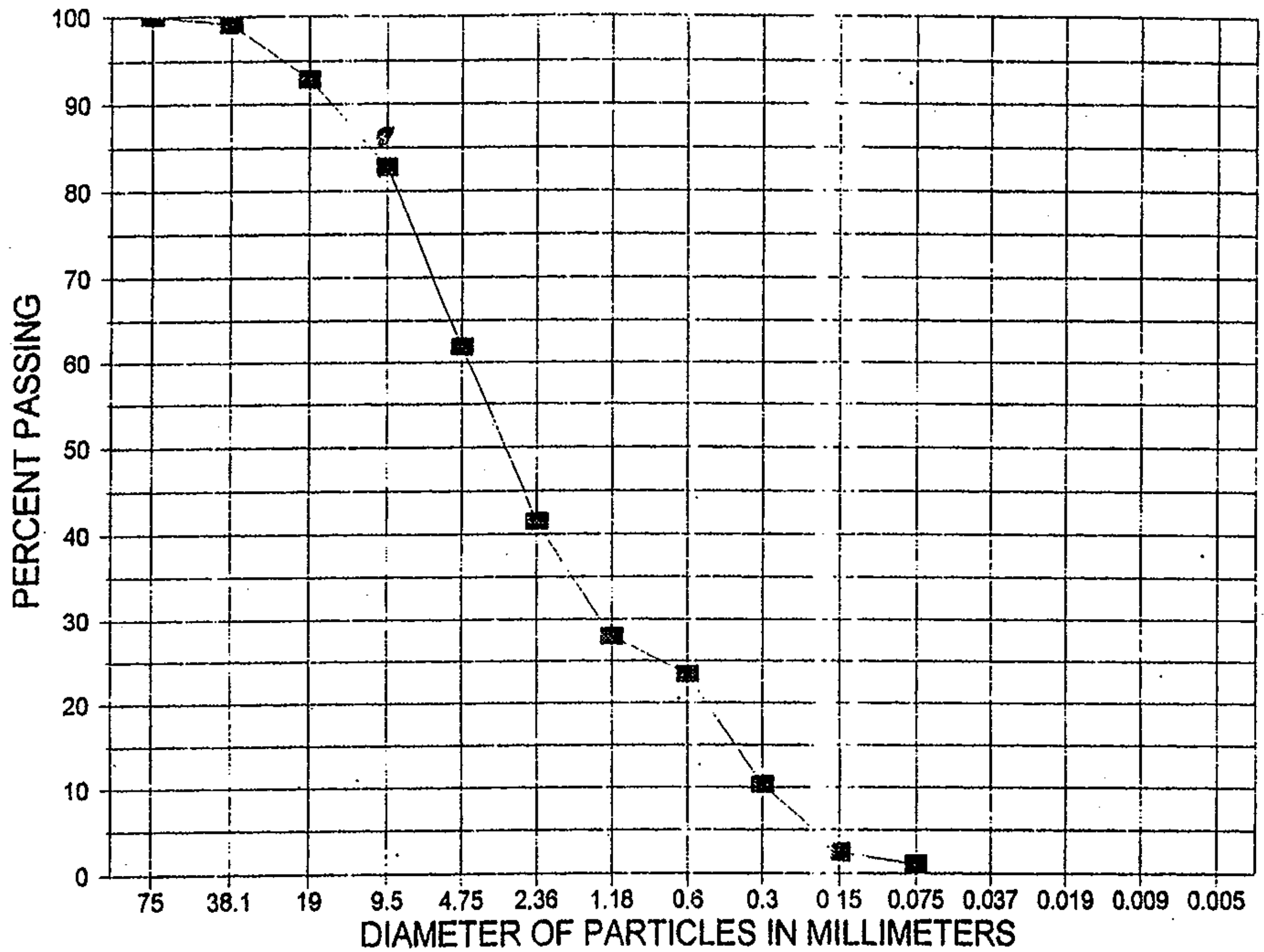
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam BSH 98-1 175.0' to 180.0'



Unified Soil Classification: SW Well Graded Sand with Gravel

% Gravel: 38.2	Maximum Size: 2"	Cu: 15.28
% Sand: 60.8	Liquid Limit:	Cc: 1.32
% Fines: 1.0	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 175' to 180'

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 24.08

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 22	(4.22)						
WET MASS RETAINED							
DRY MASS RETAINED		-0	0.21	1.49	2.46	5.05	
DRY MASS PASSING		24.08	23.87	22.38	19.92	14.87	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	99.1	92.9	82.7	61.8	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 917.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ———— = .0755	
DISH NO. 523	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME	DATE 11-21-98	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	270	549		41.4	2.36 mm	Max. size = 2"
16	180	369		27.9	1.18 mm	Gravel = 38.2
30	59	310		23.4	600 µm	Sand = 60.8
50	173	137		10.3	300 µm	Fines = 1.0
100	105	32		2.4	150 µm	SW = Well Graded Sand
200	19	13		1.0	75 µm	with Gravel
PAN		TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE	
TOTAL						

HYDROMETER ANALYSIS

HYDROMETER NO.		DISPERSING AGENT
STARTING TIME	DATE	AMOUNT mL

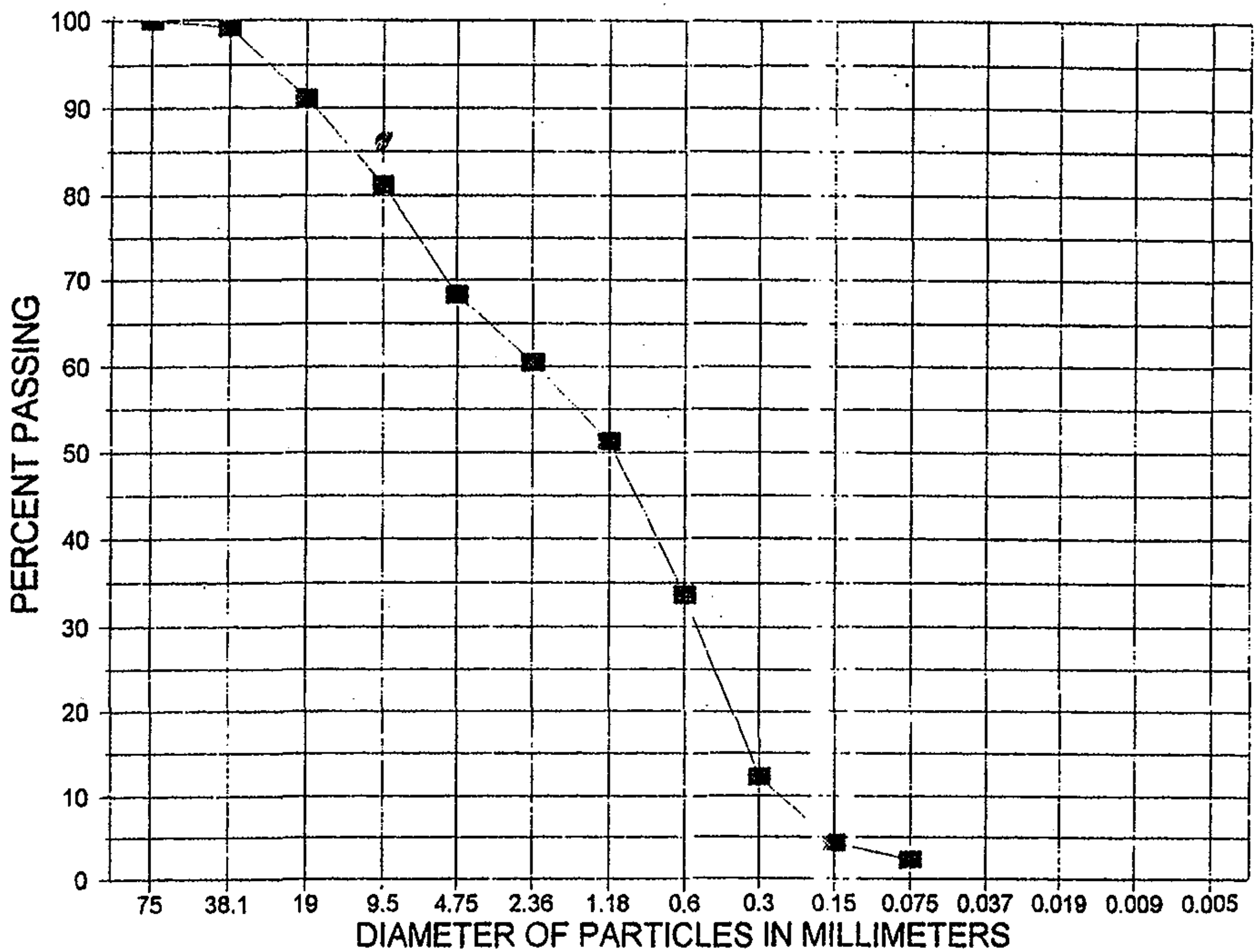
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

* Not required for standard test.

GPO 853-859

Cle Elum Dam BSH 98-1 180.0' to 185.0'



Unified Soil Classification: SP Poorly Graded Sand with Gravel

% Gravel: 31.7 Maximum Size: 1.75" Cu: 9.25

% Sand: 66.0 Liquid Limit: Cc: 0.50

% Fines: 2.3 Plastic Limit:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BS1198-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 180' to 185'	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 26.91

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER	202						
WET MASS RETAINED							
DRY MASS RETAINED		0	0.21	2.17	2.68	3.47	
DRY MASS PASSING		26.91	26.70	24.53	21.85	18.38	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING		100	99.2	91.2	81.2	68.3	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 741.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = [illegible]	
DISH NO. 522	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME	DATE	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	86	658		60.4	2.36 mm	Max size = 1 3/4"
16	99	559		51.3	1.18 mm	Gravel - 31.7
30	193	366		33.6	600 µm	Sand = 66.0
50	233	133		12.2	300 µm	Fines = 2.3
100	86	47		4.3	150 µm	SP = Poorly Graded Sand
200	22	25		2.3	75 µm	with Gravel
PAN		TESTED AND COMPUTED BY	DATE	CHECKED BY		DATE
TOTAL						

HYDROMETER ANALYSIS

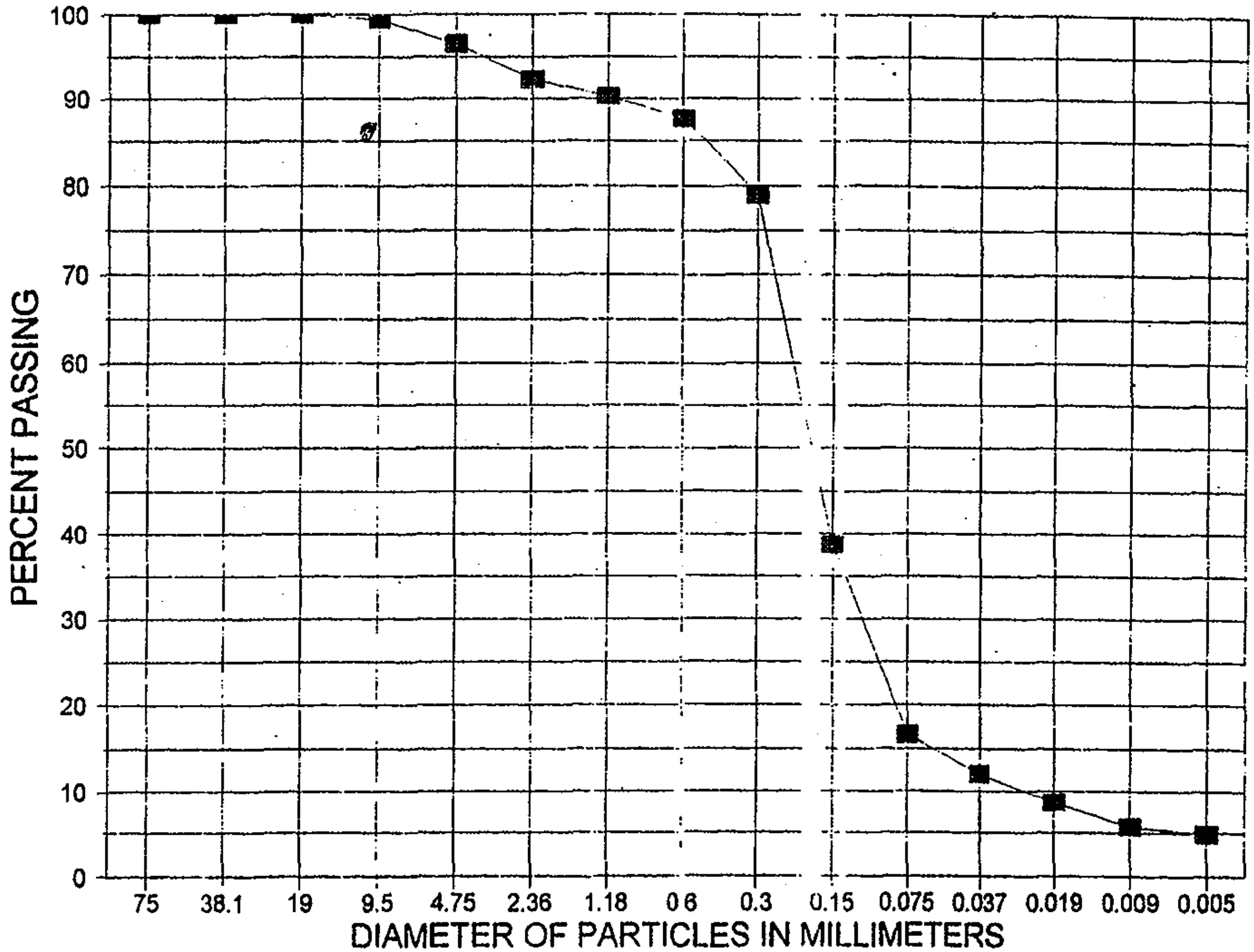
HYDROMETER NO.	DISPERSING AGENT	
STARTING TIME	DATE	AMOUNT mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min							37 µm	
4 min							19 µm	
19 min							9 µm	
60 min							5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
min*							2 µm	
5 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

Cle Elum Dam BSH 98-1 185.0' to 190.0'



Unified Soil Classification: SM Silty Sand

% Gravel: 3.5 Maximum Size: 0.75" Cu:

% Sand: 79.9 Liquid Limit: Cc:

% Fines: 16.6 Plastic Limit:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 185' to 190'	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 3.38

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 3B							
WET MASS RETAINED							
DRY MASS RETAINED				0	0.02	0.10	
DRY MASS PASSING				3.38	3.36	3.26	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING				100	99.4	96.5	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 100.7 g

$$\text{FACTOR} = \frac{\text{\% TOTAL PASSING NO. 4}}{\text{DRY MASS OF SPECIMEN}} = \frac{96.5}{} = 0.9583$$

DISH NO. 241 — DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME — DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	4.4	96.3		92.3	2.36 mm	Max Size = 3/4"
16	2.1	94.2		90.3	1.18 mm	3.5% Gravel
30	2.8	91.4		87.6	600 µm	79.9 % Sand
50	9.0	82.4		79.0	300 µm	16.6% Fines
100	42.0	40.4		38.7	150 µm	SM = Silty Sand
200	23.1	17.3		16.6	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JF			

HYDROMETER ANALYSIS

HYDROMETER NO. 72	DISPERSING AGENT	
STARTING TIME 8:54	DATE 12-2-98	AMOUNT mL

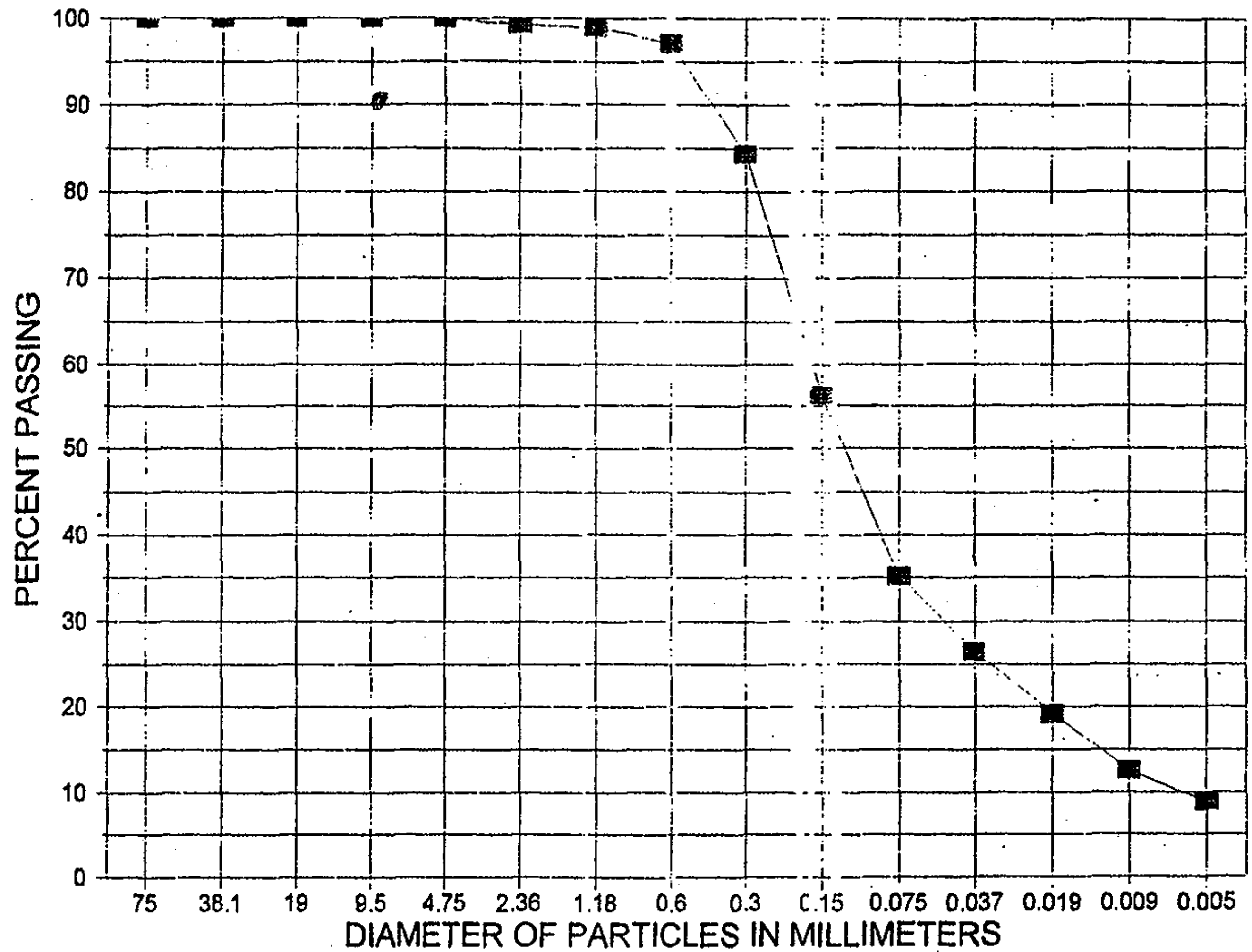
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min		17.5	-5.0	12.5		12.0	37 µm	
4 min	23.0	14.0	-5.0	9		8.6	19 µm	
19 min	23.0	11.0	-5.0	6		5.7	9 µm	
60 min	23.0	10.0	-5.0	5		4.8	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-859

Cle Elum Dam BSH 98-1 190.0' to 195.0'



Unified Soil Classification: SM Silty Sand

% Gravel: 0.0	Maximum Size: No. 4	Cu:
% Sand: 64.8	Liquid Limit:	Cc:
% Fines: 35.2	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH98-1	PROJECT	FEATURE	Cle Elum Dam
AREA	EXC. NO.	DEPTH	190.0 to 195.0

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 6C							
WET MASS RETAINED							
DRY MASS RETAINED						-0-	
DRY MASS PASSING							☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 67.9 g | FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ = ______

D.S. NO. 7 | DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR x MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	[illegible]	67.4		99.3	2.36 mm	Max Size = No. 4
	0.2	67.2		99.0	1.18 mm	-0- % Gravel
30	1.3	65.9		97.1	600 µm	64.8 % Sand
50	8.6	57.3		84.4	300 µm	35.2% Fines
100	19.1	38.2		56.3	150 µm	SM = Silty Sand
200	14.3	23.9		35.2	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JC			

HYDROMETER ANALYSIS

HYDROMETER NO. 87	DISPERSING AGENT
STARTING TIME 1:41 / DATE 12-2-98	AMOUNT mL

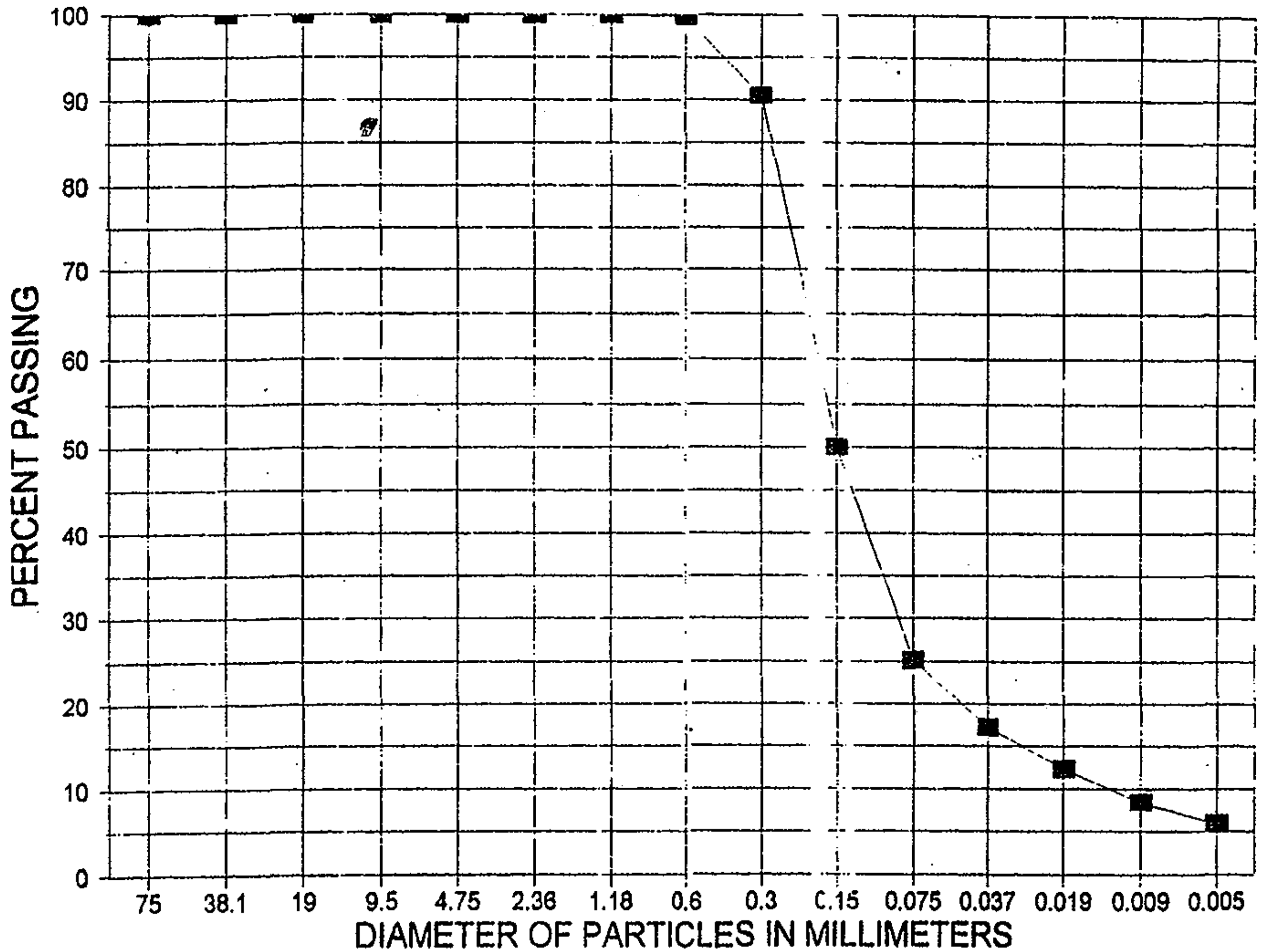
TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR x CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
								One bag marked
1 min		23.0	-5.0	18		26.5	37 µm	1 of 3
4 min	23.0	18.0	-5.0	13		19.2	19 µm	
19 min	23.0	13.5	-5.0	8.5		12.5	9 µm	
60 min	23.0	11.0	-5.0	6		8.8	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

Cle Elum Dam BSH 98-1 195.0' to 200.0'



Unified Soil Classification: SM Silty Sand

% Gravel: 0.0

% Sand: 74.9

% Fines: 25.1

Maximum Size: No. 4

Liquid Limit:

Plastic Limit:

Cu:

Cc:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO.	BS1198-1	PROJECT		FEATURE	Cle Elum Dam
AREA		EXC. NO.		DEPTH	195' to 200'

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 133							
WET MASS RETAINED							
DRY MASS RETAINED						0	
DRY MASS PASSING						3.97	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 101.8 g | FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ =

DISH NO. 37 | DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	Trace	101.8		100	2.36 mm	Max Size = No. 4
16	Trace	101.8		100	1.18 mm	0 % Gravel
30	0.2	101.6		99.8	600 µm	74.9 % Sand
50	9.5	92.1		90.5	300 µm	25.1 % Fines
100	41.2	50.9		50.0	150 µm	SM = Silty Sand
200	25.4	25.5		25.1	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JF			

HYDROMETER ANALYSIS

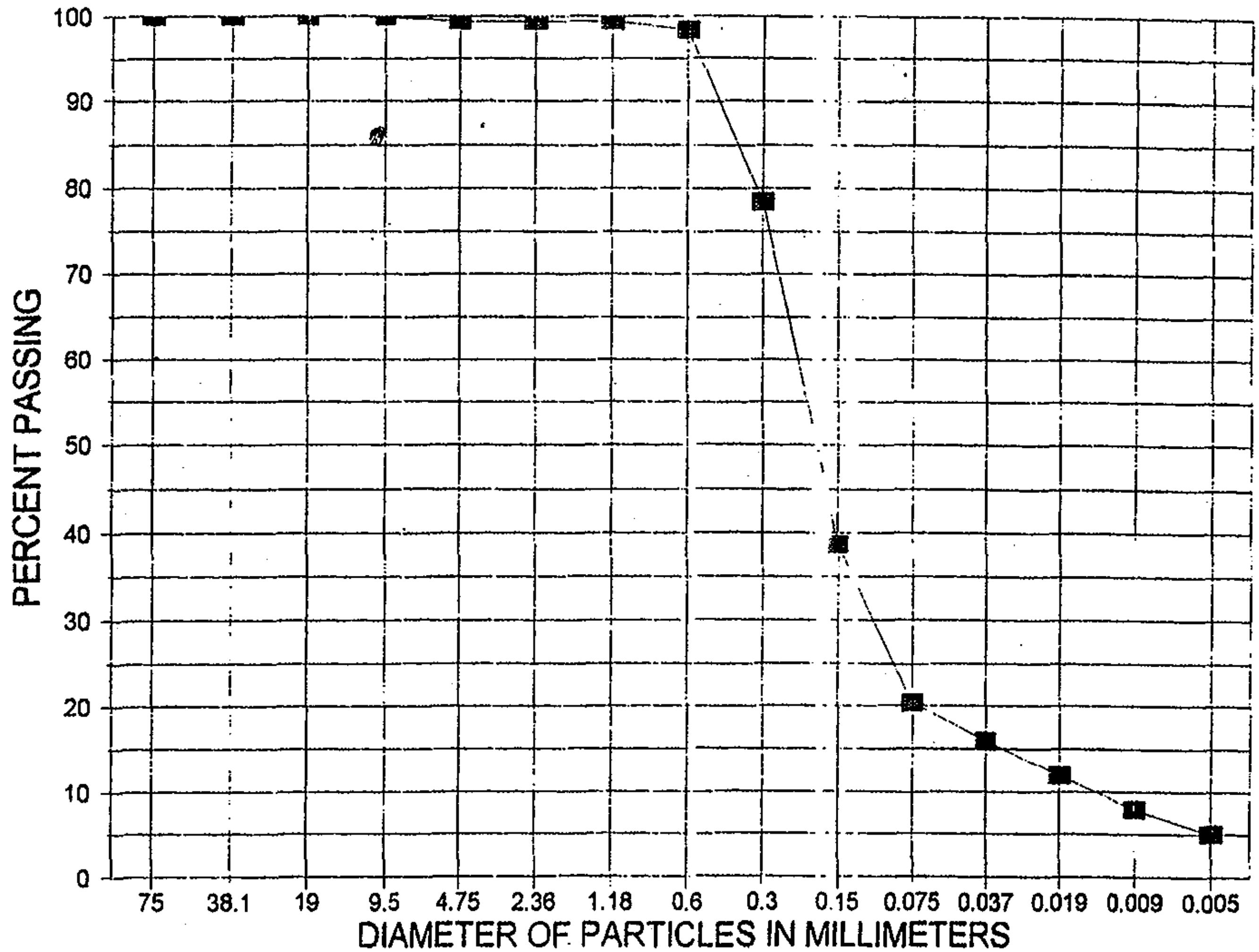
HYDROMETER NO.	36	DISPERSING AGENT	
STARTING TIME	8 49	DATE 12 2 98	AMOUNT mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min		22.0	-4.5	17.5		17.2	37 µm	
4 min	23.0	17.0	-4.5	12.5		12.3	19 µm	
19 min	23.0	13.0	-4.5	8.5		8.4	9 µm	
60 min	23.0	10.5	-4.5	6		5.9	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

Cle Elum Dam BSH 98-1 200.0' to 206.0'



Unified Soil Classification: SM Silty Sand

% Gravel: 0.6	Maximum Size: 3/8"	Cu:
% Sand: 79.1	Liquid Limit:	Cc:
% Fines: 20.3	Plastic Limit:	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 200' to 206'	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 3.55

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER D-4							
WET MASS RETAINED							
DRY MASS RETAINED					0	0.02	
DRY MASS PASSING					3.55	3.53	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING					100	99.4	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 100.2 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 99.4 / = 0.9920

DISH NO. 104 DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	Trace	100.2		99.4	2.36 mm	Max Size = 3/8"
16	Trace	100.2		99.4	1.18 mm	0.6 % Gravel
30	1.0	99.2		98.4	600 µm	79.1 % Sand
50	20.2	79.0		78.4	300 µm	20.3 % Fines
100	40.1	38.9		38.6	150 µm	SM = Silty Sand
200	18.4	20.5		20.3	75 µm	
PAN						
TOTAL		TESTED AND COMPUTED BY JF	DATE	CHECKED BY		DATE

HYDROMETER ANALYSIS

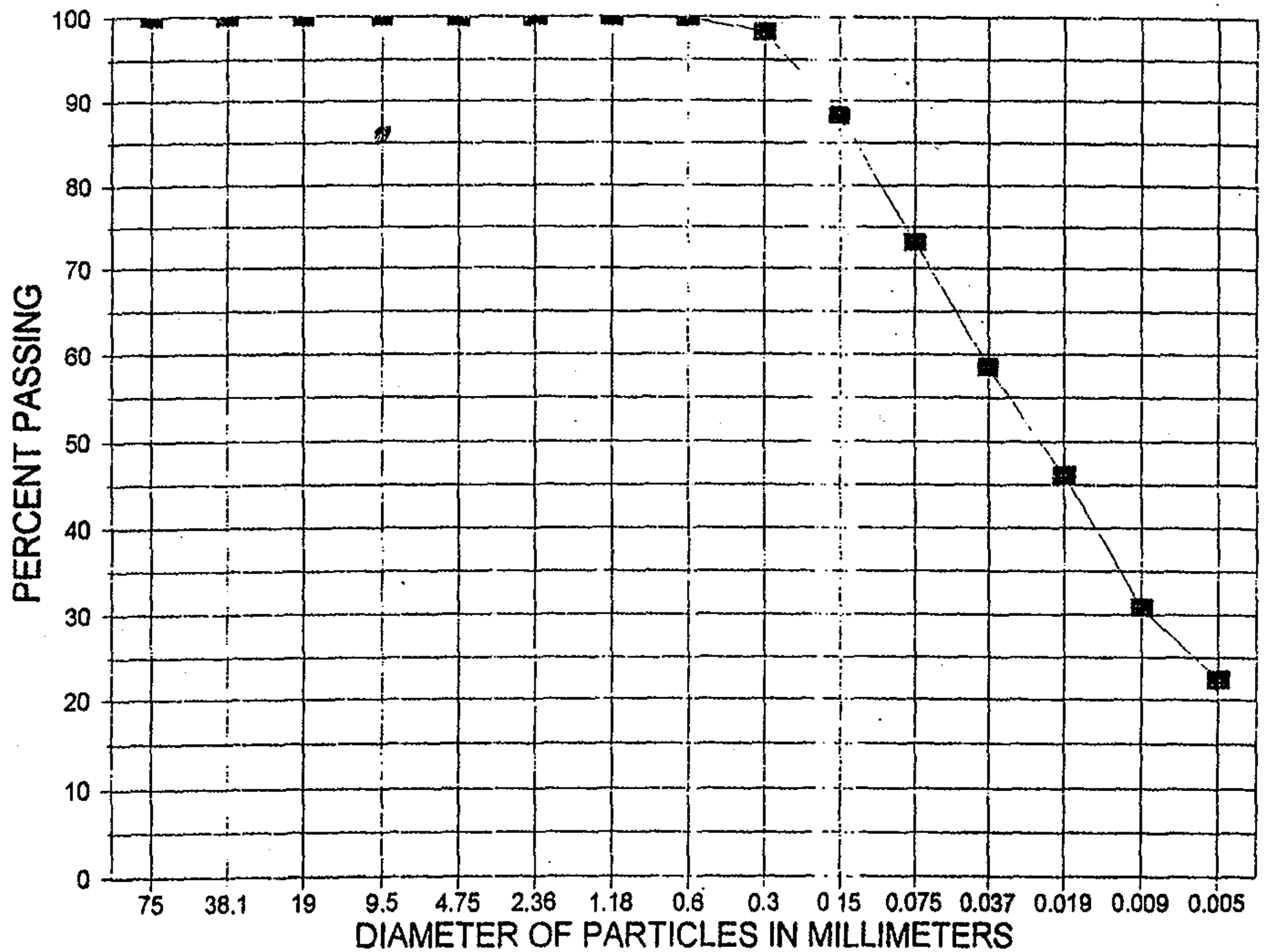
HYDROMETER NO. 87		DISPERSING AGENT
STARTING TIME 904	DATE 12-2-98	AMOUNT mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min		21.0	-5.0	16		15.9	37 µm	
4 min	23.0	17.0	-5.0	12		11.9	19 µm	
19 min	23.0	13.0	-5.0	8		7.9	9 µm	
60 min	23.0	10.0	-5.0	5		5.0	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

* Not required for standard test.

Cle Elum Dam BSH 98-1 208.6' to 210.0'



Unified Soil Classification: ML Silt with Sand

% Gravel: 0.0 | Maximum Size: No. 4 | Cu:
% Sand: 26.9 | Liquid Limit: 21.1 | Cc:
% Fines: 73.1 | Plastic Limit: Nonplastic

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 208.6 to 210.0

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER D-2							
WET MASS RETAINED							
DRY MASS RETAINED						0	
DRY MASS PASSING							☐ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 65.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = _____ = _____
[illegible] I.O. [illegible]	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	Trace	65.0		100	2.36 mm	Max Size = No. 4
16	Trace	65.0		100	1.18 mm	0 % Gravel
30	0.1	64.9		99.9	600 µm	26.9 % Sand
50	1.0	63.9		98.3	300 µm	73.1 % Fines
100	6.5	57.4		88.3	150 µm	ML = Silt with Sand
200	9.9	47.5		73.1	75 µm	
PAN						
TOTAL		TESTED AND COMPUTED BY JF		DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 72	DISPERSING AGENT	
STARTING TIME 1 31	DATE 12-2-98	AMOUNT mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
								One bag marked
1 min		43.0	-5.0	38.0		58.5	37 µm	3 of 3
4 min	23.0	35.0	-5.0	30		46.1	19 µm	
19 min	23.0	25.0	-5.0	20		30.8	9 µm	
60 min	23.0	19.5	-5.0	14.5		22.3	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ____-__

SAMPLE NO.	FEATURE	PROJECT
208.6 to 210.0	BSH 98-1	Cle Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by JFitesimmons Date 12-2-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.				28	
No. of blows (N)				25	
Mass of dish + wet soil (g)				35.33	
Mass of dish + dry soil (g)				31.34	
Mass of dish (g)				12.46	
Mass of water (g)				3.99	
Mass of dry soil (g)				18.88	
Moisture %			W_n =	21.1	
Average Plastic Limit	Nonplastic		F_n =	1.000	
			Liquid Limit	21.1	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

PI = ____ - ____ = ____

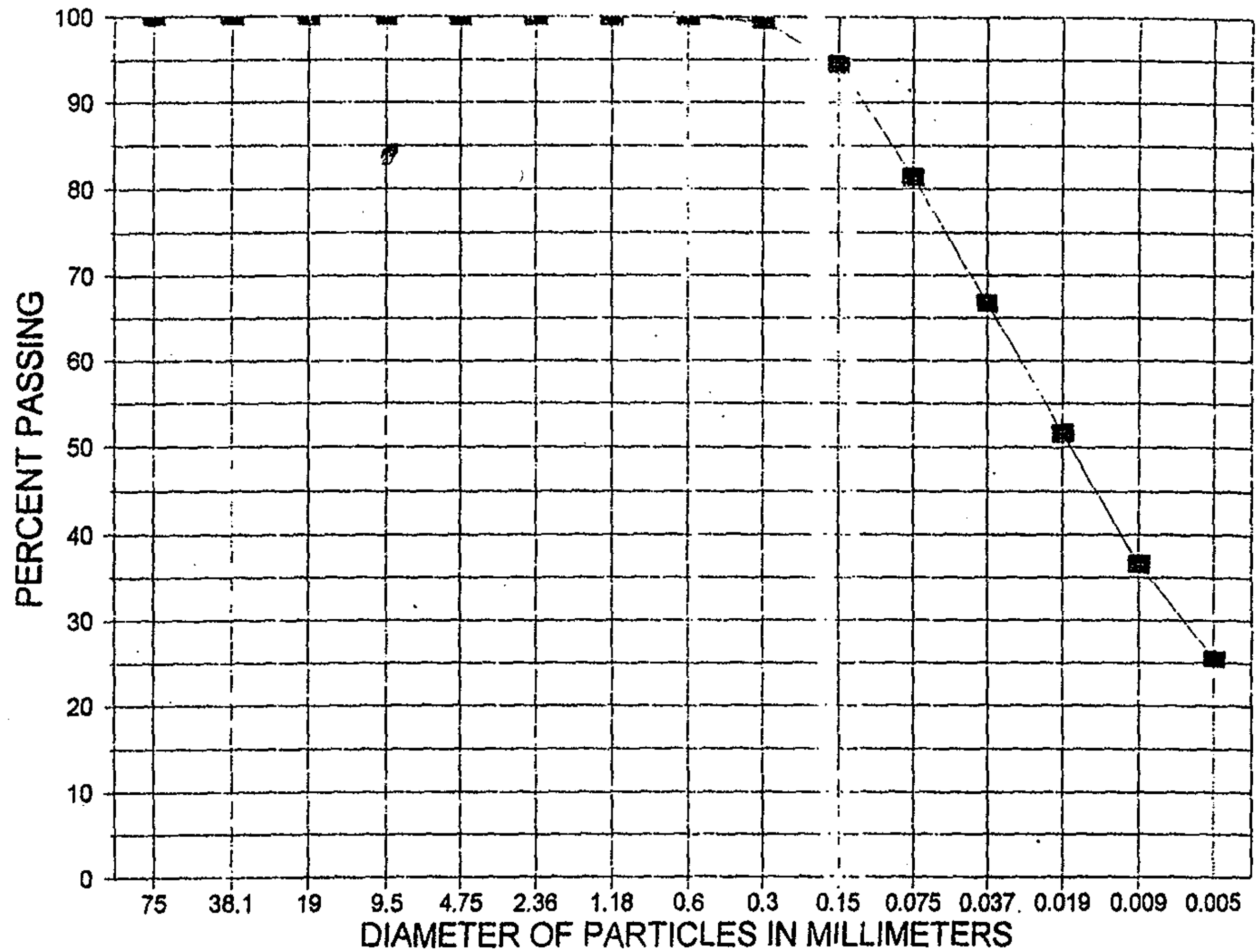
LIQUID LIMIT (LL) = 21.1
PLASTIC LIMIT (PL) = ______
PLASTICITY INDEX (PI) = Nonplastic
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

GPO 849-227

Cle Elum Dam **BSH [illegible]-1** **210.0' to 215.0'**



Unified Soil Classification: ML Silt with Sand

% Gravel: 0.0	Maximum Size:	No. 8	Cu:	
% Sand: 18.7	Liquid Limit:	21.2	Cc:	
% Fines: 81.3	Plastic Limit:	1.4		

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 210 to 215	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE 11-98	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER .5C							
WET MASS RETAINED							
DRY MASS RETAINED						-0-	
DRY MASS PASSING							☐ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 63.0 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ = ______

DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
[illegible]	-0-	63.0		100	2.36 mm	Max Size No. 8
[illegible]	Trace	63.0		100	1.18 mm	-0- % Gravel
30	Trace	63.0		100	600 µm	18.7% Sand
50	[illegible]	62.7		99.5	300 µm	81.3% Fines
100	3.2	59.5		94.4	150 µm	ML = Silt with Sand
200	8.3	51.2		81.3	75 µm	
PAN						
TOTAL		TESTED AND COMPUTED BY JWF		DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 76		DISPERSING AGENT	
STARTING TIME 1:44	DATE 12-2-98	AMOUNT	mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
								One bag marked
1 min		47.0	-5.0	42		66.7	37 µm	3 of 3
4 min	23.0	37.5	-5.0	32.5		51.6	19 µm	
19 min	23.0	28.0	-5.0	23		36.5	9 µm	
60 min	23.0	21.0	-5.0	16		25.4	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

GPO 853-659

7-1702 (11-85) Bureau of Reclamation	SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)	Designation USBR ____ - __
SAMPLE NO. 210.0 to 215.0	FEATURE BSH 98-1	PROJECT Cle Elum

Air dried ☐ Oven dried ☒ Natural ☐

Tested by ____ Date ____
Computed by ____ Date ____
Checked by ____ Date ____

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	4			33	
No. of blows (N)				26	
Mass of dish + wet soil (g)	22.55			28.83	
Mass of dish + dry soil (g)	20.88			~~11.68~~ 25.84	
Mass of dish (g)	12.45			11.68	
Mass of water (g)	1.67			2.99	
Mass of dry soil (g)	8.43			14.16	
Moisture %	19.8		W_n =	21.1	
Average Plastic Limit			F_n =	1.005	
			Liquid Limit	21.2	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

PI = ____ - ____ = ____

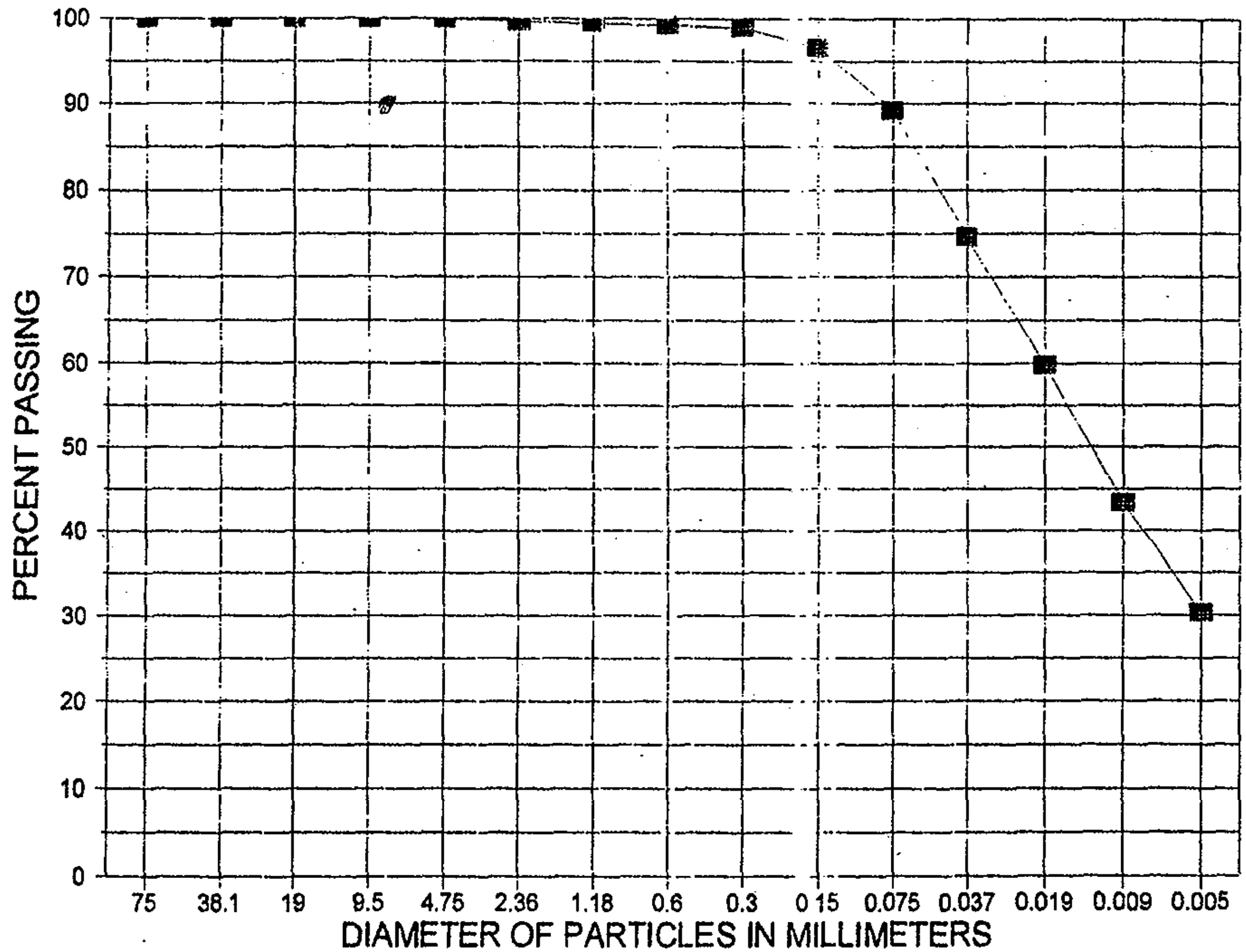
LIQUID LIMIT (LL) = 21.2
PLASTIC LIMIT (PL) = 19.8
PLASTICITY INDEX (PI) = 1.4
SHRINKAGE LIMIT (SL) = ____

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

GPO 849-227

Cle Elum Dam BSH 98-1 215.0' to 220.0'



Unified Soil Classification: ML Silt

% Gravel: 0.0	Maximum Size:	No. 4	Cu:	
% Sand: 10.8	Liquid Limit:	23.6	Cc:	
% Fines: 89.2	Plastic Limit:	3.6		

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO.	BSH 98-1	PROJECT		FEATURE	Cle Elum Dam
AREA		EXC. NO.		DEPTH	215' to 220'

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER Z							
WET MASS RETAINED							
DRY MASS RETAINED						-0-	
DRY MASS PASSING						4.56	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN	61.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN =	
DISH NO.	212	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME		DATE	

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	0.2	60.8		99.7	2.36 mm	Max Size No. 4
16	0.1	60.7		99.5	1.18 mm	-0- % Gravel
30	0.1	60.6		99.3	600 µm	10.8 % Sand
50	0.2	60.4		99.0	300 µm	89.2% Fines
100	1.5	58.9		96.6	150 µm	ML = Silt
200	4.5	54.4		89.2	75 µm	
PAN						
TOTAL		TESTED AND COMPUTED BY JF		DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO.	72		DISPERSING AGENT		
STARTING TIME	1:35	DATE	12-1-98	AMOUNT	mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min		51.0	-5.5	45.5		74.6	37 µm	
4 min	22.0	42.0	-5.5	36.5		59.8	19 µm	
19 min	22.0	32.0	-5.5	26.5		43.4	9 µm	
60 min	22.0	24.0	-5.5	18.5		30.3	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______-__

SAMPLE NO.	FEATURE	PROJECT
215.0 to 220.0	BSH 98-1	Cle Elum

Air dried ☐ Oven dried ☒ Natural ☐

Tested by: J. Fitzsimmons Date: 12-1-98
Computed by: ________ Date: ________
Checked by: ________ Date: ________

	PLASTIC LIMIT 1	PLASTIC LIMIT 2	LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2	1	2
Dish No.	9		31	
No. of blows (N)	21.65		23	
Mass of dish + wet soil (g)	20.06		30.30	
Mass of dish + dry soil (g)	12.10		26.68	
Mass of dish (g)			~~12.10~~	11.46
Mass of water (g)	1.59		~~3.62~~	3.62
Mass of dry soil (g)	7.96		~~14.58~~	15.22
Moisture % (W_n =)	20.0		~~24.8~~	23.8
Average Plastic Limit / F_n =				.990
Liquid Limit				23.6

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

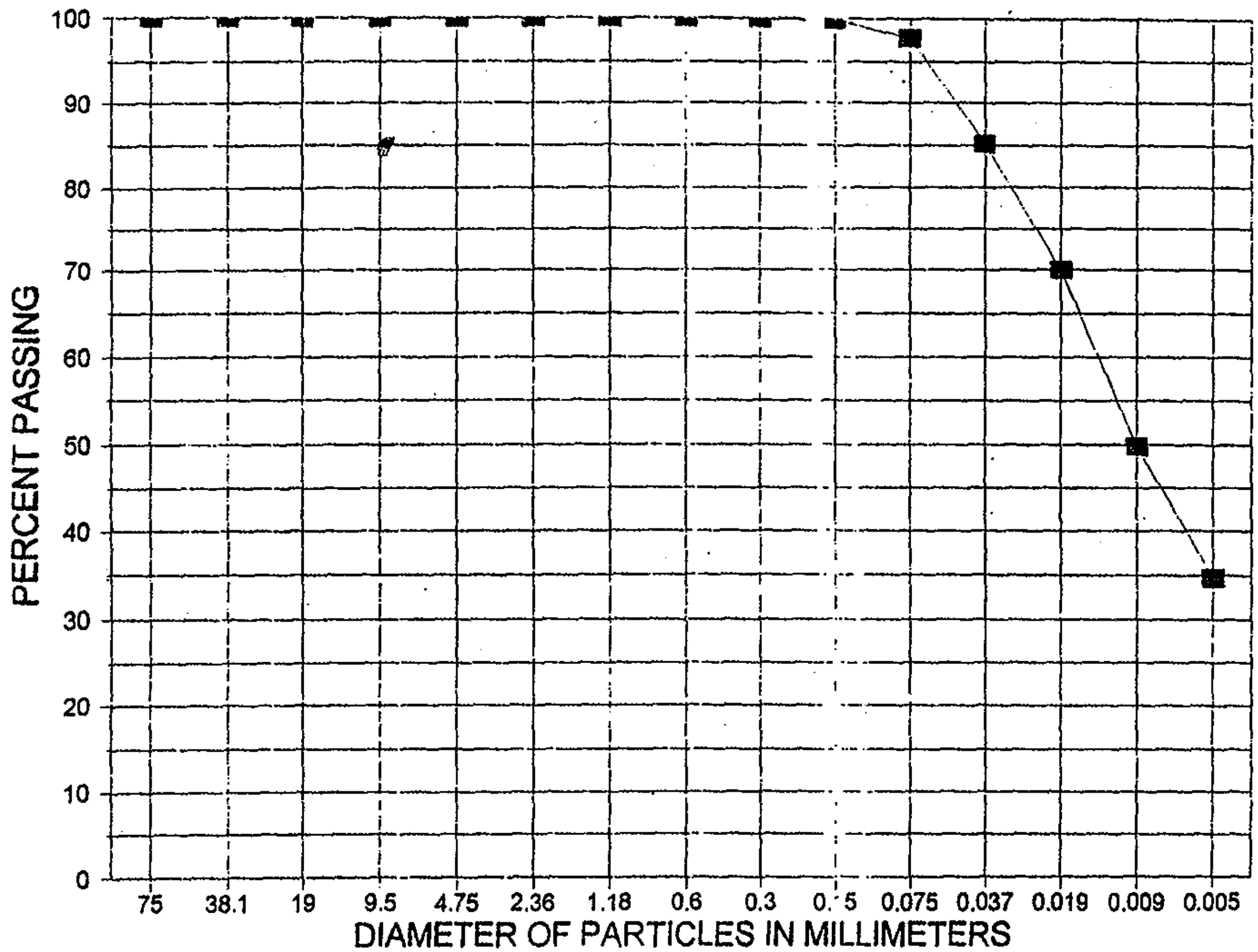
PI = _____ - _____ = _____

LIQUID LIMIT (LL) = 23.6
PLASTIC LIMIT (PL) = 20.0
PLASTICITY INDEX (PI) = 3.6
SHRINKAGE LIMIT (SL) = ________

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

Cle Elum Dam **BSH 96-1** **220.0' to 225.0'**



Unified Soil Classification: ML Silt

% Gravel: 0.0	Maximum Size:	No. 16	Cu:	
% Sand: 2.2	Liquid Limit:	25.5	Cc:	
% Fines: 97.8	Plastic Limit:	3.9		

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 220° to 225°

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 7							
WET MASS RETAINED							
DRY MASS RETAINED						-0-	
DRY MASS PASSING						3.86	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 59.3 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______

DISH NO. 22	DRY MASS OF SPECIMEN (SIEVED)
SIEVING TIME	DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	-0-	59.3		100	2.36 mm	Max Size = No. 16
16	Trace	59.3		100	1.18 mm	-0- % Gravel
30	Trace	59.3		100	600 µm	2.2% Sand
50	Trace	59.3		100	300 µm	97.8 % Fines
100	0.1	59.2		99.8	150 µm	ML = Silt
200	1.2	58.0		97.8	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JF			

HYDROMETER ANALYSIS

HYDROMETER NO. 76	DISPERSING AGENT	
STARTING TIME 140	DATE 12-1-98	AMOUNT mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min		56.0	-5.5	50.5		85.2	37 µm	
4 min	22.0	47.0	-5.5	41.5		70.0	19 µm	
19 min	22.0	35.0	-5.5	29.5		49.8	9 µm	
60 min	22.0	26.0	-5.5	20.5		34.6	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
435 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

* Not required for standard test.

