# APPENDIX E
# GEOTECHNICAL CONSIDERATIONS

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# SECTION 1 PROJECT GEOLOGY

## 1.1 GEOLOGIC SETTING

Eagle Gorge Reservoir (later renamed Howard A. Hanson Dam) was authorized by the Flood Control Act of 17 May 1950 (Public Law 516, 81st Congress, 2d Session), as a flood control project. Construction began in 1958 and was completed in February 1962. First water was impounded in December 1961. The project provides for a normal maximum reservoir capacity of 106,000 acre-feet of flood pool storage at elevation 1,206 feet which is in excess of the 100 year flood occurrence. During the summer a conservation pool to augment natural low flows and to provide water for the City of Tacoma is impounded at a maximum reservoir elevation of 1,141 (occasionally up to 1,145) feet.

Howard A. Hanson Dam is located on the Green River in western Washington. The dam spans a narrow rock canyon located 5 miles inside the western Cascade margin. To the east, the Cascade Range rises sharply to elevations over 7,000 feet. The Cascades are a complex mountain system composed of sedimentary, metamorphic, and intrusive and extrusive igneous rocks. The ancestral Green River was tributary to the Cedar River drainage prior to the glaciation of the Puget Sound Lowland. Before the last glacial event the river flowed out the North Fork Valley to the Cedar. During the Pleistocene, glacial ice extended eastward up into the alpine valley headwaters. The ice and subsequent moraines diverted the proto-Green River from its North Fork Valley exit to its present course where it emerges from the Cascade Mountain front south of the North Fork Valley. The diverted river flowed on a bedrock floor at elevation 1,000 feet in the river gorge. This gorge is presently buried north of the damsite. The nearest (southwest) rim of the ancestral valley is located several hundred feet northeast of the right abutment of Howard Hanson Dam.

During subsequent interglacial periods, the Green River cut its channel approximately 150 feet deeper resulting in oversteepened side slopes and collapse of the eastern valley side. Several episodes of deposition, erosion, and landsliding may have followed. The present gorge beneath the dam was cut as a result of river blockage by the last massive slide off the northeast valley wall. Today this landslide is a major landform forming part of the right abutment of Howard Hanson Dam, Plates E-1 and E-2.

## 1.2 TECTONIC AND SEISMIC SETTING

The present North Cascade Range was uplifted during the Late Tertiary by a series of complex folds and faults. One such fault was the Green River fault, see Plate E-1. The fault is a west-northwest trending zone of indefinite width; its map trace is some 1,500 feet

north of the dam. Active during the Miocene and/or Pliocene time the fault shows about 4,000 feet of horizontal right lateral movement through combination strike-slip and dip-slip components. Between the area of the dam and mountain front, the Green River exploits the fault zone and parallels its trace. The right abutment landslide obscures the fault trace at the dam. The fault zone probably contributed to the landslide and may be one of its causes (U.S. Army Corps of Engineers, 1983). In this area of the North Cascades, most major faults strike northwest and dip southwest. An exception is a major fault striking northeast across the damsite and dipping at high angle towards the northwest. This fault zone was dominant in the foundation of the dam structure. The dam is located in Seismic Zone 3 which corresponds to a seismic coefficient of 0.10 for the lateral earthquake force. The dam has a design earthquake analysis that identifies dynamic earthquake motions and response (U.S. Army Corps of Engineers, 1983). This engineering seismology study together with its update on page 27 in Position Paper on Seismic Hazard to Corps of Engineers Dams from Cascadian Subduction Zone Earthquakes, June 1994, USACE Seattle, Engineering District is sufficient for new construction.