7-1702 (11-85) Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ____ - __

SAMPLE NO. 220.0 to 225.0 | FEATURE BSH 98-1 | PROJECT Cle Elum

Air dried ☐ | Oven dried ☒ | Natural ☐

Tested by JWFitzsimmons Date 11-30-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	33			1	
No. of blows (N)				29	
Mass of dish + wet soil (g)	19.56			26.59	
Mass of dish + dry soil (g)	18.16			23.82	
Mass of dish (g)	11.68			12.73	
Mass of water (g)	1.40			2.77	
Mass of dry soil (g)	6.48			11.09	
Moisture %	21.6		W_n =	25.0	
Average Plastic Limit			F_n =	1.018	
			Liquid Limit	25.5	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PI = LL - PL

PLASTICITY INDEX:

PI = ____ - ____ = ____

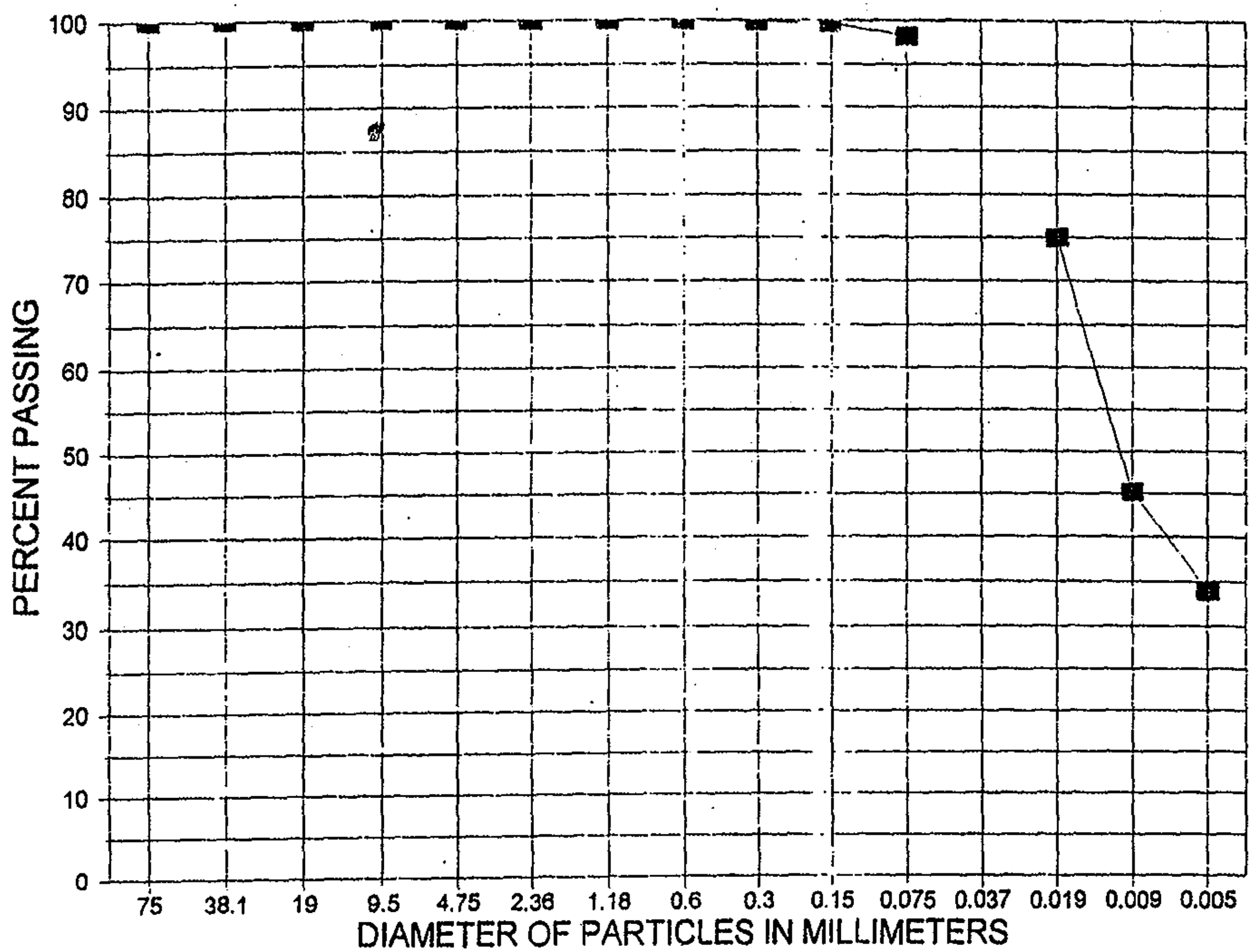
LIQUID LIMIT (LL) = 25.5
PLASTIC LIMIT (PL) = 21.6
PLASTICITY INDEX (PI) = 3.9
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __
USBR 5300 - __
USBR 5350 - __
USBR 5360 - __
USBR 5365 - __

Remarks: ML

GPO 849-227

Cle Elum Dam BSH 98-1 225.0' to 230.0'



Unified Soil Classification: ML Silt

% Gravel: 0.0
% Sand: 1.7
% Fines: 98.3

Maximum Size: No. 30
Liquid Limit: 23.8
Plastic Limit: 2.8

Cu:
Cc:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 225.0 to 230.0

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 7							
WET MASS RETAINED							
DRY MASS RETAINED						0	
DRY MASS PASSING						4.58	☐ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 70.8 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = [illegible]

DISH NO. [illegible] | DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8					2.36 mm	Max Size = No. 30
16					1.18 mm	Gravel = 0
30	0	70.8		100	600 µm	Sand = 1.7
50	0.1	70.7		99.9	300 µm	Fines = 98.3
100	0.1	70.6		99.7	150 µm	ML = Silt
200	1.0	69.6		98.3	75 µm	
PAN						
TOTAL		TESTED AND COMPUTED BY		DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 72 | DISPERSING AGENT Sodium Hexametaphosphate

STARTING TIME 12:54 | DATE 11-21-98 | AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
								Sample too big,
1 min	23.5	?	-5.0	—		—	37 µm	could not get
4 min	23.5	58	-5.0	53.0		74.9	19 µm	1 min. reading
19 min	23.5	37	-5.0	32.0		45.2	9 µm	
60 min	23.5	29	-5.0	24.0		33.9	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JF			

*Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______ - __ __

SAMPLE NO. 225.0 - 230.0 | FEATURE BSH 98-1 | PROJECT Cle Elum Dam

Air dried ☐
Oven dried ☒
Natural ☐

Tested by J Fitzsimmons Date 11-23-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	25			28	
No. of blows (N)				24	
Mass of dish + wet soil (g)	19.65			30.61	
Mass of dish + dry soil (g)	18.37			27.11	
Mass of dish (g)	12.26			12.46	
Mass of water (g)	1.28			3.50	
Mass of dry soil (g)	6.11			14.65	
Moisture %	21.0		W_n =	23.9	
Average Plastic Limit			F_n =	0.995	
			Liquid Limit		

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n\left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

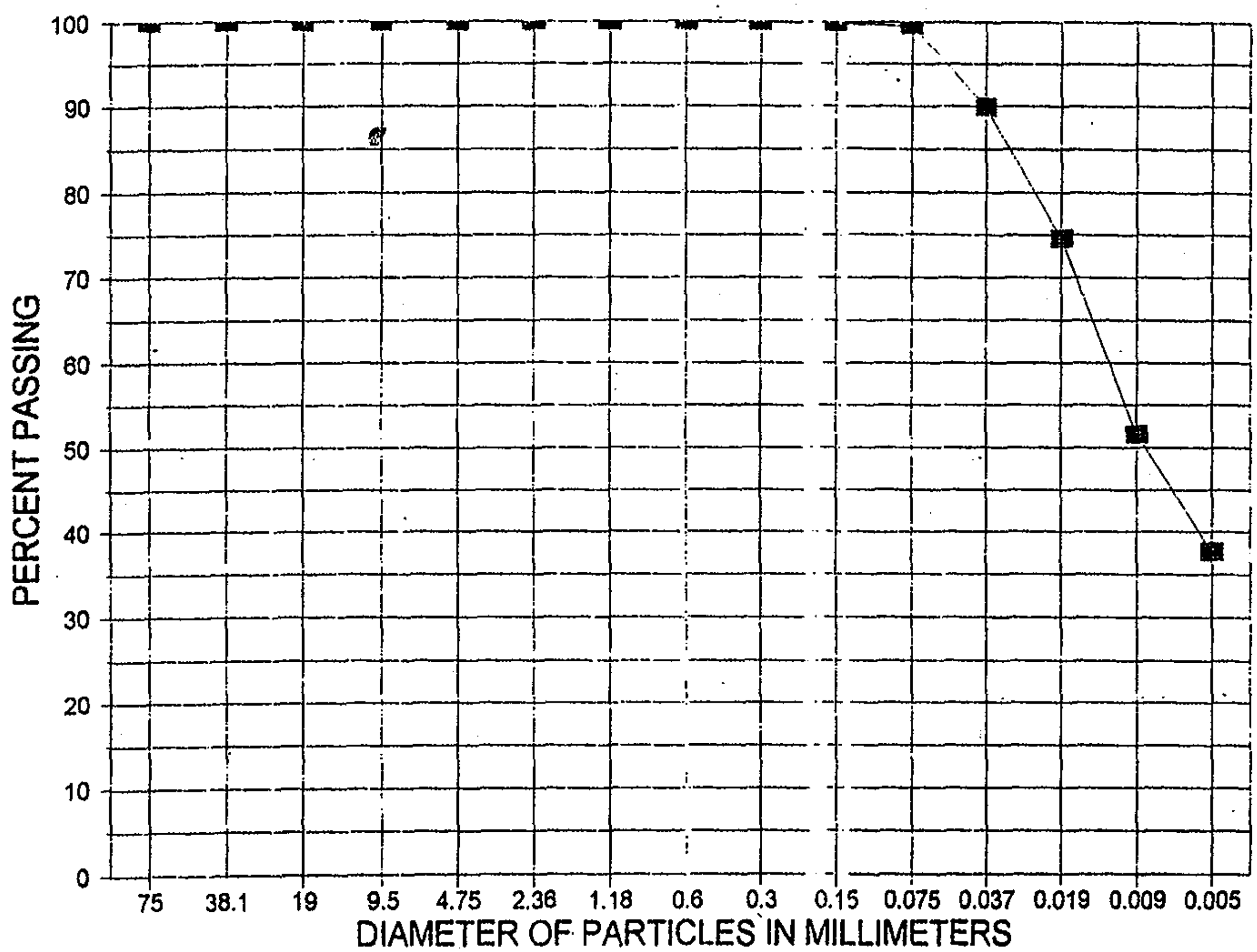
PI = ____ - ____ = ____

LIQUID LIMIT (LL) = 23.8
PLASTIC LIMIT (PL) = 21.0
PLASTICITY INDEX (PI) = 2.8
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

Cle Elum Dam BSH 98-1 230.0' to 235.0'



Unified Soil Classification: ML Silt

% Gravel: 0.0
% Sand: 0.5
% Fines: 99.5

Maximum Size: No. 8
Liquid Limit: 25.8
Plastic Limit: 2.8

Cu:
Cc:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE CleElum Dam
AREA	EXC. NO.	DEPTH 230.0 to 235.0

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 8							
WET MASS RETAINED							
DRY MASS RETAINED						-0-	
DRY MASS PASSING						4.40	☐ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 65.1 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ = ______

D.S. NO. DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	-0-	65.1		100	2.36 mm	Max Size No 8
16	Trace	65.1		100	1.18 mm	-0- % Gravel
30	Trace	65.1		100	600 µm	0.5 % Sand
50	Trace	65.1		100	300 µm	99.5 % Fines
100	0.1	65.0		99.9	150 µm	ML = Silt
200	0.2	64.8		99.5	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY | DATE | CHECKED BY | DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 72 DISPERSING AGENT Sodium Hexametaphosphate

STARTING TIME DATE 11-23-98 AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	20.5	64?	5.5	58.5		89.9	37 µm	
4 min	20.5	54	5.5	48.5		74.5	19 µm	
19 min	21	39	5.5	33.5		51.5	9 µm	
60 min	21	30	5.5	24.5		37.6	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY JF | DATE | CHECKED BY | DATE

*Not required for standard test.

GPO 853-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______ - __ __

SAMPLE NO.	FEATURE	PROJECT
23[illegible]0 - [illegible]	[illegible]H 7R 1	[illegible]le Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by [illegible] Date ______
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	7			34	
No. of blows (N)				[illegible]	
Mass of dish + wet soil (g)	21.72			29.32	
Mass of dish + dry soil (g)	19.56			25.84	
Mass of dish (g)	12.35			[illegible]	
Mass of water (g)	1.66			3.48	
Mass of dry soil (g)	7.21			13.78	
Moisture %	23.0		W_n =	25.3	
Average Plastic Limit			F_n =	1.018	
			Liquid Limit	25.8	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PI = LL - PL

PLASTICITY INDEX:

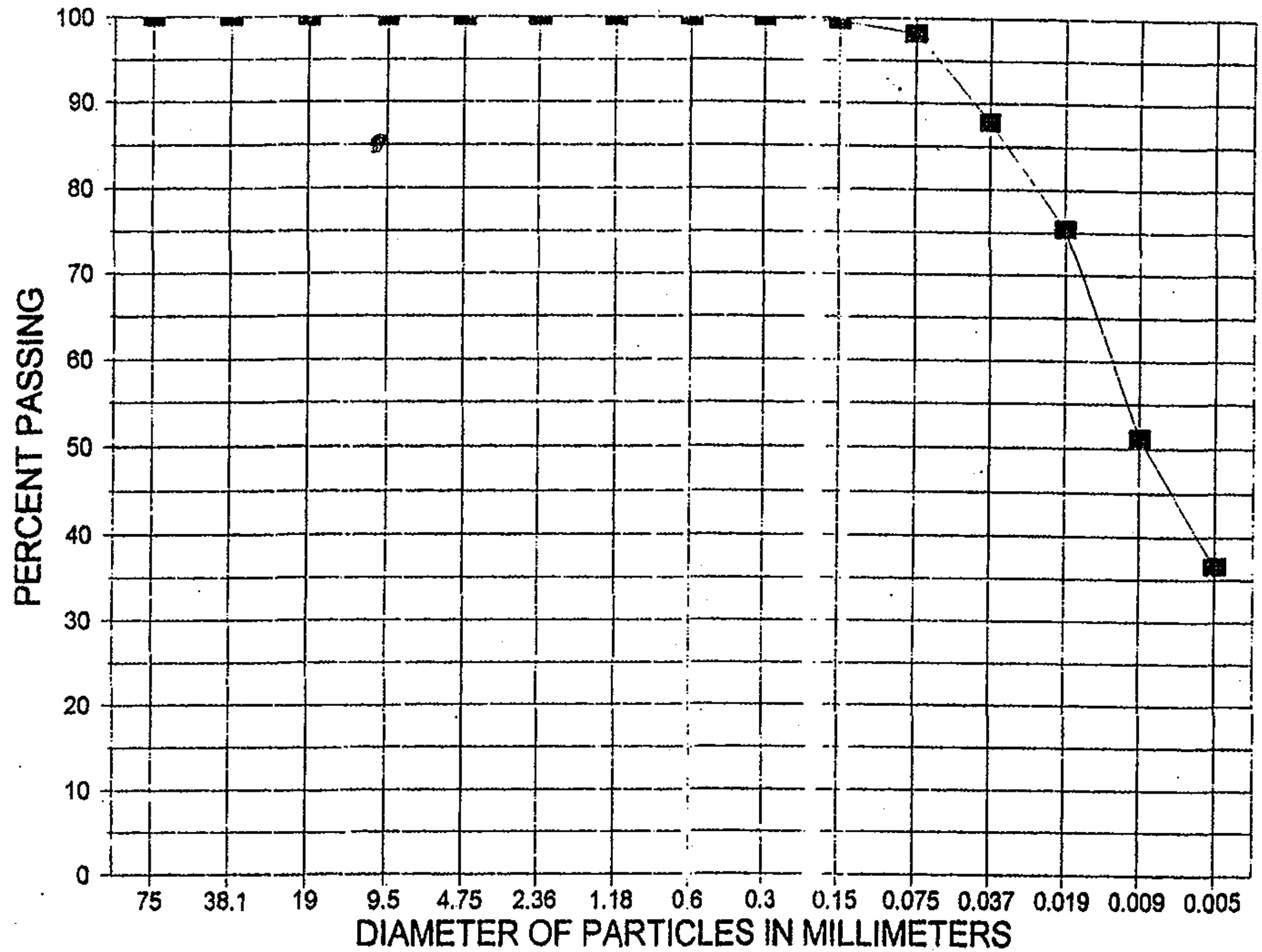
PI = _____ - _____ = _____

LIQUID LIMIT (LL) = 25.8
PLASTIC LIMIT (PL) = 23.0
PLASTICITY INDEX (PI) = 2.8
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

Cle Elum Dam BSH 98-1 235.0' to 240.0'



Unified Soil Classification: CL-ML Silty Clay

% Gravel: 0.0	Maximum Size: No. 50	Cu:
% Sand: 1.8	Liquid Limit: 25.6	Cc:
% Fines: 98.2	Plastic Limit: 4.4	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

MPLE NO. RSH98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 235° to 240°

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN 3.95

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 3							
WET MASS RETAINED							
DRY MASS RETAINED						0	
DRY MASS PASSING						3.95	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 68.3 g FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = 1.4641

C.S. NO. [illegible] DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8					2.36 mm	Max Size = 50
16					1.18 mm	Gravel = 0
30					600 µm	Sand = 1.8
50	0	68.3		100	300 µm	Fines = 98.2
100	0.3	68.0		99.6	150 µm	CL-ML = Silty Clay
200	0.9	67.1		98.2	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 76		DISPERSING AGENT Sodium Hexametaphosphate
STARTING TIME 12:50	DATE 11-21-98	AMOUNT 125 mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min	24	65	5.0	60.0		87.8	37 µm	
4 min	24	56.5	5.0	51.5		75.4	19 µm	
19 min	24	40	5.0	35.0		51.2	9 µm	
60 min	24	30	5.0	25.0		36.6	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
YF			

*Not required for standard test.

GPO 833-659

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ________

SAMPLE NO.	FEATURE	PROJECT
235.0 - 240.0	BSH 98-1	Cle Elum Dam

Air dried ☐ Tested by JFitzsimmons Date 11-23-9?
Oven dried ☒ Computed by ________ Date ________
Natural ☐ Checked by ________ Date ________

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	23			38	
No. of blows (N)				23	
Mass of dish + wet soil (g)	20.40			29.79	
Mass of dish + dry soil (g)	18.95			26.08	
Mass of dish (g)	12.10			11.73	
Mass of water (g)	1.45			3.71	
Mass of dry soil (g)	6.85			14.35	
Moisture %	21.2		W_n =	25.9	
Average Plastic Limit			F_n =	.990	
			Liquid Limit	25.6	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

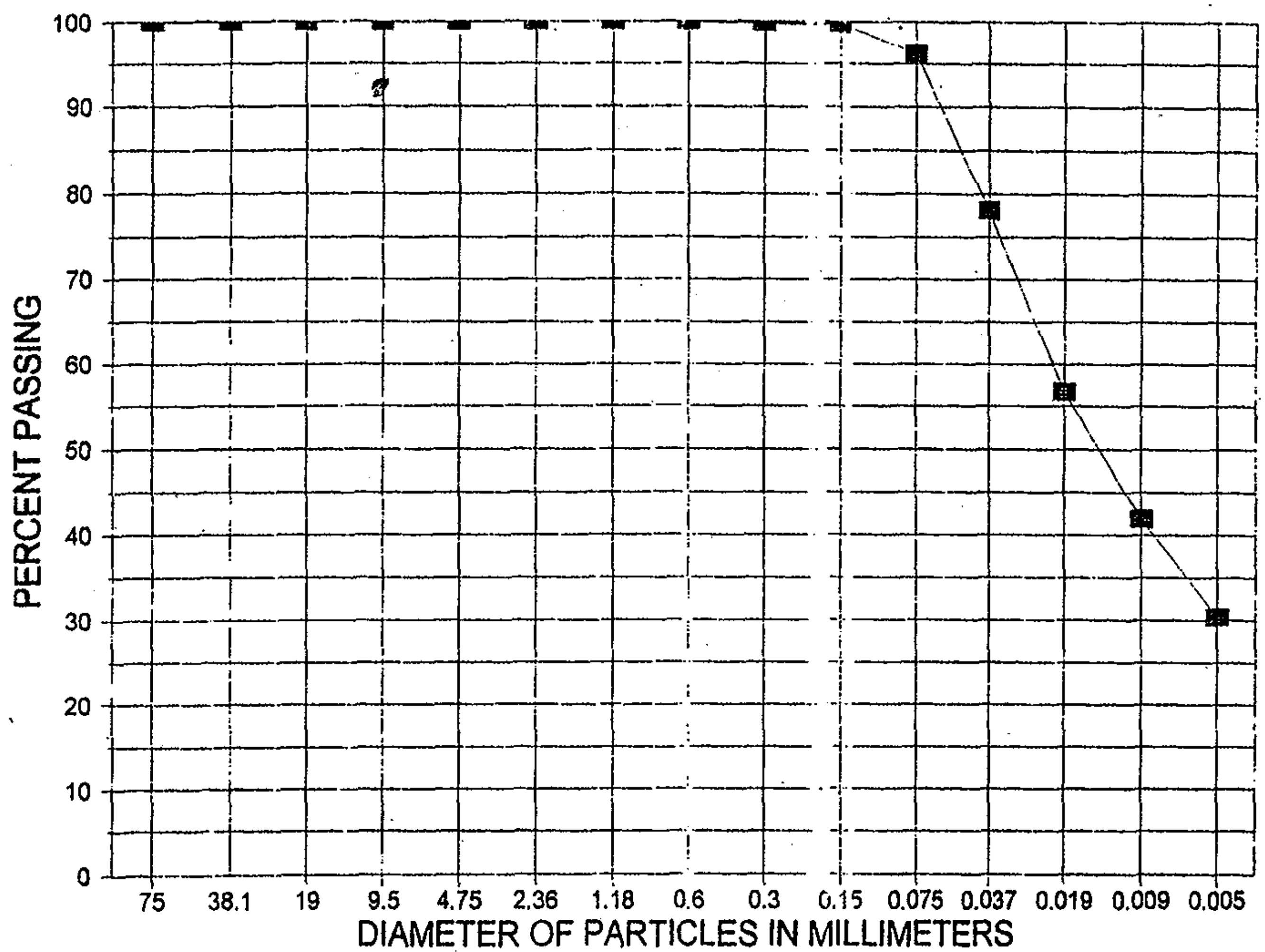
PI = ____ - ____ = ____

LIQUID LIMIT (LL) = 25.6
PLASTIC LIMIT (PL) = 21.2
PLASTICITY INDEX (PI) = 4.4
SHRINKAGE LIMIT (SL) = ________

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: CL-ML

Cle Elum Dam BSH 98-1 240.0' to 245.0'



Unified Soil Classification: ML Silt

% Gravel: 0.0	Maximum Size: No. 4	Cu:
% Sand: 3.8	Liquid Limit: 23.5	Cc:
% Fines: 96.2	Plastic Limit: 3.1	

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-__
Designation USBR 5330-__
Designation USBR 5335-__

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam	
AREA	EXC. NO.	DEPTH 210.0 to 215.5	

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 6C							
WET MASS RETAINED							
DRY MASS RETAINED						0	
DRY MASS PASSING						5.47	☒ lbm ☐ kg ☐ g
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 61.0 g	FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN =	
DISH NO. 8	DRY MASS OF SPECIMEN (SIEVED)	
SIEVING TIME		DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	0.2	60.8		100	2.36 mm	Max Size No. 4
16	0	60.8		100	1.18 mm	0 % Gravel
30	Trace	60.8		100	600 µm	3.8 % Sand
50	0.1	60.7		99.8	300 µm	96.2 % Fines
100	0.1	60.6		99.7	150 µm	ML = Silt
200	2.1	58.5		96.2	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY JF	DATE	CHECKED BY	DATE

HYDROMETER ANALYSIS

HYDROMETER NO. 87		DISPERSING AGENT	
STARTING TIME 1:45	DATE 12-1-98	AMOUNT mL	

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min		53.0	-5.5	47.5		78.1	37 µm	
4 min	22.0	40.0	-5.5	34.5		56.7	19 µm	
19 min	22.0	31.0	-5.5	25.5		41.9	9 µm	
60 min	22.0	24.0	-5.5	18.5		30.4	5 µm	AUXILIARY TESTS: USBR 5205-__ USBR 5300-__
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______ - __

SAMPLE NO. 240.0 to 245.0 | FEATURE BSH 98-1 | PROJECT Cle Elum

Air dried ☐ Oven dried ☐ Natural ☐

Tested by J.Fitzsimmons Date 12-1-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	5			2	
No. of blows (N)				25	
Mass of dish + wet soil (g)	20.98			30.76	
Mass of dish + dry soil (g)	19.54			27.26	
Mass of dish (g)	12.48			12.34	
Mass of water (g)	1.44			3.50	
Mass of dry soil (g)	7.06			14.92	
Moisture %	20.4		W_n =	23.5	
Average Plastic Limit			F_n =	1.000	
			Liquid Limit	23.5	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n \left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

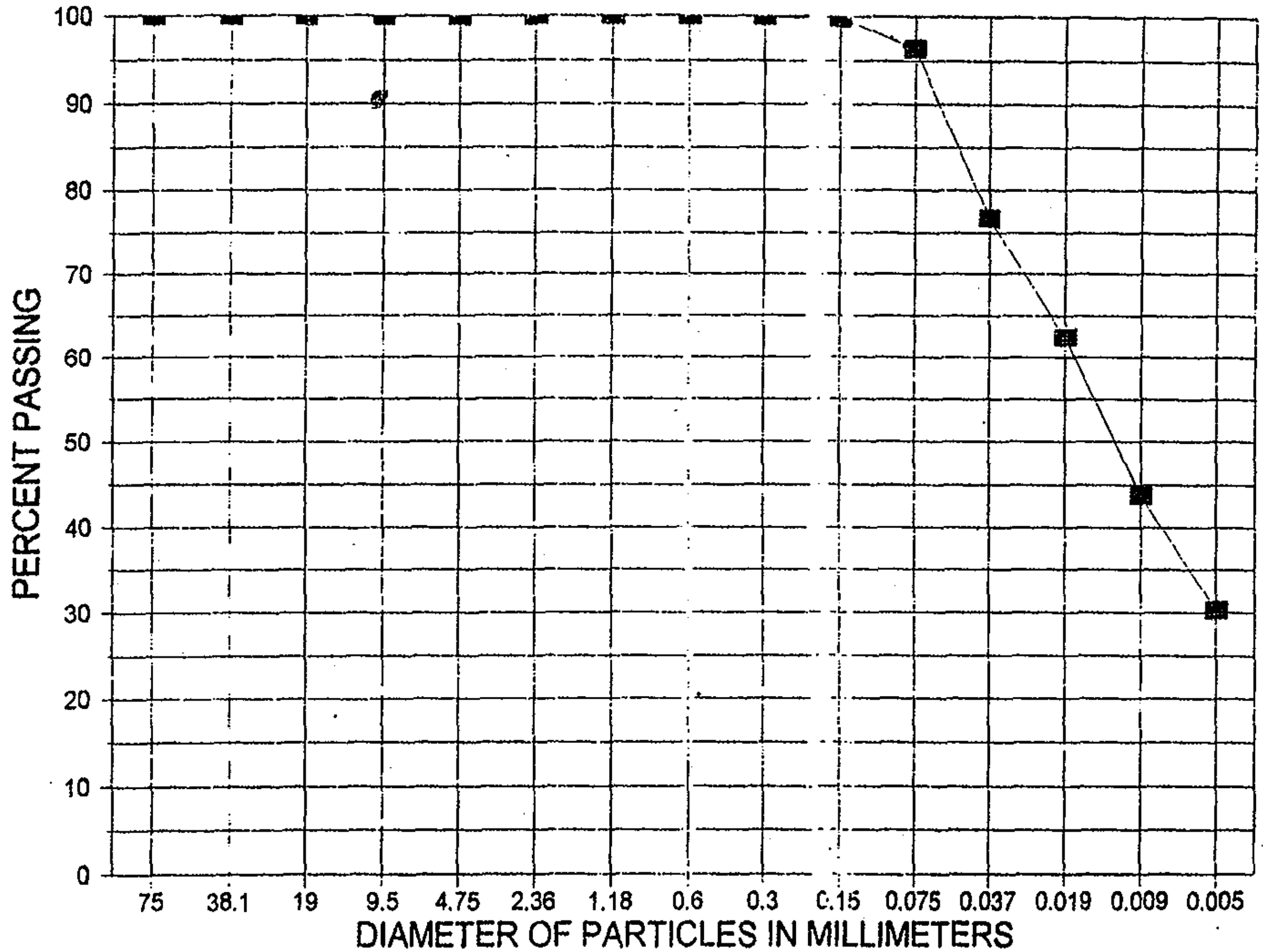
PI = ____ - ____ = ____

LIQUID LIMIT (LL) = 23.5
PLASTIC LIMIT (PL) = 20.4
PLASTICITY INDEX (PI) = 3.1
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

Cle Elum Dam **BSH 98-1** **245.0' to 250.0'**



Unified Soil Classification: ML Silt

% Gravel: 0.0
% Sand: 3.6
% Fines: 96.4

Maximum Size: No. 8
Liquid Limit: 22.9
Plastic Limit: 2.4

Cu:
Cc:

7-1451 (9-86)
Bureau of Reclamation

GRADATION ANALYSIS

Designation USBR 5325-_
Designation USBR 5330-_
Designation USBR 5335-_

SAMPLE NO. BSH 98-1	PROJECT	FEATURE Cle Elum Dam
AREA	EXC. NO.	DEPTH 245' to 250'

GRADATION OF GRAVEL SIZES

TESTED AND COMPUTED BY	DATE	% MOISTURE CONTENT OF + NO. 4	WET MASS OF TOTAL SPECIMEN
CHECKED BY	DATE	% MOISTURE CONTENT OF - NO. 4	TOTAL DRY MASS OF SPECIMEN

SIEVE SIZE		3" (75 mm)	1-1/2" (37.5 mm)	3/4" (19.0 mm)	3/8" (9.5 mm)	NO. 4 (4.75 mm)	PAN
MASS OF CONTAINER AND RETAINED MATERIAL							
MASS OF CONTAINER 1 B							
WET MASS RETAINED							
DRY MASS RETAINED						0	
DRY MASS PASSING						4.70	☒ lbm ☐ kg ☐
% OF TOTAL PASSING						100	

GRADATION OF SAND SIZES

DRY MASS OF SPECIMEN 56.1 g | FACTOR = % TOTAL PASSING NO. 4 / DRY MASS OF SPECIMEN = ______ =

DISH NO. 22 | DRY MASS OF SPECIMEN (SIEVED)

SIEVING TIME | DATE

SIEVE NO.	MASS RETAINED (g)	MASS PASSING (g)	FACTOR X MASS PASSING = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
8	0	56.1		100	2.36 mm	Max Size = No. 8
16	Trace	56.1		100	1.18 mm	0 % Gravel
30	Trace	56.1		100	600 µm	3.6 % Sand
50	Trace	56.1		100	300 µm	96.4 % Fines
100	0.1	56.0		99.8	150 µm	ML = Silt
200	1.9	54.1		96.4	75 µm	
PAN						
TOTAL						

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE
JF			

HYDROMETER ANALYSIS

HYDROMETER NO. 36 | DISPERSING AGENT

STARTING TIME 1:50 | DATE 12-1-98 | AMOUNT mL

TIME	TEMP °C	HYD READ	HYD CORR	CORR READ	FACTOR X CORRECT READ = % OF TOTAL PASSING	% OF TOTAL PASSING	PARTICLE DIAMETER	REMARKS
1 min		48.0	-5.0	43		76.7	37 µm	
4 min	22.0	40.0	-5.0	35		62.4	19 µm	
19 min	22.0	29.5	-5.0	24.5		43.7	9 µm	
60 min	22.0	22.0	-5.0	17		30.3	5 µm	AUXILIARY TESTS: USBR 5205-_ _ USBR 5300-_ _
7 h 15 min*							2 µm	
25 h 45 min*							1 µm	

TESTED AND COMPUTED BY	DATE	CHECKED BY	DATE

*Not required for standard test.

7-1702 (11-85)
Bureau of Reclamation

SOIL CONSISTENCY TEST (ONE-POINT LIQUID LIMIT METHOD)

Designation USBR ______ - __

SAMPLE NO.	FEATURE	PROJECT
248.0 to 250.0	BSH 98-1	Cle Elum

Air dried ☐
Oven dried ☒
Natural ☐

Tested by J. Fitzsimmons Date 12-1-98
Computed by ______ Date ______
Checked by ______ Date ______

	PLASTIC LIMIT 1	PLASTIC LIMIT 2		LIQUID LIMIT 1	LIQUID LIMIT 2
Trial No.	1	2		1	2
Dish No.	16			8	
No. of blows (N)				22	
Mass of dish + wet soil (g)	21.66			31.42	
Mass of dish + dry soil (g)	19.99			27.91	
Mass of dish (g)	11.85			12.80	
Mass of water (g)	1.67			3.51	
Mass of dry soil (g)	8.14			15.11	
Moisture %	20.5		W_n =	23.2	
Average Plastic Limit			F_n =	0.985	
			Liquid Limit	22.9	

SHRINKAGE LIMIT

1. Shrinkage Dish No.		
2. Mass of dish + wet soil (g)		
3. Mass of dish + dry soil (g)		
4. Mass of dish (g)		
5. Mass of water (2 - 3) (g)		
6. Mass of dry soil (W_o) (3 - 4) (g)		
7. % Moisture (5/6 x 100)		
8. Vol. Shrinkage Dish (V)		
9. Vol. Dry Soil (V_o)		
10. $V - V_o$ = (8 - 9)		
11. $\frac{V - V_o}{W_o} \times 100 = \left(\frac{10}{6} \times 100\right)$		
12. Shrinkage Limit (7 - 11)		
13. Shrinkage Ratio (6/9)		

$$LL = W_n\left(\frac{N}{25}\right)^{0.120}$$

$$F_n = \left(\frac{N}{25}\right)^{0.120}$$

$$LL = (F_n)(W_n)$$

N	F_n
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

PLASTICITY INDEX: PI = LL - PL

PI = ____ - ____ = ____

LIQUID LIMIT (LL) = 22.9
PLASTIC LIMIT (PL) = 20.5
PLASTICITY INDEX (PI) = 2.4
SHRINKAGE LIMIT (SL) = ______

Auxiliary tests:
USBR 5205 - __ __
USBR 5300 - __ __
USBR 5350 - __ __
USBR 5360 - __ __
USBR 5365 - __ __

Remarks: ML

Appendix C

APPENDIX C

Standard Penetration Test Results

Standard Penetration Test Results

The following is a description of our evaluation of the standard penetration tests that were conducted in Hole Numbers DH-92-2 and DH-92-5. This evaluation is based on review of information provided in the following documents:

- Final Draft copies of the Geologic Log of Drill Hole Nos. DH-92-2 and DH-92-5.
- Standard Penetration Test - Field Data Sheets for Drill Hole Nos. DH-92-2 and DH-92-5.

Plots of the cumulative penetration versus cumulative blows are provided on the attached figures for Drill Holes Nos. DH-92-2 and DH-92-5. The following is a summary of the information provided in the logs and data sheets for each SPT, including comments relating to the cumulative penetration versus cumulative blows information shown in the attached plots.

HOLE NO. DH-92-2

SPT penetration depth interval: 129.5 - 130.2 ft.

cleanout depth: 129.0 ft.

seating depth interval: 129.0 - 129.5 ft.

recovery: No recovery - sample limited to single gravel particle 35 mm in diameter lodged in shoe of sampler: cleanout run through interval returned fine to coarse, angular to rounded sand with fine gravel; heavy color of return water suggests greater than 15% of fines present; maximum size returned, 15 mm.

comments: Reportedly tapped rods ahead 0.1 ft through slough prior to test. Plot of cumulative penetration versus cumulative blows shows gradual flattening of the slope with no marked break in the slope.

shear wave velocity: 1306 fps

SPT penetration depth interval: 134.3-134.8 ft.

cleanout depth: 133.9 ft.

seating depth interval: 133.8 - 134.3 ft.

recovery: No recovery.

comments: Reported 0.1 ft of slough in hole at start of test. Plot of cumulative penetration versus cumulative blows shows an irregular s-shaped curvature. This irregular slope may be a result of pushing gravels away from the tip of the sampler during penetration.

shear wave velocity: 1279 fps

SPT penetration depth interval: 139.2-139.8 ft.

cleanout depth: 138.7 ft.

seating depth interval: 138.7 - 139.2 ft.

recovery: No recovery. Noted heavy gray color indicating migration of grout from DH-92-1, first noted at approximately 129 ft. Cleanout run through test interval returned

predominantly medium to coarse sand with some fine gravel and minor fine sand; maximum size returned 15 mm, dark gray in color. Noted change in water color from gray (grout) to reddish tan/reddish brown at 142 ft. No fines detected except for suspended particles in return.
comments: Plot of cumulative penetration versus cumulative blows shows gradual flattening of the slope with no marked break in the slope.
shear wave velocity: 1200 fps

SPT penetration depth interval: 144.7-145.2 ft.
cleanout depth: 144.4 ft.
seating depth interval: 144.2 - 144.7 ft.
recovery: No recovery. Cleanout run through interval returned broadly graded, fine to coarse sand with predominantly fine gravel; dark gray; maximum size returned 20 mm. Noted prominent iron staining on many individual particles.
comments: About 0.2 ft slough in hole at start of test, string fell 0.4 ft on first blow; remarked rods. Plot of cumulative penetration versus cumulative blows shows gradual flattening of the slope with no marked break in the slope.
shear wave velocity: 1413 fps

HOLE NO. DH-92-5

SPT penetration depth interval: 38.1 - 38.4 ft.
cleanout depth: TUBEX to 36.8, CS at 36.2 ft.
seating depth interval: 37.6 - 38.1 ft.
recovery: 100 percent recovery. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s. Re-tripped w/ maxibarrel for additional sample. About 60% fine to coarse, hard, subangular to rounded gravel: about 30% fine to coarse, hard angular to rounded sand; about 10% nonplastic fines with rapid dilatancy; maximum size 80 mm; moist; dark gray; heterogeneous; no reaction with HCl. LAB TEST DATA: 64% gravel, 31% sand, 5% fines; Cu = 48.0, Cc = 1.29; laboratory classification of sample is WELL-GRADED GRAVEL WITH SILT AND SAND (GW-GM)s.
comments: Sampler 0.8 ft deeper than bottom of TUBEX at start of test. Plot of cumulative penetration versus cumulative blows shows easy penetration for first approximately 0.3 ft with a relatively constant slope for further penetration.
shear wave velocity: 1372 fps

SPT penetration depth interval: 55.9 - 56.3 ft.
cleanout depth: TUBEX to 55.6, CS at 55.0 ft.
seating depth interval: 55.4 - 55.9 ft.
recovery: No recovery. Re-tripped w/ maxibarrel from 55.2 to 56.0 ft. with 38% recovery. POORLY GRADED GRAVEL WITH SAND (GP)s. About 75% fine to coarse hard, angular to subrounded gravel; about 20% fine to coarse, hard, angular to

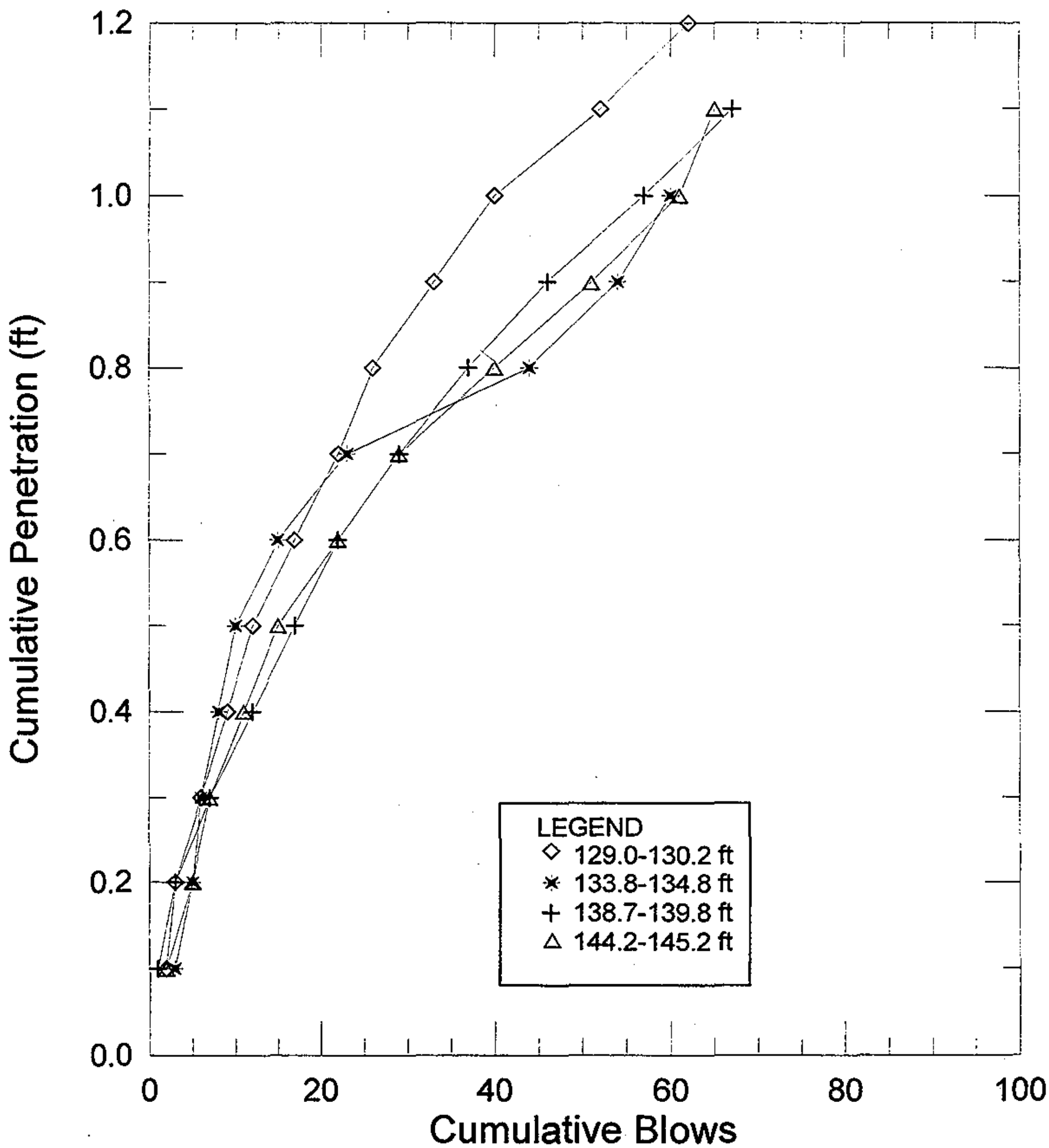
rounded sand; about 5% nonplastic fines with rapid dilatancy; maximum size 40 mm; wet, dark gray; heterogeneous; no reaction with HCl. LAB TEST DATA: 80% gravel, 18% sand, 2% fines; Cu = 40.5, Cc = 7.45.
comments: First 0.2 feet of seating depth interval likely through slough in bottom of ODEX casing. Plot of cumulative penetration versus cumulative blows shows easy penetration for first approximately 0.3 ft with a relatively constant slope for further penetration.
shear wave velocity: 705 fps

SPT penetration depth interval: 76.4 - 76.8 ft.
cleanout depth: TUBEX to 76.2, CS at 75.6 ft.
seating depth interval: 75.9 - 76.4 ft.
recovery: 56 percent recovery. POORLY GRADED GRAVEL WITH SAND (GP)s. About 55% fine to coarse, hard, angular to subrounded gravel; about 40% fine to coarse, hard, angular to rounded sand; about 5% nonplastic fines with rapid dilatancy; maximum size 50 mm; wet, dark gray; heterogeneous; no reaction with HCl.
comments: First 0.3 feet of seating depth interval likely through slough in bottom of ODEX casing. Plot of cumulative penetration versus cumulative blows shows gradual flattening of the slope with no marked break.
shear wave velocity: 964 fps

SPT penetration depth interval: 97.2 - 97.7 ft.
cleanout depth: TUBEX to 96.8, CS at 96.2 ft.
seating depth interval: 96.7 - 97.2 ft.
recovery: 20 percent recovery limited to 3 coarse gravels 20 to 35 mm in diameter. Tripped back in with maxibarrel from 96.3 to 98.3 ft and got 35% recovery. POORLY GRADED GRAVEL WITH SAND (GP). About 60% fine to coarse, hard, angular to subrounded gravel; about 35% fine to coarse, hard, angular to rounded sand; about 5% nonplastic fines with rapid dilatancy; maximum size 55 mm; wet, dark gray; heterogeneous; no reaction with HCl. LAB TEST DATA: 72% gravel, 26% sand, 2% fines; Cu = 30.3, Cc = 1.98; laboratory classification of sample is WELL-GRADED GRAVEL WITH SAND (GW).
comments: First 0.1 feet of seating depth interval likely through slough in bottom of ODEX casing. Plot of cumulative penetration versus cumulative blows shows easy penetration for first approximately 0.5 ft with a relatively constant slope for further penetration.
shear wave velocity: 1957 to 1688 fps

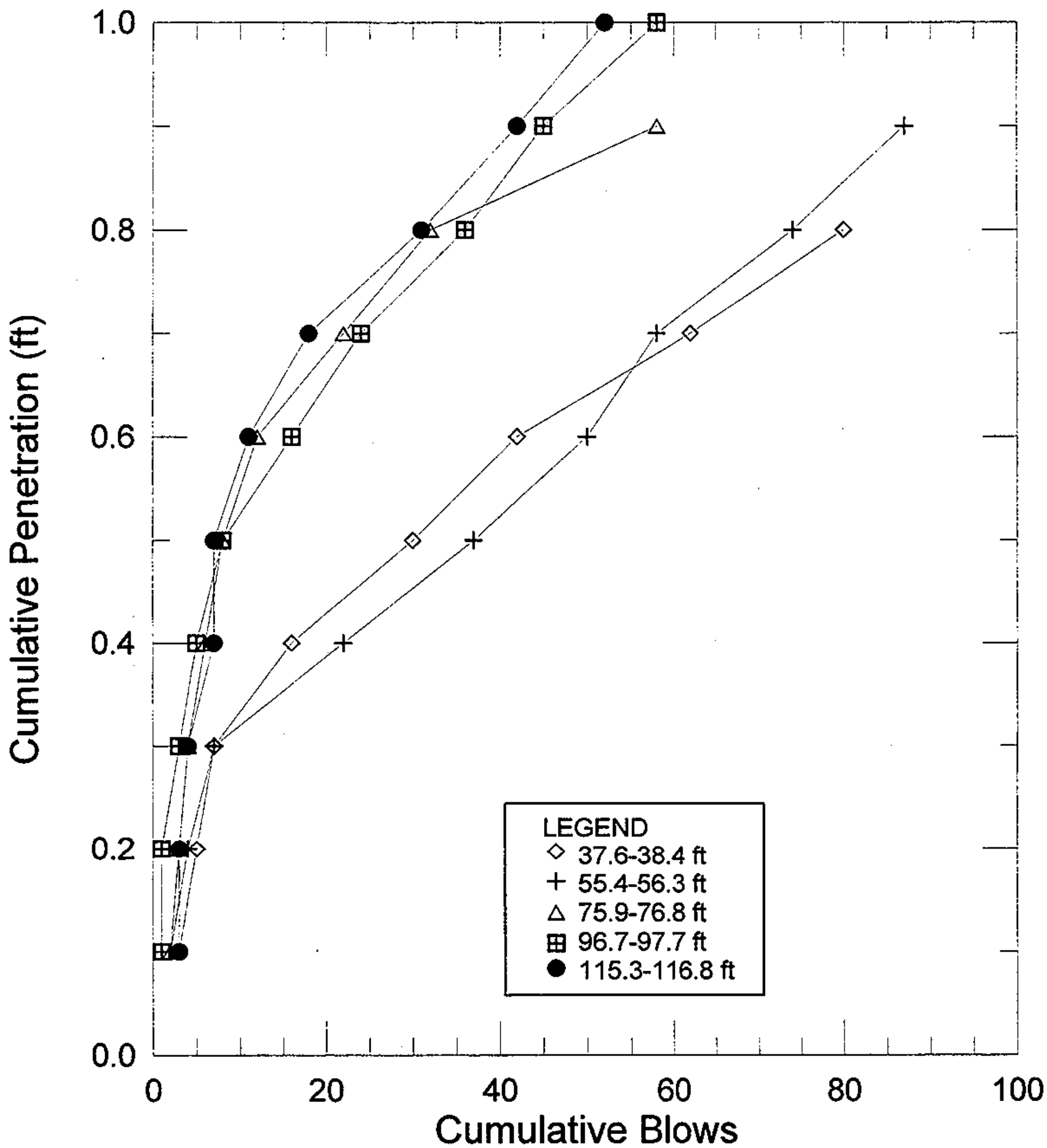
SPT penetration depth interval: 115.8 - 116.3 (116.8) ft.
cleanout depth: TUBEX to 115.6, CS at 115.0 ft.
seating depth interval: 115.3 - 115.8 ft.

recovery: No recovery. Overdrove SPT additional 0.5 ft to improve sample recovery, sample recovery limited to 0.5 ft of slough. Trip back in with maxibarrel from 115.2 to 117.2 ft with 65 % recovery. Bottom 0.8 ft of sample is gap-graded and completely lacking in fine sand. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM). About 55% fine to coarse, hard, subangular to rounded gravel; about 35% fine to coarse, hard, angular to rounded sand; about 10% nonplastic fines with rapid dilatancy; maximum size 55 mm; wet, blue gray; heterogeneous, no reaction with HCl. LAB TEST DATA: 64% gravel, 34% sand, 2% fines; Cu = 20.9, Cc = 1.40; laboratory classification of sample is WELL-GRADED GRAVEL WITH SAND (GW).
comments: First 0.3 feet of seating depth interval likely through slough in bottom of ODEX casing. Plot of cumulative penetration versus cumulative blows shows easy penetration for first approximately 0.6 ft with a relatively constant slope for further penetration.
shear wave velocity: 1166 fps



DH-92-2.GRF

Project No. D97287	Cle Elum Dam Cle Elum, Washington	DH-92-2 Cumulative Penetration vs. Cumulative Blows	Figure C-1
Woodward-Clyde			



DH-92-5.GRF

Project No. D97287	Cle Elum Dam Cle Elum, Washington	DH-92-5 Cumulative Penetration vs. Cumulative Blows	Figure C-2
Woodward-Clyde			

Appendix D

APPENDIX D

Geologic Descriptions

APPENDIX D

GEOLOGIC DESCRIPTIONS

Five main geologic units have been identified in the foundation of Cle Elum Dam as a result of field investigation work dating back as early as 1905. Locations of Cle Elum Dam's investigations are shown on Figure 4 of Appendix "D", geologic plan map (drawing 33-100-2400). In approximate order from youngest to oldest (shallowest to deepest), these geologic units are:

- **Ice-contact Lakebed Sediments (Qgi)**
- **Glacial Till (Qgt)**
- **Coarse-grained Glacial Outwash (Qgo_1)**
- **Fine-grained Glacial Outwash (Qgo_2)**
- **Glaciolacustrine Sediments (Qgl)**

The general characteristics of these five geologic units are discussed in the following paragraphs.

Ice-contact Lakebed Sediments (Qgi)

The natural Lake Cle Elum was formed by damming of the Cle Elum River with a terminal moraine deposited by a Pleistocene alpine glacier. Cle Elum Dam was constructed across the natural outlet of the lake which had been eroded through the moraine by the Cle Elum River following the retreat of the glacial ice. The moraine is composed chiefly of glacial till (Qgt), but likely includes layers, lenses, and stringers of outwash (both Qgo_1 and Qgo_2), especially near the downstream contact with the outwash plain, as discussed below. The upstream section of the terminal moraine is composed of the intensely deformed layer of ice-contact lakebed sediments (Qgi). The upstream, lakeside portion of the terminal moraine consists of a prominent, but poorly exposed layer of deformed lakebed sediments which were gouged from the bottom of Lake Cle Elum and plastered up against the morainal till by the alpine glacier. These ice-contact lakebed sediments (Qgi) are probably derived, at least in part, from the older glaciolacustrine sediments (Qgl) that are present deep in the foundation; however, they have significantly different engineering properties due to overconsolidation of the Qgi by the glacial ice. These ice-contact lakebed sediments form an integral part of the dam's foundation by acting as a natural barrier to seepage migrating from the reservoir into the terminal moraine foundation. The importance of this natural semi-impervious blanket was recognized early in the investigations (Bryan, 1927; Ransome, 1930) and the location of the dam was sited to take advantage of this feature. A concerted effort was made during construction of the dam to prevent damage or penetration of the Qgi layer. Windows in the natural blanket were identified during construction and corrected with placement of impervious material to maintain tightness of the reservoir (USBR, undated). The ice-contact lakebed sediments (Qgi) are poorly described in preconstruction logs at the dam site, but references to thicknesses ranging from 25 to 45 feet appear in several of the older reports (Bryan, 1927; Ransome, 1930; USBR, undated).

Recent investigations have been concentrated on the dam crest and downstream areas and have not encountered the Qgi materials. Field mapping in 1992 and 1995 revealed that much of the area upstream of the dam is now covered by a veneer of loose sediment derived from wave erosion of the glacial till, and outcrops of the Qgi were only noted on the extreme right shoreline over 1000 feet right of the spillway. A field sample collected from a representative outcrop of the Qgi was submitted for laboratory testing in 1995 and was found to have the following composition: 66 percent low plasticity fines and 34 percent sand. Drop stones consisting of coarse gravel and cobbles are present in the material, but comprise less than 5 percent by volume of the unit. These ice-contact sediments are laminated to stratified and have been intensely deformed with highly contorted and truncated bedding planes common in the unit. The Qgi unit is overconsolidated due to its placement by glacial ice.

Glacial Till (Qgt)

The glacial till (Qgt) forms the foundation of both dam abutments, but it has been eroded out of the maximum section, as shown on geologic section C-C', see Figure 6A of Appendix "D". It also underlies the main dike and three small saddle dikes located east of the dam. The thickness of the till is highly variable at the dam site, due in part to its use as the primary source of impervious embankment material. Large borrow pits were located on the moraine crest on both abutments of the dam. The maximum thickness of the till noted in preconstruction explorations was about 150 feet.

The till has not been intercepted in any of the recent explorations and our present knowledge of the material is based on exposures of the moraine along the abutments of the dam. The till (Qgt) consists chiefly of gravel, cobbles, and boulders floating in a matrix of silty sand. Representative outcrops of the till are typically composed of about 40 percent predominantly fine to medium sand, about 35 percent nonplastic fines with rapid dilatancy, about 25 percent fine to coarse gravel, and about 5 to 30 percent by volume of oversize, including up to about 5 percent boulders. A representative field sample of the minus 3-inch fraction was submitted for laboratory testing in 1995 and was found to have the following composition: 73 percent sand, 14 percent gravel, and 13 percent fines. The higher fines content observed in this material is a diagnostic feature of the till, in that it can be readily used to distinguish this material from adjacent outwash deposits (Qgo_1 and Qgo_2). Boulders, including large glacial erratics, are common in the till and can reach very large sizes due to direct transport by the alpine glacier. One erratic observed in the old borrow area right of the spillway was measured at 8 feet by 6 feet by 3 ft in size. The till is generally chaotic and heterogeneous in character, showing no indications of stratification or bedding. The till is variably compact, ranging from dense (excavates with a moderate to heavy blow with a rock hammer), to loose (readily excavates with a light hammer blow). The till is susceptible to wave-induced erosion; shoreline erosion is currently a problem at private tracts of land on the east side of the reservoir.

The glacial till (Qgt) was the primary borrow source for the impervious section of the dam embankment. Most of this material was borrowed from the moraine crest right of the spillway. Up to 60 vertical feet of material were removed from this area. Supplemental borrow pits were excavated left of the main dike in later stages of construction, as available material on the right abutment had been exhausted. The right abutment borrow area was believed to have been excavated to the crest elevation of the dam, approximately elevation 2250. However, field surveys conducted in 1998 verified the existence of a low area on the right abutment, where the topographic surface drops to elevation 2247, along an access trail used by local recreationists.

Coarse-grained Glacial Outwash (Qgo_1)

Most of Cle Elum Dam is founded on laterally extensive deposits of coarse-grained glacial outwash (Qgo_1). These deposits underlie the maximum section of the dam, extend laterally beneath both abutments, and continue as extensive terraces for several miles downstream of the dam. The coarse-grained outwash is composed chiefly of fluvial sediments deposited by glacial meltwater adjacent to and downstream of the till that comprises the terminal moraine. As indicated by drill holes located on and adjacent to the crest of the dam, the complex stratigraphy of this coarse-grained outwash unit likely interfingers and intertwines with the till materials along the contact. The thickness of the Qgo_1 unit is variable at the site, and it has not exceeded 130 feet in any of the explorations completed to date which have fully penetrated it.

The coarse-grained outwash (Qgo_1) is composed primarily of gravel and cobbles with boulders and a finer-grained matrix of fine to coarse sand. The coarse-grained outwash unit is distinguished from its underlying fine-grained outwash (Qgo_2) on the basis of its high concentrations of oversize material (i.e., cobbles and boulders) which are not present in significant volume in the Qgo_2 unit. Exposures of the coarse-grained outwash downstream from the dam reveal a composition of about 60 to 80 percent fine to coarse gravel, 15 to 35 percent fine to coarse sand, a trace to about 5 percent fines and about 5 to 25 percent oversize (by volume). The maximum particle dimension observed in the outcrops of outwash was 2.5 feet. Representative laboratory testing of the minus 3-inch portion of field samples collected showed gradations ranging from 41 to 85 percent gravel, 14 to 58 percent sand, and 1 to 15 percent fines. Laboratory classifications of the field samples included Poorly Graded Gravel with Sand (GP)s, Poorly Graded Gravel with Silt and Sand (GP-GM)s, Poorly Graded Gravel with Clay and Sand (GP-GC)s, Well-graded Gravel with Sand (GW)s, Well-graded Gravel with Silt and Sand (GW-GM)s, Clayey Gravel with Sand (GC)s, and Poorly Graded Sand with Gravel (SP)g. Oversize material was present in most of the sample intervals, but could not be sampled due to barrel diameter limitations; the maximum size reported from the samples was 65 mm. The Qgo_1 unit varies from heterogeneous to crudely stratified. It includes discontinuous layers, stringers, and lenses of both open-work gravel with no matrix and predominantly finer-grained beds of fine sand and/or silt. Of particular interest is a layer of stiff "blue clay", reported in the construction history of Cle Elum Dam as the foundation of the cutoff trench. Construction photographs do give some credence to this notation in the construction history by an indication of a change in material type near the base of the cutoff trench and by what appears to be a large pond of standing water which obscures the floor of the excavation. Review of preconstruction test pit and drill hole logs located upstream of the dam crest (see cross section B-B′ on drawing 33-100-2402, Figure 6 of Appendix "D") suggest lateral continuity of this "blue clay" layer, at least upstream and adjacent to the cutoff trench.

Fine-grained Glacial Outwash (Qgo_2)

The fine-grained outwash (Qgo_2) is defined entirely on the basis of subsurface explorations. It is not exposed at the ground surface in the vicinity of the dam. The Qgo_2 outwash unit consists of fluvial deposits of primarily sand and gravel which were laid down by glacial meltwater downstream from the active ice margin of the alpine glacier. This unit is distinguished from the overlying coarse-grained outwash unit (Qgo_1) by a general lack of oversize material (i.e., cobbles and boulders), which would suggest deposition at some distance from the terminal front of the ice sheet. The unit was intercepted in preconstruction test pits 25, 26, and 53, in the 1978 pump well (CE-5), the 1981 exploration for the downstream powerplant site (DH-81-2), the four cross-hole shear wave borings completed in the 1992 dam safety investigation (DH-92-1, -2, -4, and -5), and in four Becker Hammer test holes drilled in 1998 (BDH98-2, -3, -4 and BSH98-1). From the above mentioned explorations, which have penetrated through the entire unit, it has been determined that the thickness of the Qgo_2 varies from 40 to 45 feet.

Because of the varying drilling and sampling techniques used, downhole artesian pressures, and heaving sand conditions; our knowledge of the Qgo_2 physical properties is limited to 5 drive samples which were obtained from DH-92-2 and from 8 grab samples collected from BSH98-1. These samples showed that the fine-grained outwash is composed chiefly of gravel and sand, with typically trace concentrations of fines and little or no oversize material. Gradation tests run on field samples consisted of 0 to 69 percent gravel, 30 to 38 percent sand and 1 to 22 percent fines. These materials were classified as Poorly Graded Gravel with Sand (GP)s, Well-graded Gravel with Sand (GW)s, Poorly Graded Sand with Gravel (SP)g, Poorly Graded Sand with Silt and Gravel (SP-SM)g, Poorly Graded Sand (SP), Well-graded Sand with Gravel (SW)g, and Silty Sand (SM). The maximum particle size recovered in the samples was 50 mm. The fine-grained outwash is crudely stratified with irregular layers, lenses, and stringers of fine sand and silt. These layers include areas of fine-grained material which have exhibited heaving or flowing conditions under little or no reservoir head. In preconstruction explorations at the site, these materials were identified as a "quick sand".

Glaciolacustrine Sediments (Qgl)

The glaciolacustrine sediments (Qgl) consist predominantly of fine-grained materials which were deposited within an ancestral glacial lake. The Qgl was formed as a result of the Cle Elum River being dammed at the Bullfrog terminal moraine, about 4 miles downstream from the present location of Cle Elum Dam (Porter, 1976). This ancestral lake was subsequently infilled with sediment from a later glacial advance (Ronald advance) and has been recognized only from subsurface drilling data. Drilling at Cle Elum Dam has never penetrated through the glaciolacustrine sediments into the underlying materials and its thickness at the dam site has not been determined. Test drilling at the proposed MountainStar resort area downstream of the dam has shown the Qgl deposit to be about 135 feet thick (AESI, 1999). The glaciolacustrine sediments at that site are underlain by a complexly interbedded and poorly understood sequence of alluvium, glacial outwash and lacustrine sediments. Radiocarbon dating of a large wood fragment recovered from near the top of the glaciolacustrine sediments in Becker test hole BDH98-3 has estimated the age of this unit to be 40,600 years (plus or minus 1800 years). This radiocarbon date indicates that infilling of the ancestral lake had been completed prior to the last glacial advance (Domerie advance) which blocked the Cle Elum River and formed the natural Lake Cle Elum. The date also correlates well with the date of a wood fragment previously recovered from the glaciolacustrine sediments downstream at the MountainStar site.

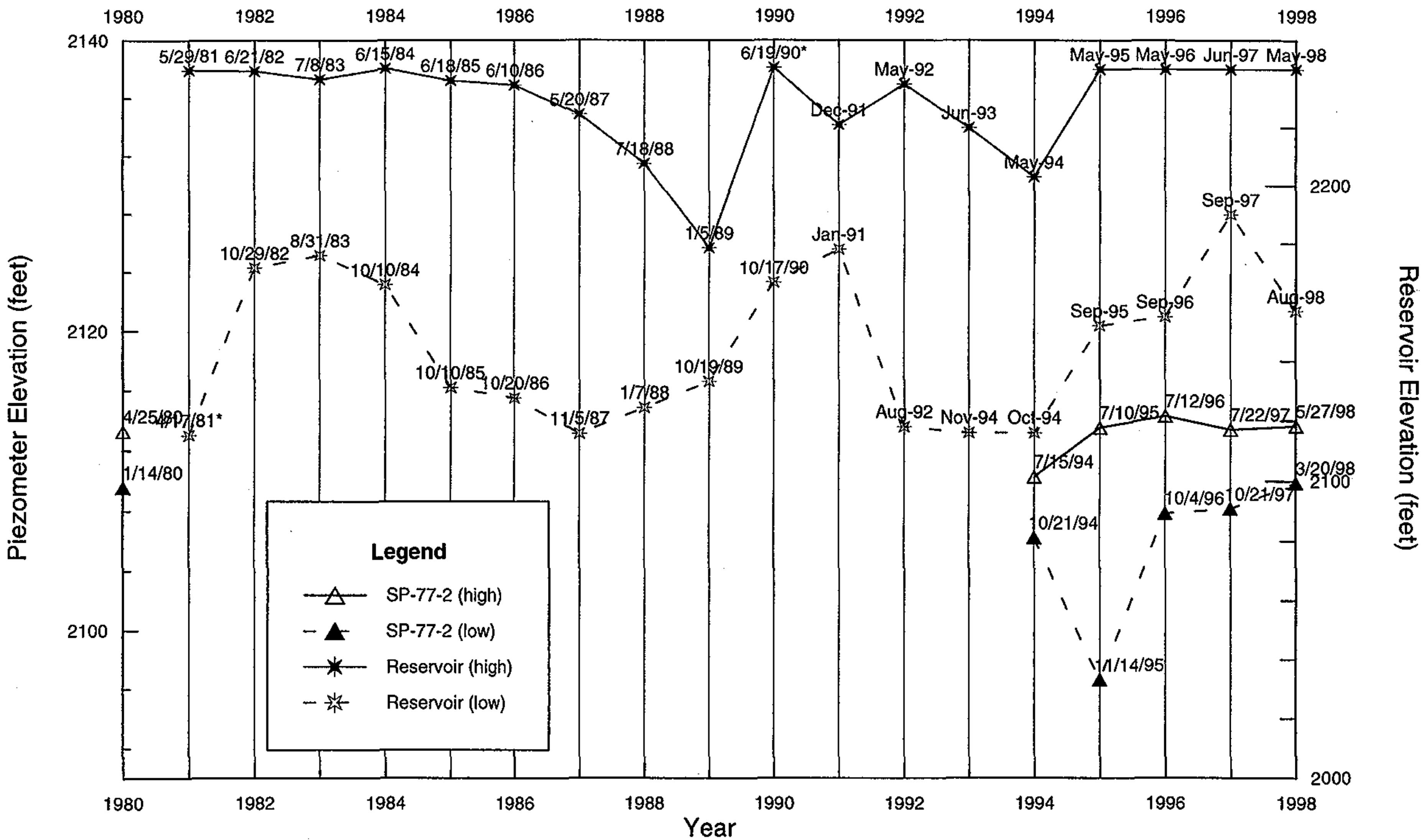
The glaciolacustrine sediments (Qgl) are described on the basis of two drive samples obtained from the bottom of DH-92-2 and from 13 grab samples collected from Becker hole BSH98-1. The glaciolacustrine sediments are composed primarily of silty and clayey fines with high concentrations of predominantly fine sand in the upper approximate 20 feet of the unit. Gradation tests of field samples varied from 17 to 99 percent nonplastic to low plasticity silty and clayey fines, 1 to 80 percent fine to medium sand, and 0 to 3 percent gravel. The samples were classified as Silt (ML), Silt with Sand (ML)s, Silty Clay (CL-ML), Sandy Silty Clay s(CL-ML) and Silty Sand (SM). The sand, which is concentrated in the upper 20 feet of the unit, likely represents a transition from the lacustrine conditions in the ancestral lake to deltaic deposition in shallower water as infilling of the lake neared completion. The glaciolacustrine sediments are black to dark gray in color, and are stratified in horizontal layers and laminations ranging from 1 to 75 mm thick. Organic debris, including large wood fragments, is common in this material. The glaciolacustrine sediments are relatively compact, likely due to the thick sequence of glacial outwash overlying the unit.

APPENDIX E

Piezometer Information

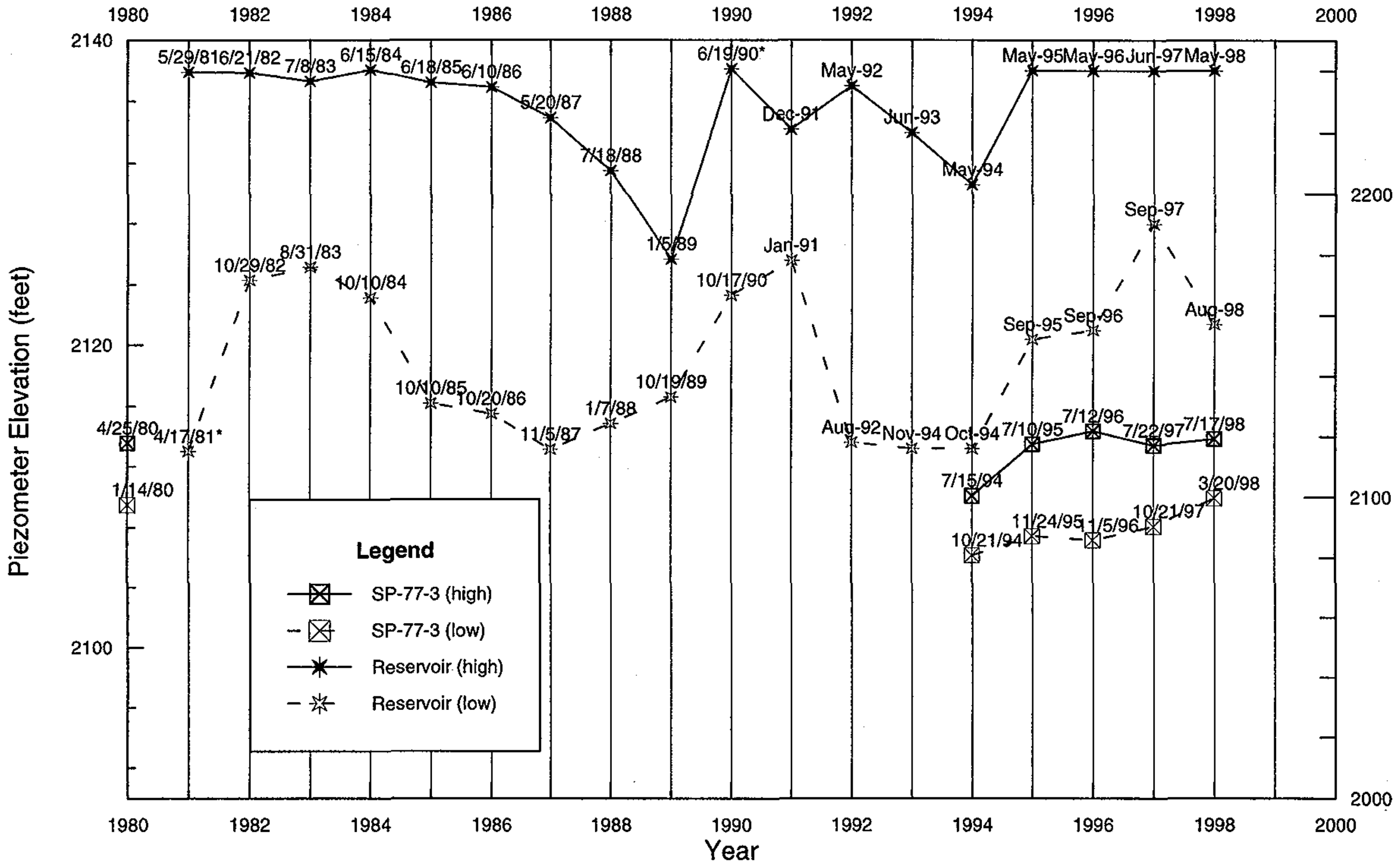
Table E-1
SUMMARY OF RANGE IN PIEZOMETER/WELL AND RESERVOIR ELEVATIONS (1980 TO PRESENT)

Year	Change in Reservoir (feet)	Range of Piezometer and Observation Well Readings (ft)							
		SP-77-2	SP-77-3	SP-78-4	SP-78-5	SP-81-2UP	SP-81-2LO	PT-92-3	PT-92-6
1980		3.7	4.1	3.9	3.8				
1981	124.6					5.0	3.7		
1982	67.7					5.2	5.5		
1983	60.6					1.2	0.2		
1984	74.4					3.7	3.6		
1985	105.1					4.3	4.3		
1986	107.0								
1987	109.0					3.3	3.4		
1988	83.2					8.7	9.3		
1989	45.5					4.1	4.4		
1990	73.9					4.2	4.5		
1991	43.0								
1992	117.0					4.0	4.4		
1993	104.0					5.1	4.2		
1994	87.0	4.1	3.9	3.7		3.6	3.7	3.7	3.8
1995	88.0	16.9	6.1	5.8		4.8	4.8	4.9	5.9
1996	85.0	6.4	7.2	6.2		4.8	5.2	5.6	6.9
1997	50.0	5.3	5.3	4.8		4.2	4.5	4.4	5.1
1998	83.0	3.8	3.9	3.5		3.6	3.5	3.5	3.7



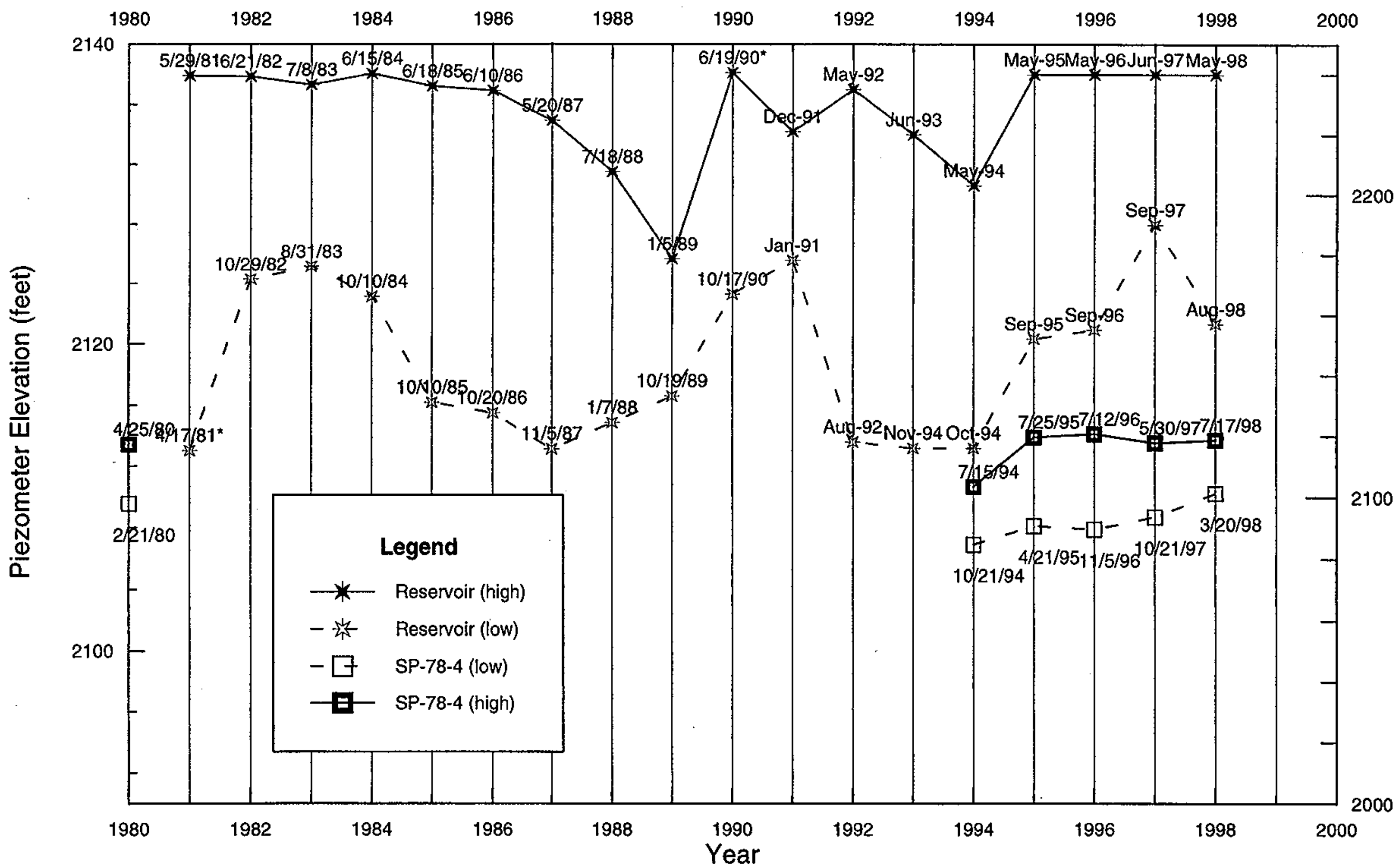
SP-77-2.GRF with ce-piez.xls (sheet 2) / 12/11/98 / KAF

Project No. D97287	Cle Elum Dam Cle Elum, Washington	Record of Max/Min Piezometer Values SP-77-2	Figure E-1
Woodward-Clyde			



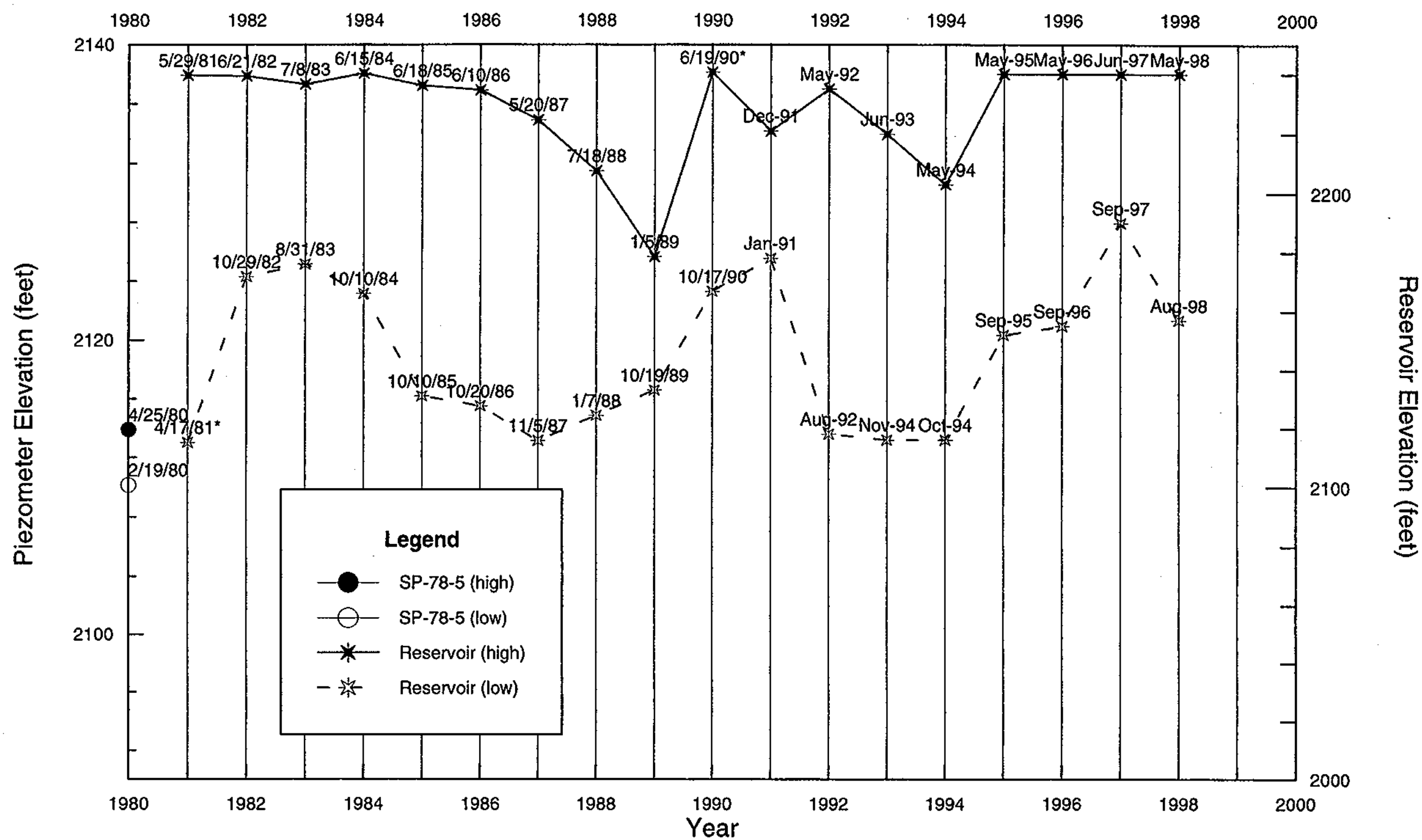
SP-77-3.GRF with ce-piez.xls (sheet 2) / 12/11/98 / KAF

Project No. D97287	Cle Elum Dam Cle Elum, Washington	Record of Max/Min Piezometer Values SP-77-3	Figure E-2
Woodward-Clyde			



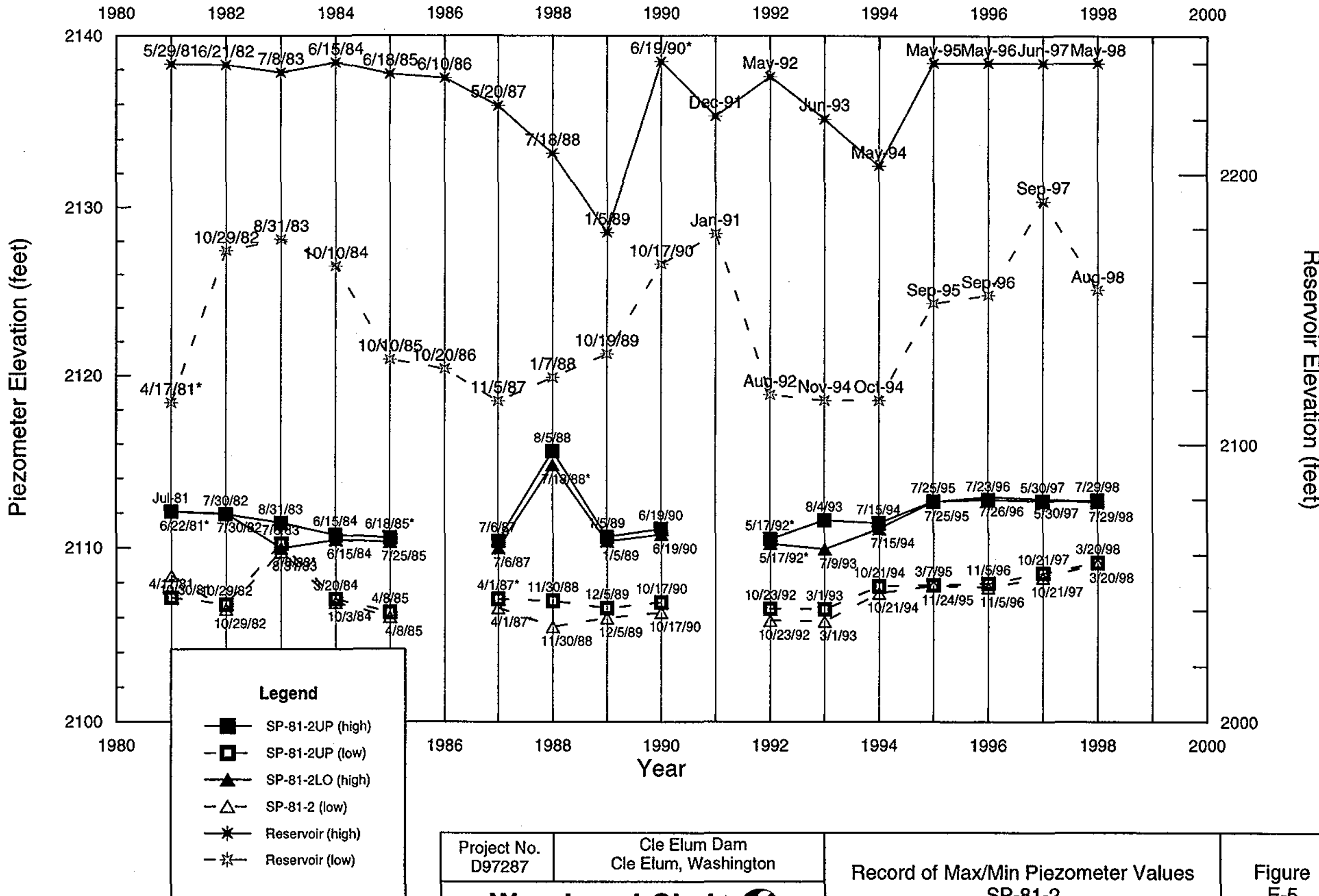
SP-78-4.GRF with ce-piez.xls (sheet 2) / 12/11/98 / KAF

Project No. D97287	Cle Elum Dam Cle Elum, Washington	Record of Max/Min Piezometer Values SP-78-4	Figure E-3
Woodward-Clyde			



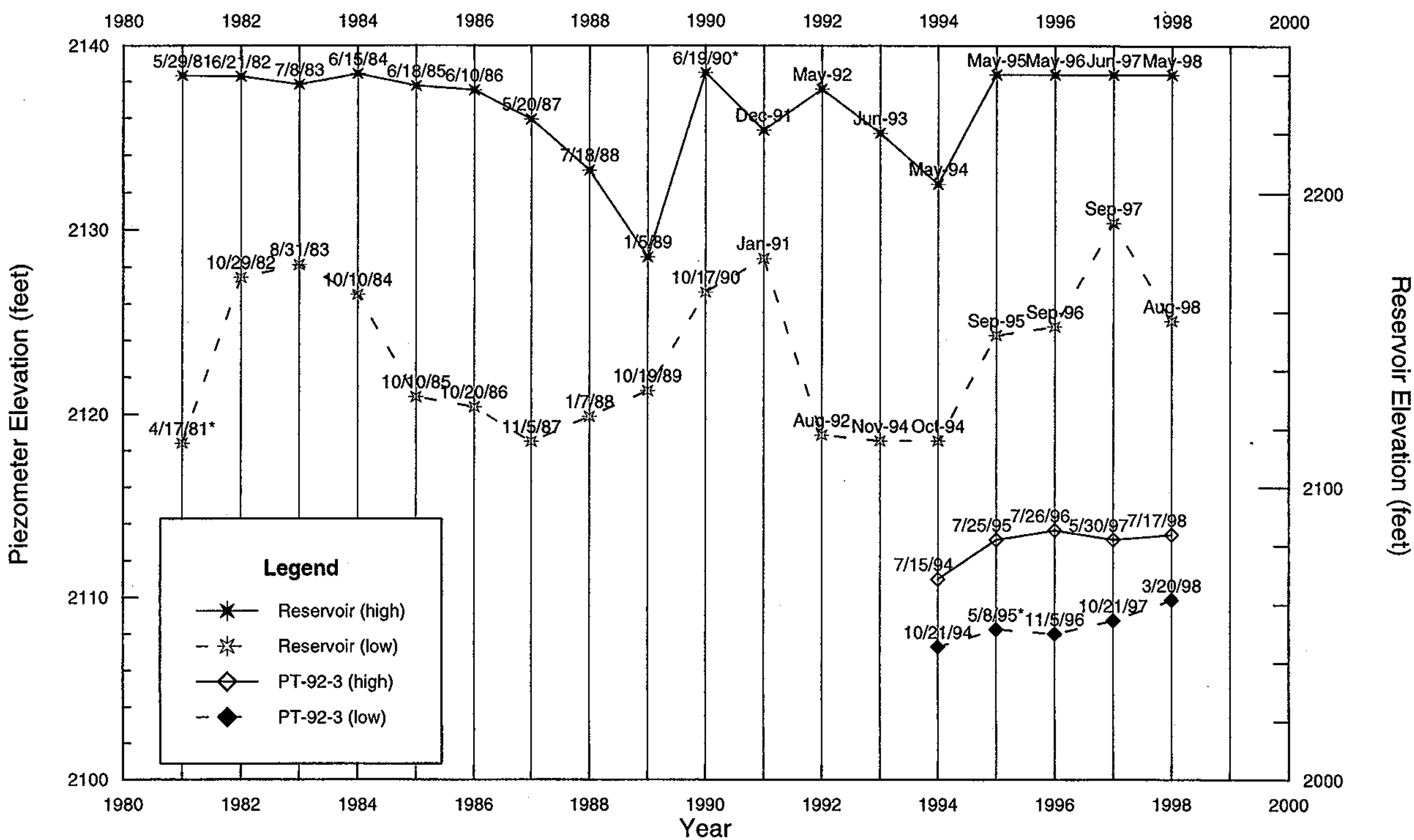
Project No. D97287	Cle Elum Dam Cle Elum, Washington	Record of Max/Min Piezometer Values SP-78-5	Figure E-4
Woodward-Clyde			

SP-78-5.GRF with ce-piez.xls (sheet 2) / 12/11/98 / KAF



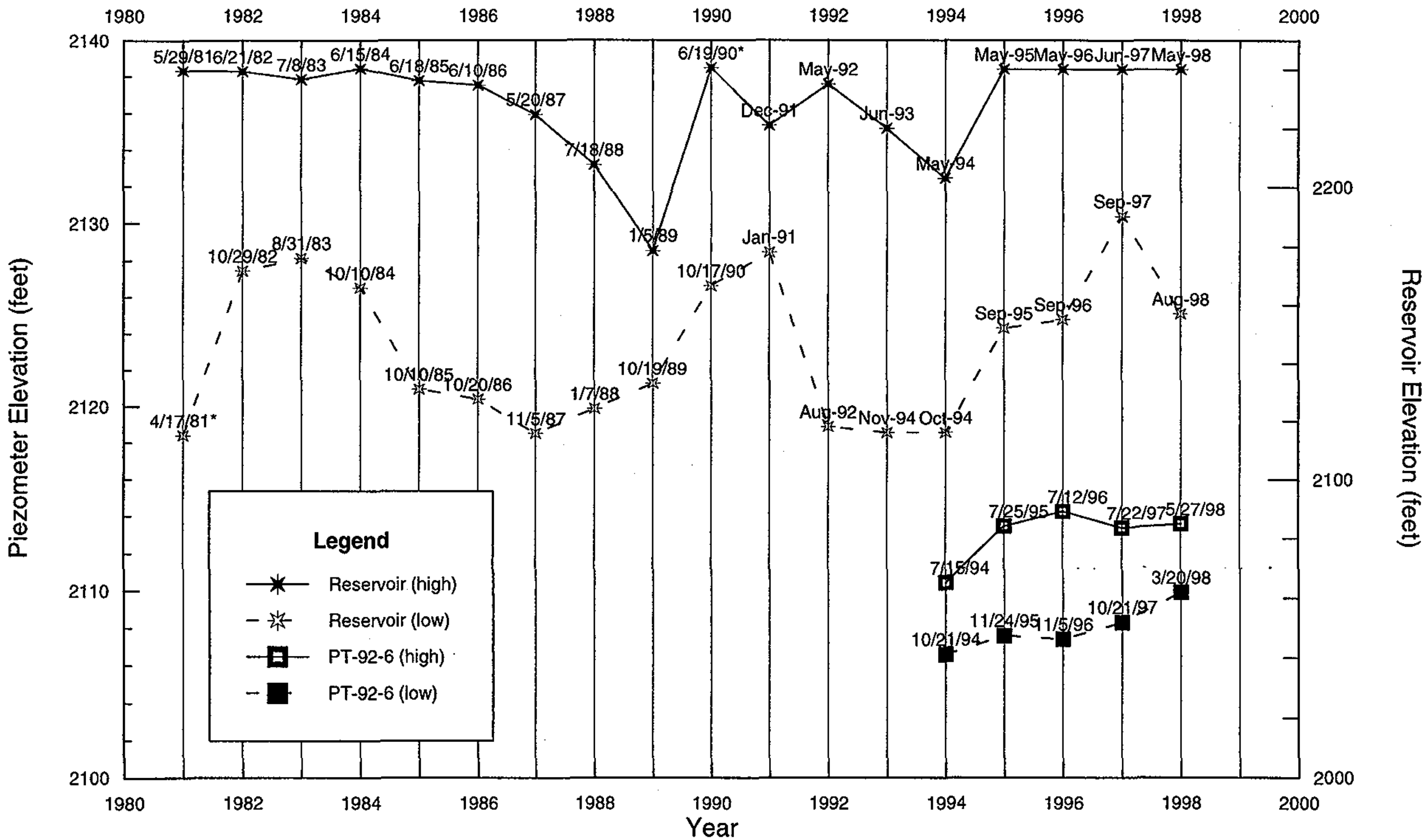
SP-81-2.GRF with ce-piez.xls (sheet 2) / 12/11/98 / KAF

Project No. D97287	Cle Elum Dam Cle Elum, Washington	Record of Max/Min Piezometer Values SP-81-2	Figure E-5
Woodward-Clyde			



Project No. D97287	Cle Elum Dam Cle Elum, Washington	Record of Max/Min Piezometer Values PT-92-3	Figure E-6
Woodward-Clyde			

PT-92-3.GRF with ce-piez.xls (sheet 2) / 12/11/98 / KAF



Project No. D97287	Cle Elum Dam Cle Elum, Washington	Record of Max/Min Piezometer Values PT-92-6	Figure E-7
Woodward-Clyde			

PT-92-6.GRF with ce-piez.xls (sheet 2) / 12/11/98 / KAF

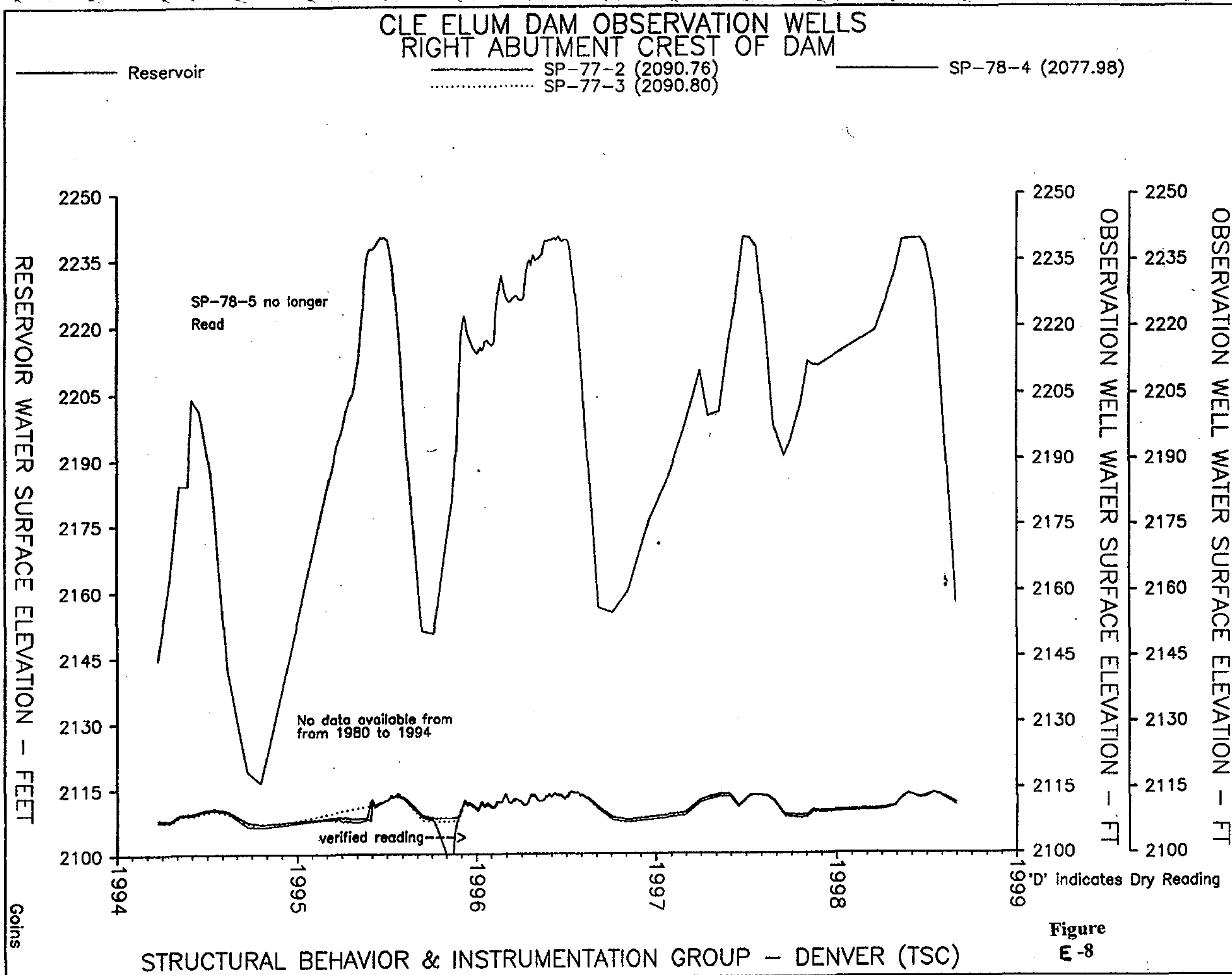
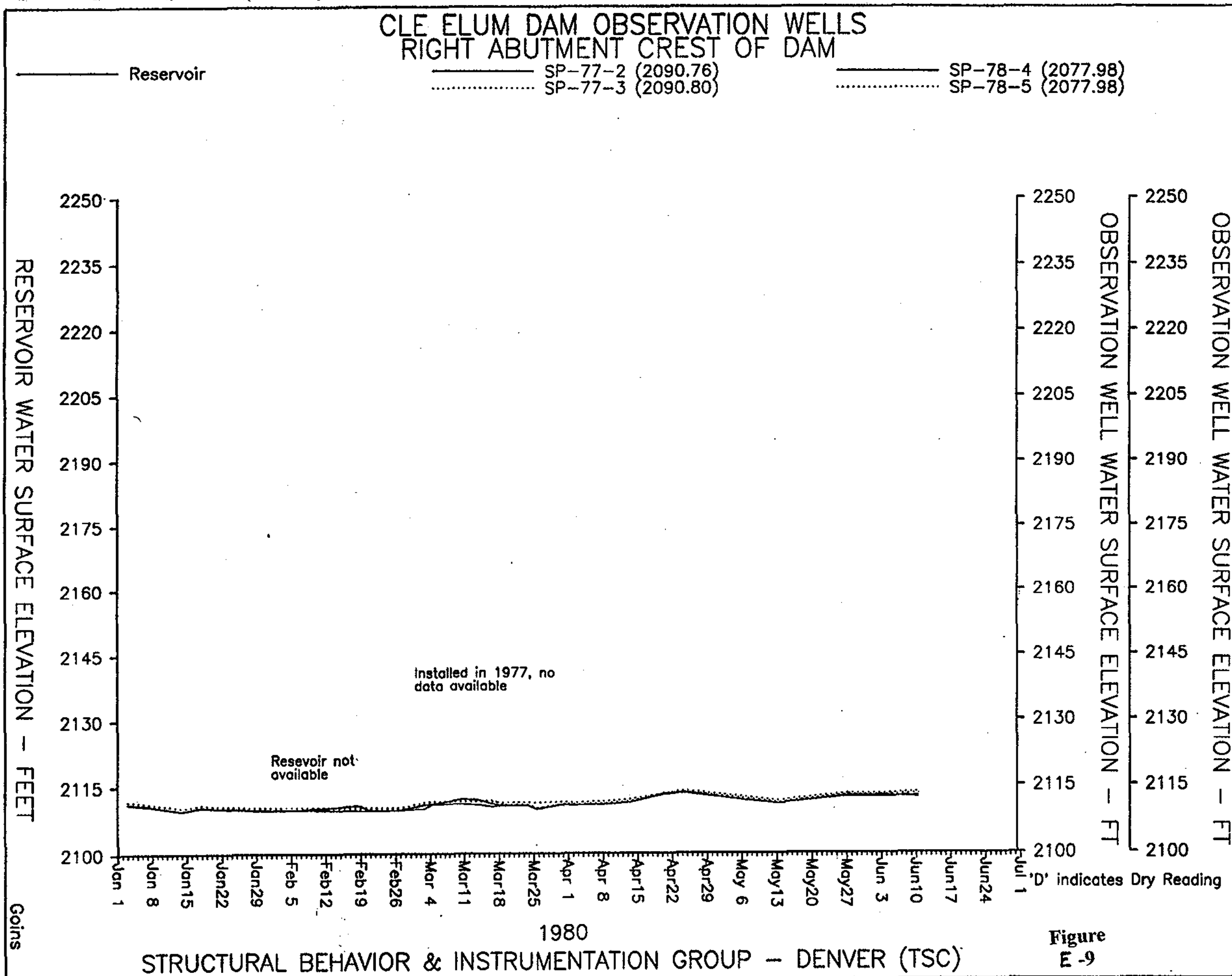