## 1.3 SITE GEOLOGY

### 1.3.1 Bedrock

The Howard Hanson Dam project lies within a series of Tertiary age volcanic rocks. Locally, these rocks are known as the Eagle Gorge Andesite and regionally they correlate with the Fifes Peak formation of early Miocene age. Regional dip of the bedrock is 35° southeast. Bedrock at the project site is composed of andesitic and basaltic flows, tuffs, and breccias with associated basic and acidic dikes and sills. The entire assemblage is so faulted, sheared and hydrothermally altered that it has few mappable structures and stratigraphic patterns (U.S. Army Corps of Engineers, 1963). The Green River channel beneath the dam has been eroded in bedrock to approximately elevation 1,000 feet. The Howard Hanson Dam foundation report lists five distinct rock types found at the dam. These rock types are shown on Plate E-3 and a brief description follows:

- *Basalt*: Hard to moderately hard, dense, blocky, black, generally not badly affected by hydrothermal alteration or weathering, moderately fractured, occurring in the form of thin flows, dikes and sills.

- *Andesite*: Moderately hard, dense, dark green to dark gray, irregular to blocky fractures, sometimes massive, fine-grained to porphyritic, minor hydrothermal alteration.

- *Basalt Pyroclastics (Tuff)*: Moderately hard to soft, with medium grained, dark gray tuffaceous matrix with fragments of hard dense basalt. Highly susceptible to hydrothermal

alteration and weathering. This rock has a general agglomeratic texture with seams of pure tuff.

• *Andesite Pyroclastics (Tuff):* Soft, light gray, fine-grained matrix with moderately hard fragments, granular to agglomeratic texture. Generally highly altered by hydrothermal action, the rock deteriorates readily upon exposure to the atmosphere.

• *Felsite*: Hard, dense, light gray, occurs as dikes and sills.

(1) Left Abutment. The left abutment contains all of the above rock types. The bedrock is hard to moderately hard, except in the hydrothermally altered zones where the rock is predominantly soft. Bedrock is moderately to intensely fractured. Several fault and shear zones trending east-west and southeast-northwest were mapped in the canyon walls and inside the diversion tunnel during project construction.

(2) Right Abutment. At the dam, the right abutment is a short, sharp, narrow rock ridge dividing the present and ancestral Green River valleys. Bedrock rises steeply to elevation 1,150 feet, see Plate E-4, then drops away to elevation 850 feet into the ancestral valley. Bedrock is predominantly andesitic pyroclastics interspersed with zones of pure tuffs and intrusions of basaltic rocks. The rock is hydrothermally altered and weaker than most of the rock forming the left abutment.

### 1.3.2 Overburden

The overburden overlying left abutment rock is composed of silty, sandy gravel slopewash. On the right abutment overburden consists of landslide debris and both fluvial and lacustrine sediments.

### 1.3.3 Eagle Gorge Landslide (Right Abutment)

Landslide materials rest on the right abutment bedrock surface as well as fluvial and lacustrine deposits. Slide materials are composed of a heterogeneous assemblage of rock blocks as much as 20 feet in diameter and varying amounts of interstitial fine-grained material. Blocks are composed of volcanic tuffs and breccias. The slide surface rises northeastward to elevation 1,300 feet.

### 1.3.4 Groundwater

Rock joints and faults of various spacing and orientations occur in both abutments. Permeability within the rock depends on the width and interconnection of these features.

Groundwater originating from the adjacent hillside above the upstream left abutment has been found to be under moderate pressure. This condition was experienced in 1956 during the initial dam exploration program, again in 1960 during the construction of the existing diversion tunnel, and most recently in May, 1996, within a single exploration boring near the proposed fish passage facility footprint. The latter boring penetrated a pressurized water bearing unit at a depth of 143 feet and produced 40-gallon per minute flow at the surface. The unit was grouted 6 days later and flow was shutoff. The project crew have diverted the minor seepage draining from the overburden covered hillside south of the existing gate tower to prevent erosion of the access road. Within 200 feet south of the gate tower, the overburden covering the bedrock surface is as much as 75 feet thick.

Groundwater also occurs in the right abutment overburden materials, where at least two distinct overburden aquifers have been identified, see Section 3. Aquifer recharge is by precipitation runoff and by direct communication with the reservoir. Seepage through right abutment sediments and landslide debris had been recognized before construction of the dam. A 560-foot-long semi-impervious gravel/rock blanket was placed on the right abutment as part of the original construction to control seepage through the 2,000-foot-long ancient buried river channel (Galster, 1989).