CLE ELUM DAM OBSERVATION WELLS
RIGHT ABUTMENT CREST OF DAM
Reservoir
SP-77-2 (2090.76)
SP-77-3 (2090.80)
SP-78-4 (2077.98)
SP-78-5 no longer Read
No data available from from 1980 to 1994
verified reading---->
RESERVOIR WATER SURFACE ELEVATION - FEET
OBSERVATION WELL WATER SURFACE ELEVATION - FT
OBSERVATION WELL WATER SURFACE ELEVATION - FT
2250
2235
2220
2205
2190
2175
2160
2145
2130
2115
2100
1994
1995
1996
1997
1998
1999
'D' indicates Dry Reading
Goins
STRUCTURAL BEHAVIOR & INSTRUMENTATION GROUP - DENVER (TSC)

Figure E-8



CLE ELUM DAM OBSERVATION WELLS
RIGHT ABUTMENT CREST OF DAM
Reservoir
SP-77-2 (2090.76)
SP-77-3 (2090.80)
SP-78-4 (2077.98)
SP-78-5 (2077.98)
RESERVOIR WATER SURFACE ELEVATION - FEET
OBSERVATION WELL WATER SURFACE ELEVATION - FT
OBSERVATION WELL WATER SURFACE ELEVATION - FT
2250
2235
2220
2205
2190
2175
2160
2145
2130
2115
2100
Installed in 1977, no data available
Resevoir not available
Jan 1
Jan 8
Jan15
Jan22
Jan29
Feb 5
Feb12
Feb19
Feb26
Mar 4
Mar11
Mar18
Mar25
Apr 1
Apr 8
Apr15
Apr22
Apr29
May 6
May13
May20
May27
Jun 3
Jun10
Jun17
Jun24
Jul 1
'D' indicates Dry Reading
1980
Goins
STRUCTURAL BEHAVIOR & INSTRUMENTATION GROUP - DENVER (TSC)

Figure E-9

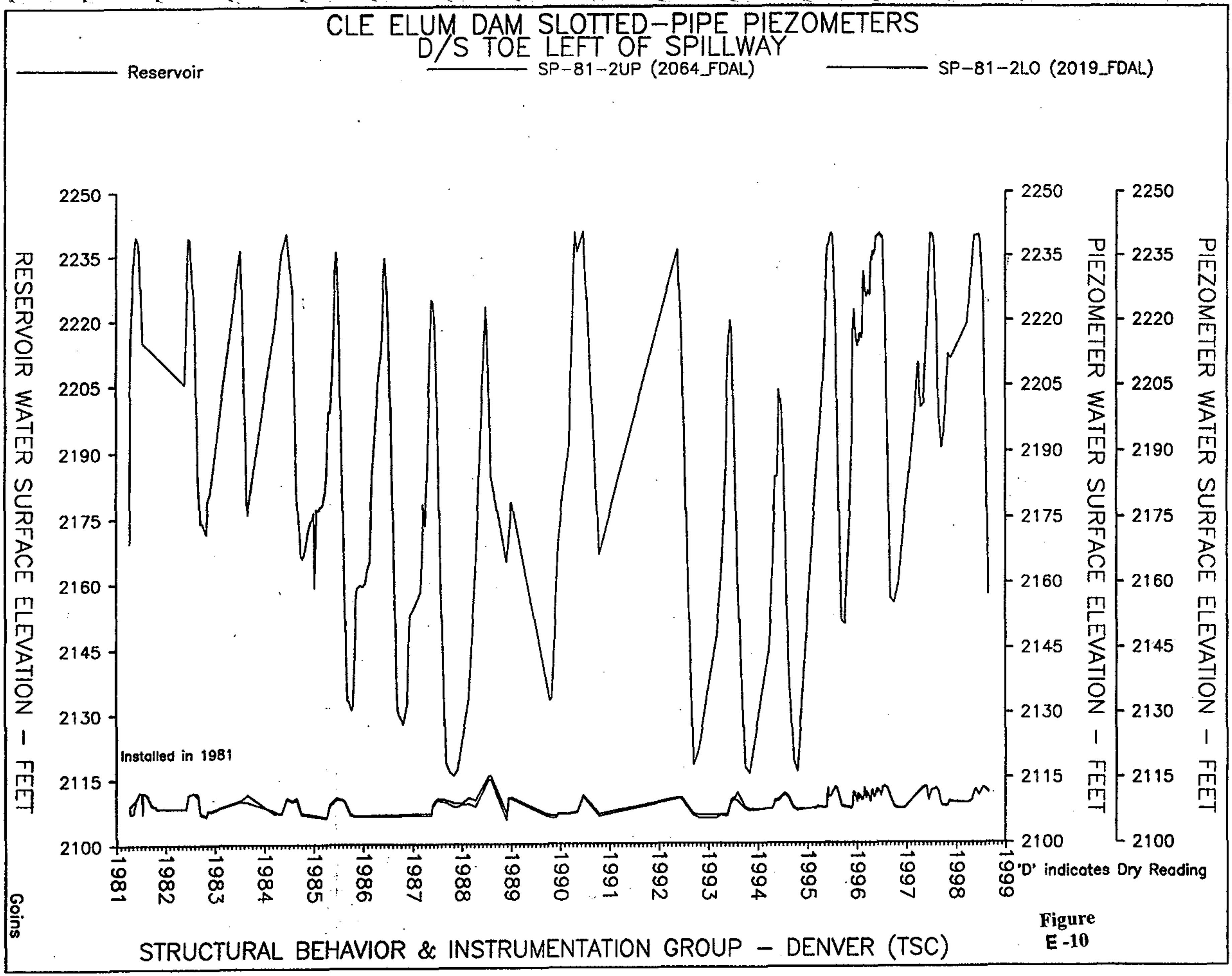

CLE ELUM DAM SLOTTED-PIPE PIEZOMETERS
D/S TOE LEFT OF SPILLWAY
Reservoir
SP-81-2UP (2064_FDAL)
SP-81-2LO (2019_FDAL)
RESERVOIR WATER SURFACE ELEVATION - FEET
PIEZOMETER WATER SURFACE ELEVATION - FEET
PIEZOMETER WATER SURFACE ELEVATION - FEET
2250
2235
2220
2205
2190
2175
2160
2145
2130
2115
2100
Installed in 1981
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
'D' indicates Dry Reading
Goins
STRUCTURAL BEHAVIOR & INSTRUMENTATION GROUP - DENVER (TSC)

Figure
E -10

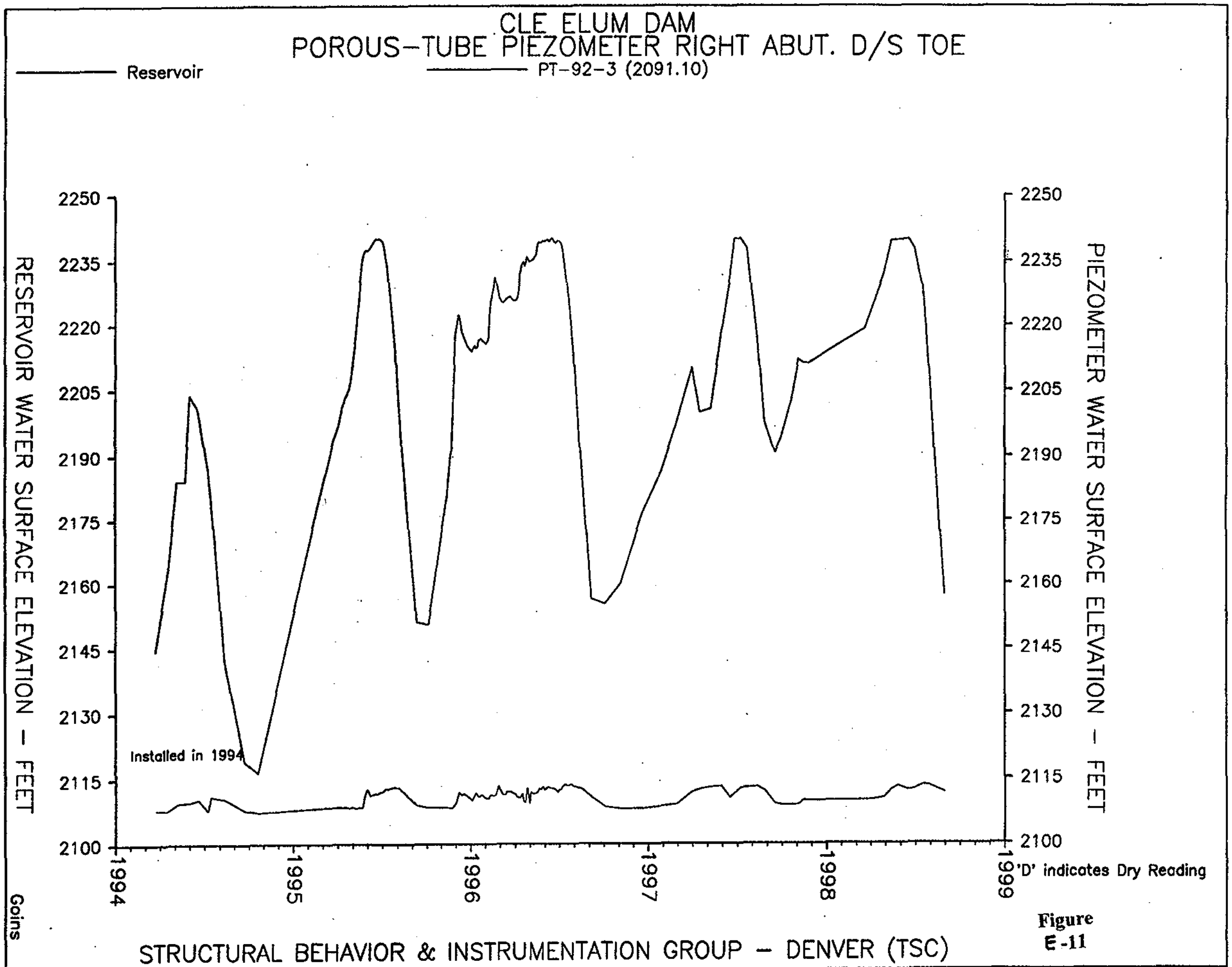
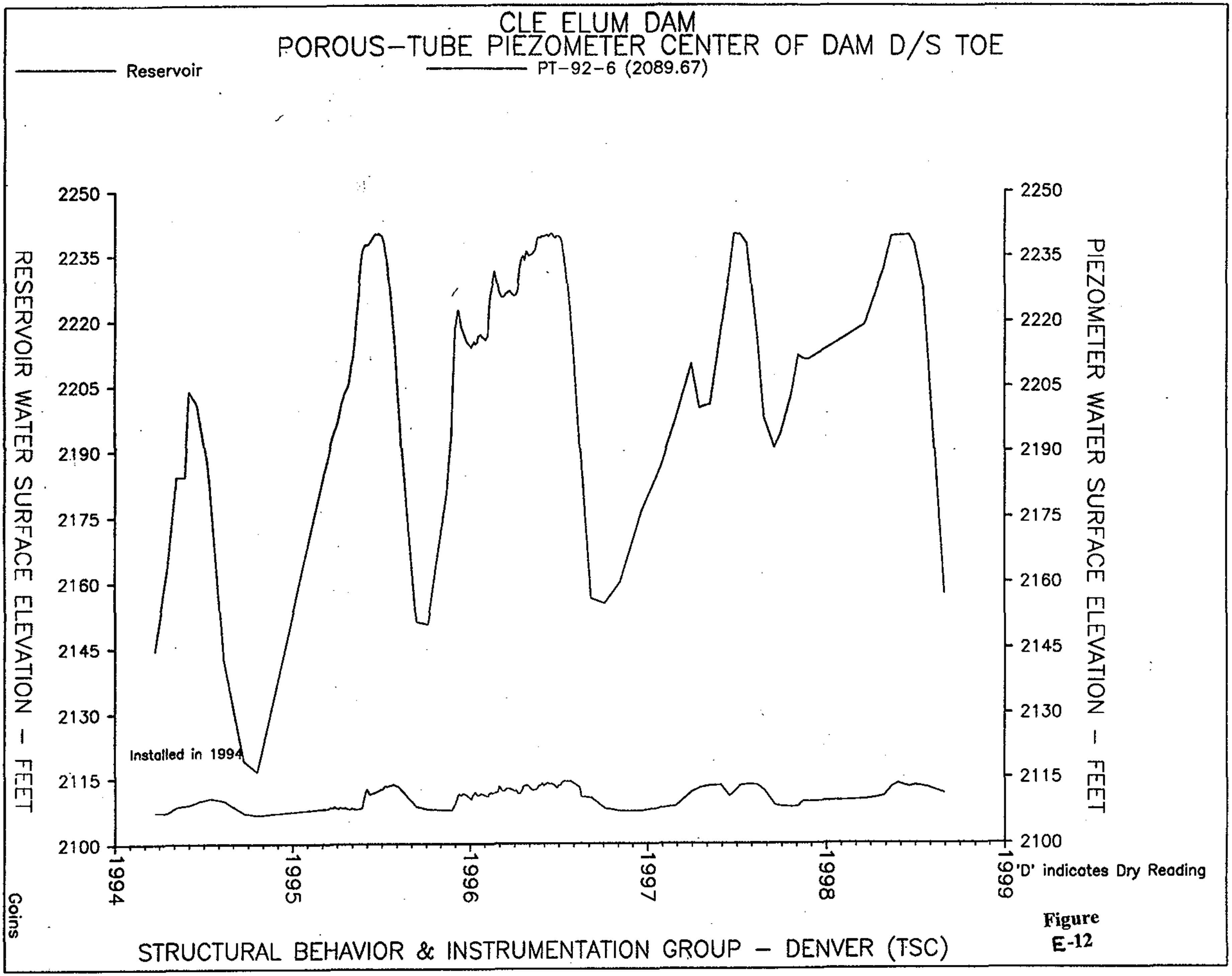

CLE ELUM DAM
POROUS-TUBE PIEZOMETER RIGHT ABUT. D/S TOE
Reservoir
PT-92-3 (2091.10)
RESERVOIR WATER SURFACE ELEVATION - FEET
PIEZOMETER WATER SURFACE ELEVATION - FEET
2250
2235
2220
2205
2190
2175
2160
2145
2130
2115
2100
Installed in 1994
1994
1995
1996
1997
1998
1999
'D' indicates Dry Reading
Goins
STRUCTURAL BEHAVIOR & INSTRUMENTATION GROUP - DENVER (TSC)

Figure
E-11



CLE ELUM DAM
POROUS-TUBE PIEZOMETER CENTER OF DAM D/S TOE
Reservoir
PT-92-6 (2089.67)
RESERVOIR WATER SURFACE ELEVATION - FEET
PIEZOMETER WATER SURFACE ELEVATION - FEET
2250
2235
2220
2205
2190
2175
2160
2145
2130
2115
2100
Installed in 1994
1994
1995
1996
1997
1998
1999
'D' indicates Dry Reading
Goins
STRUCTURAL BEHAVIOR & INSTRUMENTATION GROUP - DENVER (TSC)

Figure E-12

Appendix F

APPENDIX F

Deformation Analyses

Job: Cle Elum Dam
Project No: 68-FD97287-00
Sheet ___ of ___
Description: Newmark Analyses
Computed by: KAF
Date: 1/21/99
Checked by: JWP
Date: 02/02/00

Reference

PROBLEM: Determine new yield acceleration (a_y) for Cle Elum Dam using different properties for the material, assuming no liquefaction. Use new a_y for Newmark analyses to determine relative displacement under earthquake loading for one short duration EQ and one long duration EQ

GIVEN: Approximate internal geometry of the dam and material properties. Acceleration time histories for magnitude 7 and 9 earthquakes at Cle Elum Dam. See Figures F-1 through F-8)

ASSUMPTIONS: (1) Assume the following properties for the layers previously deemed potentially liquefiable: $\gamma = 110$ pcf, $\phi' = 30°$, and $c' = 0$ psf.
(2) As stated.

SOLUTION:

I. Determine yield acceleration (a_y)
- Using utexas3, determine seismic coefficient which results in F.S. = 1.0, This coefficient is equal to a_y. (See utexas3 file at end of section: CE-1)
- Circular surfaces passing through the full height dam were used
- $a_y = 0.26$

II. Determine relative displacement
- Used TNMN program (Newmark analysis)
- Used acceleration time histories for:
  (1) 10,000 year, M7, horizontal 1
  (2) 10,000 year, M9, horizontal 1

*Note: for this analysis, only used 2 of the 8 time histories provided by Ivan Wong.

Job ______ Project No. ______ Sheet ____ of ____

Description ______ Computed by ______ Date ______

Checked by ______ Date ______

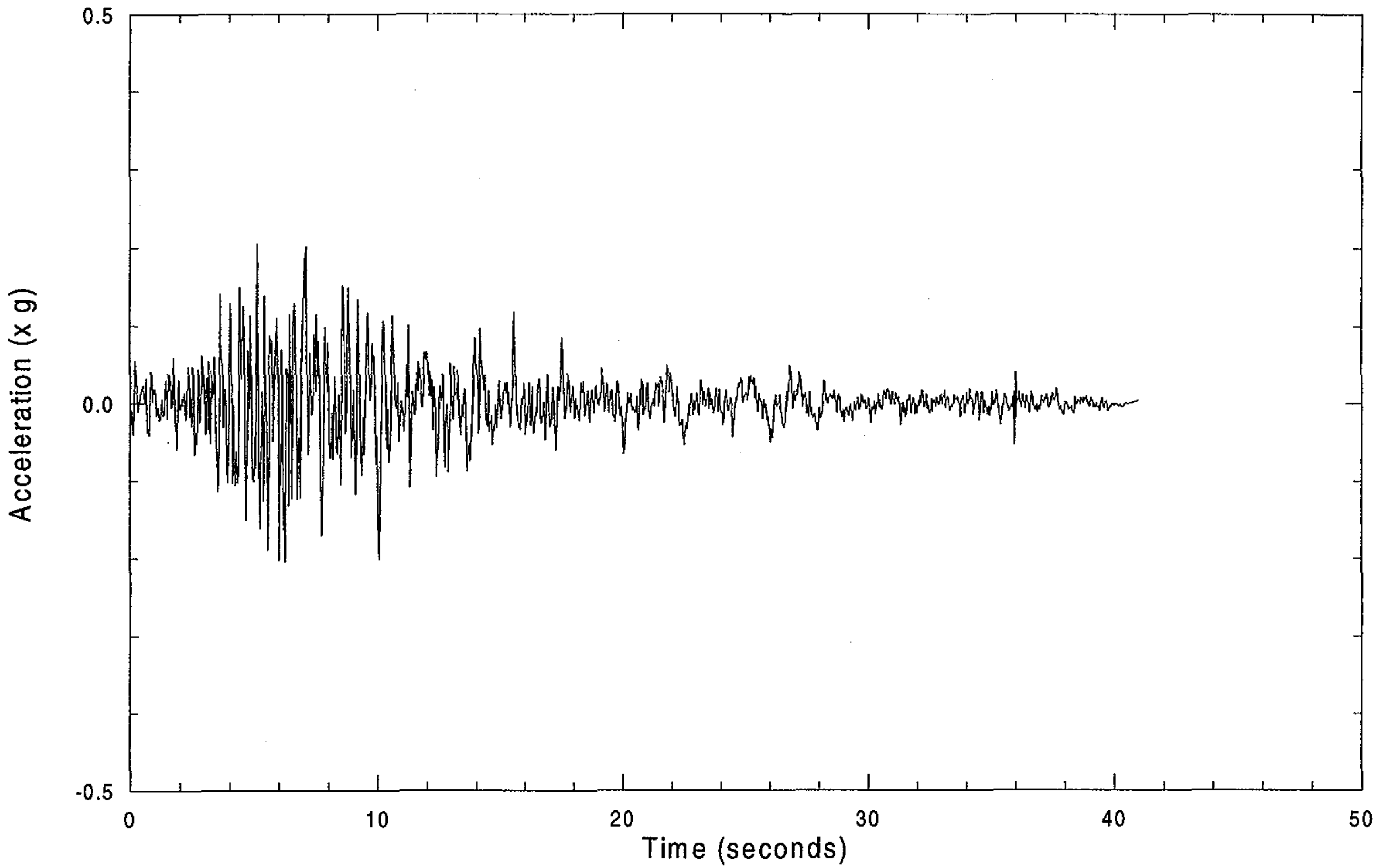
Reference

- Input files:
  - (1) 10k70h1b.in — M7 EQ
  - (2) 10km90h1.in, 10km9h1b.in, 10km9h1c.in, 10km9h1d.in, 10km9h1e.in, 10km9h1f.in, 10km9h1g.in — M9 EQ

    *Note: Numerous files required due to long time duration.

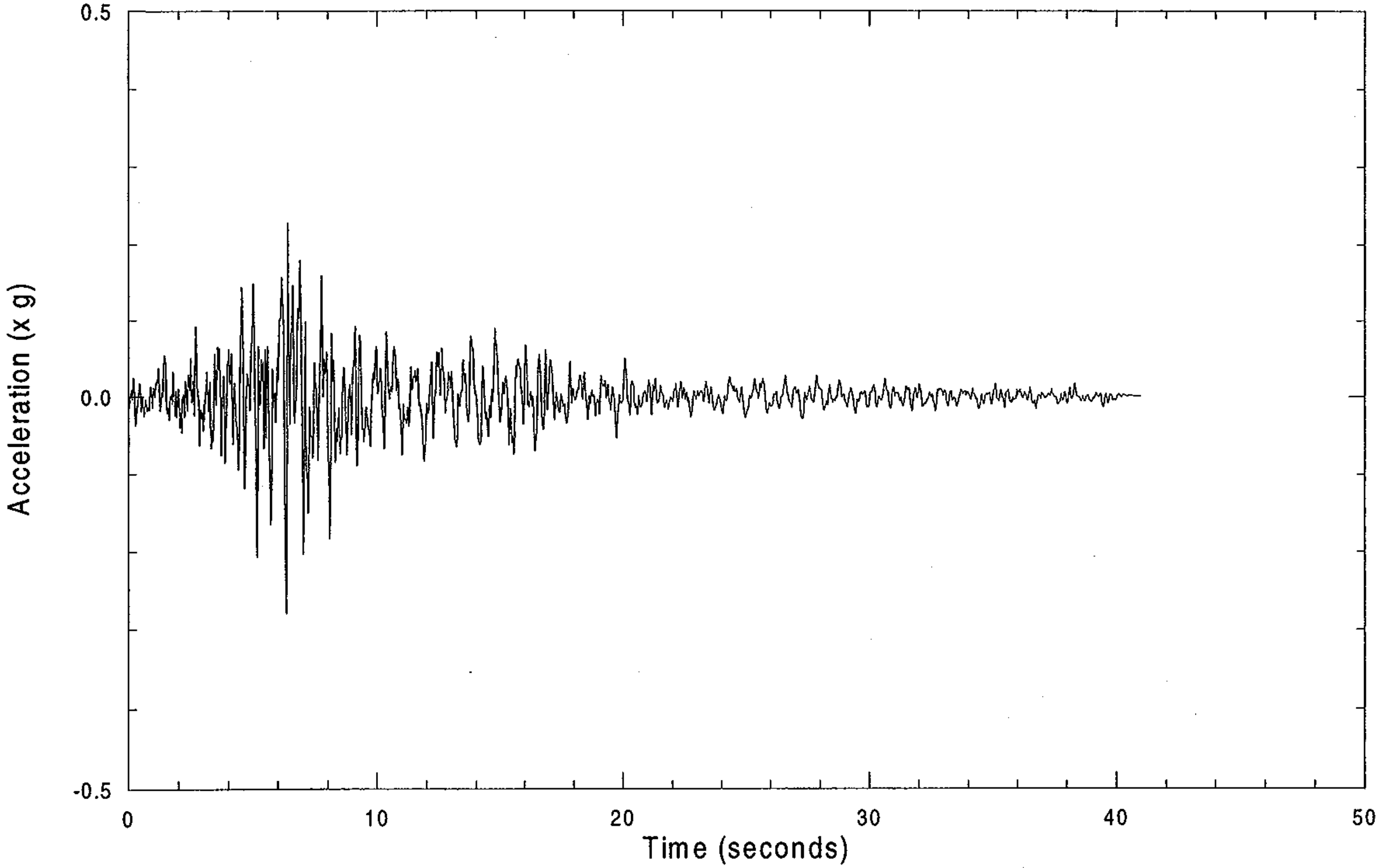
- Plotted only normal motions for these 2 time histories, showing acceleration, relative velocity, and relative displacement. (See attached grapher files - Figures E-9 and E-10)

*- Negligible displacements were observed using the existing time histories and the yield acceleration of 0.26g.



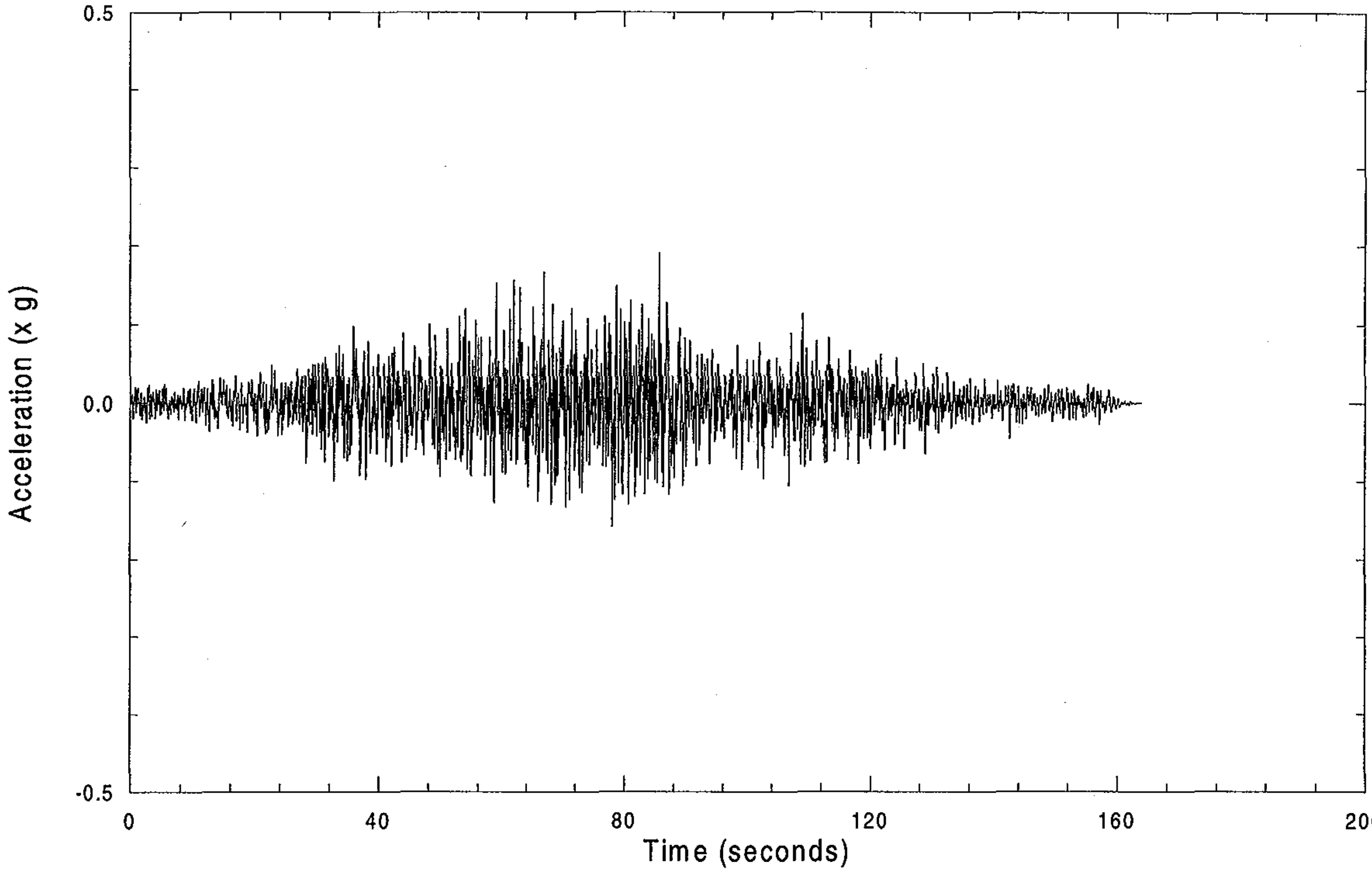
Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Acceleration Time History 10,000 year - Magnitude 7 Horizontal 1	Figure F-1
Woodward-Clyde			

10KM70H1.GRF with 10km70h1.xls / 10/22/98 / kaf



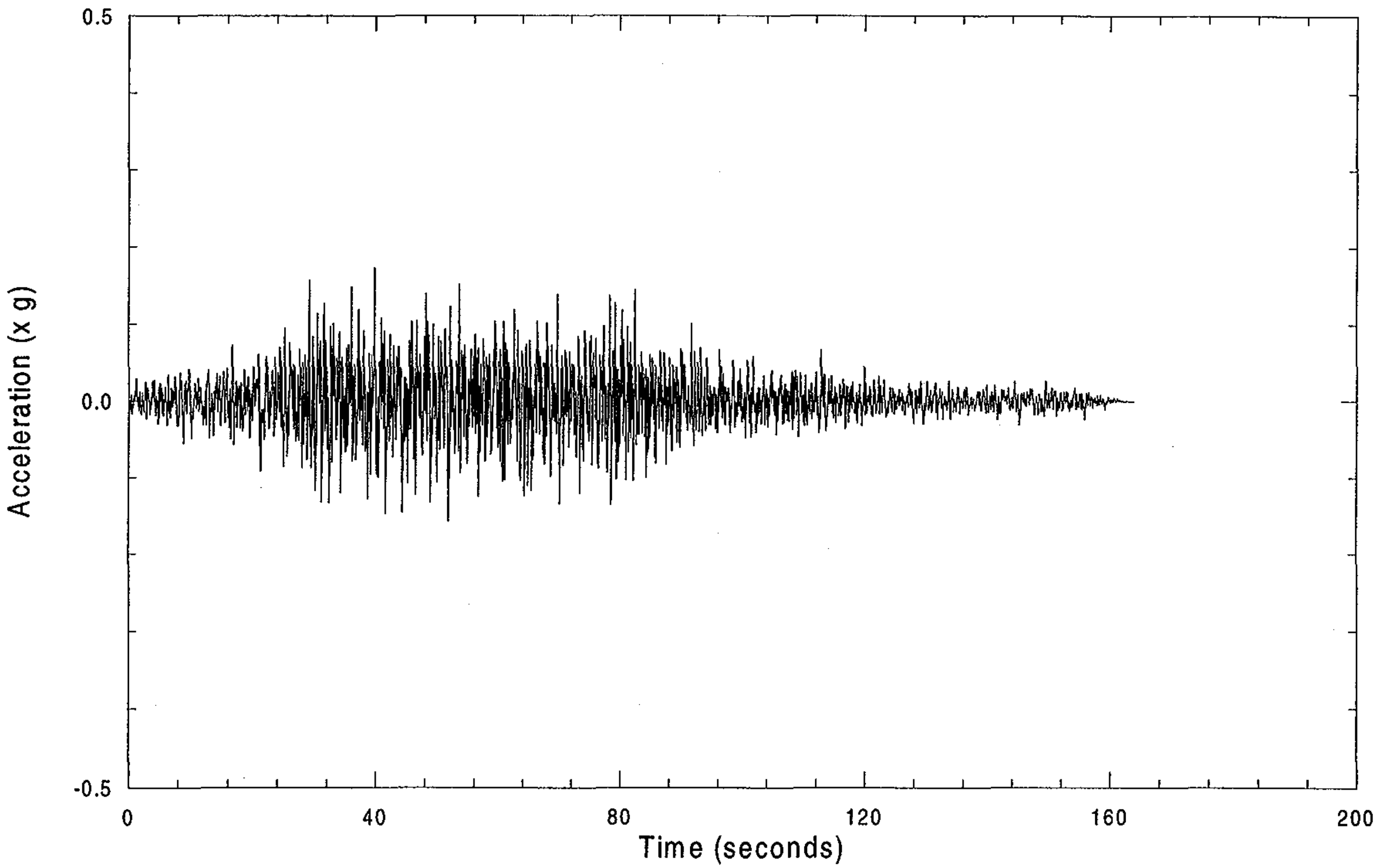
Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Acceleration Time History 10,000 year - Magnitude 7 Horizontal 2	Figure F-2
Woodward-Clyde			

10KM70H2.GRF with 10km70h2.xls / 10/22/98 / kaf



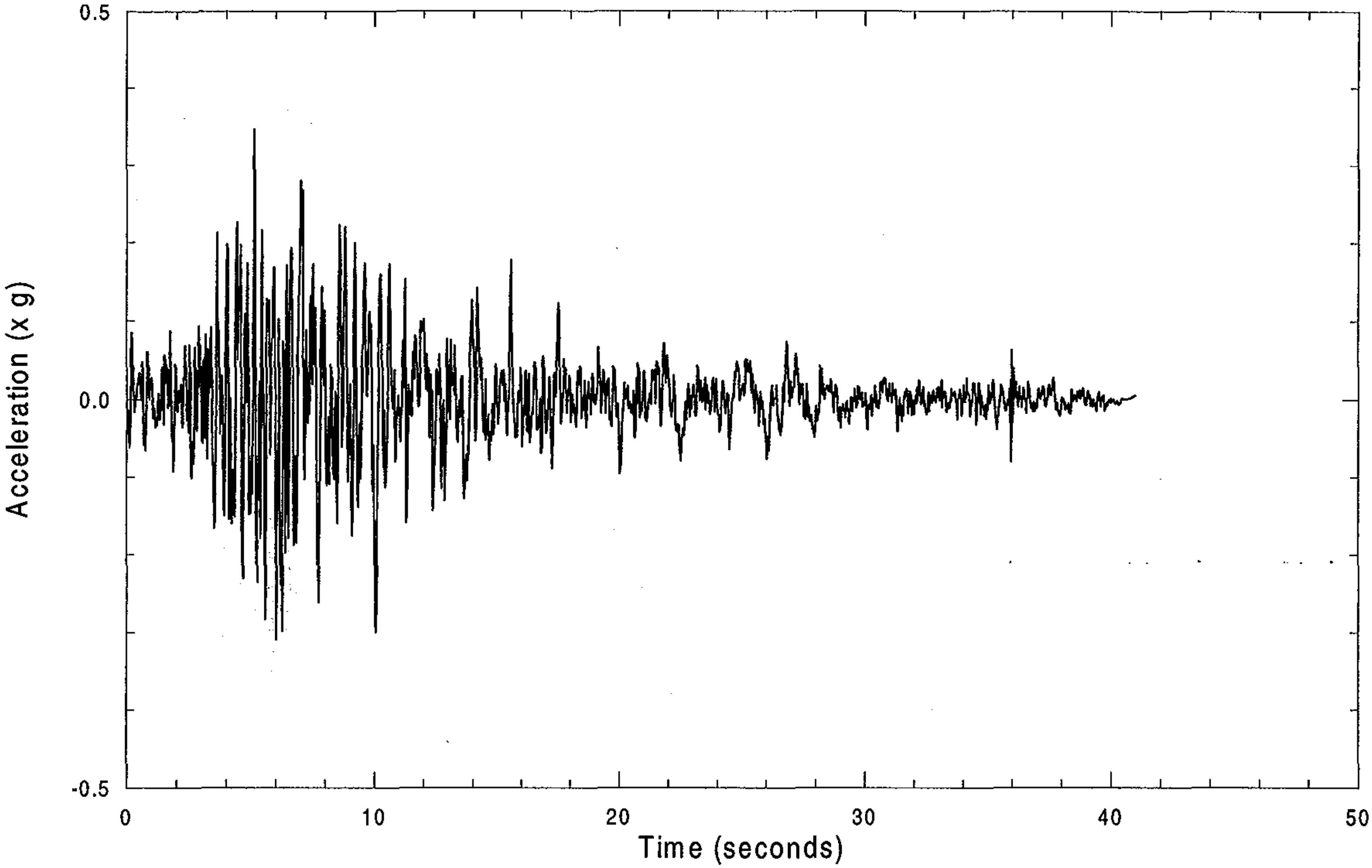
10KM90H1.GRF with 10km90h1.xls / 10/22/98 / kal

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Acceleration Time History 10,000 year - Magnitude 9 Horizontal 1	Figure F-3
Woodward-Clyde			



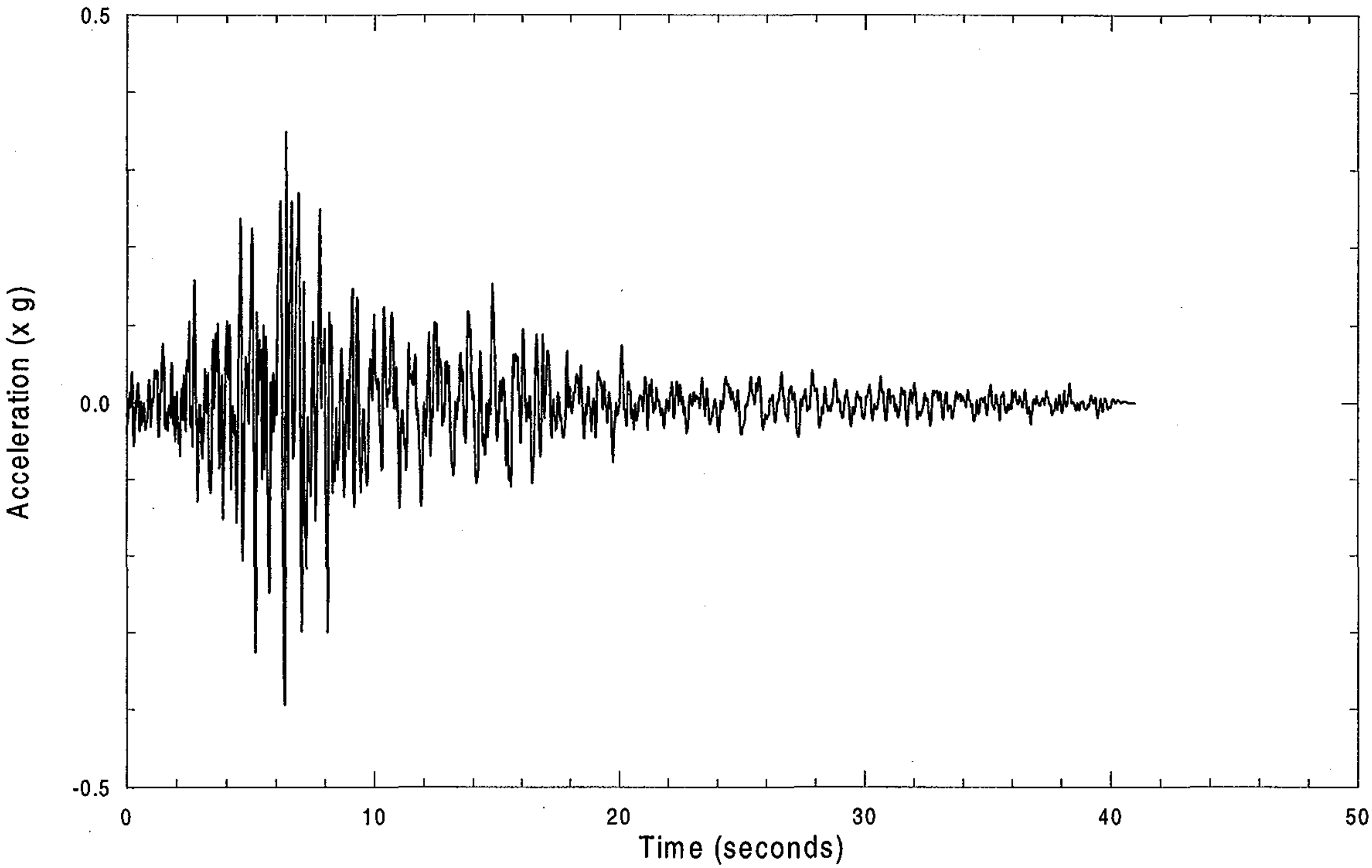
Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Acceleration Time History 10,000 year - Magnitude 9 Horizontal 2	Figure F-4
Woodward-Clyde			

10KM90H2.GRF with 10km90h2.xls / 10/22/98 / kal



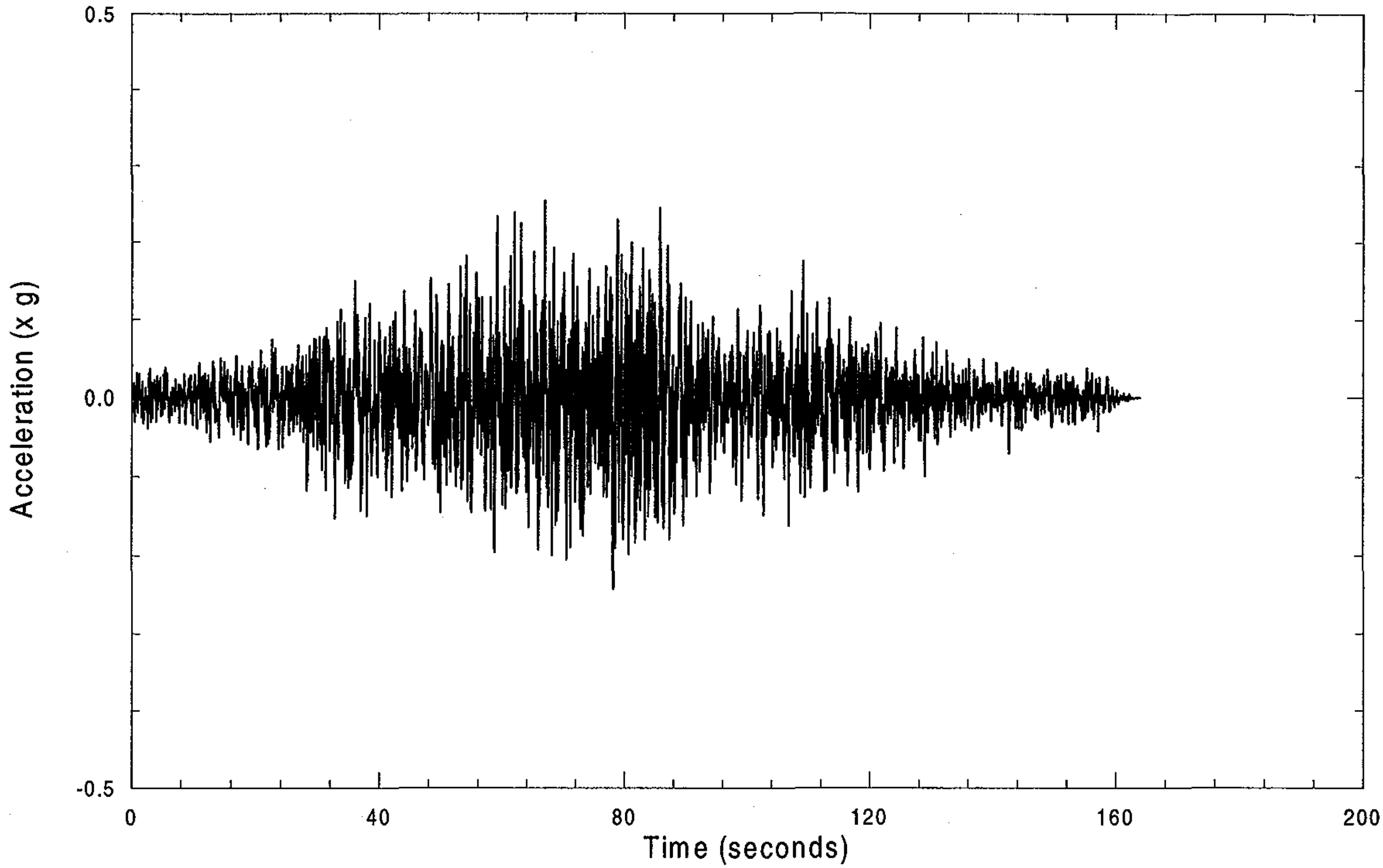
Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Acceleration Time History 50,000 year - Magnitude 7 Horizontal 1	Figure F-5
	Woodward-Clyde		

50KM70H1.GRF with 50km70h1.xls / 10/27/98 / kaf



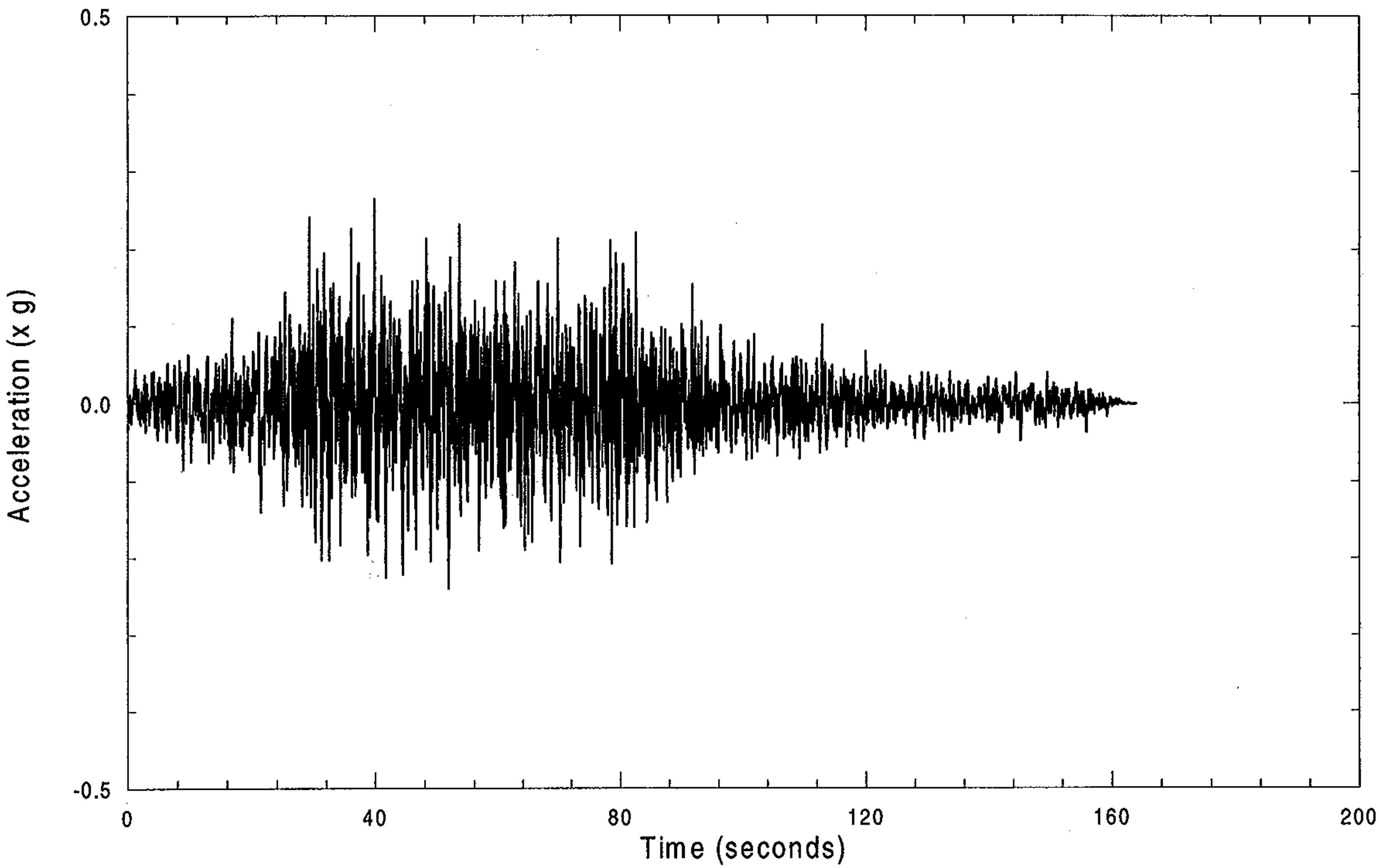
50KM70H2.GRF with 50km70h2.xls / 10/27/98 / kaf

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Acceleration Time History 50,000 year - Magnitude 7 Horizontal 2	Figure F-6
Woodward-Clyde			



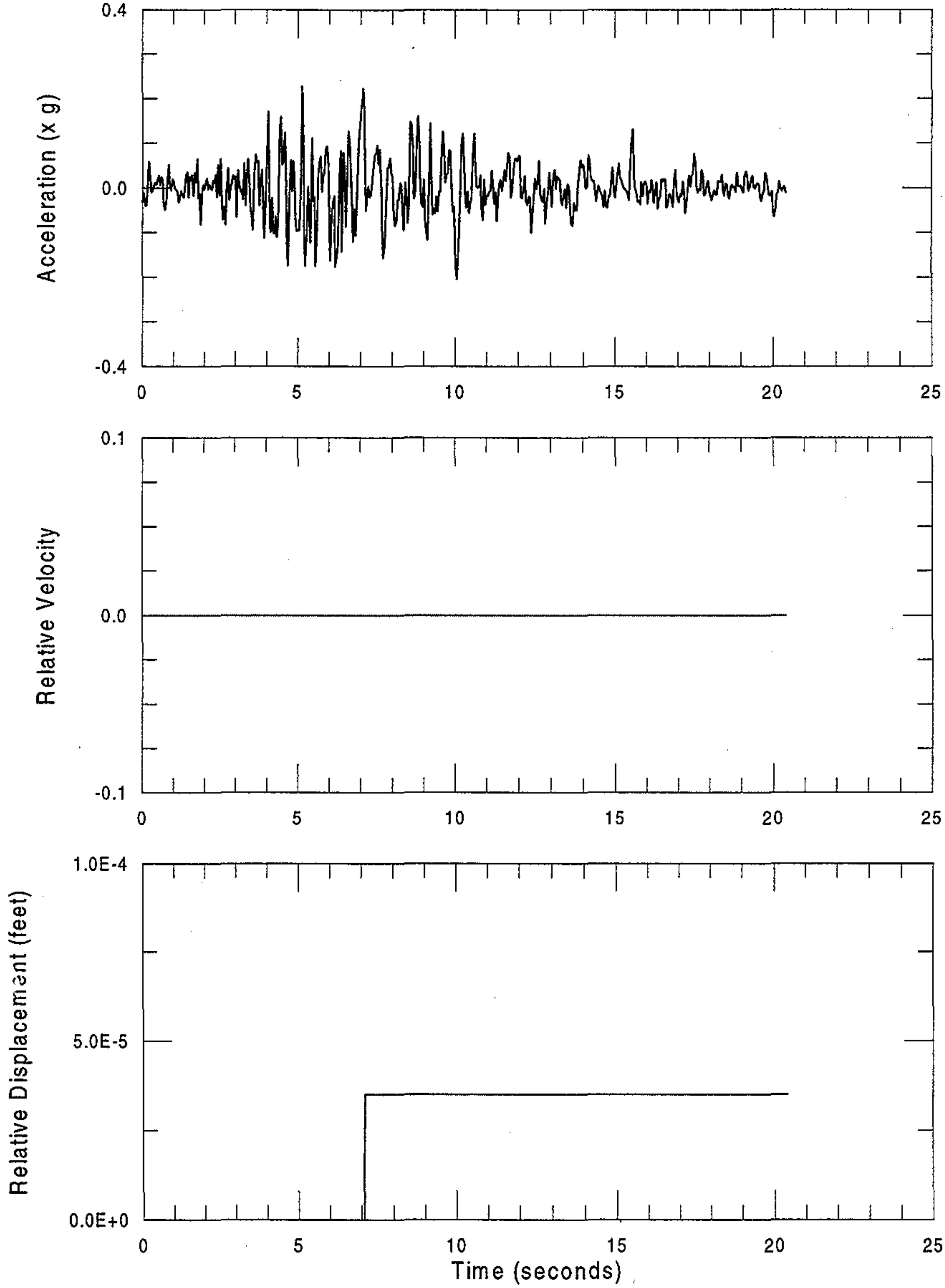
Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Acceleration Time History 50,000 year - Magnitude 9 Horizontal 1	Figure F-7
Woodward-Clyde			

50KM90H1.GRF with 50km90h1.xls / 10/27/98 / kaf



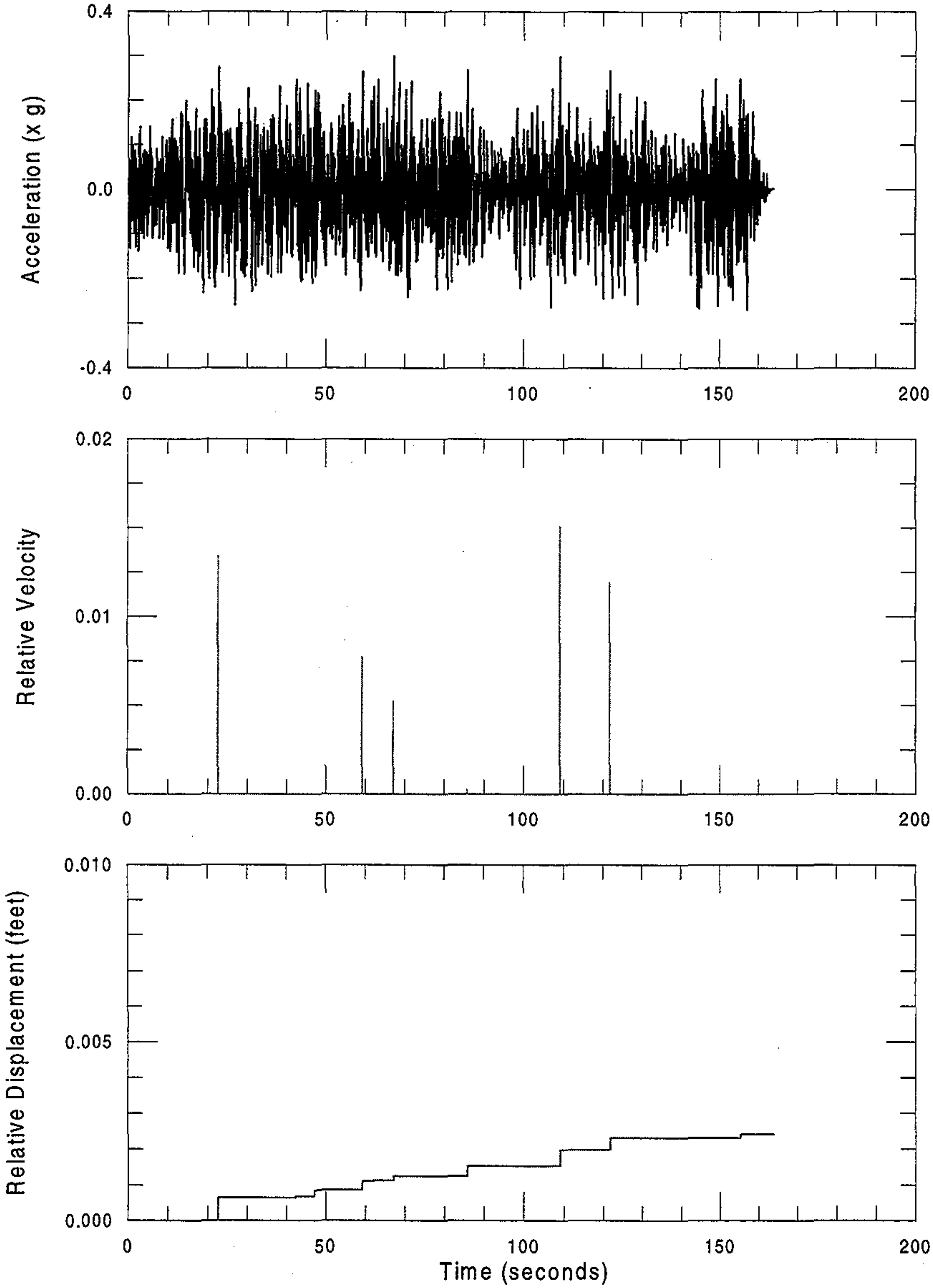
50KM90H2.GRF with 50km90h2.xls / 10/27/98 / kaf

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Acceleration Time History 50,000 year - Magnitude 9 Horizontal 2	Figure F-8
Woodward-Clyde			



10M7H1BN.GRF with 10k7h1bn.xls / 1/20/99 / KAF

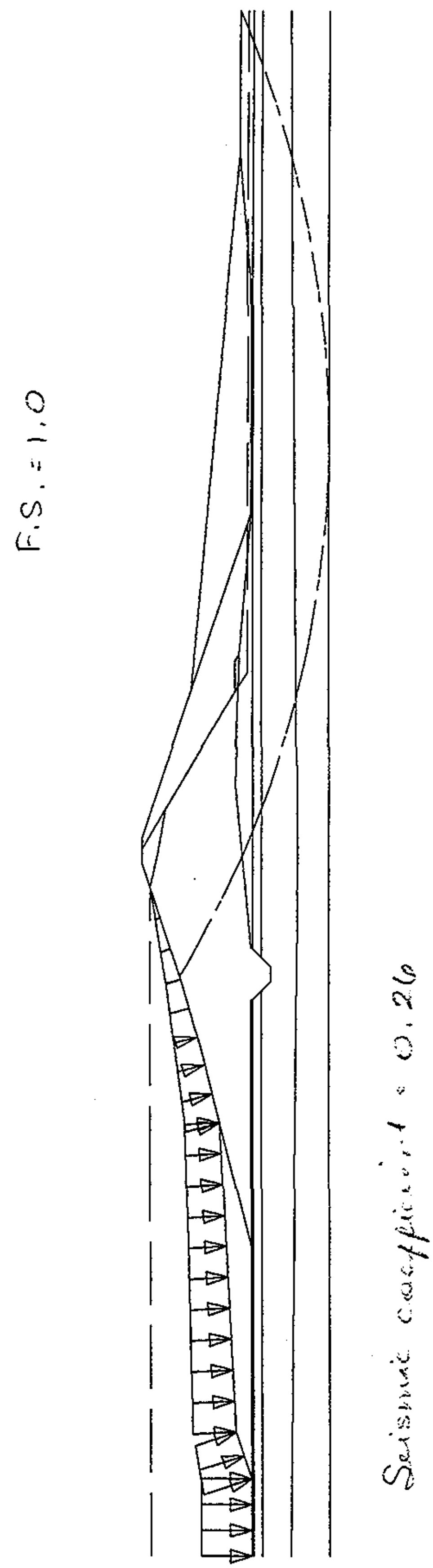
Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	NORMAL MOTION 10,000 YEAR - MAGNITUDE 7 HORIZONTAL 1	Figure F-9
Woodward-Clyde			



10K9H1N.GRF with 10k9h1an.xls, 10k9h1bn.xls, 10k9h1cn.xls, 10k9h1dn.xls, 10k9h1en.xls, 10k9h1fn.xls, 10k9h1gn.xls / 1/21/99 / KAF

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	NORMAL MOTION 10,000 YEAR - MAGNITUDE 9 HORIZONTAL 1	Figure F-10
Woodward-Clyde			

FIGURE F-11



```
HEADING==================================================
***** CLE ELUM DAM - Cle Elum, Washington -- Stability Analysis *****
WC Project No. D97287    Maximum Section
File: CE-1.IN By: KAF Date: 1/19/99
PROFILE LINES============================================
1 1 Impervious upstream blanket
        100     110
        160     130
        560     150

2 2 Compacted impervious fill
        400     110
        560     150
        660     175
        747.5   200
        897.5   250
        917.5   250

3 3 Compacted pervious fill
        917.5   250
        932.5   250
        1124.5  186

4 4 Uncompacted pervious berm
        1124.5  186
        1813.8  125

5 3 Compacted pervious fill
        1124.5  186
        1352.5  110

6 2 Compacted impervious fill
        917.5   250
        1121.5  130
        1161.5  130
        1170    125

7 5 Foundation (coarse)
        0       110
        400     110
        720     110
        722.1   107.9

8 6 Foundation (fine)
        0       107.9
        440     107.9
        722.1   107.9
        733.1   96.9

9 5 Foundation (coarse)
        0       96.9
        400     96.9
        733.1   96.9
        745     085
        765     085
        776.9   96.9

10 6 Foundation (fine)
        776.9   96.9
        787.9   107.9

11 5 Foundation (coarse)
        787.9   107.9
        790     110
        1000    130
        1170    125
        1352.5  110
        1650    110
        1813.8  125
        2000    125

12 6 Foundation (fine)
        787.9   107.9
        1200    107.9
        2000    107.9

13 5 Foundation (coarse)
        776.9   96.9
        1200    96.9
        2000    96.9

14 7 Foundation (fine)
        0       060
        900     050
        2000    060

15 8 Foundation
        0       10
        1000    10
        2000    10


MATERIAL=========================
1 Impervious upstream blanket
 115
Conventional Shear
 0 30
Piezometric Line
1
2 Compacted impervious fill
 137
Conventional Shear
 0 30
Piezometric Line
1
3 Compacted pervious fill
 120
Conventional Shear
 0 33
Piezometric Line
1
4 Uncompacted pervious berm
 115
Conventional Shear
 0 30
Piezometric Line
1
5 Foundation (coarse)
115
Conventional Shear
 0 31
Piezometric Line
1
6 Foundation (fine)
110
Conventional Shear
 0 30
Piezometric Line
1
7 Foundation (fine)
110
Conventional Shear
 0 30
Piezometric Line
1
8 Foundation
```

```
110
Conventional Shear
 0 30
Piezometric Line
1

SURFACE PRESSURES
        0       110     8112    0
        100     110     8112    0
        100     110     8112    0
        160     130     6864    0
        160     130     6864    0
        560     150     5616    0
        560     150     5616    0
        747.5   200     2496    0
        747.5   200     2496    0
        867.5   240     0       0

PIEZOMETRIC LINE DATA=============
 1 62.4
        0       240
        500     240
        867.5   240
        910     230
        968.5   220
        1121.5  130
        1147    115
        1500    115
        1650    115
        1813.8  115
        2000    115


ANALYSIS==========================
CIRCULAR SEARCH
        1400    400     10       10
TANGENT
        10
SEISMIC COEFFICIENT
0.26

PLOT==============================
COMPUTE===========================
```

Appendix G

APPENDIX G

Filter Compatibility Analyses

APPENDIX G

Filter Compatibility Analyses

Section G-1: Reclamation Filter Analyses

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY David Curran	DATE 4-1-92	PROJECT Yakima	SHEET 1 OF
CHKD BY	DATE	FEATURE Cle Elum Dam	
DETAILS			

ANALYSIS OF: PERVIOUS SHELL / IMPERVIOUS FILL AND PERVIOUS SHELL / FOUNDATION FILTER CABALITIES.

DISCUSSION: The pervious shell on the downstream side of Cle Elum Dam should be of a compatible composition so that it acts as an adequate filter for both the impervious fill and for the pervious foundation.

There is no drainage blanket or vertical drain incorporated into the design of the pervious shell, therefore the shell is assumed to be homogeneous. Also, the entire shell will therefore have the same filtering capabilities of the shell / fill and shell / foundation contact locations.

Requirements for Filter / fill analogy: Sources = "Design of Small Dams", "Design Stand 13, CH 5"

(1). $\frac{D_{15} \text{ of filter}}{D_{15} \text{ of base (fill)}} \geq 5$ provided the filter doesn't contain more than 5% fines

so From SOD Book: $\frac{D_{15}\text{ filter}}{D_{15}\text{ fill}} = \frac{1\text{ mm}}{0.02} = 50$ ✓

(2.) Also, filter does contain < 5% of fines ✓

(3.) $\frac{D_{15} \text{ of filter}}{D_{85} \text{ of fill}} \leq 5$

FILTER: $C_U = \frac{D_{60}}{D_{10}} = \frac{30\text{ mm}}{0.7\text{ mm}} = 43$

$C_c = \frac{(D_{30})^2}{(D_{10} \times D_{60})} = \frac{(5^2)}{(0.7)(60)} = 0.6$

FROM SOD Book: $\frac{D_{15}\text{ filter}}{D_{85}\text{ fill}} = \frac{1\text{ mm}}{7\text{ mm}} = 0.14$ ✓

a 35% is larger than 3" is 3"?

NOTE: 3" should be largest particle size to avoid segregation of filter ← NO

(4) filter should BE UNIFORMALLY GRADED = No; is well graded ← No
≠ ≤ 6 cm coarse from SOD

(5) FILTER k SHOULD BE 25 times greater than base k } is MET

IF D_{15} of filter > (5) D_{15} Fill

1m > (5)(0.02) Notes same as No 1 ✓

(6) Filters should have a maximum size particle of 3 inches. No
However, in this case the Fill is also somewhat coarse so?
... 20 % > 3" — ? > ?

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

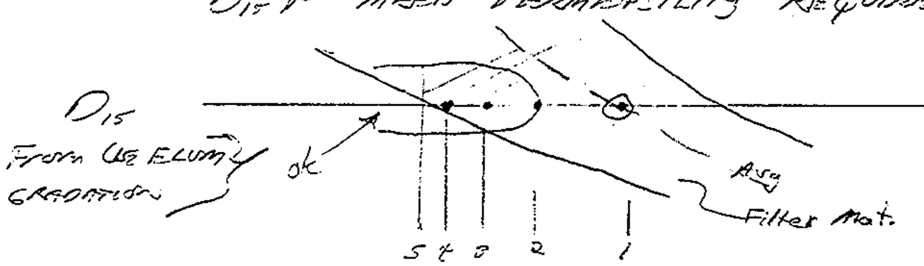
BY David Curran	DATE 4-1-92	PROJECT Yakima	SHEET 2 OF ___
CHKD BY	DATE	FEATURE Cle Elum Dam	
DETAILS			

(7) k is usually 1.5 to 8

to check $k = 0.35\,(D_{15}\ \text{Filter})^2$ ← Note: for moderate to uniformly graded sand and gravel filters. This filter is actually sand or gravel w/ % of cobbles.

so: $k = 0.35\,(1\,mm)^2 = 0.35$ ← close

IN THIS CASE ABOUT 30 % of the band width @ $D_{15}F$ MEET PERMEABILITY REQUIREMENTS. SEE below



IF USE 4mm, then ok
IF USE 3mm then ok
IF USE ≤ 2mm then No

Determination of Filter / Fill gradation limits = "Design St. 13, ch 5"

(8) pg 5.8 C.) 1.) CORRECTION FACTOR = $\dfrac{100}{\%\ \text{passing No.4 sieve Fill}}$

$= \dfrac{100}{82\ \%} = 1.22$

2.) Mult. % passing each sieve size < No.4 Fill by correction factor

No.6 : (80)(1.22) = 98
No.8 : (78)(1.22) = 95
No.10 : (75)(1.22) = 92
No.14 : (73)(1.22) = 89
No.16 : (71)(1.22) = 87
No.20 : (67)(1.22) = 82
No.30 : (62)(1.22) = 76
No.40 : (57)(1.22) = 70
No.50 : (50)(1.22) = 61
No.70 : (43)(1.22) = 52
No.100 : (38)(1.22) = 46
No.140 : (32)(1.22) = 39
No.200 : (28)(1.22) = 34
0.05mm : (23)(1.22) = 28
0.03mm : (18)(1.22) = 22
0.02mm : (14)(1.22) = 17
0.01mm : (8)(1.22) = 10
0.005mm : (3)(1.22) = 4

} see enclosure 1 for new plot

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY David Curron	DATE 4-1-92	PROJECT Yakima	SHEET 3 OF
CHKD BY	DATE	FEATURE Cle Elum Dam	
DETAILS			

D.) 1st - place Fill soil in a category

= CATEGORY 3 because 34% is < No. 200 and 34 is between 15 - 39

E) Determine max. D_{15} Filter in accordance w/ table 2
Note 3 max D_{15} filter does not have to be < 0.20 mm

so since category 3; Filter criteria is as follows:

$$D_{15} \text{ filter} \le 0.7mm + \frac{(40-A)(4 \times D_{85} \text{ Fill} - 0.7mm)}{25}$$

WHERE: A = % passing No. 200 after regrading (Fill ?)
A = 34 (from above)

and: When $4 \times D_{85}$ Fill < 0.7m, use 0.7 mm
(4)(7mm) is not < 0.7m so use calc. value

1" used smallest D_{85}

so: $D_{15} \text{ Filter} \le 0.7mm + \frac{(40-34)(4 \times 7mm - 0.7mm)}{25}$

= 75 avg.

$D_{15} \text{ filter} \le 0.7mm + \frac{(6)(27.3)}{25}$

$\frac{(6)(4 \times 1 - 0.7)}{25}$ = 0.79 ≈ 0.7

$D_{15_{max.}}$ filter = 4 mm ≤ 7.3 ✓ for avg D_{85} band

4 ≤ 1.49? NO

And D_{15} filter is = 1mm in a range from a min. = 0.5 mm and a max. of 4 mm, the whole band being below 7.3 mm, so is Ok

F.) to ensure sufficient permeability, set minimum D_{15} filter ≥ (5) D_{15} Fill, but no less than 0.1 ; min D_{15} = 0.5

just makes it

so: (5)(0.02) = 0.1 < 0.5 ✓

MEETS BOTH REQUIREMENTS OF > 0.1 and ≥ (5) D_{15} Fill

G.) Set maximum particle size = 3 inches — No ?
Maximum particle size ≈ 7+ inches
and ≈ 20% of material > 3 inches
– however this material has to filter fill material that is as large as 24 inches (however a small %)

Maximum size passing #200 is < 5% ✓

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY David Curran	DATE 4-7-92	PROJECT Yakima	SHEET 4 OF
CHKD BY	DATE	FEATURE Cle Elum Dam	
DETAILS			

NO!

8.) Coarser Filters / gravel zones that serve both as filters and drains, the ratio D_{90} filter / D_{10} filter should decrease rapidly with increasing D_{10} filter size. See Table 3. in guidelines.

so: D_{90} filter / D_{10} filter = 100 mm / 0.7 = 143 ?

have min D_{10} fil = 0.2 mm max D_{90} fil = 200 mm

Table 3 says since have < 0.5 mm D_{10} fil, then max D_{90} should only be 20 mm

even if use average band width:

have avg. D_{10} fil = 0.7 mm, then need ≤ 25 mm D_{90} filter

Note: The above criteria is necessary to prevent segregation. Because the filter band has such a wide range of grain sizes, segregation is imminent.

(9.) To protect fine grained soils, need staged filters.

- Not sure if applicable here. If applicable (probably is) then dont have or NO

(10.) Gap graded & unstable, broadly graded fill material from gravel to clay such as glacial tills (somewhat the case here) that are internally unstable (however, the core here should be stable). Filter should be designed to protect the fine matrix of impervious fill rather than the total range of particle sizes. FILTER DOES PROTECT The fine Matrix pretty well ✓

Summary: The pervious fill meets some filter requirements for the impervious fill, but not all requirements.
- It meets permeability requirements
- It is well graded, however is also gap-graded and therefore is a possibility segregation could have occured. It has a high percentage of coarse material; much > required max. 3" size.
- It has filtering capabilities for drainage, however is questionable whether it will prevent piping of fines from the impervious fill
- It really should have a secondary or staged filter to protect the fines which it does not have.

10/22/92 - Also the D_{15} filter is a little too large to filter out the adjusted D_{85} fill material, so could get some movement of fines. But overall, considering if an avg or smaller D_{85} fill is used, then filter ok.
= A concern but not FATAL dam safety problem.

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY	DATE	PROJECT	SHEET 5 OF
D. Curran	10-20-92		
CHKD BY	**DATE**	**FEATURE**	
		Cle Elum Dam	
DETAILS			

FROM "INTRO. TO GEOTECHNICAL ENGINEERING" HOLTZ & KOVACS, 1981

Gradation requirements for protective filters are given in Table 7-4. The first ratio, R_{15}, ensures that the small particles of the material to be protected are prevented from passing through the pores of the filter; the second ratio, R_{50}, ensures that seepage forces within the filter are reasonably small. If the criteria in this table cannot be met by one layer of filter material, then a zoned or multilayered filter can be designed and specified.

Some additional practical requirements for the design of filters are also shown in Table 7-4.

TABLE 7-4 Gradation Requirements for Filter Materials*

Filter Material Characterisitics	R_{15}	R_{50}
Uniform grain size filters, C_u = 3 to 4	—	5 to 10
Graded filters, subrounded particles	12 to 40	12 to 58
Graded filters, angular particles	6 to 18	9 to 30

$$R_{15} = \frac{D_{15} \text{ of filter material}}{D_{15} \text{ of material to be protected}}$$

$$R_{50} = \frac{D_{50} \text{ of filter material}}{D_{50} \text{ of material to be protected}}$$

Notes: Maximum size of the filter material should be less than 76 mm (3 in.). Use the minus No. 4 fraction of the base material for setting filter limits when the gravel content (plus No. 4) is more than 10%, and the fines (minus No. 200) are more than 10%. Filters must not have more than 5% minus No. 200 particles to prevent excessive movement of fines in the filter and into drainage pipes. The grain size distribution curves of the filter and the base material should approximately parallel in the range of finer sizes.

*After U.S.B.R. (1974).

JO8 FOR CLE ELUM CORE / SEMIPERVIOUS ZONES

$$R_{15} = \frac{D_{15} \text{ filter}}{D_{15} \text{ fill}} = \frac{1 \text{ mm}}{0.02} = 50 > \text{recommended}$$

$$R_{50} = \frac{D_{50} \text{ filter}}{D_{50} \text{ fill}} = \frac{20 \text{ mm}}{0.2 \text{ mm}} = 100 > \text{recommended}$$

JG8 The above criteria is not satisfied and therefore a secondary filter would have been preferred. The semipervious zone also serves a dual purpose besides just filtering / draining seepage and that is for stability. Even though a filter zone would have been prefered, it is not expected that a problem exist because of the long gradient provided by the rather large semipervious zone. If core materials are carried into the semipervious zone, it is ?{ doubtful that any significant embankment subsidence would stem from it. Also, most all of the hydraulic head would be lost when any seepage reaches the semipervious zone.

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY Curran	DATE 10-20-92	PROJECT	SHEET 6 OF
CHKD BY	DATE	FEATURE Cle Elum Dam	
DETAILS			

See sheet 4, H)

H. Design the filter limits within the maximum and minimum values determined in steps E, F, and G. Standard gradations may be used if desired. Plot the limit values and connect all the minimum and maximum points with straight lines. To minimize segregation and related effects, filters should have relatively uniform grain-size distribution curves, without "gap grading" - sharp breaks in curvature indicating absence of certain particle sizes. This may require setting limits that reduce the broadness of filters within the maximum and minimum values determined. Sand filters with $D_{90}F$ less than about 20 millimeters generally do not need limitations on filter broadness to prevent segregation. For coarser filters and gravel zones that serve both as filters and drains, the ratio $D_{90}F/D_{10}F$ should decrease rapidly with increasing $D_{10}F$ size. The limits in table 3 are suggested for preventing segregation during construction of these coarser filters.

Table 3. - $D_{10}F$ and $D_{90}F$ limits for preventing segregation

Minimum $D_{10}F$ (mm)	Maximum $D_{90}F$ (mm)
<0.5	20
0.5 - 1.0	25
1.0 - 2.0	30
2.0 - 5.0	40
5.0 - 10	50
10 - 50	60

Not met (bracketed: 20 – 50)

As far as the semipervious zone acting as a "Filter", the criteria is not met. There is an area on the gradation curve that indicates some "gap-grading" somewhere in the 45% finer range.

The 3 factors that hurt the semipervious zone's filter capabilities are the >3" size particles, the fact that the filter is (so too?) well graded and segregation is likely, and because there is some "gap-grading"

<u>However</u>, when looking @ this zone as a drainage and stabilizing zone, the semipervious zone is satisfactory.

7-1654 (1-89)
Bureau of Reclamation

COMPUTATION SHEET

BY D. Curran	DATE 10-16-92	PROJECT Yakima	SHEET 7 OF
CHKD BY	DATE	FEATURE Cle Elum Dam	
DETAILS			

Analysis Cont.: Check for the filtering capabilities against piping of the embankment materials through the foundation and into the semipervious shell, ie. the foundation/semi-pervious transition zone.

Using Gradation Curves from drill hole log data on drwg. 33-D-3998

– Going through the same checks starting on sheet 1

(1) $\frac{D_{15}\text{ filter}}{D_{15}\text{ found.}} \geq 5$ = yes for all curves ✓

(2) filter fines < 5% = yes ✓

(3) $\frac{D_{15}\text{ filter}}{D_{85}\text{ found.}} \leq 5$ = yes for all curves ✓

(4) filter uniformally graded = <u>No</u>, it is well graded

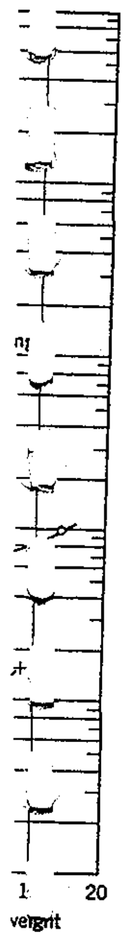
(5) Permeability: $D_{15}\text{ filter} > (5) D_{15}\text{ fill}$
$1 > (5)(0.3)$ = NO for 101' band (probably too deep) ✓
$1 > (5)(0.15)$ = yes ok for 55' depth ✓ and shallower

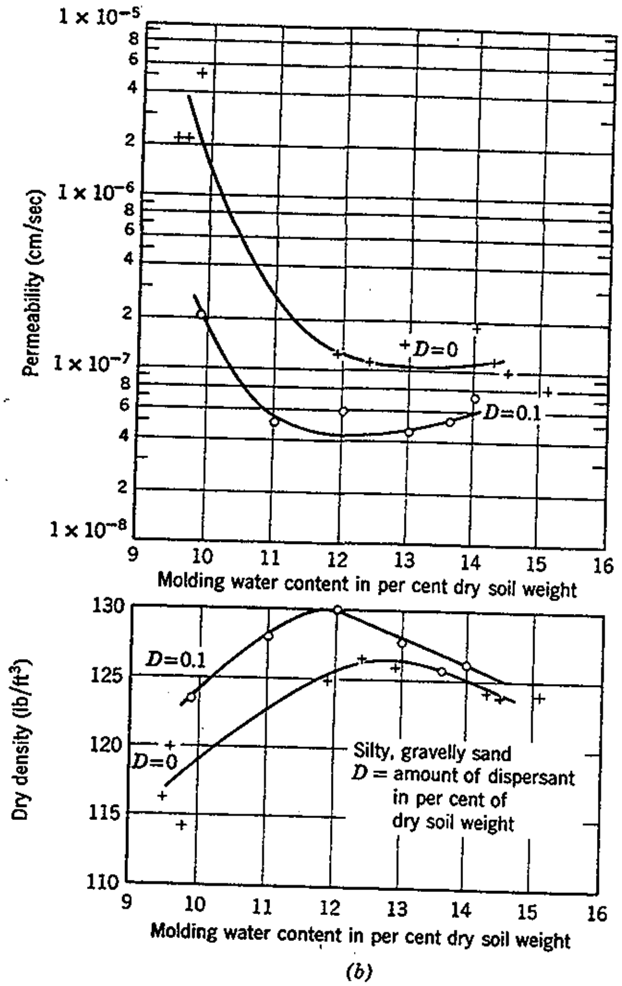
(6) Filter should be max of 3" ⇒ <u>NOT MET</u>

Summary:

The gradation curves for the foundation material is fairly representative of the core, with the exception of some larger cobbles; boulders mixed into the foundation.

Filter capabilities of the semipervious zone to filter against piping from the foundation is very similar to the results shown on sheets 1 → 7. Segregation and "large" filter materials is the main problem, although it is not anticipated that seepage or piping will ever be a problem w/ the long hydraulic gradient path. The semipervious zone will help with filtering as well as with lengthening the seepage path and dissipating pore water pressures.





rı_ability. (*a*) Effect of mixing on permeability. Jamaica clay. /. (From Lambe, 1955.)

cı_abric." nportance. a; : of silt ea lity for es for flow fact was

important degree of u. 19.12, at the would be / channels ts n Fig. degree of ıent of a oe use of

nfluencing u icating

field conditions when determining field permeability in the laboratory.

19.4 FILTER REQUIREMENTS

There are certain situations in earth structures that require filters. First, water cannot be permitted to exit on the slope of a dam, as was discussed in Chapter 18. Second, the movement of particles from one soil to another or from a soil into a drainage structure by flowing water cannot be permitted. If this were permitted, the resulting soil erosion could cause serious stability difficulties with the earth structure. Soil erosion is prevented by soil layers, called filters.

The design of a proper filter consists of choosing the dimensions of the filter and of choosing a material for the filter such that:

1. Sufficient head is lost in flow through the filters.
2. No significant invasion of soil is permitted into the filter.

The selection of a filter to meet the first requirer depends on both the type of soil and the flow patter the earth structure under consideration. Figure 1 presents a useful plot for the design of a filter for out of a slope. For a given slope and permeability ir structure, Fig. 19.13 enables one to select combinat of filter thickness and permeability. This figure developed from flow nets, as illustrated by the two shown.

The requirements of a filter to keep soil particles invading the filter significantly are based on particle These requirements were developed from tests Terzaghi which were later extended by the Corp Engineers at Vicksburg. The resulting filter speci tions relate the grading of the protective filter to th the soil being protected by the following:

$$\frac{D_{15}\,\text{Filter}}{D_{85}\,\text{Soil}} < 5 \quad (1$$

$$4 < \frac{D_{15}\,\text{Filter}}{D_{15}\,\text{Soil}} < 20 \quad (1$$

$$\frac{D_{50}\,\text{Filter}}{D_{50}\,\text{Soil}} < 25 \quad (1$$

where D_{15}, D_{50}, and D_{85} are the particle sizes frc particle size distribution plot at 15, 50, and {

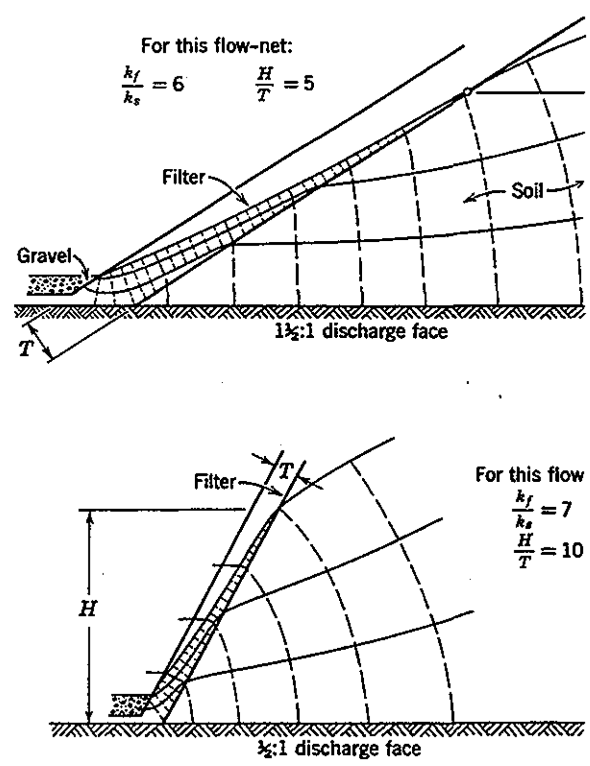
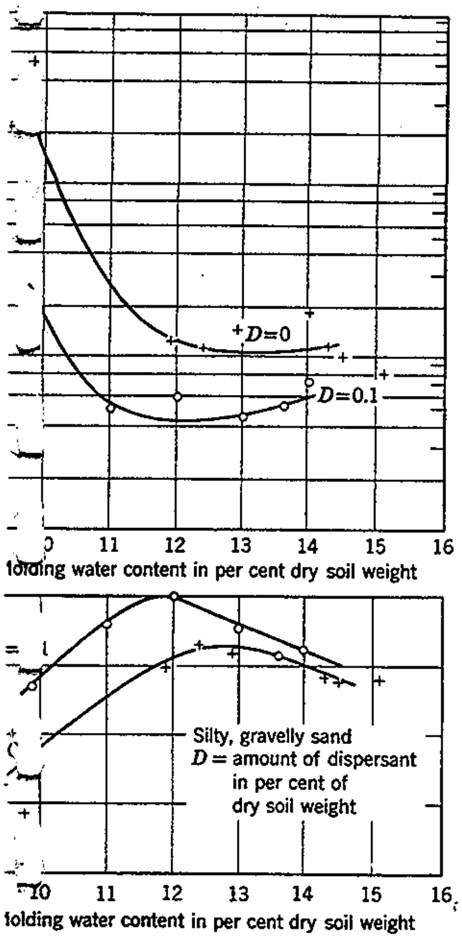


Fig. 19.13 Filte



(b)

nixing on permeability. Jamaica clay.

ditions when determining field permeability in a ry.

LTER REQUIREMENTS

a certain situations in earth structures that l s. First, water cannot be permitted to exit ope of a dam, as was discussed in Chapter 18. th movement of particles from one soil to o from a soil into a drainage structure by vater cannot be permitted. If this were per- he resulting soil erosion could cause serious ficulties with the earth structure. Soil s evented by soil layers, called filters.

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s ificant invasion of soil is permitted into the
r

The selection of a filter to meet the first requirement depends on both the type of soil and the flow pattern in the earth structure under consideration. Figure 19.13 presents a useful plot for the design of a filter for flow out of a slope. For a given slope and permeability in the structure, Fig. 19.13 enables one to select combinations of filter thickness and permeability. This figure was developed from flow nets, as illustrated by the two nets shown.

The requirements of a filter to keep soil particles from invading the filter significantly are based on particle size. These requirements were developed from tests by Terzaghi which were later extended by the Corps of Engineers at Vicksburg. The resulting filter specifications relate the grading of the protective filter to that of the soil being protected by the following:

$$\frac{D_{15}\,\text{Filter}}{D_{85}\,\text{Soil}} < 5 \qquad (19.10)$$

$$4 < \frac{D_{15}\,\text{Filter}}{D_{15}\,\text{Soil}} < 20 \qquad (19.11)$$

$$\frac{D_{50}\,\text{Filter}}{D_{50}\,\text{Soil}} < 25 \qquad (19.12)$$

where D_{15}, D_{50}, and D_{85} are the particle sizes from a particle size distribution plot at 15, 50, and 85%,

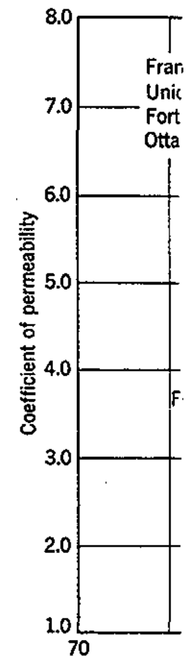
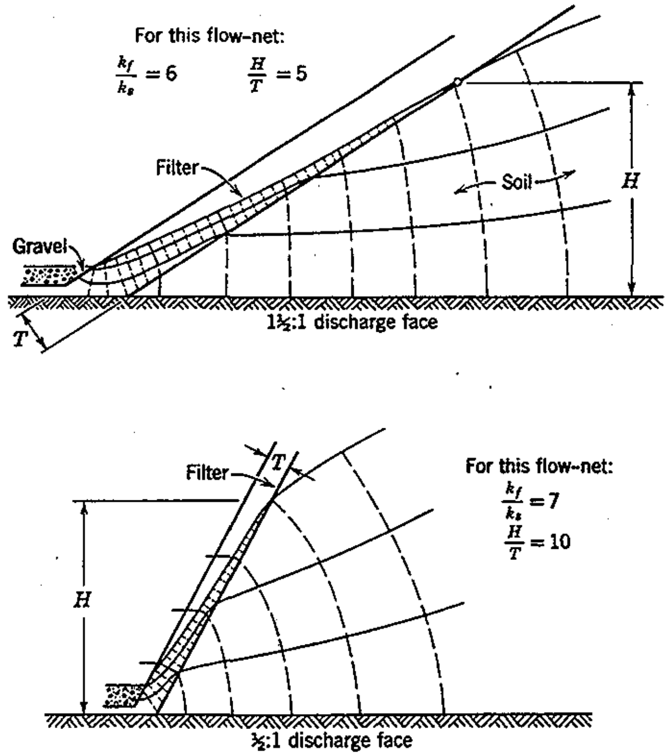
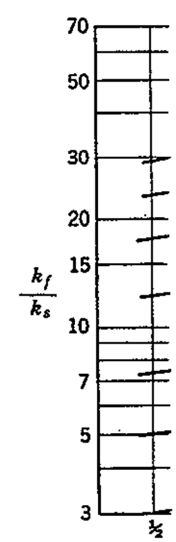


Fig. 19.12 Pe
various sands (





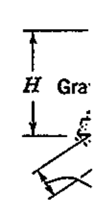
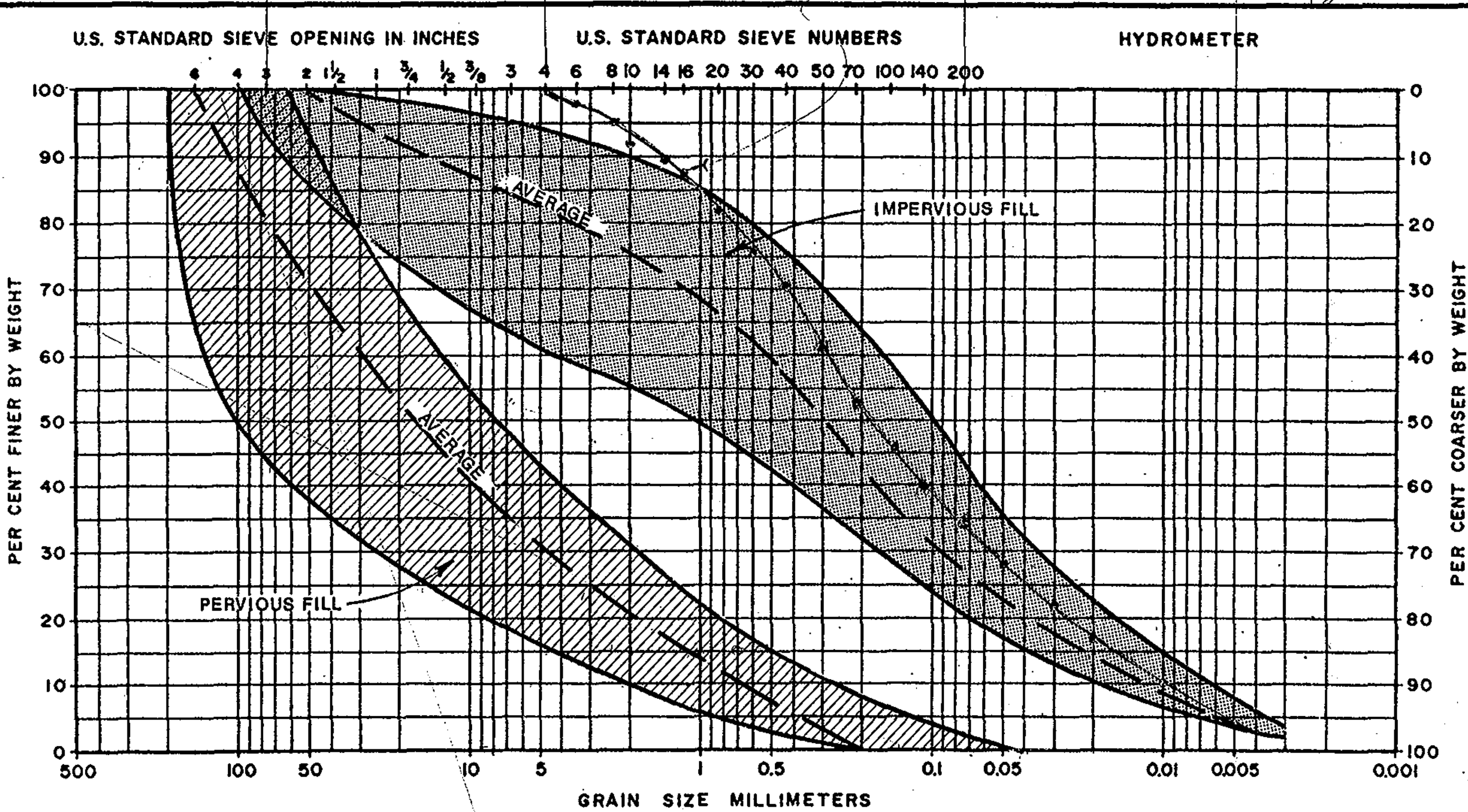


Fig. 19.13 Filter design (From Cedergren,



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

FROM:
Analysis of materials for Cle Elum Dam, 1933
USBR

U.S. Bureau of Reclamation DENVER, COLORADO	CLE ELUM DAM Yakima Project Washington	CLE ELUM DAM EMBANKMENT FILL
GEOTECHNICAL ENGINEERS INC. ENGLEWOOD • COLORADO	PROJECT No. 86229	FEB. 1987

respectively, finer by weight. The expressions not only limit particle movement from the soil into the filter to a small zone at the interface between the soil and filter but also ensure that the permeability of the filter is considerably greater than that of the soil. A better method of selecting filter permeability is to use the pattern of flow for the actual problem at hand, such as Fig. 19.13 for a slope.

19.5 SUMMARY OF MAIN POINTS

1. Permeability is the soil property that indicates the relative ease with which a fluid will flow through the soil.
2. The range of permeability is extremely large, going from 1 cm/sec for gravel to below 10^{-8} cm/sec for clay.
3. Permeability depends on the characteristics of both the permeant and the soil. Viscosity, unit weight, and polarity are the major permeant characteristics. Particle size, void ratio, composition, fabric, and degree of saturation are the major soil characteristics.
4. Filters are essential features of most water retenti structures of soil. They serve to give the desir flow pattern and to prevent internal erosion.

PROBLEMS

19.1 Derive Eq. 19.1.

19.2 Estimate the permeability for the soil whose partic size distribution curve is given in Fig. 3.3.

19.3 Estimate the "percent passing a 200 sieve" for ea soil *A* and soil *B* in Example 18.5.

19.4 On the basis of the permeability data given for tl zones in the dam in Problem 18.7, identify the type of soil each zone.

19.5 Water is to flow from the soil whose particle si distribution is given in Fig. 3.3 into a gravel drain. The grav consists of uniform particles 2 in. in diameter. On a plot c "Percent Finer" versus "Particle Diameter (mm)" plot th curve in Fig. 3.3 and that for a filter material meeting th requirements stated by Eqs. 19.10, 19.11, and 19.12.

19.6 A soil ($k = 10^{-1}$ cm/sec) is to be used as a filter for soil ($k = 5 \times 10^{-3}$ cm/sec) which exists in an embankmen with a discharge face of 1 vertical to 2 horizontal. The flov breaks out of the embankment at a height of 25 ft. Select th thickness for the filter on the basis of Fig. 19.13.

Filter Compatibility Analyses

Section G-2: URSGWCFS
Filter Analyses

Subject CLE ELUM DAM FILTER COMPATIBILITY
Project No. 68-F0D97287.00
By JWR
Checked By KAF
Task No. 00600
File No.
Date 01/25/00
Date 2/2/00
Sheet 1 OF 7

EVALUATE PERVIOUS ZONE WITH RESPECT TO IMPERVIOUS ZONE FOR NO EROSION AND CONTINUOUS EROSION BOUNDARIES USING THE METHOD GIVEN IN:

"Filter Testing for Dams – No Erosion and Continuing Erosion Boundaries," Foster, M. and Fell, R., 1999, Proceedings 8th Australia New Zealand Conference on Geomechanics, Vitharna and Colman (Eds), Hobart, Vol 2, pp. 503-511.

A. Foster and Fell suggest:

① Filter criteria recommended by Sherard and Dunnigan, 1989, as adopted by USBR and others, are based on no erosion conditions. They are prudently conservative for design of new filters.

② For evaluating existing dams, particularly in a risk analysis, it may be appropriate to also consider continuous erosion boundaries – D_{15} above which erosion is essentially continuous.

B. NO EROSION BOUNDARIES, ACCORDING TO FOSTER AND FELL

For average impervious fill:

% FINES = 34%, TYPE 4, $D_{85B} = 1.1mm$

$(D_{15})_{NE} = 1.6\, D_{F15d}$, $D_{F15d} = \left[\frac{35 - \%\,fines}{20}(4\,D_{B85} - 0.7)\right] + 0.7$ ✓

(see Table 1, Foster and Fell)

$(D_{15})_{NE} = 1.42mm$ (Note: was 1.59 from USBR) ✓

→ From Foster and Fell

Table 1. Summary results of statistical analysis of the no erosion boundary of filter tests.

Base Soil Group	Fines content *(1)*	Design Criteria of Sherard and Dunnigan (1989)	Range of DF15 for No Erosion Boundary	Proposed Criteria for No Erosion Boundary
1	≥ 85%	DF15 ≤ 9 DB85	6.4 - 13.5 DB85	DF15 ≤ 9 DB85
2	35 - 85%	DF15 ≤ 0.7mm	0.7 - 1.7mm	DF15 ≤ 0.7mm
3	< 15%	DF15 ≤ 4 DB85	6.8 - 10 DB85	DF15 ≤ 7 DB85
4	15 - 35%	DF15 ≤ (40-pp%75μm) x (4DB85-0.7)/25 + 0.7	1.6 - 2.5 DF15 of Sherard and Dunnigan design criteria	DF15 ≤ 1.6 DF15d, where DF15d = (35-pp%75μm)(4DB85-0.7)/20+0.7

Notes: (1) The subdivision for soil group 2 and 4 was modified from 40% passing 75μm, as recommended by Sherard and Dunnigan (1989), to 35% based on the analysis of the filter test data.

For finest impervious fill:

% fines = 48%, Type 2, D_{85B} = 0.6mm

$(D_{15})_{NE}$ = 0.7 mm

(see Table 1, Foster and Fell)

C. CONTINUING EROSION BOUNDARIES, ACCORDING TO FOSTER AND FELL

For average impervious fill:

Corrected gradation (corrected to max. size of 4.75mm) (see calculations for USBR criteria):

D_{95B} = 3.0mm > 2.0mm ∴ use D_{F15} corresponding to 0.25g/cm² in Figure 6 of Foster and Fell:

% fine-medium sand = 85 − 34 = 51% ✓
(75μ − 1.18mm)

$(D_{15})_{CE}$ = 9.5 mm ✓

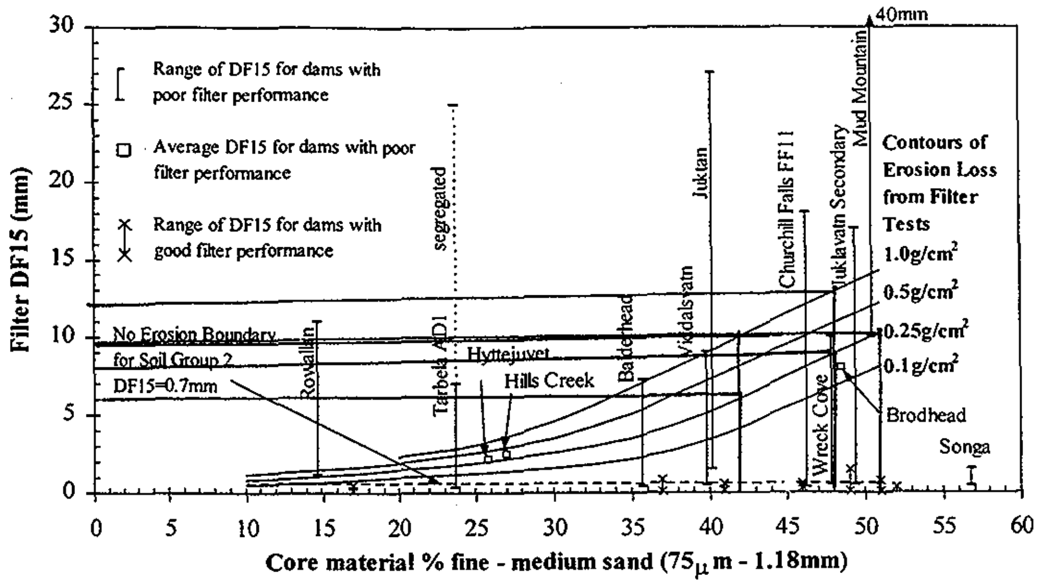


Figure 6: Comparison of erosion losses measured in filter tests to dams with poor and good filter performance.

↳ from Foster and Pell

For finest impervious fill:

Corrected gradation:

$D_{95B} = 2$ mm ∴ use methods for both $D_{95B} < 2$mm and $D_{95} > 2$mm

$D_{95B} \geq 2$mm, as above for average impervious, use D_{F15} corresponding to $0.25 g/cm^2$ in Figure 6

% fine-medium sand = 92✓ − ~~44~~ 47 = ~~48%~~ 45%

$(D_{15})_{CE} = 8.0$ mm ✓

$D_{95B} \leq 2$mm, $D_{F15} = 9 \times D_{B95} = 9 \times 2$mm $= 18$ mm ✓ $= (D_{15})_{CE}$

Conservatively use 8.0 mm ✓

For average impervious fill:

Uncorrected gradation: $D_{95B} = 35$ ~~30~~ mm > 2mm ✓

Estimate D_{15F} from Figure 6

% fine-medium sand = 69 − 27 = ~~34%~~ 42% ✓

$(D_{15})_{CE} = 6$ mm ✓

For finest impervious fill:

Uncorrected gradation: $D_{95B} = 8$ ~~6~~ mm > 2mm

Estimate D_{15F} from Figure 6

% fine-medium sand = 87 − 45 = 42%

$(D_{15})_{CE} = 6$ mm ✓

D. COMPARISON OF NO EROSION AND CONTINUING EROSION BOUNDARIES TO ACTUAL D_{15F}'s:

~~FOR~~ FOR EXISTING PERVIOUS SOIL:

AVG. GRADATION: $(D_{15})_{avg} = 1.1$ mm ✓

COARSEST GRADATION: $(D_{15})_{crst} = 4$ mm ✓

FOR AVERAGE IMPERVIOUS SOIL:

$(D_{15})_{NE} = 1.42$, $(D_{15})_{CE} = 6$ to 9.5 mm ✓

SO, $(D_{15})_{avg} < (D_{15})_{NE}$, AND

$(D_{15})_{NE} < (D_{15})_{crst} < (D_{15})_{CE}$ ✓

Subject: CLE ELUM DAM FILTER COMPATIBILITY   Project No. 68-F0D97287.00

By: JWP   Checked By: KAF   Task No. 00600

File No.

Date: 01/25/00   Date: 2/2/00   Sheet: 5 OF 7

FOR FINEST IMPERVIOUS SOIL:

$(D_{15})_{NE} = 0.7\text{ mm}$, $(D_{15})_{CE} = 6$ to 8 mm

SO, $(D_{15})_{NE} < (D_{15})_{avg} < (D_{15})_{CE}$, AND ✓

$(D_{15})_{NE} < (D_{15})_{crst} < (D_{15})_{CE}$ ✓

E. EVALUATE THE ~~B~~ CONTINUING EROSION BOUNDARY FOR THE FINEST GRADATION OF THE IMPERVIOUS FILL AND COMPARE TO CHARACTERISTICS OF PERVIOUS FILL

Use the following criteria proposed by Foster and Fell:

(i) average DF15 greater than the DF15 which yields an erosion loss of 0.25g/cm^2 in the CEF test, as represented by the 0.25g/cm^2 contour line in Figure 6, and/or

(ii) an upper limit DF15 greater than the DF15 which yields an erosion loss of 1.0g/cm^2 in the CEF test, as represented by the 1.0g/cm^2 contour line.

Using the corrected gradation for the finest impervious fill:

% fine-medium sand = ~~48~~ 45%

(i) $(D_{F15})_{CE} = 8.0\text{ mm}$ from 0.25 g/cm^2 contour on Figure 6 ✓

(ii) $(D_{F15})_{CE} = 12.0\text{ mm}$ from 1.00 g/cm^2 contour on Figure 6 ✓

Subject CLE ELUM DAM FILTER COMPATIBILITY Project No. 68-FOD97287.00

By JWF Checked By KAF Task No. 00600

File No.

Date 01/25/00 Date 2/2/00 Sheet 6 OF

Using uncorrected gradation for the finest impervious fill:

% fine-medium sand = 42% ✓

(i) $(D_{F15})_{CE}$ = 6.0 mm from 0.25 g/cm² contour on Figure 6 ✓

(ii) $(D_{F15})_{CE}$ = 9.5 mm from 1.00 g/cm² contour on Figure 6 ✓

Comparison to pervious zone gradations:

Gradation	$(D_{15F})_{ACTUAL}$	$(D_{15F})_{CE}$
Average	4.1 mm ✓	6 to 8 mm (1) ✓
Coarsest	4 mm ✓	9.5 to 12 mm (2) ✓

(1) From criterion (i), above.

(2) From criterion (ii), above.

In both cases $(D_{15F})_{ACTUAL} < (D_{15F})_{CE}$

F. SUMMARY

In summary, for the criteria recommended by Foster and Fell:

1) Comparing the average impervious fill to the pervious fill

$(D_{15})_{ACTUAL} < (D_{15F})_{NE} < (D_{15F})_{CE}$ ✓

and

Subject CLE ELUM DAM FILTER COMPATIBILITY Project No. 68-F0D97282.00

By JWF Checked By KAF Task No. 00600

File No.

Date 01/25/00 Date 2/2/00 Sheet 7 OF 7

2) Comparing the finest impervious fill with the average or coarsest pervious fill

$$(D_{15})_{NB} < (D_{15})_{ACTUAL} < (D_{15})_{CE}$$

However, it should be noted that the pervious material is likely susceptible to segregation during placement, as indicated in calculations using USBR criteria. Hence, there may be some locations where segregation occurred and conditions are worse than indicated above.

Filter Testing for Dams - No Erosion and Continuing Erosion Boundaries

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Summary The results of a statistical analysis of laboratory filter tests from the literature, including those by Sherard and Dunnigan (1989), and the results of laboratory tests carried out at the University of New South Wales are used to determine criteria for the boundaries of filter test behaviour. These boundaries are compared to the characteristics of dams that have experienced good and poor filter performance to allow the practical application of the criteria to the safety assessment of other dams.

1. INTRODUCTION

One of the primary functions of the filter downstream of the core is to prevent the development of piping through the dam in the event of a concentrated leak through the core. The good performance of dams with filters designed in accordance with modern design criteria have proven that these filters are capable of reliably sealing concentrated leaks (Sherard and Dunnigan, 1989; Peck 1990). However, many existing dams have filters that do not satisfy these criteria, being too coarse by design or having segregated during construction. In the review of the safety of these structures, it is necessary to evaluate the likelihood of damages to the dam in the event of piping developing in the core of the dam, potentially leading to failure (breaching) of the dam. The main issues of concern in these circumstances are:

(i) If a concentrated leak forms through the core of the dam, will the filter prevent continuing erosion of the core material (i.e. will the leak be eventually sealed by the filter)?
(ii) How much erosion of the core material is required for the filter to seal the leak and can this be tolerated?

Since the 1920s there have been numerous experimental and theoretical studies into the development of filter criteria for the design of dams. Despite this, there is little guidance in the literature on the assessment of filters of existing dams, particularly for the situation where filters do not meet current criteria.

Modern design criteria are based on laboratory tests that simulate a crack in the core of a dam exiting into the downstream filter. One of the most widely used criteria are those recommended by Sherard and Dunnigan (1989). This criteria is based on the results of the No Erosion Filter (NEF) test which allows no visible erosion of a 1mm diameter hole through the base specimen.

2. FILTER TEST BOUNDARIES

The success/fail criteria of filter test behaviour is usually represented as some measure of erosion loss of the base material. Terms developed to categorise filter test behaviour are as follows:

(i) *No erosion*: - filter seals with practically no erosion of the base material.
(ii) *Some erosion*: - filter seals after "some" erosion of the base material.
(iii) *Continuing erosion*: - the filter is too coarse to allow the eroded base materials to seal the filter allowing unrestricted erosion of the base soil.

The boundaries of the filter test behaviour categories are the no erosion and continuing erosion boundaries as shown in Figure 1.

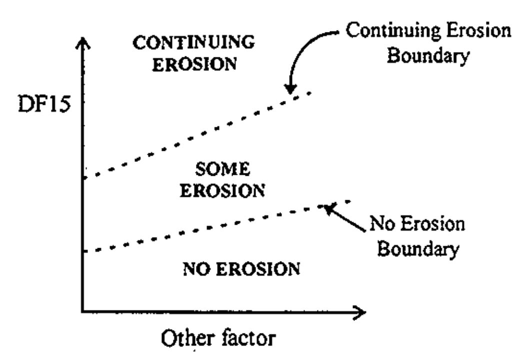

Figure 1. Erosion boundaries of filter test behaviour.

Foster, M. and Fell, R. (1999) Filter testing for dams – no erosion and continuing erosion boundaries. *Proceedings 8th Australia New Zealand Conference on Geomechanics*, Vitharana and Colman (eds.), Hobart, Vol. 2, pp. 503-511.

Table 1. Summary results of statistical analysis of the no erosion boundary of filter tests.

Base Soil Group	Fines content *(1)*	Design Criteria of Sherard and Dunnigan (1989)	Range of DF15 for No Erosion Boundary	Proposed Criteria for No Erosion Boundary
1	≥ 85%	DF15 ≤ 9 DB85	6.4 - 13.5 DB85	DF15 ≤ 9 DB85
2	35 - 85%	DF15 ≤ 0.7mm	0.7 - 1.7mm	DF15 ≤ 0.7mm
3	< 15%	DF15 ≤ 4 DB85	6.8 - 10 DB85	DF15 ≤ 7 DB85
4	15 - 35%	DF15 ≤ (40-pp%75μm) x (4DB85-0.7)/25 + 0.7	1.6 - 2.5 DF15 of Sherard and Dunnigan design criteria	DF15 ≤ 1.6 DF15d, where DF15d = (35-pp%75μm)(4DB85-0.7)/20+0.7

Notes: (1) The subdivision for soil group 2 and 4 was modified from 40% passing 75μm, as recommended by Sherard and Dunnigan (1989), to 35% based on the analysis of the filter test data.

3. STATISTICAL ANALYSIS OF FILTER TESTS

The purpose of the statistical analysis was to determine criteria for the no erosion and continuing erosion boundaries of filter test behaviour. Experimental data used in the statistical analysis of filter tests was collected from the following sources;

(i) **U.S. Soil Conservation Service (USSCS),** reported in Sherard, Dunnigan and Talbot (1984a, 1984b), Sherard and Dunnigan (1989) and unpublished reports by Sherard (1985).
(ii) **US Bureau of Reclamation (USBR)** tests, reported in Karpoff (1955) and USBR (1960).
(iii) **US Corp of Engineers** (1953)
(iv) **Kenney et al** (1985)
(v) **Wyangala and Copeton** Dam filter tests, Water Conservation and Irrigation Commission (1964, 1969).
(vi) **Khor and Woo** (1989) - No Erosion Filter tests.

Only the summary results of the statistical analysis are discussed in this paper, however details of the methodology and results of the analysis are given in Foster and Fell (1998).

3.1 No Erosion Boundary

The analysis of the no erosion boundary was performed on the four soil groups of base soils defined by Sherard and Dunnigan (1989). The experimental range and the proposed criteria are summarised in Table 1 together with the design criteria of Sherard and Dunnigan.

The statistical analysis of the filter test data generally confirmed the interpretation of the NEF tests by Sherard and Dunnigan (1989). For soil group 1 base soils, the proposed criteria for the no erosion boundary corresponds to a probability of erosion of 0.5. The erosion losses suffered in the NEF tests with DF15 slightly coarser than the no erosion boundary were only minor before the filters sealed.

The proposed criteria of the no erosion boundaries for soil group 2 base soils corresponds to the lower boundary of the NEF tests of DF15=0.7mm. The lower cutoff for this soil group was changed from 40% fines content (passing 75μm), as suggested by Sherard and Dunnigan, to 35% to allow for the results of some NEF tests on base soils with fines content in the range 35-40% with no erosion boundaries as low as DF15=0.7mm.

The proposed criteria of the no erosion boundaries for soil group 3 and 4 base soils are coarser than the corresponding Sherard and Dunnigan design criteria because the design criteria have factors of safety included. The filter tests with filters only slightly coarser than the no erosion boundary suffered considerable erosion, and therefore, the proposed boundaries correspond to the lower bound of the experimental data.

3.2. Continuing Erosion Boundary

The slot and slurry tests carried out by the USSCS (Sherard, et al 1984b) used success/fail criteria which conveniently corresponds to the definition of the continuing erosion boundary. In successful slot and slurry tests, the filter sealed after some erosion of the preformed slot or slurry material. In unsuccessful tests, virtually all of the slurry was washed through the filter and the filter was never sealed (i.e. continuing erosion of the base material).

The soils tested in the slot and slurry tests were generally clays, silts and sandy clays and classified as soil groups 1 and 2. As reported in Sherard et al (1984b), the experimental data for these tests showed a poor relationship of DF15 vs DB85, with DF15/DB85 in the range 9-57. Following the publication of the 1984 ASCE paper, Sherard found the slot and slurry tests defined a continuing erosion boundary given by DF15/9 ≥ DB98 to DB100 for soils with DB85<0.1mm (Sherard, 1985). DF15/9 approximates the effective opening size of uniformly graded filters (Sherard et al 1984a). This implies the filter only needs to be capable of stopping the very coarsest particles of base material for self-filtering to occur for fine grained soils.

The analysis of the filter test data of soil group 1 base soils found DF15/DB95 gives a better fit to the experimental data than DF15/DB85 and that DF15/9=DB95 of the experimental data corresponds to the lower limit of the continuing erosion boundary. For tests with DF15/DB95 < 9, all of the filter tests were eventually sealed.

For base soils with DB85>0.1mm, there was insufficient data to determine criteria for the continuing erosion boundary. The majority of the NEF tests were aimed at defining the no erosion boundary and the coarsest filters used were generally only slightly coarser than the no erosion boundary. Also it was often difficult to judge from the descriptions if the filter was eventually sealed for the tests that were judged by the investigators as failures.

4. CONTINUING EROSION FILTER TESTS

Additional filter tests were carried out using a modified version of the NEF test, called Continuing Erosion Filter (CEF) tests, to determine the continuing erosion boundary for soils with DB85>0.1mm. The test procedures of the CEF tests were essentially the same as those of the NEF test, as described by Sherard and Dunnigan (1989) but with the following modifications to the procedure:

- water passing through the filter during the tests was collected and the eroded materials dried and weighed to determine the loss of base soil required to seal the filter;
- progressively coarser filters were used until the filter was not sealed;
- thicker base specimens were used to allow for greater erosion losses.

Details of the CEF test setup are shown in Figure 2.

The tests were carried out for such a time until it was evident the filter was sealed or it was judged that the filter was not going to seal no matter how much erosion of the base soil occurred. The filters were judged to have sealed when all of the following conditions were reached:

(a) full mains pressure was maintained in the space above the base specimen as measured on the pressure gauge,
(b) water passing through the filter was clear, and
(c) the flow rate of water passing through the filter had decreased substantially from the initial flow and was relatively constant.

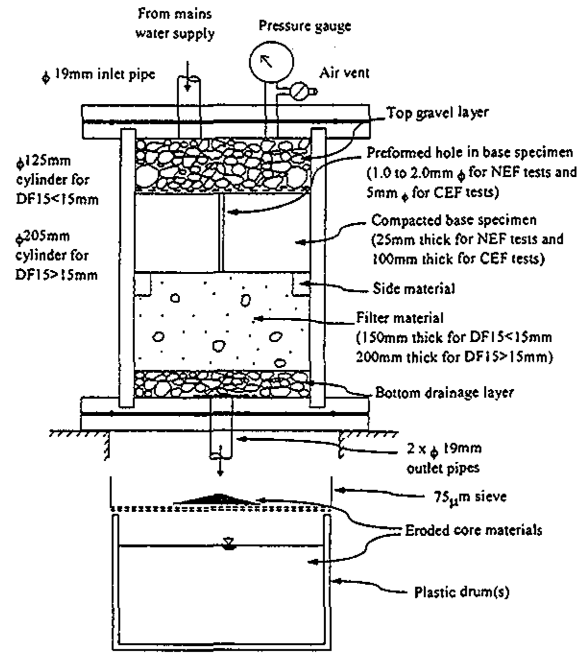

Figure 2: Continuing erosion filter test apparatus.

4.1 Results of CEF Tests

Eight base soils were tested using the no erosion and continuing erosion test procedures. The soils were obtained by project sponsors from natural deposits or from the embankment materials of existing dams in Australia and New Zealand. The characteristics of the base soils are presented in Table 2 and the gradation curves are shown in Figure 3.

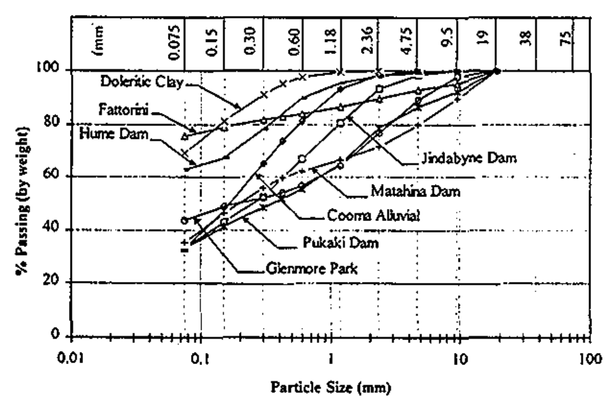

Figure 3: Gradations of base soils.

The differences between the Pinhole Dispersion classification and the Emerson class for soils 4 and 5 in Table 2 are due to the relatively high sand content which make these soils highly erodible in the Pinhole Dispersion test.

Table 3 presents a summary of the results of the NEF and CEF tests. The no erosion boundary obtained from the NEF tests and the coarsest filter sealed in the CEF tests are shown for each of the base soils tested.

Table 2. Characteristics of the base soils tested.

Soil No.	Name	Geological Origin	Index Properties		Gradation		Dispersivity	
			LL	PI	% fines <75μm	DB85 (mm)	Pinhole Dispersion	Emerson Class
1	Fattorini Creek	Colluvial	42	19	76	0.8	D1	1
2	Doleritic clay	Residual (dolerite)	62	22	70	0.2	ND1	5
3	Hume Dam	Tertiary alluvial	33	15	63	0.4	D1	1
4	Pukaki Dam	Glacial till	NP	NP	36	6.8	D1	5
5	Jindabyne Dam	Residual (granite)	38	11	34	1.5	D1	5
6	Matahina Dam	Residual (greywacke)	26	8	33	4.1	D1-D2	2
7	Cooma Alluvial	Alluvial	31	10	33	0.7	PD1	2
8	Glenmore Park	Residual (shale)	42	21	44	3.7	PD1-PD2	2

Table 3: Summary of No Erosion and Continuing Erosion Filter tests

Soil Name	No Erosion Boundary DF15 (mm)	Coarsest Filter Sealed in CEF Tests DF15 (mm)	Filter Not Sealed in CEF Tests DF15 (mm)
Fattorini Creek	0.2 - 0.3	1.0	2.0
Doleritic clay	0.5 - 0.7	3.35	4.75
Hume Dam	0.3 - 0.5	9.5	12.7
Pukaki Dam	2.0 - 3.35	38	-
Jindabyne Dam	4.75 - 6.7	25	-
Matahina Dam	1.0 - 2.0	9.5	12.7
Cooma Alluvial	6.7 - 9.5	12.7	19
Glenmore Park	0.7 - 1.0	12.7	19

The results show that coarse filters with DF15 several times larger than the DF15 for no erosion were capable of being sealed in the CEF tests. Generally, the DF15 of the coarsest filter that was sealed was in the range of 4 to 17 times the DF15 obtained for the no erosion boundary (except for Cooma Alluvial which was only 1.6 times higher).

The no erosion boundaries obtained for the two dispersive base soils, Fattorini and Hume Dam, are lower than the Sherard and Dunnigan design criteria for soil group 2 soils (DF15≤0.7mm). Sherard and Dunnigan claimed the no erosion boundary is independent on the dispersivity of the soil (Sherard 1985; Sherard and Dunnigan 1989). However, in the USSCS study, only 2 of the 28 group 1 soils and none of the group 2 soils were dispersive and the results of the NEF tests on the two dispersive soils in this study show the no erosion boundary can be lower than the design criteria. Whilst the NEF tests on the Fattorini Dam and Hume Dam soils with DF15=0.7mm failed to meet the criteria of the NEF test, the initial concentrated leaks were successfully sealed without significant erosion (hole enlarged to 2-4mm diameter).

4.2 Factors influencing erosion losses to seal concentrated leaks

The results of the CEF tests were subdivided into two groups based on the observed behaviour - soils with DB95 > 2mm and soils with DB95 < 2mm. For base soils with DB95 < 2mm, the filter was sealed for tests with filters corresponding to filter opening sizes (DF15/9) equal up to about DB95. For tests with DF15/9 > DB95 the filter was not sealed and large erosion losses occurred. This is the same as the criteria for group 1 soils, and it is concluded that the continuing erosion boundary for all base soils with DB95 < 2mm is given by DF15/DB95 < 9.

For base soils with DB95 > 2mm, relatively large erosion losses were measured for filters with DF15/9 much less than DB95. It was not possible to define a continuing erosion boundary for these soils due to difficulties in the interpretation imposed by the limited flow capacity of the test apparatus and due to the restriction of the maximum sized DF15 of the filter (38mm) that could be tested in the test cylinder.

The erosion losses measured in the CEF tests are related to the proportion of fine to medium sand sizes in the base soils. Figure 4 shows the erosion losses plotted against the DF15 of the filter and the percentage of base particles with sizes in the range 75μm - 1.18mm (after the grading of the soil is regraded to a maximum particle size of 4.75mm) for the base soils with DB95 > 2mm. The erosion losses are expressed as the mass of loss per area of filter face sealed.

It can be seen from Figure 4 that for a constant DF15 size, the erosion losses tend to be lower for base soils with higher proportions of fine to medium sand sizes. Contours of equal erosion loss, determined by interpolation between the data points, are shown plotted on Figure 4. The contours cover the range of DF15 of about 2 to 13mm which correspond to filter opening sizes (given by DF15/9) in the range of 0.2 to 1.4mm, i.e. about the same as fine to medium sand sizes.

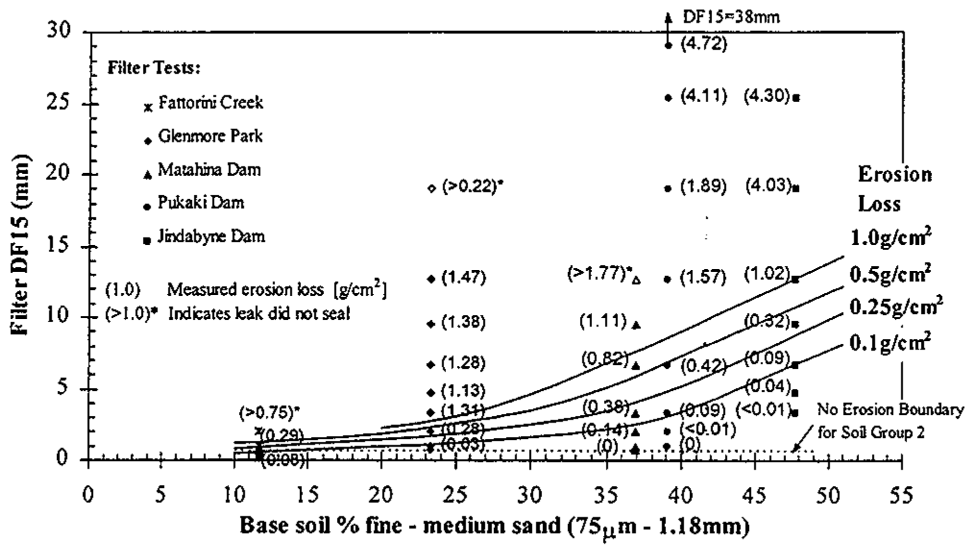

Figure 4: Erosion losses of base soil measured in the.CEF tests.

Therefore base soils with a low proportion of fine to medium sand sizes would be expected to require larger erosion losses to yield the same quantity of particle sizes necessary for self-filtering of the base soil to occur for this range of filter sizes.

5. FILTER PERFORMANCE OF DAMS

There are numerous cases of incidents described in the literature involving piping of core materials into downstream filters in central core earth and rockfill dams (Ripley 1984). While these incidents have resulted in damages to the dam in the form of sinkholes and large leakages, none have actually resulted in failure (i.e. breaching) of the dam (Foster, Fell and Spannagle, 1998).

Figure 5 presents the gradations of the filters of some of the dams with poor filter performance. The case histories generally involved piping of core materials into coarse or segregated downstream filters in zoned earthfill or central core earth and rockfill dams. The dams were generally constructed in the 1960's to 1970's which coincides to a period when there was a trend away from the use of uniformly-graded multiple filters and towards the use of a single filter of substantial width and broad gradation (Response by Ripley in ICOLD, 1994). The filter gradings shown in Figure 5 have wide gradings and low proportions of sand sizes which would tend to make them susceptible to segregation during construction and also potentially make them internally unstable.

There are also several reported cases of concentrated leaks that have developed through the cores of dams but which have evidently sealed due to the downstream filter as evidenced by observations of near hydrostatic piezometer levels in the downstream section of the core and 'wet seams' in the core (Sherard 1985). Peck (1990) also describes several examples from the literature of dams which have shown evidence of some form of filtering action has taken place at the core-filter interface.

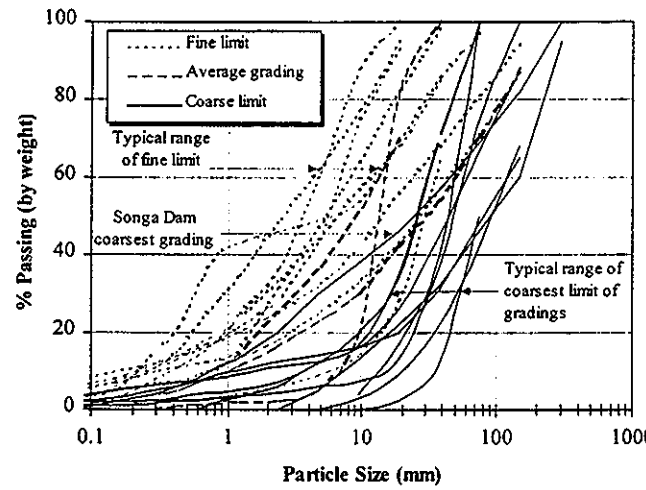

Figure 5. Gradings of filters which have experienced poor filter performance.

Only two dams, Rowallan Dam and Whitemans Dam, were found in the literature which have experienced poor filter performance involving piping of fine grained core materials with DB95 < 2mm. In both cases, the finest core material and coarsest filter combination fall into the continuing erosion category as defined by the laboratory tests, i.e., DF15/9 > DB95. At Rowallan Dam, the filter with the coarsest grading has a filter opening size (DF15/9) of 11/9 = 1.2mm and this is larger than the DB95 of the finest grading of contact clay soil of 0.9mm. At Whitemans Dam, core materials were eroded into the downstream gravel zone and the filter opening size of this coarsest gravel zone material=1.0/9= 0.11mm and the DB95 of the finest core grading is 0.075mm.

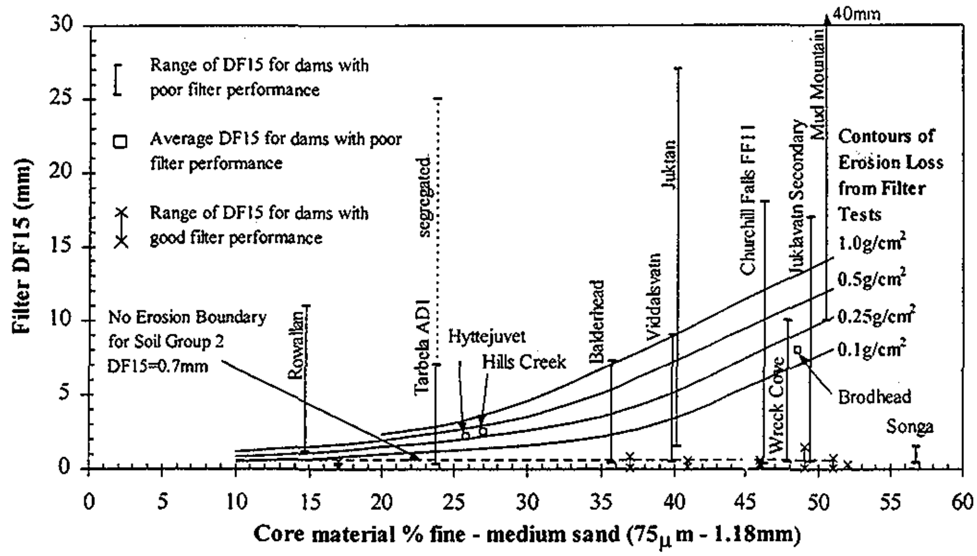

Figure 6: Comparison of erosion losses measured in filter tests to dams with poor and good filter performance.

The other dams with poor filter performance generally have broadly graded core materials which fall into soil group 2 and 4 type soils (fines content 15-85%) and have DB95>2mm which places them in the soil types where a continuing erosion boundary could not be identified by the CEF tests. Figure 6 shows the range of DF15 of the filter plotted against the average percentage of fine-medium sand sizes (%75μm - 1.18mm) of the core material for the dams which have had poor and good filter performance. The contours of equal erosion losses from the CEF tests and the no erosion boundary for soil group 2 soils (DF15=0.7mm) are shown on the plot. The % fine-medium sand has been taken off the grading curves of the core materials after adjustment to a maximum particle size of 4.75mm.

Dams with good filter performance generally have filters with an average DF15 ≤ 0.5mm which is finer than the Sherard and Dunnigan design criteria for soil group 2 base soils (DF15 ≤ 0.7mm). The coarsest gradings are only slightly coarser than this (DF15 up to 1.5mm).

Dams with poor filter performance have filters with an average DF15 > 1.0mm and generally with DF15 greater than or equal to about the 0.25g/cm² contour of erosion loss. Where a range of filter gradations is given, the coarsest grading is significantly coarser than the design criteria. Balderhead Dam has the finest coarse limit grading of the filter (DF15 = 7mm) and this is 10 times coarser than the recommended design criteria. The DF15 for the coarsest gradings is typically greater than or equal to about the 1.0g/cm² contour.

One notable exception is Songa Dam which has a range of DF15 of 0.4-1.5mm and this is considerably lower than the other dams with poor filter performance. However the gradings of the filter for Songa Dam have a wide grading and low proportion of sand sizes which, as discussed further on, would have made the filters particularly susceptible to segregation during placement. Therefore it is likely that the actual gradings of the filter in this dam are probably locally much coarser than that shown.

6. PROPOSED CONTINUING EROSION BOUNDARY FOR SOILS WITH DB95>2mm

The continuing erosion boundary proposed for soils with DB95 > 2mm defines the filter DF15 that has the potential to result in increases in leakages and in the formation of sinkholes and tunnels through the core in the event of a concentrated leak developing through the core. The criteria are based on the comparison of the CEF test results to the characteristics of the dams with good and poor filter performance, as shown in Figure 6. The proposed criteria are as follows:

(i) average DF15 greater than the DF15 which yields an erosion loss of 0.25g/cm² in the CEF test, as represented by the 0.25g/cm² contour line in Figure 6, and/or

(ii) an upper limit DF15 greater than the DF15 which yields an erosion loss of 1.0g/cm² in the CEF test, as represented by the 1.0g/cm² contour line.

The continuing erosion boundary for soils with DB95 > 2mm is based on CEF tests on base soils with fines content greater than about 30%. As shown by the no erosion boundaries for soil groups 3 and 4, the self-filtering capabilities of soils with fines content less than 30% are more likely to be influenced by grain sizes coarser than fine to medium sand sizes and so the contours of erosion losses shown in Figure 6 are probably not applicable to these soils. In the absence of any other basis on which to develop criteria, the proposed criteria for the continuing erosion boundary are based on excessive erosion in the laboratory tests. For soil group 3 soils, <15% fines content, significant erosion losses (defined as > 100g base material loss) occurred for DF15/DB85 > 9. For soil group 4 soils, with fines content of 15-35%, the descriptions of the unsuccessful NEF tests suggest the erosion losses are significant for filters with DF15 slightly coarser than the no erosion boundary. Therefore, the proposed criteria is based on the upper limit of the no erosion boundary given by:

DF15 > 2.5DF15design,

where DF15design is given by:

DF15design = (35-pp%75μm)(4DB85-0.7)/20+0.7

7. CONCLUSIONS - APPLICATION OF FILTER TEST EROSION BOUNDARIES

7.1 Design of Filters for New Dams

Whilst it has been demonstrated that filters coarser than the filters recommended by the Sherard and Dunnigan (1989) criteria are capable of sealing concentrated leaks, the authors do not advocate the relaxation of the filter criteria for the design of critical filters for new dams. Dams with filters designed and constructed in accordance with these criteria have proven in practice that they are capable of reliably sealing concentrated leaks. The criteria have become widely accepted in practice and they are not considered to be unduly conservative. However some additional issues, raised by the findings of this study, which should be considered when designing filters in accordance with the criteria recommended by Sherard and Dunnigan (1989). These are described in the following points.

(i) Design of filters for dispersive soils

Sherard and Dunnigan recommended the same DF15 irrespective of the dispersivity of the core material, however it appears this was based on only a limited number tests on dispersive soils. The NEF tests carried out on two dispersive soils in this study required filters finer than that recommended by the design criteria. Therefore, for the design of critical filters for dispersive core materials, it is recommended that NEF tests be carried out to confirm the DF15 for no erosion.

(ii) Soil Groups 2 and 4 subdivision

It is recommended that the subdivision of soil groups 2 and 4 should be changed to a fines content of 35% instead of 40% as defined by Sherard and Dunnigan (1989). Some NEF tests on soils with 35-40% fines content indicated the no erosion boundary to be as low as DF15 = 0.7mm which is the design criteria for soil group 2.

7.2 Assessment of Filters of Existing Dams

An assessment of filters of existing dams should consider how the filter may perform in the event of a concentrated leak developing through the core. Filter performance is classified into three categories as described in the following points.

(i) *Seal with no erosion* - rapid sealing of the concentrated leak with no potential for damage and no or only minor increases in leakage.

(ii) *Seal with some erosion* - sealing of the concentrated leak but with the potential for some damage and minor to moderate increases in leakage.

(iii) *Partial or no seal with large erosion* - slow sealing or no sealing of the concentrated leak with the potential for large erosion losses and large increases in seepage, potential for the development of sinkholes on the crest and erosion tunnels through the core.

Table 4 shows the likely filter performance based on the filter characteristics relative to the filter test erosion boundaries. The assignment of the qualitative likelihood terms shown are based on the comparisons of the case histories with good and poor filter performance to the filter test erosion boundaries on the assumption that the filter materials are not susceptible to segregation or internal instability. If poor construction practices were used and/or if the filter gradings have characteristics that are susceptible to segregation or internal instability, then the likelihood terms should be adjusted towards poor filter performance being more likely.

Table 4. Likelihood of the filter performance in the event of a concentrated leak.

Comparison of DF15 in the dam to the filter test erosion boundaries		Likelihood of filter performance in the event of a concentrated leak		
Average DF15 in the dam	**Coarsest DF15 in the dam**	**Seals with No Erosion**	**Seals with Some Erosion**	**Partial or No Seal with Large Erosion**
< NE	< NE	Highly Likely	Unlikely	Highly Unlikely
< NE	>NE and < CE	Equally Likely		Unlikely
> NE	< CE	Unlikely	Equally Likely	
> NE and < CE	> CE	Unlikely	Unlikely	Likely
> CE	> CE	Highly Unlikely	Unlikely	Highly Likely

Notes: NE = No Erosion Boundary, CE = Continuing Erosion Boundary

Characteristics of sand-gravel filters that would tend to make them susceptible to segregation are:

(i) broad grading, with maximum particle sizes > 75mm,
(ii) a low percentage of sand sizes (<40% finer than 4.75mm), and
(iii) poor construction practices, e.g. end dumping from trucks, high lift heights and poor control of stockpile and handling operations.

Even though a particular dam may have filters which are coarser than the continuing erosion boundary, this does not necessarily infer the dam will fail in the event of a concentrated leak. An assessment of the likelihood of a piping event leading to failure of the dam needs to take into consideration the likelihood of the progression of piping leading to some breaching mechanism such as toe unravelling or crest settlement leading to overtopping. In an event tree approach, this is considered by the branches leading on from the assessment of filter performance. An overview of the factors affecting the progression of piping are given in Fell and Foster (1999).

8. ACKNOWLEDGEMENTS

The support of the 17 sponsors of the research project, Dams Risk Assessment - Estimation of the Probability of Failure, and the Australian Research Council is acknowledged. The sponsors are:

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- Department of Land and Water Conservation
- Department of Land and Water Conservation (Dam Safety)
- Electricity Corporation, New Zealand
- Goulburn Murray Water
- Gutteridge Haskins and Davey
- Hydro-Electric Corporation, Tasmania
- Melbourne Water
- NSW Department of Public Works and Services
- NSW Dam Safety Committee
- Pacific Power
- Department of Natural Resources, Queensland
- Snowy Mountains Engineering Corporation
- Snowy Mountains Hydro-Electricity Authority
- SA Water
- Sydney Water Corporation
- Western Australia Water Corporation

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Job CLE ELUM DAM — Project No. D97287 — Sheet ___ of ___

Description FILTER COMPATABILITY EVALUATION — Computed by MJH / KAF — Date 3/11/99 / 2/2/00

Checked by JWR — Date 2/2/00

Reference

PROBLEM: EVALUATE THE FILTER COMPATABILITY OF PERVIOUS SHELL AND PERVIOUS FILL FOR THE FOLLOWING 4 CASES:

(1) AVG. IMPERVIOUS / AVG. PERVIOUS

(2) AVG. IMPERVIOUS / COARSEST PERVIOUS

(3) FINEST IMPERVIOUS / AVG. PERVIOUS

(4) FINEST IMPERVIOUS / COARSEST PERVIOUS

GIVEN: GRAIN SIZE DISTRIBUTION CURVES

REFERENCES: USBR (1989) "PROTECTIVE FILTERS" DESIGN STANDARDS No. 13 - EMBANKMENT DESIGN.

SOLUTION:

⇒ ONLY AVERAGE IMPERVIOUS / AVG. PERVIOUS FILL WAS FOUND TO BE ACCEPTABLE ACCORDING TO THE ABOVE REFERENCE

(SEE FOLLOWING PAGES FOR CALCULATIONS

Job CLE ELUM DAM | Project No. D97287 | Sheet ___ of ___

Description FILTER COMPATABILITY EVALUATION | Computed by MJH | Date 3/11/99

Checked by JWF | Date 01/25/00

Reference

CORRECTION OF AVG. IMPERVIOUS

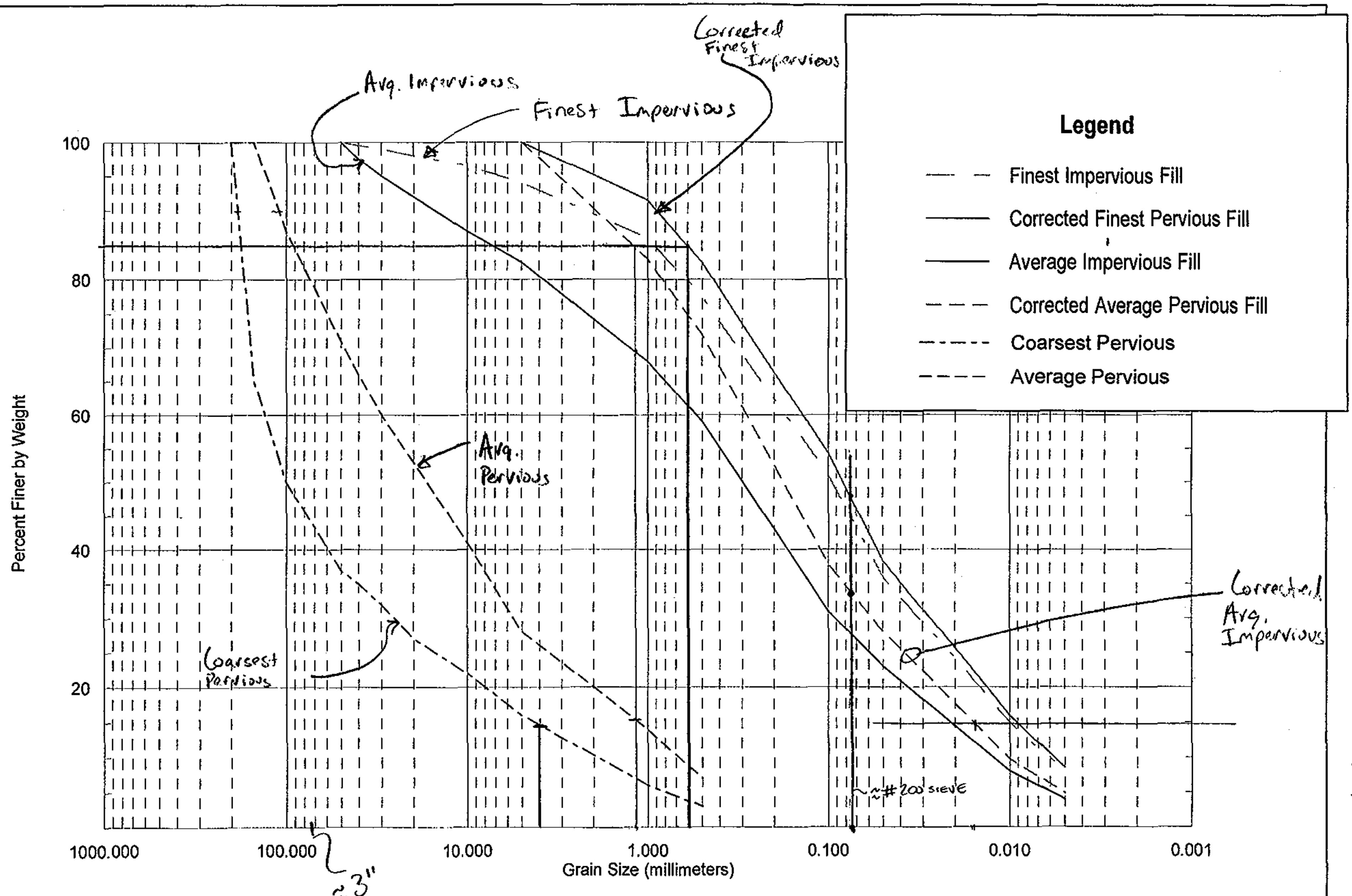
SIZE (mm)	FINEST IMPERVIOUS	% PASSING CORRECTED FINEST IMP.	AVG IMPERVIOUS	CORRECTED AVG IMPERVIOUS
200	100	100	100	100
100	100	100	100	100
50	100	100	100	100
40	99.5	100	97.5	100
30	99	100	95	100
20	98	100	92	100
10	96.5	100	87	100
5	94	100	82.5	100
1	86	91.5 ✓	68	83 ✓
.5	77.5	82.5 ✓	59	72 ✓
.1	51	54.26 ✓	31	37.8 ✓
.05	36	38.3 ✓	23	28.1 ✓
.01	15	16 ✓	8	9.8 ✓
.005	8	8.5 ✓	4	4.9 ✓

#4 % PASSING FINEST IMPERVIOUS = 94

CORRECTION FACTOR = $\frac{100}{94}$ = 1.064

#4 % PASSING AVG. IMPERVIOUS = 82

CORRECTION FACTOR = $\frac{100}{82}$ = 1.220



Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	FILTER COMPATIBILITY	Figure
Woodward-Clyde			

FILTER.GRF with filter.xls /3/11/99 / kaf modified by mjh

3/11/99

Page 3/9

FROM CORRECTED CURVES DETERMINE CATEGORY OF SOIL

FOR BASE SOIL

CORRECTED FINEST IMPERVIOUS FILL
48% PASSING #200 SIEVE

CATEGORY 2 SOIL ✓

CORRECTED AVG. IMPERVIOUS FILL
34% PASSING #200 SIEVE

CATEGORY 3 SOIL ✓

DETERMINE MAX. D_{15F} FOR THE 2-CATEGORIES OF SOIL

CATEGORY 2 $D_{15F} \leq 0.7\,mm$ ✓

CATEGORY 3 $D_{15F} \leq 0.7mm + \frac{(40-A)(4 \times D_{85B} - 0.7mm)}{25}$ ✓

DETERMINE $D85_B$ FOR CORRECTED FINEST & AVG. IMPERVIOUS

$D85_B$ FOR CORRECTED AVG. IMPERVIOUS = **1.1 mm** ✓

$D85_B$ FOR CORRECTED FINEST IMPERVIOUS = **.6 mm** ✓

DETERMINE ACCEPTABILITY OF 4 CASES BY DESIGN STDS. No. 13

1.) AVG. IMPERVIOUS / AVG. PERVIOUS

CATEGORY 3 BASE SOIL

$$D_{15F} \leq 0.7\text{mm} + \frac{(40-A)(4 \times D_{85B} - 0.7\text{mm})}{25}$$ ✓

D_{85B} = 1.1 mm for Avg. impervious ✓

A = 34 ✓

$$D_{15F} \leq 0.7\text{mm} + \frac{(40-34)(4 \times 1.1 - 0.7)}{25}$$

$$\leq 0.7\text{mm} + \frac{6\,(3.7)}{25}$$

$$\leq 0.7\text{mm} + 0.89\text{mm}$$

$$\leq 1.59\text{mm}$$ ✓

D_{15F} MAX = 1.59 ✓

D_{15} ACTUAL = 1.1 mm ✓

1.1 mm < 1.59

ACCEPTABLE ✓

2.) AVG. IMPERVIOUS / COARSEST PERVIOUS

D_{ISF} MAX = 1.59 ✓

D_{ISF} ACTUAL = 4 mm ✓

D_{ISF} ACTUAL > D_{ISF} MAX **UNACCEPTABLE** ✓

3.) FINEST IMPERVIOUS / AVG. PERVIOUS

$D_{ISF} \leq 0.7$ mm ✓

D_{ISF} MAX = 0.7 mm ✓

D_{ISF} ACTUAL = 1.1 mm ✓

D_{ISF} ACTUAL > D_{ISF} MAX **UNACCEPTABLE** ✓

4.) FINEST IMPERVIOUS / COARSEST PERVIOUS

$D_{ISF} \leq 0.7$ mm ✓

D_{ISF} MAX = 0.7 mm ✓

D_{ISF} ACTUAL = 4 mm ✓

D_{ISF} ACTUAL > D_{ISF} MAX **UNACCEPTABLE** ✓

URS Greiner Woodward Clyde

Job: CLE ELUM DAM | Project No. D97287 | Sheet ___ of ___
Description: FILTER COMPATABILITY EVAL | Computed by: MJH | Date: 3/11/95
Checked by: JWF | Date: 01/25/00

Reference

FOR 4 CASES LOOK AT PERMEABILITY

$D_{15F} \geq 5D_{15B}$

1.) AVG. IMPERVIOUS / AVG. PERVIOUS

$D_{15F} = 1.1\,mm$ ✓
$D_{15B} = .017\,mm$ ✓

$1.1 \geq .017 \times 5$

$1.1 \geq .085\,mm$ ✓ **OK FOR PERMEABILITY** ✓

2.) AVG. IMPERVIOUS / COARSEST PERVIOUS

$D_{15F} = 4\,mm$ ✓
$D_{15B} = .017\,mm$ ✓

$4\,mm \geq .017 \times 5$
$4 \geq .085\,mm$ ✓ **OK FOR PERMEABILITY** ✓

3.) FINEST IMPERVIOUS / AVG. PERVIOUS

$D_{15F} = 1.1\,mm$ ✓
$D_{15B} = .009\,mm$ ✓

$1.1 \geq .009 \times 5$
$1.1 \geq .045$ **OK FOR PERMEABILITY** ✓

4.) FINEST IMPERVIOUS / COARSEST PERVIOUS

$D_{15F} = 4\,mm$ ✓
$D_{15B} = .009\,mm$ ✓
$4 \geq .045$ **OK FOR PERMEABILITY** ✓

URS Greiner Woodward Clyde

Job: CLE ELUM DAM | Project No.: D97287 | Sheet ___ of ___

Description: FILTER COMPATABILITY EVAL | Computed by: MJH | Date: 3/11/99

Checked by: JWR | Date: 07/25/99

Reference

LOOK AT CRITERIA THAT SAYS MAX. PARTICLE SIZE OF FILTER = 3" AND MAXIMUM % PASSING #200 SIEVE = 5%

CONSIDER AVG. PERVIOUS & COARSEST PERVIOUS

- BOTH MAT'LS HAVE PARTICLES OVER 3 INCHES ✓
- LESS THAN 5% PASSING #200 SIEVE FOR BOTH CASES ✓

DON'T MEET ACCEPTABLE LIMITS FOR MAX. SIZE FOR BOTH FILTER CASES. ✓

FOR FILTER LOOK AT D_{10} & D_{90} AS WITH POINT H IN DESIGN STANDARDS 13 (TABLE 3)

THESE ARE LIMITS FOR SEGREGATION

FOR AVG. PERVIOUS D_{10F} = .7mm ✓

FOR COARSEST PERVIOUS D_{10F} = 2mm ✓

FROM TABLE 3 D_{90F} SHOULD BE A MAXIMUM OF 25 mm ✓ FOR AVG. PERVIOUS &
40 mm ✓ FOR COARSEST PERVIOUS

D_{90} ACT = 105mm ✓ FOR AVG. PERVIOUS

D_{90} ACT = 190 mm ✓ FOR COARSEST PERVIOUS

BOTH FILTER CURVES DO NOT MEET CRITERIA ✓

Appendix H

APPENDIX H

Static Stability Analyses

CLE ELUM DAM DOWNSTREAM SLOPE
STEADY SEEPAGE

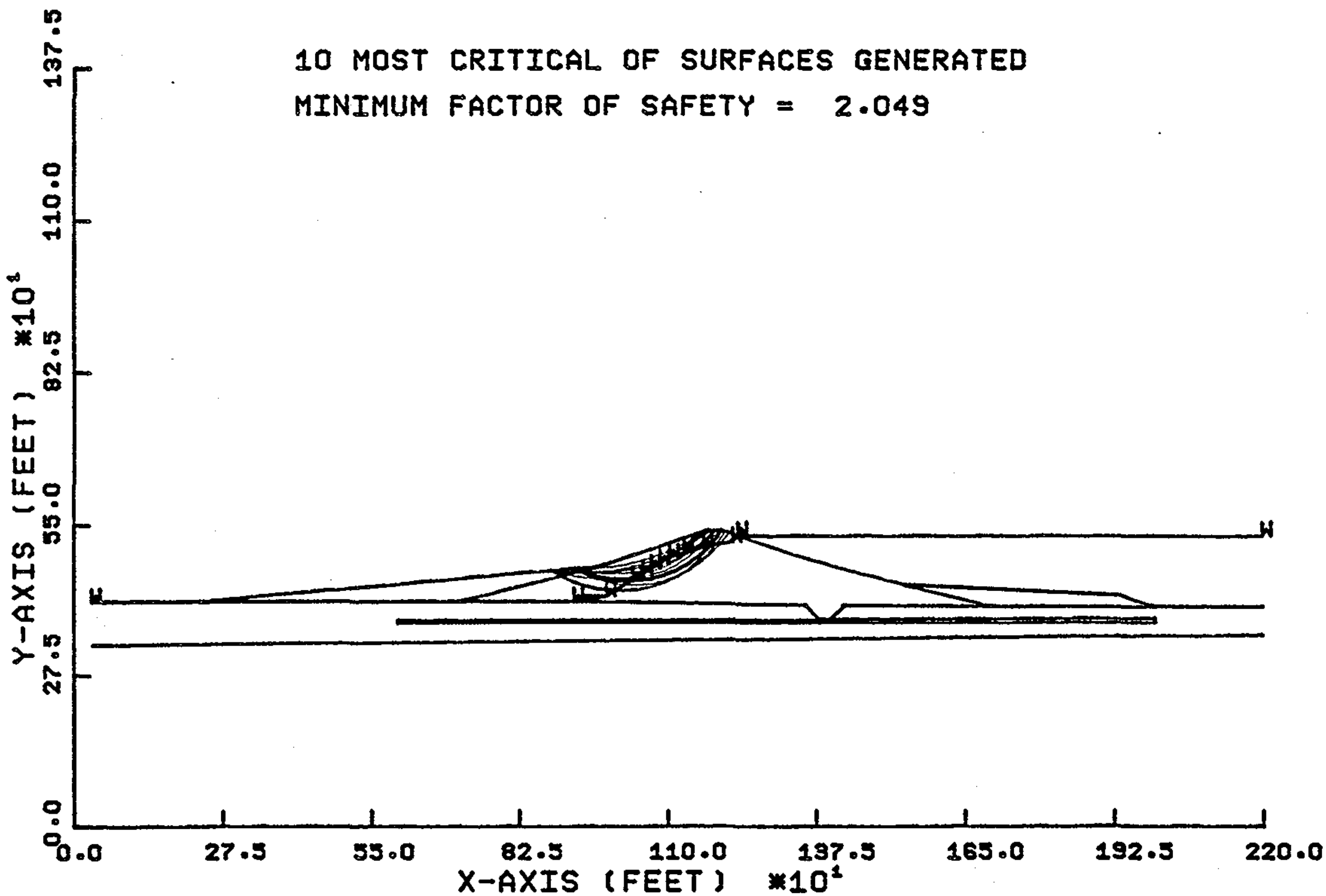


FIGURE H-1

CLE ELUM DAM UPSTREAM SLOPE
STEADY SEEPAGE

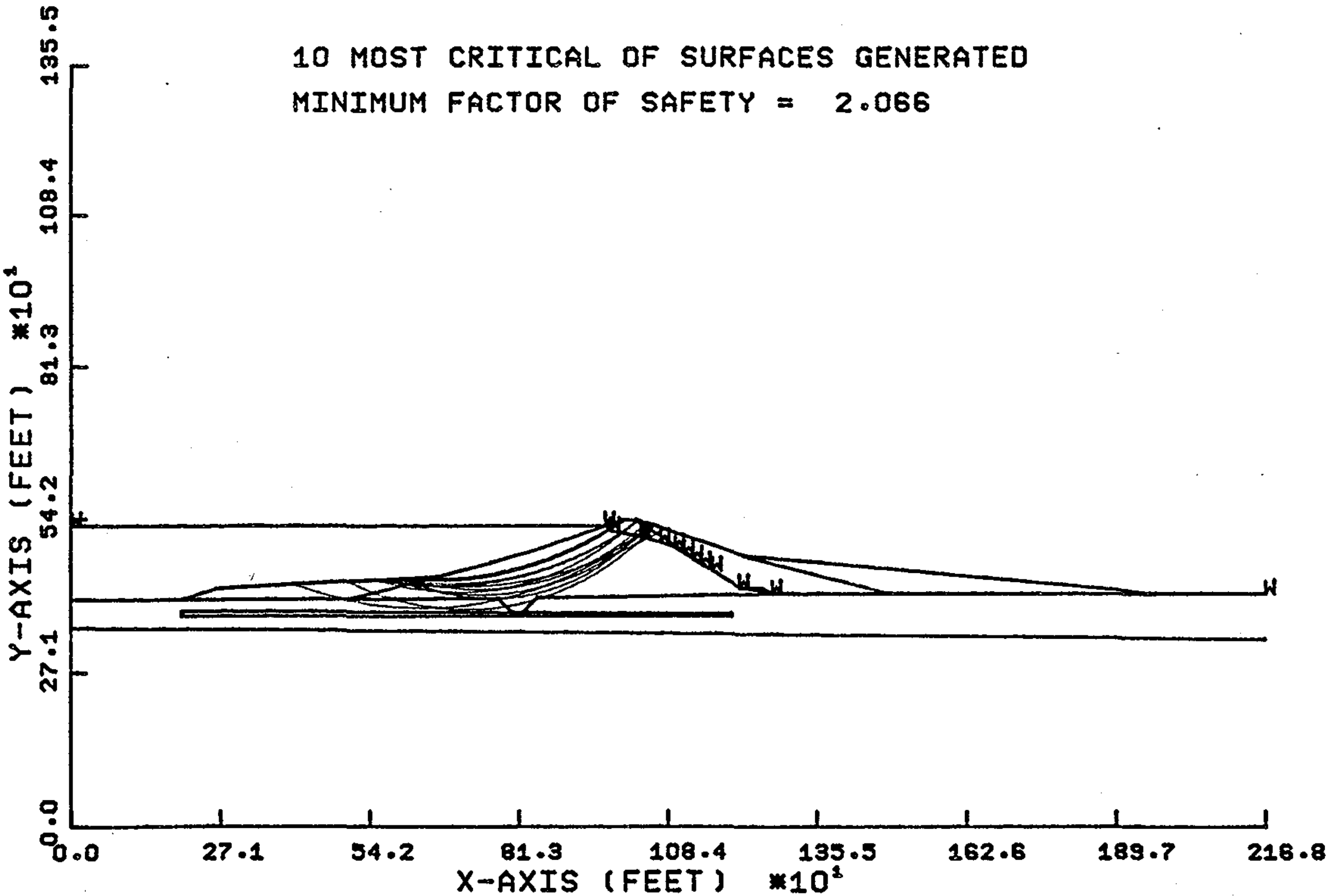


FIGURE H-2

CLE ELUM DAM UPSTREAM SLOPE
RAPID DRAWDOWN

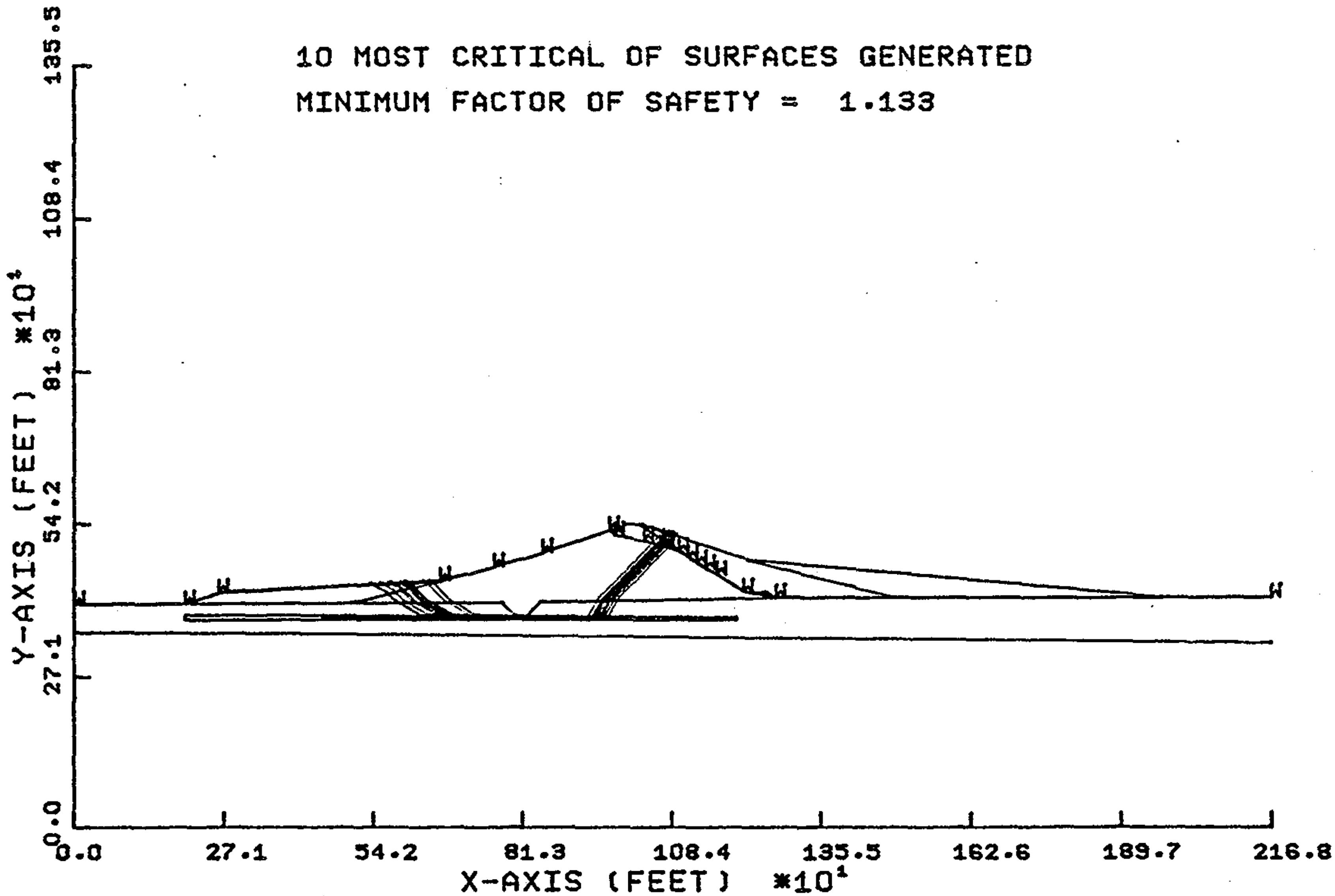
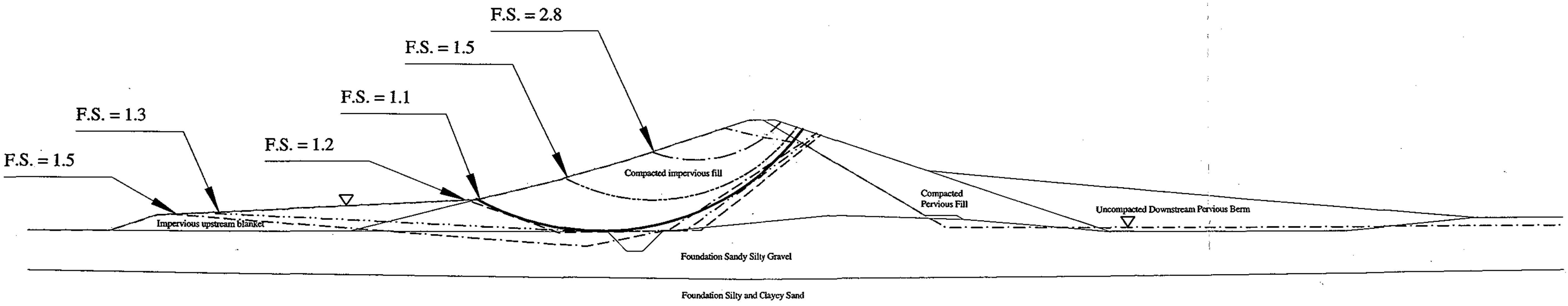


FIGURE H-3



NOTES:

1. Factor of safety values computed using an undrained shear strength for the compacted impervious fill layer, corresponding to a critical factor of safety equal to 1.1.
2. Stability analyses performed using UTEXAS3 program with the Spencer method.
3. Material strengths obtained from previous SEED report, as follows:

Material	Unit Weight (pcf)	Effective Friction Angle, ϕ' (degrees)	Cohesion (psf)	Undrained Shear Strength, s_u (psf)
Impervious U/S blanket	115	30	0	–
Compacted impervious fill (U/S)	137	30	0	2000
Compacted pervious fill (D/S)	120	33	0	–
Uncompacted D/S pervious berm	115	30	0	–
Foundation sandy silty gravel (coarse-grained)	115	31	0	–
Foundation silty and clayey sand (finer-grained)	110	30	0	–

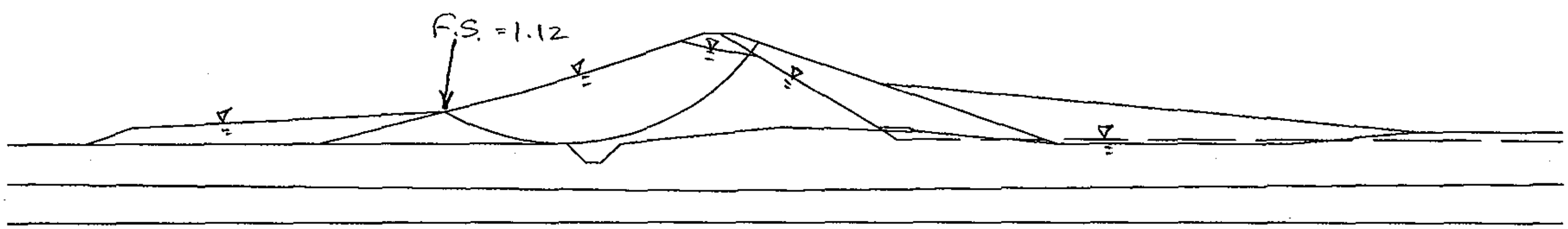
FS-CE-RD.TCW

CLE ELUM DAM
YAKIMA PROJECT
CLE ELUM, WASHINGTON

Figure:	H-4
Project No.	68-FOD97287.00
Prepared By:	KAF
Date:	2/19/99

UPSTREAM RAPID DRAWDOWN STABILITY ANALYSIS

FIGURE H-5



- Rapid Drawdown Conditions

CE-RD1

```
HEADING================================================
***** CLE ELUM DAM - Cle Elum, Washington -- Stability Analysis *****
WC Project No. D97287    Maximum Section
File: CE-RD1.IN By: KAF Date: 2/19/99
PROFILE LINES==========================================
1 1 Impervious upstream blanket
        100     110
        160     130
        560     150

2 2 Compacted impervious fill
        400     110
        560     150
        660     175
        747.5   200
        897.5   250
        917.5   250

3 3 Compacted pervious fill
        917.5   250
        932.5   250
        1124.5  186

4 4 Uncompacted pervious berm
        1124.5  186
        1813.8  125

5 3 Compacted pervious fill
        1124.5  186
        1352.5  110

6 2 Compacted impervious fill
        917.5   250
        1121.5  130
        1161.5  130
        1170    125

7 5 Foundation (coarse)
        0       110
        400     110
        720     110
        745     085
        765     085
        790     110
        1000    130
        1170    125
        1352.5  110
        1650    110
        1813.8  125
        2000    125
```

```
8 6 Foundation (fine)
        0       060
        900     050
        2000    060

9 7 Foundation
        0       10
        1000    10
        2000    10


MATERIAL=======================
1 Impervious upstream blanket
 115
Conventional Shear
 0 30
Piezometric Line
1
2 Compacted impervious fill
 137
Conventional Shear
 2000 0
Piezometric Line
1
3 Compacted pervious fill
 120
Conventional Shear
 0 33
Piezometric Line
1
4 Uncompacted pervious berm
 115
Conventional Shear
 0 30
Piezometric Line
1
5 Foundation (coarse)
115
Conventional Shear
 0 31
Piezometric Line
1
6 Foundation (fine)
110
Conventional Shear
 0 30
Piezometric Line
1
7 Foundation Soils
110
Conventional Shear
```

```
 0 30
Piezometric Line
1

PIEZOMETRIC LINE DATA============
 1 62.4
        0       110
        100     110
        160     130
        560     150
        660     175
        747.5   200
        867.5   240
        910     230
        968.5   220
        1121.5  130
        1147    115
        1500    115
        1650    115
        1813.8  115
        2000    115


ANALYSIS========================
CIRCULAR search
        750     250     5       0
TANGENT
        100

PLOT============================
COMPUTE=========================
```

Appendix I

APPENDIX I

Correlated N_{60} Values from Becker Blowcounts

Problem: Correct Becker closed-bit penetration data from the 1998 Cle Elum Dam field investigation to the Standard Penetration Test (SPT) N_{60}-values.

Given: Raw Becker blowcounts and bounce chamber pressures; Pile Drive Analyzer (PDA) data from GRL; AP-1000 drill rig with ICE 180 diesel pile hammer; 6.6" O.D. casing.

Assumptions: (1) As stated.

Solution:

(1) HARDER & SEED (1986) METHOD

I. Elevation Correction for Becker Blowcounts

- Correct bounce chamber pressures for elevation to sea level
  - at an elevation of 6000 ft, the adjustment would be 3.7 at a bounce chamber pressure (BCP) of 6 psi; for a BCP of 20 psi, the correction would be 6.2

Let: $A = \frac{(3.7 \cdot EL)}{6000}$ (Eqn. 1) $B = \frac{(6.2 \cdot EL)}{6000}$ (Eqn. 2)

where EL is elevation in feet.

Then,

$$BCP_{El.corrected} = \frac{BCP_{uncorrected} - 6}{14} \cdot (B - A) + A + BCP_{uncorrected} \quad \text{(Eqn. 3)}$$

- Correct Becker blowcounts using the corrected BCP and Figure I-1.

II. Blowcount Correction for Rig Type

- Correct to AP-1000 rig values, if using B-180 drill rig:

$$N_{bcAP1000} = 1.5 \cdot N_{bcB180} \quad \text{(Eqn. 4)}$$

- Correct Becker blowcounts for rig type by multiplying by rig factor. Because an AP-1000 rig was used, the factor is 1.

III. Correlate Corrected Becker Blowcount to SPT N_{60}

- Use correlation curve, Figure I-2. Please note that the correlation curve includes data for N_B up to 100 blows. This curve has been extrapolated to correlate beyond this range
- Approximate correlation curve is as follows:

$$0.1362 + (1.0621 \cdot N_{bc}) - (0.0065867 \cdot N_{bc}^2) + (0.000030243 \cdot N_{bc}^3) = N_{60} \quad \text{(Eqn. 5)}$$

(obtained from Becker calculation spreadsheet used by Reclamation)

(2) SY (1997) METHOD

I. Correct Becker Blowcounts for Energy

- Correct to 30% of the manufacturer's rated energy using the measured ENTHRU (from pile drive analyzer, PDA, data).
- ENTHRU = measured maximum transferred energy as % of the rated energy of 11.0 kJ.

$$N_{b30} = N_{bc} \cdot \frac{ENTHRU}{30} \qquad \text{(Eqn. 6)}$$

- Measured ENTHRU obtained from PDA tests. For depths where PDA data were not recorded, a constant ENTHRU value of 40% was used.

II. Shaft Resistance Correction

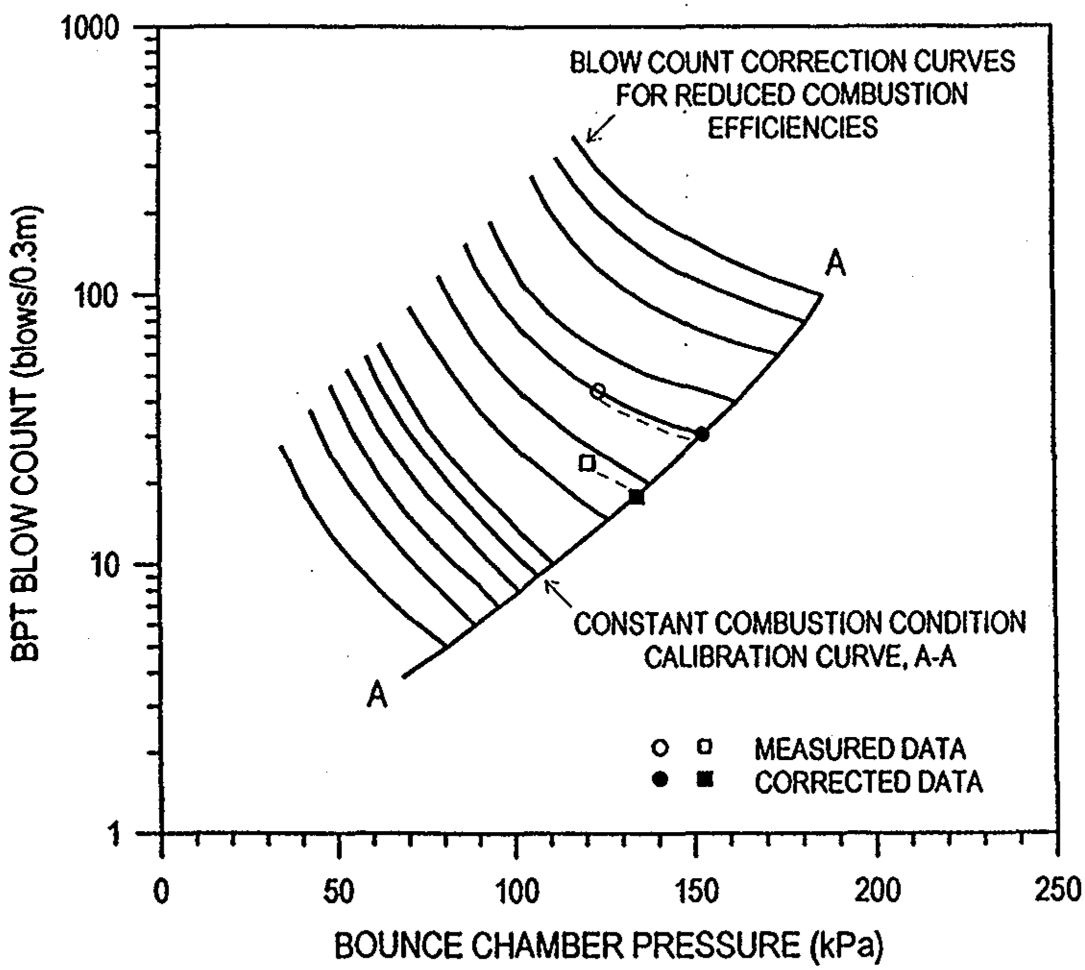
- The shaft resistance correction, R_s, is typically obtained from Case Pile Wave Analysis Program (CAPWAP) data.
- In the absence of CAPWAP data, the following generic correlation for gravel sites can be used:

$$R_s(\text{gravel sites}) = Y + 25 \cdot Y^{0.5} \qquad \text{(in kN)} \qquad \text{(Eqn. 7)}$$

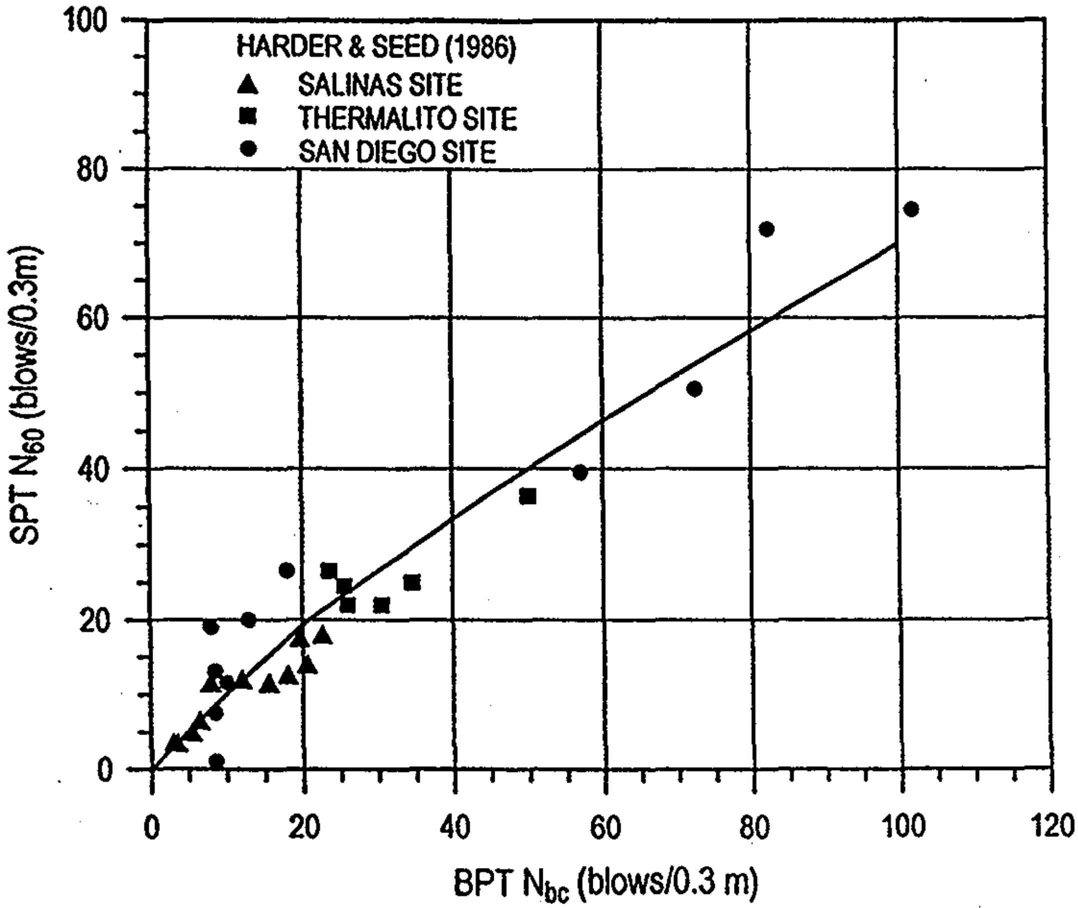
where Y = depth (in meters)

III. Correlate Corrected Blowcounts to SPT N_{60}

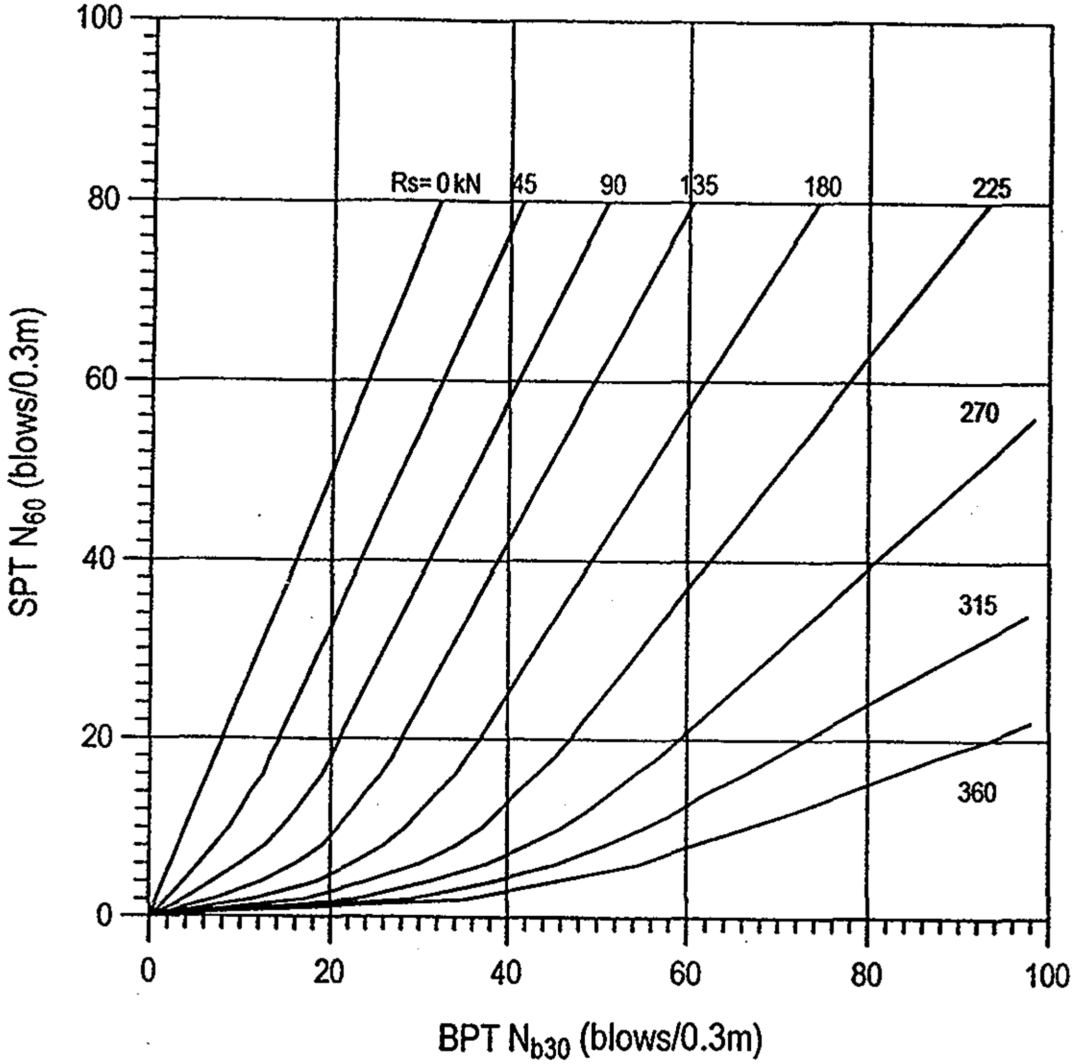
- Use N_{b30} and R_s values with Sy (1997) correlation to determine SPT N_{60} from Figure I-3. Please note that the correlation curves include points up to N_B = 100 blows. These curves have been extrapolated to correlate beyond this range.



Project No. 68F0D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	**Constant Combustion Correction Curve (Harder & Seed, 1986)**	Figure I-1
URS Greiner Woodward Clyde			



Project No. 68F0D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Correlation Between Corrected Becker & SPT Blowcounts (Harder & Seed, 1986)	Figure I-2
URS Greiner Woodward Clyde			



Project No. 68F0D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	Correlation Between Corrected Becker & SPT Blowcounts (Sy, 1997)	Figure I-3
URS Greiner Woodward Clyde			

Name of Dam: Cle Elum Dam, WA
Hole Designation: BDH98-1
Drilled by: Layne Christensen
Drill Rig: AP1000 drill rig equipped with ICE 180 hammer

		Raw Data		Harder & Seed (1986) Method							Sy (1997) Method			
Depth (ft)	ELEV. (ft)	BCP (psi)	N_B Closed	A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Measured ENTHRU	N_{b30}	Rs	N_{60}
1	2183.94	13	7	1.34676	2.25674	14.80	8	1	8	8	40	9	14	10
2	2182.94	13	7	1.34615	2.2557	14.80	8	1	8	8	40	9	20	10
3	2181.94	13	8	1.34553	2.25467	14.80	8	1	8	8	40	11	25	12
4	2180.94	13	6	1.34491	2.25364	14.80	7	1	7	7	40	8	29	8
5	2179.94	14	10	1.3443	2.2526	15.86	9	1	9	9	40	13	32	22
6	2178.94	15	15	1.34368	2.25157	16.93	12	1	12	12	40	20	36	36
7	2177.94	15	16	1.34306	2.25054	16.93	13	1	13	13	40	21	39	38
8	2176.94	15	13	1.34245	2.2495	16.93	11	1	11	11	40	17	41	30
9	2175.94	16	19	1.34183	2.24847	17.99	15	1	15	15	40	25	44	46
10	2174.94	17	37	1.34121	2.24744	19.05	27	1	27	25	40	49	47	94
11	2173.94	18	55	1.3406	2.2464	20.12	43	1	43	36	40	73	49	142
12	2172.94	17	80	1.33998	2.24537	19.05	52	1	52	42	40	107	51	208
13	2171.94	17	89	1.33936	2.24434	19.05	55	1	55	44	40	119	54	232
14	2170.94	17	97	1.33875	2.2433	19.05	57	1	57	45	40	129	56	254
15	2169.94	Readings not recorded for this depth												
16	2168.94	16	210	1.33751	2.24124	17.98	60	1	60	47	40	280	60	556
17	2167.94	18	415	1.3369	2.2402	20.11	169	1	169	137	40	553	62	1102
18	2166.94	18	400	1.33628	2.23917	20.11	169	1	169	137	40	533	64	1062
19	2165.94	19	497	1.33566	2.23814	21.17	189	1	189	170	30	497	66	990
20	2164.94	18	572	1.33505	2.2371	20.11	169	1	169	137	26	496	68	986
21	2163.94	18	410	1.33443	2.23607	20.11	169	1	169	137	28	383	70	700
22	2162.94	18	300	1.33381	2.23504	20.11	134	1	134	97	33	330	71	603
23	2161.94	18	182	1.3332	2.234	20.11	93	1	93	66	36	218	73	392
24	2160.94	19	235	1.33258	2.23297	21.17	123	1	123	87	35	274	75	497
25	2159.94	19	237	1.33196	2.23194	21.17	124	1	124	88	36	284	77	516
26	2158.94	19	260	1.33135	2.2309	21.17	133	1	133	96	36	312	78	569
27	2157.94	15	282	1.33073	2.22987	16.91	71	1	71	53	35	329	80	601
28	2156.94	15	361	1.33011	2.22884	16.91	83	1	83	60	34	409	82	751
29	2155.94	17	404	1.3295	2.2278	19.04	147	1	147	110	33	444	83	817
30	2154.94	15	280	1.32888	2.22677	16.91	71	1	71	53	35	327	85	595
31	2153.94	14	333	1.32826	2.22574	15.84	55	1	55	43	32	355	86	650
32	2152.94	15	271	1.32765	2.2247	16.90	70	1	70	52	33	298	88	542
33	2151.94	18	182	1.32703	2.22367	20.10	93	1	93	66	40	243	89	437
34	2150.94	16	245	1.32641	2.22264	17.97	67	1	67	51	40	327	91	595
35	2149.94	14	251	1.3258	2.2216	15.84	51	1	51	41	38	318	92	578
36	2148.94	14	256	1.32518	2.22057	15.84	51	1	51	41	38	324	94	591
37	2147.94	14	227	1.32456	2.21954	15.84	49	1	49	40	38	288	95	522
38	2146.94	15	206	1.32395	2.2185	16.90	60	1	60	47	37	254	97	460
39	2145.94	15	261	1.32333	2.21747	16.90	68	1	68	51	39	339	98	620
40	2144.94	18	238	1.32271	2.21644	20.09	112	1	112	79	36	286	99	518
41	2143.94	18	144	1.3221	2.2154	20.09	79	1	79	58	35	168	101	298

		Raw Data		Harder & Seed (1986) Method							Sy (1997) Method			
Depth (ft)	ELEV. (ft)	BCP (psi)	N_B Closed	A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	ENTHRU	N_{530}	Rs	N_{60}
42	2142.94	18	107	1.32148	2.21437	20.09	66	1	66	51	39	139	102	244
43	2141.94	18	108	1.32086	2.21334	20.09	67	1	67	51	39	140	104	245
44	2140.94	18	117	1.32025	2.2123	20.08	70	1	70	53	36	140	105	245
45	2139.94	18	177	1.31963	2.21127	20.08	91	1	91	65	35	207	106	370
46	2138.94	16	166	1.31901	2.21024	17.96	55	1	55	43	34	188	108	336
47	2137.94	15	290	1.3184	2.2092	16.89	73	1	73	54	33	319	109	582
48	2136.94	18	260	1.31778	2.20817	20.08	120	1	120	85	36	312	110	569
49	2135.94	17	360	1.31716	2.20714	19.02	135	1	135	98	41	492	112	907
50	2134.94	19	473	1.31655	2.2061	21.14	189	1	189	170	36	568	113	1048
51	2133.94	20	400	1.31593	2.20507	22.21	179	1	179	153	37	493	114	859
52	2132.94	20	338	1.31531	2.20404	22.20	157	1	157	122	38	428	115	742
53	2131.94	21	223	1.3147	2.203	23.27	117	1	117	83	40	297	117	507
54	2130.94	21	165	1.31408	2.20197	23.27	99	1	99	70	39	215	118	357
55	2129.94	20	155	1.31346	2.20094	22.20	93	1	93	66	40	207	119	343
56	2128.94	21	160	1.31285	2.1999	23.26	98	1	98	69	38	203	120	336
57	2127.94	21	134	1.31223	2.19887	23.26	90	1	90	65	40	179	122	292
58	2126.94	20	72	1.31161	2.19784	22.20	58	1	58	45	40	96	123	145
59	2125.94	20	42	1.311	2.1968	22.20	37	1	37	32	30	42	124	48
60	2124.94	13	61	1.31038	2.19577	14.75	22	1	22	21	30	61	125	82
61	2123.94	15	30	1.30976	2.19474	16.88	19	1	19	18	31	31	126	28
62	2122.94	18	38	1.30915	2.1937	20.07	32	1	32	28	38	48	128	58
63	2121.94	20	45	1.30853	2.19267	22.19	43	1	43	36	38	57	129	75
64	2120.94	21	63	1.30791	2.19164	23.25	56	1	56	44	39	82	130	118
65	2119.94	21	128	1.3073	2.1906	23.25	88	1	88	63	40	171	131	278
66	2118.94	21	320	1.30668	2.18957	23.25	146	1	146	109	39	416	132	721
67	2117.94	21	500	1.30606	2.18854	23.25	170	1	170	139	39	650	133	1142
68	2116.94	21	960	1.30545	2.1875	23.25	170	1	170	139	38	1216	135	1500
69	2115.94	21	960	1.30483	2.18647	23.25	170	1	170	139	35	1120	136	1500
70	2114.94	21	116	1.30421	2.18544	23.25	85	1	85	61	45	174	137	285
71	2113.94	21	150	1.3036	2.1844	23.25	95	1	95	68	45	225	138	377
72	2112.94	21	93	1.30298	2.18337	23.25	75	1	75	56	45	140	139	222

By: KAF
Date: 2/3/00

Checked by: KEL
Date: 2/3/00

Name of Dam: Cle Elum Dam, WA
Hole Designation: BDH98-1B
Drilled by: Layne Christensen
Drill Rig: AP1000 drill rig equipped with ICE 180 hammer

		Raw Data		Harder & Seed (1986) Method							Sy (1997) Method			
Depth (ft)	ELEV. (ft)	BCP (psi)	N_B Closed	A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Measured ENTHRU	N_{b30}	Rs	N_{60}
1	2182.16	10.63	13	1.34567	2.2549	12.28	8	1	8	8	40	17	14	30
2	2181.16	11.69	7	1.34505	2.25387	13.40	7	1	7	7	40	9	20	10
3	2180.16	11.69	8	1.34443	2.25283	13.40	7	1	7	7	40	11	25	12
4	2179.16	10.96	8	1.34382	2.2518	12.63	6	1	6	6	40	11	29	12
5	2178.16	12.12	11	1.3432	2.25077	13.86	8	1	8	8	40	15	32	24
6	2177.16	12.58	10	1.34258	2.24973	14.35	9	1	9	9	40	13	36	22
7	2176.16	11.37	10	1.34197	2.2487	13.06	8	1	8	8	40	13	39	22
8	2175.16	11.21	8	1.34135	2.24767	12.89	6	1	6	6	40	11	41	12
9	2174.16	9.3	15	1.34073	2.24663	10.85	7	1	7	7	40	20	44	36
10	2173.16	9.74	6	1.34012	2.2456	11.32	5	1	5	5	26	5	47	5
11	2172.16	9.24	7	1.3395	2.24457	10.79	5	1	5	5	22	5	49	5
12	2171.16	9.53	6	1.33888	2.24353	11.10	5	1	5	5	30	6	51	6
13	2170.16	12.9	9	1.33827	2.2425	14.68	8	1	8	8	36	11	54	12
14	2169.16	16.77	26	1.33765	2.24147	18.80	20	1	20	19	36	31	56	58
15	2168.16	20.02	37	1.33703	2.24043	22.26	35	1	35	31	37	46	58	86
16	2167.16	22.85	57	1.33642	2.2394	25.27	57	1	57	45	39	74	60	144
17	2166.16	23.66	155	1.3358	2.23837	26.13	112	1	112	79	36	186	62	368
18	2165.16	22.69	246	1.33518	2.23733	25.10	134	1	134	97	33	271	64	536
19	2164.16	22.73	324	1.33457	2.2363	25.14	157	1	157	122	33	356	66	708
20	2163.16	20.43	304	1.33395	2.23527	22.69	145	1	145	108	33	334	68	664
21	2162.16	19	462	1.33333	2.23423	21.17	189	1	189	170	30	462	70	851
22	2161.16	16.92	673	1.33272	2.2332	18.96	103	1	103	73	27	606	71	1120
23	2160.16	17.58	522	1.3321	2.23217	19.66	147	1	147	110	32	557	73	1028
24	2159.16	19.41	364	1.33148	2.23113	21.60	175	1	175	146	33	400	75	734
25	2158.16	18.09	299	1.33087	2.2301	20.20	134	1	134	97	32	319	77	580
26	2157.16	21.85	294	1.33025	2.22907	24.20	141	1	141	104	40	392	78	719
27	2156.16	22.89	594	1.32963	2.22803	25.30	180	1	180	154	41	812	80	1500
28	2155.16	24.19	516	1.32902	2.227	26.69	185	1	185	163	45	774	82	1437
29	2154.16	23.75	494	1.3284	2.22597	26.22	185	1	185	163	42	692	83	1281
30	2153.16	23.54	499	1.32778	2.22493	25.99	180	1	180	154	43	715	85	1326
31	2152.16	23.67	497	1.32717	2.2239	26.13	185	1	185	163	45	746	86	1383
32	2151.16	23.35	433	1.32655	2.22287	25.79	180	1	180	154	43	621	88	1148
33	2150.16	21.98	447	1.32593	2.22183	24.33	173	1	173	143	39	581	89	1075
34	2149.16	23.32	290	1.32532	2.2208	25.75	147	1	147	110	41	396	91	727
35	2148.16	22.46	277	1.3247	2.21977	24.84	136	1	136	99	40	369	92	676
36	2147.16	23.92	262	1.32408	2.21873	26.39	144	1	144	106	46	402	94	736
37	2146.16	24.16	346	1.32347	2.2177	26.64	169	1	169	137	45	519	95	958
38	2145.16	24.84	331	1.32285	2.21667	27.37	192	1	192	176	44	485	97	894
39	2144.16	24.65	306	1.32223	2.21563	27.16	182	1	182	158	45	459	98	845
40	2143.16	24.08	307	1.32162	2.2146	26.55	157	1	157	122	38	389	99	712
41	2142.16	24.51	220	1.321	2.21357	27.01	148	1	148	111	45	330	101	603

By: KAF
Date: 2/3/00

Checked by: VAR
Date: 2/3/00

Depth (ft)	ELEV. (ft)	Raw Data BCP (psi)	N_B Closed	Harder & Seed (1986) Method A	B	$BCP_{ELcorrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Sy (1997) Method Estimated ENTHRU	N_{b30}	Rs	N_{60}
42	2141.16	23.39	310	1.32038	2.21253	25.82	153	1	153	117	43	444	102	817
43	2140.16	24.45	203	1.31977	2.2115	26.94	126	1	126	90	48	325	104	591
44	2139.16	24.84	211	1.31915	2.21047	27.36	144	1	144	107	47	331	105	603
45	2138.16	24.67	272	1.31853	2.20943	27.18	169	1	169	137	46	417	106	766
46	2137.16	24.93	368	1.31792	2.2084	27.45	207	1	207	206	45	552	108	1020
47	2136.16	24.08	590	1.3173	2.20737	26.55	185	1	185	163	42	826	109	1500
48	2135.16	24.55	554	1.31668	2.20633	27.05	220	1	220	237	44	813	110	1500
49	2134.16	24.91	325	1.31607	2.2053	27.43	190	1	190	172	45	488	112	898
50	2133.16	22.49	358	1.31545	2.20427	24.85	160	1	160	126	40	477	113	879
51	2132.16	21.59	431	1.31483	2.20323	23.89	170	1	170	139	38	546	114	953
52	2131.16	23.89	245	1.31422	2.2022	26.34	139	1	139	101	44	359	115	618
53	2130.16	21.67	231	1.3136	2.20117	23.98	119	1	119	84	39	300	117	512
54	2129.16	22.9	120	1.31298	2.20013	25.28	96	1	96	68	45	180	118	296
55	2128.16	23.93	100	1.31237	2.1991	26.38	95	1	95	68	45	150	119	242
56	2127.16	21	93	1.31175	2.19807	23.26	75	1	75	56	44	136	120	217
57	2126.16	21.96	81	1.31113	2.19703	24.28	72	1	72	54	42	113	122	175
58	2125.16	20.33	86	1.31052	2.196	22.55	64	1	64	49	40	115	123	177
59	2124.16	23.74	135	1.3099	2.19497	26.17	106	1	106	74	42	189	124	312
60	2123.16	25.08	163	1.30928	2.19393	27.59	125	1	125	89	42	228	125	382
61	2122.16	24.79	161	1.30867	2.1929	27.29	124	1	124	89	40	215	126	357
62	2121.16	24.97	161	1.30805	2.19187	27.48	124	1	124	89	42	225	128	377
63	2120.16	26.06	514	1.30743	2.19083	28.63	255	1	255	344	45	771	129	1360
64	2119.16	26.25	1243	1.30682	2.1898	28.83	255	1	255	344	47	1947	130	1500
65	2118.16	26	1368	1.3062	2.18877	28.57	255	1	255	344	48	2189	131	1500
66	2117.16	24.6	1524	1.30558	2.18773	27.08	220	1	220	237	46	2337	132	1500
67	2116.16	24.5	1199	1.30497	2.1867	26.97	185	1	185	163	46	1838	133	1500
68	2115.16	24.33	1284	1.30435	2.18567	26.79	185	1	185	163	49	2097	135	1500
69	2114.16	24.88	1405	1.30373	2.18463	27.37	220	1	220	237	39	1827	136	1500

Name of Dam:	Cle Elum Dam, WA		***Drilled by:***	Layne Christensen										
Hole Designation:	BDH98-2		***Drill Rig:***	AP1000 drill rig equipped with ICE 180 hammer										

		Raw Data		Harder & Seed (1986) Method							Sy (1997) Method			
Depth (ft)	ELEV. (ft)	BCP (psi)	N_B Closed	A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Measured ENTHRU	N_{b30}	Rs	N_{60}
1	2152.72	10.46	14	1.32751	2.22448	12.07	8	1	8	8	40	19	14	32
2	2151.72	12.28	11	1.32689	2.22344	14.01	9	1	9	9	40	15	20	24
3	2150.72	11.98	6	1.32628	2.22241	13.69	6	1	6	6	40	8	25	8
4	2149.72	12.54	8	1.32566	2.22138	14.28	8	1	8	8	40	11	29	12
5	2148.72	12.75	4	1.32504	2.22034	14.51	6	1	6	6	40	5	32	5
6	2147.72	12.37	8	1.32443	2.21931	14.10	8	1	8	8	40	11	36	12
7	2146.72	15.38	20	1.32381	2.21828	17.30	16	1	16	16	40	27	39	48
8	2145.72	12.08	12	1.32319	2.21724	13.79	8	1	8	8	30	12	41	20
9	2144.72	8.5	17	1.32258	2.21621	9.98	7	1	7	7	32	18	44	32
10	2143.72	11.11	6	1.32196	2.21518	12.76	6	1	6	6	32	6	47	6
11	2142.72	12.69	10	1.32134	2.21414	14.44	9	1	9	9	34	11	49	16
12	2141.72	12.59	11	1.32073	2.21311	14.33	9	1	9	9	34	12	51	20
13	2140.72	12.8	11	1.32011	2.21208	14.55	9	1	9	9	36	13	54	22
14	2139.72	13.23	11	1.31949	2.21104	15.01	10	1	10	10	36	13	56	22
15	2138.72	14.36	14	1.31888	2.21001	16.21	12	1	12	12	39	18	58	32
16	2137.72	17.28	18	1.31826	2.20898	19.32	17	1	17	16	42	25	60	46
17	2136.72	18.66	30	1.31764	2.20794	20.78	26	1	26	24	45	45	62	86
18	2135.72	15.79	18	1.31703	2.20691	17.73	14	1	14	14	43	26	64	46
19	2134.72	14.33	11	1.31641	2.20588	16.18	10	1	10	10	42	15	66	26
20	2133.72	10.48	18	1.31579	2.20484	12.08	9	1	9	9	21	13	68	20
21	2132.72	12.78	10	1.31518	2.20381	14.53	9	1	9	9	39	13	70	12
22	2131.72	18.1	18	1.31456	2.20278	20.18	19	1	19	18	41	25	71	27
23	2130.72	18.92	26	1.31394	2.20174	21.05	25	1	25	23	43	37	73	52
24	2129.72	17.11	17	1.31333	2.20071	19.13	17	1	17	16	46	26	75	31
25	2128.72	15.89	13	1.31271	2.19968	17.83	12	1	12	12	45	20	77	18
26	2127.72	14.43	11	1.31209	2.19864	16.28	10	1	10	10	44	16	78	14
27	2126.72	13.63	9	1.31148	2.19761	15.42	9	1	9	9	41	12	80	11
28	2125.72	14.58	11	1.31086	2.19658	16.43	10	1	10	10	43	16	82	13
29	2124.72	15	9	1.31024	2.19554	16.88	10	1	10	10	43	13	83	11
30	2123.72	13.05	12	1.30963	2.19451	14.81	9	1	9	9	26	10	85	9
31	2122.72	13	11	1.30901	2.19348	14.75	9	1	9	9	31	11	86	10
32	2121.72	13.7	11	1.30839	2.19244	15.49	10	1	10	10	38	14	88	12
33	2120.72	13.66	10	1.30778	2.19141	15.45	9	1	9	9	40	13	89	12
34	2119.72	15.18	11	1.30716	2.19038	17.07	12	1	12	12	43	16	91	13
35	2118.72	19.31	27	1.30654	2.18934	21.46	26	1	26	24	42	38	92	52
36	2117.72	25.05	52	1.30593	2.18831	27.56	57	1	57	45	48	83	94	138
37	2116.72	26.26	61	1.30531	2.18728	28.84	68	1	68	51	47	96	95	161
38	2115.72	25.68	118	1.30469	2.18624	28.22	114	1	114	80	47	185	97	328
39	2114.72	25.39	172	1.30408	2.18521	27.91	129	1	129	92	45	258	98	467
40	2113.72	22.95	232	1.30346	2.18418	25.32	130	1	130	93	39	302	99	548
41	2112.72	25.42	246	1.30284	2.18314	27.94	158	1	158	123	44	361	101	659

By: KAF
Date: 2/3/00

Checked by: KSR
Date: 2/3/00

Depth (ft)	ELEV. (ft)	Raw Data BCP (psi)	N_B Closed	Harder & Seed (1986) Method A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Sy (1997) Method Estimated ENTHRU	N_{b30}	Rs	N_{60}
42	2111.72	25.99	440	1.30223	2.18211	28.55	255	1	255	344	44	645	102	1195
43	2110.72	25.59	595	1.30161	2.18108	28.12	255	1	255	344	46	912	104	1500
44	2109.72	26.16	724	1.30099	2.18004	28.73	255	1	255	344	45	1086	105	1500
45	2108.72	26.37	483	1.30038	2.17901	28.95	255	1	255	344	46	741	106	1373
46	2107.72	26.65	347	1.29976	2.17798	29.25	229	1	229	260	46	532	108	982
47	2106.72	26.6	303	1.29914	2.17694	29.19	207	1	207	205	48	485	109	892
48	2105.72	26.52	187	1.29853	2.17591	29.10	149	1	149	112	44	274	110	497
49	2104.72	25.24	158	1.29791	2.17488	27.74	123	1	123	88	39	205	112	368
50	2103.72	21.74	127	1.29729	2.17384	24.02	91	1	91	65	35	148	113	260
51	2102.72	26.66	91	1.29668	2.17281	29.25	96	1	96	68	52	158	114	255
52	2101.72	26.43	91	1.29606	2.17178	29.00	96	1	96	68	50	152	115	244
53	2100.72	25.41	90	1.29544	2.17074	27.92	92	1	92	66	47	141	117	226
54	2099.72	25.97	109	1.29483	2.16971	28.51	110	1	110	77	46	167	118	273
55	2098.72	25.31	119	1.29421	2.16868	27.81	108	1	108	76	45	179	119	292
56	2097.72	25.91	173	1.29359	2.16764	28.45	142	1	142	104	46	265	120	449
57	2096.72	26.85	231	1.29298	2.16661	29.44	171	1	171	140	48	370	122	636
58	2095.72	26.55	225	1.29236	2.16558	29.12	168	1	168	135	47	353	123	606
59	2094.72	26.9	188	1.29174	2.16454	29.49	149	1	149	112	48	301	124	512
60	2093.72	22.04	119	1.29113	2.16351	24.33	89	1	89	64	43	171	125	278
61	2092.72	26.9	92	1.29051	2.16248	29.49	97	1	97	69	53	163	126	264
62	2091.72	27.18	126	1.28989	2.16144	29.79	118	1	118	83	50	210	128	350
63	2090.72	26.84	184	1.28928	2.16041	29.43	147	1	147	110	48	294	129	501
64	2089.72	25.52	116	1.28866	2.15938	28.02	113	1	113	80	44	170	130	278
65	2088.72	26.16	133	1.28804	2.15834	28.70	122	1	122	86	46	204	131	337
66	2087.72	26.65	159	1.28743	2.15731	29.22	135	1	135	97	47	249	132	420
67	2086.72	24.64	140	1.28681	2.15628	27.08	116	1	116	82	43	201	133	332
68	2085.72	24.97	103	1.28619	2.15524	27.43	101	1	101	72	44	151	135	244
69	2084.72	25.22	102	1.28558	2.15421	27.70	101	1	101	71	45	153	136	247
70	2083.72	24.43	88	1.28496	2.15318	26.86	85	1	85	61	43	126	137	199
71	2082.72	25.44	93	1.28434	2.15214	27.93	94	1	94	67	51	158	138	256
72	2081.72	24.56	103	1.28373	2.15111	26.99	96	1	96	68	47	161	139	262
73	2080.72	24.63	89	1.28311	2.15008	27.07	91	1	91	65	46	136	140	217
74	2079.72	25.01	114	1.28249	2.14904	27.47	106	1	106	74	47	179	141	292
75	2078.72	25.24	146	1.28188	2.14801	27.71	118	1	118	84	46	224	142	373
76	2077.72	26.04	147	1.28126	2.14698	28.56	129	1	129	92	50	245	143	413
77	2076.72	26.28	114	1.28064	2.14594	28.81	112	1	112	79	51	194	145	319
78	2075.72	25.95	123	1.28003	2.14491	28.46	117	1	117	82	50	205	146	341
79	2074.72	25.44	186	1.27941	2.14388	27.92	134	1	134	97	48	298	147	507
80	2073.72	25.48	356	1.27879	2.14284	27.96	202	1	202	196	46	546	148	953
81	2072.72	26.11	536	1.27818	2.14181	28.63	255	1	255	344	48	858	149	1500
82	2071.72	26	600	1.27756	2.14078	28.51	255	1	255	344	48	960	150	1500
83	2070.72	25.01	591	1.27694	2.13974	27.46	220	1	220	237	46	906	151	1500
84	2069.72	24.18	900	1.27633	2.13871	26.58	185	1	185	163	45	1350	152	1500
85	2068.72	26.8	608	1.27571	2.13768	29.36	255	1	255	344	48	973	153	1500
86	2067.72	26.25	489	1.27509	2.13664	28.77	255	1	255	344	47	766	154	1351
87	2066.72	25.23	353	1.27448	2.13561	27.69	201	1	201	194	44	518	155	903
88	2065.72	25.05	302	1.27386	2.13458	27.50	181	1	181	156	43	433	156	750
89	2064.72	24.27	255	1.27324	2.13354	26.67	142	1	142	104	40	340	157	584
90	2063.72	24.7	216	1.27263	2.13251	27.12	146	1	146	109	42	302	158	421
91	2062.72	24.66	185	1.27201	2.13148	27.08	134	1	134	97	45	278	159	383

By: KAF
Date: 2/3/00

Checked by: KAF
Date: 2/3/00

Depth (ft)	ELEV. (ft)	Raw Data: BCP (psi)	Raw Data: N_B Closed	Harder & Seed (1986) Method: A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Sy (1997) Method: Estimated ENTHRU	N_{b30}	Rs	N_{60}
92	2061.72	25.33	165	1.27139	2.13044	27.79	126	1	126	90	47	259	160	355
93	2060.72	25.82	194	1.27078	2.12941	28.31	152	1	152	116	49	317	161	442
94	2059.72	25.6	191	1.27016	2.12838	28.07	151	1	151	114	49	312	162	434
95	2058.72	25.28	160	1.26954	2.12734	27.73	124	1	124	88	48	256	163	352
96	2057.72	25.16	162	1.26893	2.12631	27.60	125	1	125	89	47	254	164	347
97	2056.72	25.11	178	1.26831	2.12528	27.55	131	1	131	94	47	279	166	385
98	2055.72	24.84	184	1.26769	2.12424	27.26	134	1	134	97	47	288	167	400
99	2054.72	24.67	196	1.26708	2.12321	27.08	138	1	138	101	45	294	168	409
100	2053.72	25.45	273	1.26646	2.12218	27.91	169	1	169	138	49	446	169	635
101	2052.72	25.54	414	1.26584	2.12114	28.00	220	1	220	237	47	649	169	940
102	2051.72	25.92	573	1.26523	2.12011	28.40	255	1	255	344	48	917	170	1500
103	2050.72	25.57	544	1.26461	2.11908	28.03	255	1	255	344	47	852	171	1500
104	2049.72	24.36	397	1.26399	2.11804	26.74	184	1	184	161	44	582	172	841
105	2048.72	23.27	260	1.26338	2.11701	25.59	138	1	138	101	42	364	173	514
106	2047.72	23.79	244	1.26276	2.11598	26.14	138	1	138	101	43	350	174	491
107	2046.72	23.34	420	1.26214	2.11494	25.66	180	1	180	154	41	574	175	829
108	2045.72	23.9	905	1.26153	2.11391	26.25	185	1	185	163	42	1267	176	1500
OPEN BIT DRILLING CONDUCTED FROM 108 TO 122 FEET.														
123	2030.72	22.7	301	1.25228	2.09841	24.96	143	1	143	106	34	341	191	479
124	2029.72	22.74	362	1.25166	2.09738	25.00	169	1	169	137	47	567	191	818
125	2028.72	23.42	262	1.25104	2.09634	25.72	139	1	139	101	46	402	192	569
126	2027.72	22.23	160	1.25043	2.09531	24.46	101	1	101	71	50	267	193	367
127	2026.72	20.94	125	1.24981	2.09428	23.09	87	1	87	63	46	192	194	254
128	2025.72	23.24	116	1.24919	2.09324	25.53	95	1	95	67	44	170	195	223
129	2024.72	23.48	189	1.24858	2.09221	25.78	117	1	117	82	51	321	196	449
130	2023.72	23.64	213	1.24796	2.09118	25.95	124	1	124	88	48	341	197	478
131	2022.72	23.38	239	1.24734	2.09014	25.67	132	1	132	95	49	390	198	553
132	2021.72	22.82	255	1.24673	2.08911	25.08	137	1	137	99	48	408	199	580
133	2020.72	22.55	217	1.24611	2.08808	24.79	118	1	118	84	47	340	200	476
134	2019.72	22.94	173	1.24549	2.08704	25.20	112	1	112	79	45	260	201	356
135	2018.72	22.11	86	1.24488	2.08601	24.32	76	1	76	56	49	140	202	178
136	2017.72	21.71	87	1.24426	2.08498	23.90	71	1	71	53	47	136	202	172
137	2016.72	22.25	87	1.24364	2.08394	24.47	76	1	76	56	45	131	203	126
138	2015.72	22.93	60	1.24303	2.08291	25.19	60	1	60	47	48	96	204	83
139	2014.72	23.17	79	1.24241	2.08188	25.44	74	1	74	55	49	129	205	125
140	2013.72	22.72	95	1.24179	2.08084	24.96	80	1	80	58	50	158	206	162
141	2012.72	23	186	1.24118	2.07981	25.26	116	1	116	82	46	285	207	324
142	2011.72	22.82	1363	1.24056	2.07878	25.07	180	1	180	154	47	2135	208	1500

By: KAF
Date: 2/3/00

Checked by: KEL
Date: 2/3/00

Name of Dam: Cle Elum Dam, WA
Hole Designation: BDH98-3
Drilled by: Layne Christensen
Drill Rig: AP1000 drill rig equipped with ICE 180 hammer

		Raw Data		Harder & Seed (1986) Method							Sy (1997) Method			
Depth (ft)	ELEV. (ft)	BCP (psi)	N_B Closed	A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Measured ENTHRU	N_{b30}	Rs	N_{60}
1	2128.53	6.299	25	1.31259	2.19948	7.63	6	1	6	6	40	33	14	62
2	2127.53	7.01	11	1.31198	2.19845	8.39	6	1	6	6	40	15	20	24
3	2126.53	9.71	7	1.31136	2.19741	11.26	6	1	6	6	40	9	25	10
4	2125.53	12.01	10	1.31074	2.19638	13.70	8	1	8	8	40	13	29	22
5	2124.53	12.71	11	1.31013	2.19535	14.44	9	1	9	9	40	15	32	24
6	2123.53	11.89	11	1.30951	2.19431	13.57	8	1	8	8	40	15	36	24
7	2122.53	12.85	12	1.30889	2.19328	14.59	9	1	9	9	40	16	39	28
8	2121.53	13.2	11	1.30828	2.19225	14.96	9	1	9	9	40	15	41	24
9	2120.53	12.17	12	1.30766	2.19121	13.87	8	1	8	8	40	16	44	28
10	2119.53	17.38	31	1.30704	2.19018	19.40	24	1	24	22	40	41	47	78
11	2118.53	17.79	26	1.30643	2.18915	19.84	23	1	23	21	40	35	49	64
12	2117.53	18.8	35	1.30581	2.18811	20.91	29	1	29	26	40	47	51	88
13	2116.53	16.75	29	1.30519	2.18708	18.73	22	1	22	21	40	39	54	72
14	2115.53	14.31	17	1.30458	2.18605	16.14	13	1	13	13	40	23	56	40
15	2114.53	16.92	25	1.30396	2.18501	18.91	20	1	20	19	40	33	58	62
16	2113.53	20.68	55	1.30334	2.18398	22.91	48	1	48	39	39	72	60	138
17	2112.53	19.81	85	1.30273	2.18295	21.98	63	1	63	48	35	99	62	194
18	2111.53	20.86	111	1.30211	2.18191	23.10	83	1	83	60	31	115	64	224
19	2110.53	21.12	14	1.30149	2.18088	23.37	20	1	20	19	32	15	66	24
20	2109.53	23.16	308	1.30088	2.17985	25.54	152	1	152	116	39	400	68	796
21	2108.53	24.69	272	1.30026	2.17881	27.16	169	1	169	137	41	372	70	680
22	2107.53	25.16	232	1.29964	2.17778	27.66	153	1	153	117	41	317	71	578
23	2106.53	25.04	265	1.29903	2.17675	27.53	166	1	166	133	41	362	73	663
24	2105.53	24.95	199	1.29841	2.17571	27.44	140	1	140	102	44	292	75	529
25	2104.53	24.68	207	1.29779	2.17468	27.15	143	1	143	106	45	311	77	565
26	2103.53	25.01	167	1.29718	2.17365	27.50	127	1	127	91	45	251	78	452
27	2102.53	25.03	144	1.29656	2.17261	27.52	118	1	118	83	45	216	80	388
28	2101.53	25.01	137	1.29594	2.17158	27.49	115	1	115	81	45	206	82	368
29	2100.53	25.01	157	1.29533	2.17055	27.49	123	1	123	87	45	236	83	424
30	2099.53	24.78	168	1.29471	2.16951	27.25	127	1	127	91	47	263	85	477
31	2098.53	26.23	196	1.29409	2.16848	28.79	153	1	153	117	47	307	86	559
32	2097.53	25.8	202	1.29348	2.16745	28.33	156	1	156	120	46	310	88	563
33	2096.53	25.04	140	1.29286	2.16641	27.52	116	1	116	82	44	205	89	368
34	2095.53	24.73	125	1.29224	2.16538	27.19	110	1	110	78	44	183	91	326
35	2094.53	24.47	109	1.29163	2.16435	26.91	98	1	98	69	45	164	92	289
36	2093.53	23.13	73	1.29101	2.16331	25.49	69	1	69	52	43	105	94	178
37	2092.53	22.25	67	1.29039	2.16228	24.55	62	1	62	48	43	96	95	163
38	2091.53	22.86	78	1.28978	2.16125	25.20	73	1	73	54	43	112	97	191
39	2090.53	23.72	106	1.28916	2.16021	26.11	97	1	97	69	43	152	98	266
40	2089.53	24.59	137	1.28854	2.15918	27.03	115	1	115	81	47	215	99	385
41	2088.53	25.69	144	1.28793	2.15815	28.20	127	1	127	91	49	235	101	424

By: KAF
Date: 2/3/00

Checked by: KEP
Date: 2/8/00

Depth (ft)	ELEV. (ft)	Raw Data BCP (psi)	N_B Closed	Harder & Seed (1986) Method A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Sy (1997) Method Estimated ENTHRU	N_{b30}	Rs	N_{60}
42	2087.53	25.64	146	1.28731	2.15711	28.15	128	1	128	92	51	248	102	448
43	2086.53	26.14	159	1.28669	2.15608	28.68	135	1	135	97	51	270	104	490
44	2085.53	26.12	221	1.28608	2.15505	28.65	166	1	166	133	52	383	105	702
45	2084.53	24	123	1.28546	2.15401	26.40	102	1	102	72	50	205	106	368
46	2083.53	24.01	126	1.28484	2.15298	26.41	103	1	103	73	50	210	108	377
47	2082.53	24.8	140	1.28423	2.15195	27.25	116	1	116	82	50	233	109	420
48	2081.53	25.28	183	1.28361	2.15091	27.76	133	1	133	96	49	299	110	542
49	2080.53	26.03	319	1.28299	2.14988	28.55	215	1	215	223	51	542	112	1001
50	2079.53	24.38	361	1.28238	2.14885	26.80	173	1	173	144	52	626	113	1157
51	2078.53	24.53	446	1.28176	2.14781	26.96	185	1	185	163	52	773	114	1363
52	2077.53	24.86	271	1.28114	2.14678	27.31	168	1	168	137	50	452	115	784
53	2076.53	24.95	256	1.28053	2.14575	27.40	162	1	162	128	49	418	117	724
54	2075.53	25.49	354	1.27991	2.14471	27.97	202	1	202	194	52	614	118	1075
55	2074.53	25.37	267	1.27929	2.14368	27.85	167	1	167	134	53	472	119	820
56	2073.53	24.52	174	1.27868	2.14265	26.94	117	1	117	83	53	307	120	525
57	2072.53	25.51	218	1.27806	2.14161	27.99	147	1	147	110	55	400	122	690
58	2071.53	26.11	202	1.27744	2.14058	28.63	156	1	156	120	57	384	123	661
59	2070.53	24.67	133	1.27683	2.13955	27.10	113	1	113	80	55	244	124	409
60	2069.53	23.72	146	1.27621	2.13851	26.09	109	1	109	77	57	277	125	471
61	2068.53	24.11	176	1.27559	2.13748	26.50	118	1	118	83	46	270	126	456
62	2067.53	22.98	212	1.27498	2.13645	25.30	124	1	124	88	43	304	128	517
63	2066.53	22.84	375	1.27436	2.13541	25.15	173	1	173	143	42	525	129	917
64	2065.53	26.42	269	1.27374	2.13438	28.95	190	1	190	171	48	430	130	746
65	2064.53	26.78	188	1.27313	2.13335	29.33	149	1	149	112	50	313	131	535
66	2063.53	25.93	201	1.27251	2.13231	28.43	156	1	156	120	47	315	132	537
67	2062.53	25.37	145	1.27189	2.13128	27.83	118	1	118	83	45	218	133	363
68	2061.53	25.88	208	1.27128	2.13025	28.37	159	1	159	124	45	312	135	534
69	2060.53	24.75	260	1.27066	2.12921	27.17	164	1	164	131	43	373	136	642
70	2059.53	25.26	403	1.27004	2.12818	27.71	220	1	220	237	47	631	137	1108
71	2058.53	24.59	332	1.26943	2.12715	27.00	165	1	165	131	42	465	138	807
72	2057.53	23.65	190	1.26881	2.12611	26.00	117	1	117	83	42	266	139	451
73	2056.53	22.67	184	1.26819	2.12508	24.96	108	1	108	76	40	245	140	413
74	2055.53	23.33	221	1.26758	2.12405	25.66	126	1	126	90	42	309	141	528
75	2054.53	23.38	212	1.26696	2.12301	25.71	124	1	124	88	41	290	142	492
76	2053.53	23.27	254	1.26634	2.12198	25.59	136	1	136	99	41	347	143	597
77	2052.53	23.02	360	1.26573	2.12095	25.33	168	1	168	136	40	480	145	836
78	2051.53	25.36	414	1.26511	2.11991	27.81	220	1	220	237	46	635	146	1113
79	2050.53	25.17	246	1.26449	2.11888	27.60	158	1	158	123	47	385	147	665
80	2049.53	24.66	207	1.26388	2.11785	27.06	143	1	143	106	47	324	148	555
81	2048.53	23.07	324	1.26326	2.11681	25.37	157	1	157	122	41	443	149	768
82	2047.53	22.89	350	1.26264	2.11578	25.18	165	1	165	132	40	467	150	811
83	2046.53	23.65	301	1.26203	2.11475	25.99	150	1	150	114	42	421	151	730
84	2045.53	23.87	238	1.26141	2.11371	26.22	136	1	136	99	42	333	152	571
85	2044.53	23.75	188	1.26079	2.11268	26.09	121	1	121	86	41	257	153	433
86	2043.53	24.2	215	1.26018	2.11165	26.57	130	1	130	93	43	308	154	526
87	2042.53	24.96	184	1.25956	2.11061	27.37	134	1	134	97	46	282	155	480
88	2041.53	25.12	196	1.25894	2.10958	27.54	138	1	138	101	47	307	156	525
89	2040.53	24.34	165	1.25833	2.10855	26.71	115	1	115	81	45	248	157	417
90	2039.53	24.51	165	1.25771	2.10751	26.89	115	1	115	81	47	259	158	355
91	2038.53	23.06	442	1.25709	2.10648	25.35	180	1	180	154	41	604	159	874

Depth	ELEV.	Raw Data		Harder & Seed (1986) Method							Sy (1997) Method			
Depth (ft)	ELEV. (ft)	BCP (psi)	N_B Closed	A	B	$BCP_{El.corrected}$ (psi)	El. Corrected N_{BC}	Rig Factor	Final N_{BC}	N_{60}	Estimated ENTHRU	N_{b30}	Rs	N_{60}
92	2037.53	22.8	428	1.25648	2.10545	25.08	180	1	180	154	40	571	160	823
93	2036.53	22.72	229	1.25586	2.10441	24.99	122	1	122	86	40	305	161	425
94	2035.53	22.66	133	1.25524	2.10338	24.92	93	1	93	66	40	177	162	233
95	2034.53	23.15	113	1.25463	2.10235	25.44	94	1	94	67	42	158	163	205
96	2033.53	24.17	81	1.25401	2.10131	26.52	79	1	79	58	45	122	164	149
97	2032.53	24	93	1.25339	2.10028	26.34	89	1	89	64	45	140	166	176
98	2031.53	24.47	113	1.25278	2.09925	26.84	99	1	99	70	46	173	167	227
99	2030.53	24.67	124	1.25216	2.09821	27.05	110	1	110	77	46	190	168	253
100	2029.53	24.8	255	1.25154	2.09718	27.19	162	1	162	128	41	349	169	490
101	2028.53	23.87	539	1.25093	2.09615	26.20	185	1	185	163	43	773	169	1126
102	2027.53	24.17	517	1.25031	2.09511	26.52	185	1	185	163	42	724	170	1052
103	2026.53	23.33	546	1.24969	2.09408	25.62	180	1	180	154	43	783	171	1141
104	2025.53	24.14	326	1.24908	2.09305	26.48	163	1	163	129	42	456	172	652
105	2024.53	23.92	346	1.24846	2.09201	26.25	169	1	169	137	43	496	173	710
106	2023.53	24.08	188	1.24784	2.09098	26.42	121	1	121	86	42	263	174	362
107	2022.53	24.24	539	1.24723	2.08995	26.59	185	1	185	163	42	755	175	1099
108	2021.53	24.32	600	1.24661	2.08891	26.67	185	1	185	163	38	760	176	1108
OPEN BIT DRILLING CONDUCTED FROM 108 TO 122 FEET.														
123	2006.53	20.71	37	1.23736	2.07341	22.83	35	1	35	31	45	56	191	50
124	2005.53	21.8	51	1.23674	2.07238	23.98	48	1	48	39	46	78	191	85
125	2004.53	22.39	78	1.23613	2.07135	24.60	70	1	70	53	48	125	192	154
126	2003.53	23.11	89	1.23551	2.07031	25.37	81	1	81	59	48	142	193	181
127	2002.53	23.28	108	1.23489	2.06928	25.54	92	1	92	66	47	169	194	221
128	2001.53	23.04	166	1.23428	2.06825	25.29	110	1	110	77	44	243	195	332
129	2000.53	23.04	206	1.23366	2.06721	25.29	122	1	122	86	41	282	196	389
130	1999.53	23.08	160	1.23304	2.06618	25.33	108	1	108	76	48	256	197	352
131	1998.53	23.81	224	1.23243	2.06515	26.10	132	1	132	95	48	358	198	505
132	1997.53	23.48	267	1.23181	2.06411	25.75	140	1	140	103	48	427	199	608
133	1996.53	22.97	115	1.23119	2.06308	25.21	95	1	95	67	48	184	200	244
134	1995.53	23.53	127	1.23058	2.06205	25.80	98	1	98	69	49	207	201	278
135	1994.53	23.99	219	1.22996	2.06101	26.29	131	1	131	94	50	365	202	515
136	1993.53	23.5	527	1.22934	2.05998	25.77	180	1	180	154	48	843	202	1500
137	1992.53	23.4	791	1.22873	2.05895	25.66	180	1	180	154	47	1239	203	1500
138	1991.53	23.55	1017	1.22811	2.05791	25.82	180	1	180	154	49	1661	204	1500
139	1990.53	23.66	924	1.22749	2.05688	25.93	180	1	180	154	47	1448	205	1500

N60-983x

By: KAF
Date: 2/3/00

Checked by: KAF
Date: 2/3/00

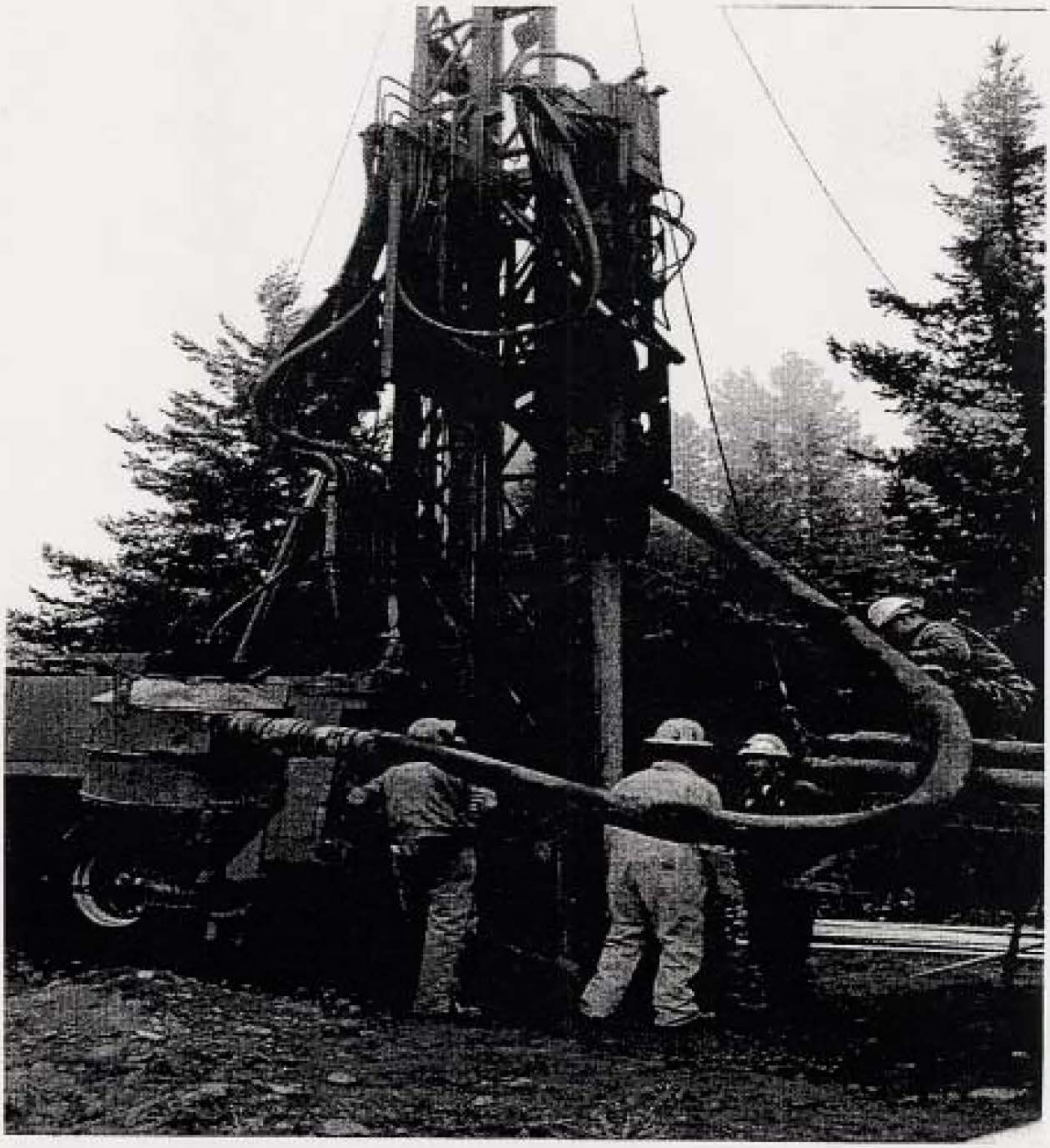
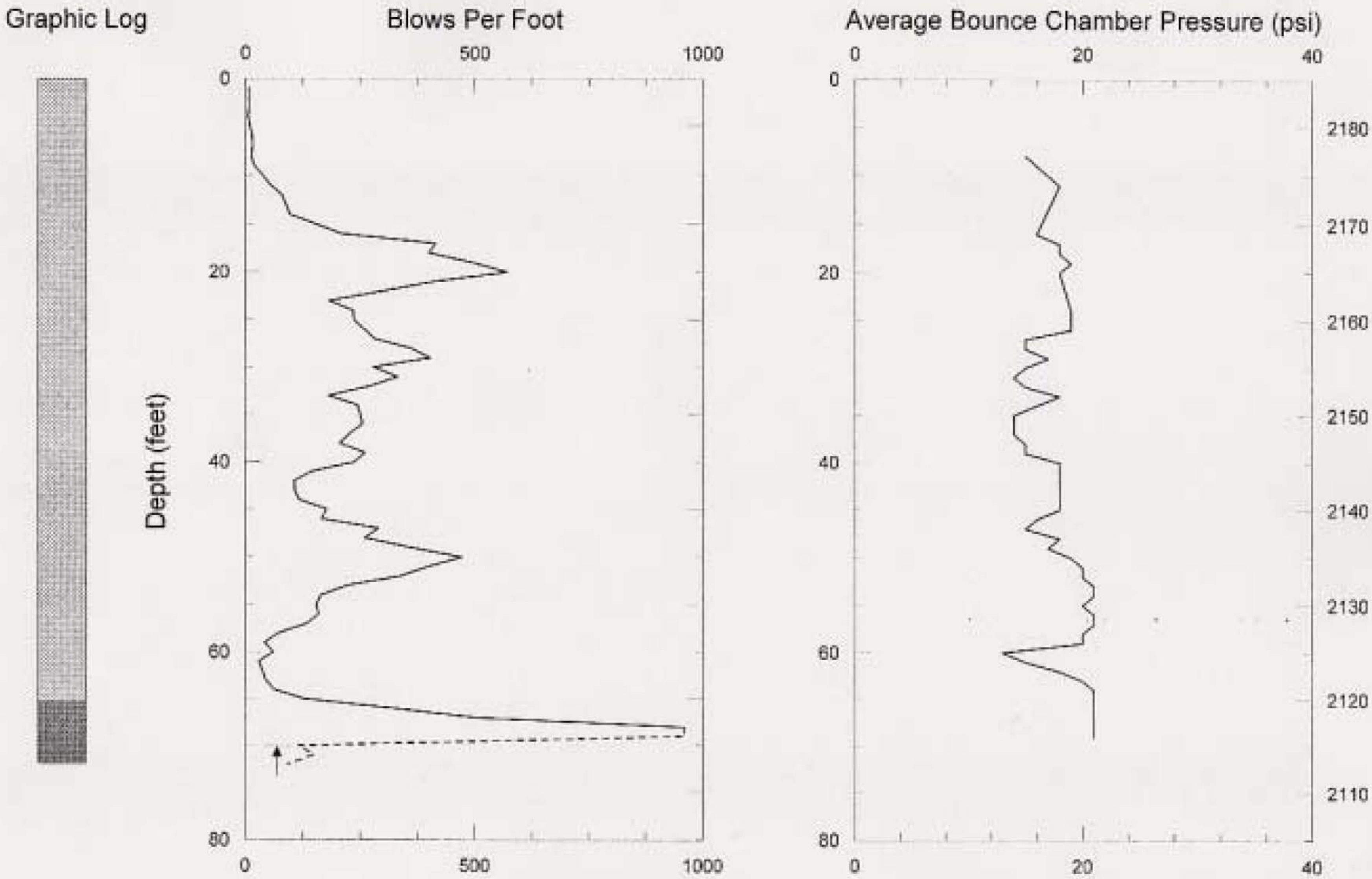


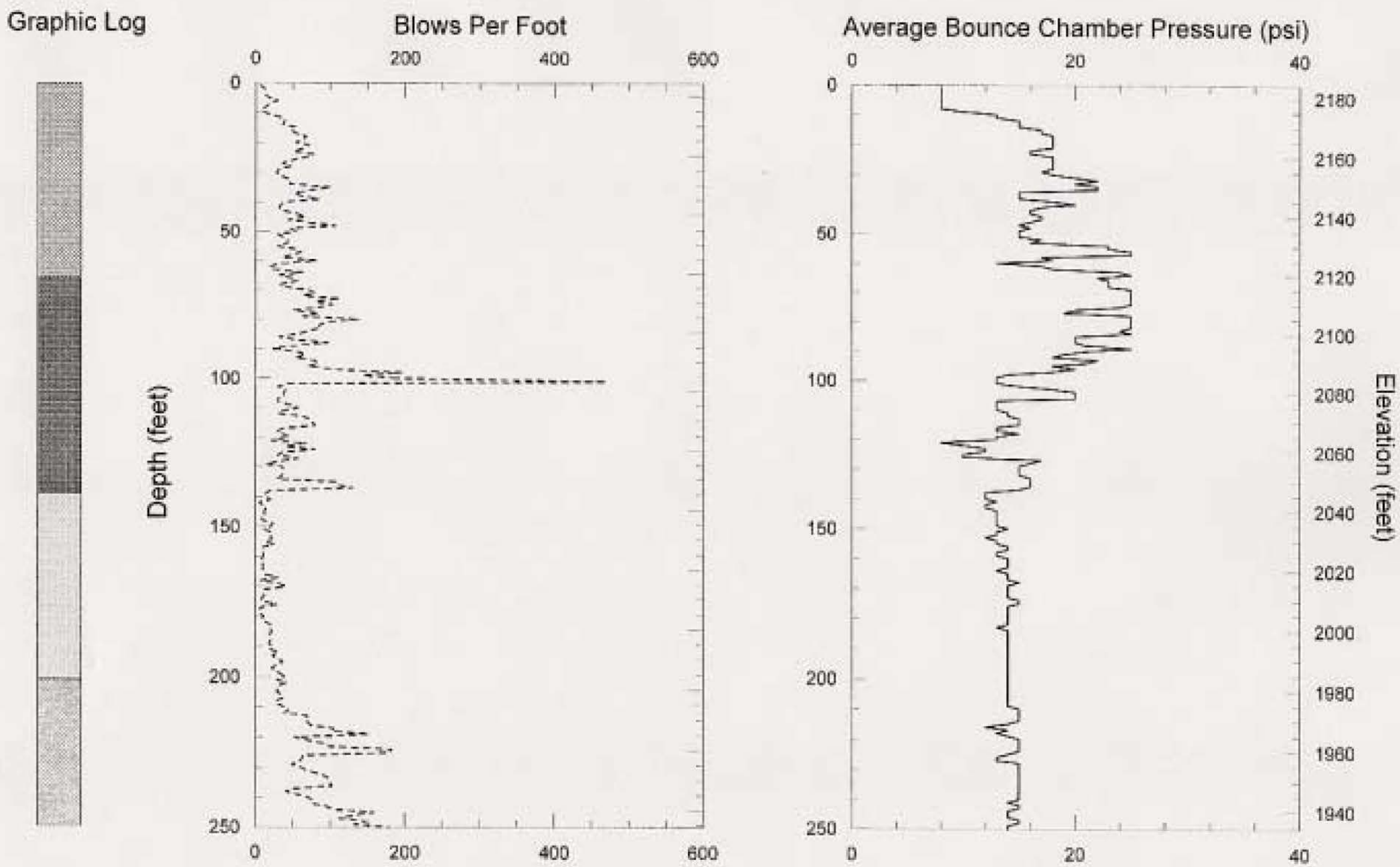
Figure B-1
BECKER SAMPLE HOLE BEING DRILLED AT CLE ELUM DAM



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-1	Figure B-3
Woodward-Clyde			

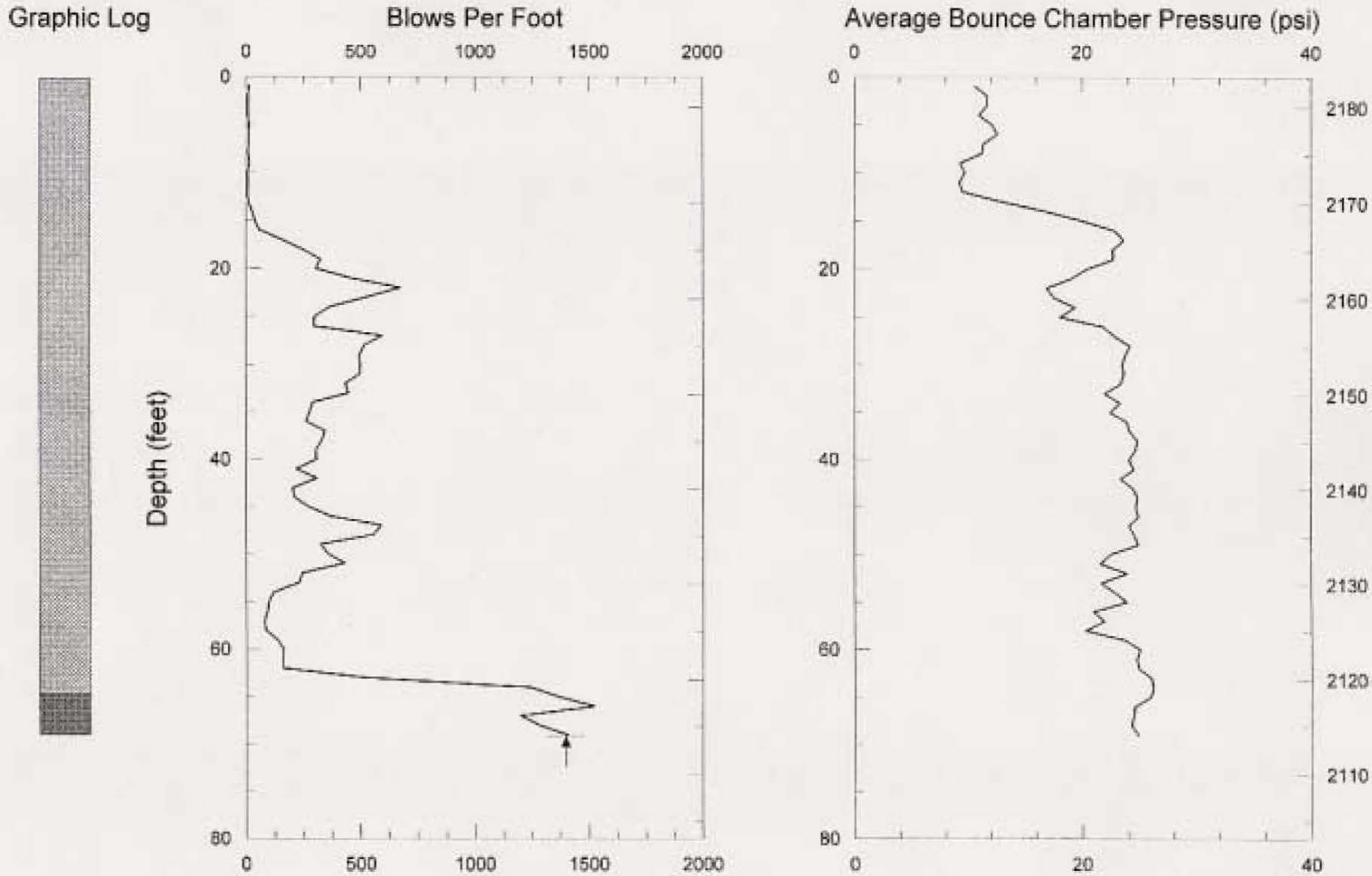
BDH98-1.GRF with bdh98-1.xls / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER SAMPLE HOLE BSH98-1	Figure B-4
Woodward-Clyde			

BSH98-1.GRF with bsh98-1.xls / 11/30/98 / KAF

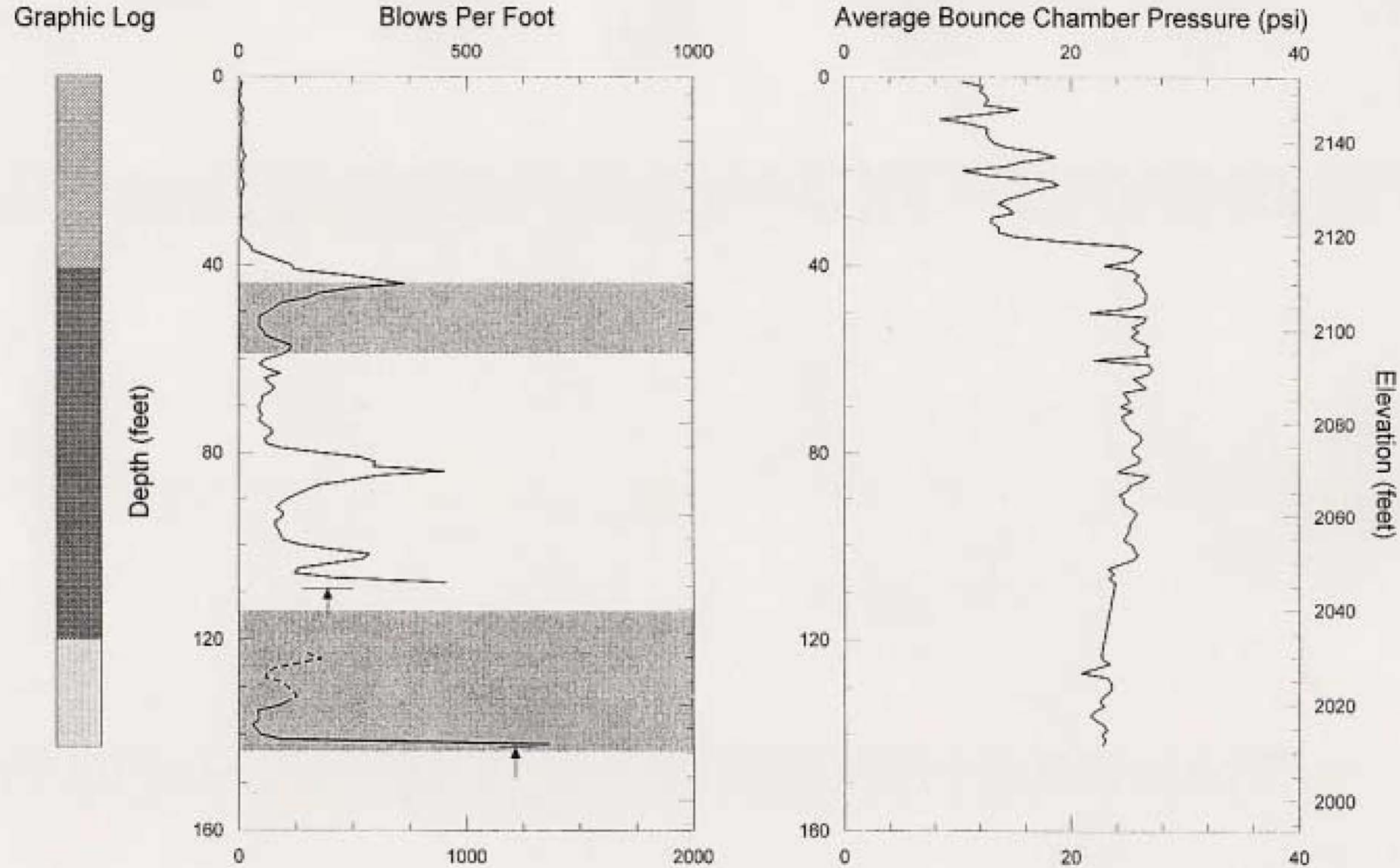


NOTES:

1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-1B	Figure B-5
Woodward-Clyde			

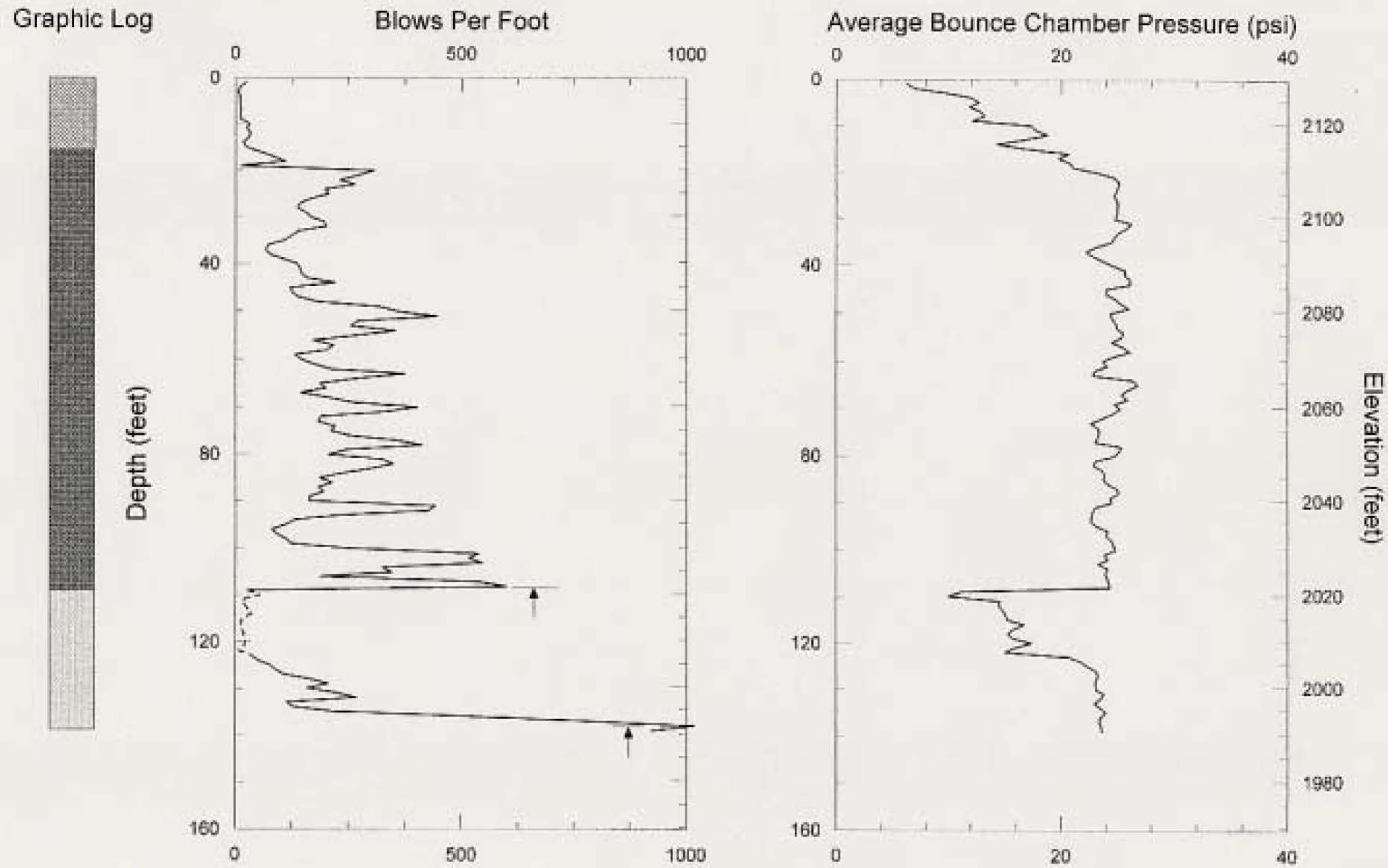
BDH98-1B.GRF with bdh98-1b.xls / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-2	Figure B-6
Woodward-Clyde			

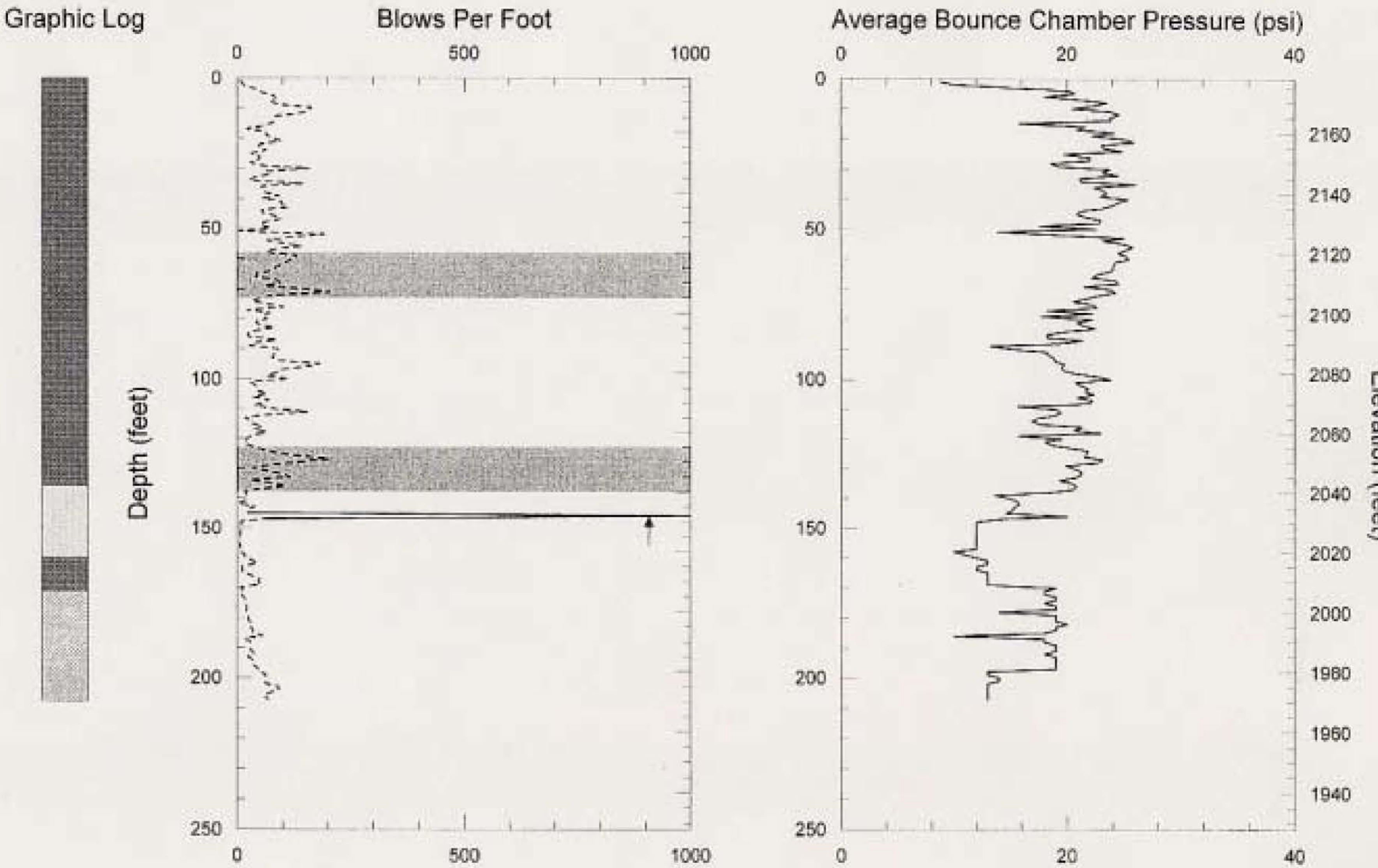
BDH98-2.GRF with bdh98-2.dat / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-3	Figure B-7
Woodward-Clyde			

BDH98-3.GRF with bdh98-3.xls / 11/30/98 / KAF



NOTES:
1. Legend and Notes on Figure B-9.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	BECKER DRILL HOLE BDH98-4	Figure B-8
Woodward-Clyde			

LEGEND

- EMBANKMENT AND/OR DOWNSTREAM BERM - FILL
- GLACIAL OUTWASH (COARSE-GRAINED) - SANDY GRAVELS, COBBLES, BOULDERS
- GLACIAL OUTWASH (FINE-GRAINED) - SAND
- LAKEBED SEDIMENTS - CLAY

- ——— CLOSED-BIT DRILLED INTERVAL
- ------ OPEN-BIT DRILLED INTERVAL
- ↑ PRACTICAL RIG REFUSAL
- LOWER SHEAR WAVE VELOCITY LAYER
- AREA WHERE LOWER OPEN-BIT BLOW COUNTS WERE RECORDED

NOTES

1. GRAPHIC LOGS ARE BASED ON SAMPLING, DRILLING RESISTANCE, AND KNOWLEDGE OF DAM CONSTRUCTION.
2. BECKER PENETRATION AND SAMPLE TESTS WERE DRILLED IN NOVEMBER OF 1998 BY LAYNE CHRISTENSEN OF TACOMA, WASHINGTON.
3. PRACTICAL RIG REFUSAL WAS DEFINED BY 400 BLOWS FOR 3 INCHES OR LESS PENETRATION.
4. LOWER SHEAR WAVE VELOCITY LAYERS WERE IDENTIFIED DURING THE 1992-93 CROSSHOLE SHEAR WAVE TESTS.
5. APPROXIMATE LOCATIONS OF BECKER TEST HOLES ARE SHOWN ON FIGURE B-2.

Project No. D97287	CLE ELUM DAM CLE ELUM, WASHINGTON	LEGEND AND NOTES	Figure B-9
	Woodward-Clyde		

LEGEND.GRF / 12/1998 / KAF