## 1.4 RESERVOIR AREA

From the dam the reservoir area extends seven miles eastward up the Green River and four miles northerly up the North Fork, Plate E-1. Most of the overburden slope materials are glacial stream and lake deposits. Rocks bordering the reservoir are andesite flows, andesitic tuffs, and breccias which are typically hydrothermally altered and deeply weathered. Reservoir slope stability has not been a serious problem since water was first impounded to the conservation pool at elevation 1,141 feet in December 1961. Since the initial filling of the reservoir there have been four major flood pools that exceeded elevation 1,160 feet. The first flood occurred on 5 December 1975 with a peak of 1,175.8 feet. The second flood peaked at 1,173.6 feet on 4 December 1977. The third flood peaked at 1,167.2 feet on 1 December 1995. The fourth and maximum to date occurred on 10 February 1996 with a peak of 1,183.2 feet.

# SECTION 2 RESERVOIR SLOPE STABILITY

## 2.1 GENERAL

Slope stability issues around the reservoir are not considered to be detrimental as there are no developed lands or structures to be threatened other than a logging road and a railroad line. Reservoir landslides of damaging magnitude are not anticipated. The entire reservoir area was mapped by geologists during the early 1980s as part of a project seismic evaluation. Their original field maps are in Geology Section files. Other available information includes drill hole and test pit data completed in 1955 for the Northern Pacific Railway relocation. This information is available in Design Memorandum No. 4 and Supplements. Project personnel routinely cruise the lake looking for new and renewed slope movement and District geotechnical staff periodically check the reservoir slopes every 5 years and document their findings by memorandum.

The reservoir rim between elevations 1,170 feet and 1,210 feet will be impacted by the proposed additional water storage project. For this reason the Seattle District geotechnical staff have made several boat trips during 1993 through 1995 to assess potential for slope failure within the proposed pool raise area. They identified zones of current and potential instability, but observed no unstable slopes that would negatively impact project safety.

## 2.2 SLOPE FAILURE CRITERIA

The magnitude and type of slope failures vary with height, steepness, and composition of the slopes. For glaciolacustrine materials, failure is dependent on the sand-silt-clay ratio within the deposit, and on groundwater conditions. Steep slopes in glaciolacustrine deposits tend to fail by slumping, slump-earth flow landsliding and by calving. Slopes in free draining materials such as sand and gravel erode by raveling and tend to achieve stable slopes at 1V on 3H.

## 2.3 PRE- AND EARLY RESERVOIR LANDSLIDES

In 1995 a literature search was made for reports documenting existing landslides in the vicinity prior to filling of the reservoir. The only slide area documented is located on the west bank of Charley Creek, and is briefly discussed in Design Memorandum 19, Supplement No. 1. Although no as-built documents were found, office correspondence suggests that the Charley Creek slide was buttressed at the toe. Slides have been occurring at this site for many years and are independent of the reservoir's existence.

Soon after initial reservoir filling, a large slide occurred along the east side of the North Fork Green River. It was a quarter-mile-long slump failure of a terrace in glaciolacustrine sediments. Numerous springs were observed at the base of the terrace at elevation 1,125 feet. The slide was in a remote area and caused no damage to the project or private facilities (Galster, 1989).

## 2.4 RECENT LANDSLIDES

Wave erosion accounts for most of the numerous slip-off slides along the reservoir shoreline. Only one massive rotational slide has been documented since the reservoir filling. This slide occurred in early December 1995 following a period of intense rainfall. The actual causal factor for the slide was man-induced. The crest had been loaded with rock and soil debris trucked from an area further upstream. The rotational slide occurred 1.7 miles upstream of the dam at the downstream end of a rock canyon. The landslide is located on the south bank of the reservoir in the SW1/4 of the SW1/4 of Section 35, Township 21 North , Range 8 East, (W.M.) in King County, Washington. Vehicle access to the slide area is by way of the mainline Weyerhaeuser log haul road. A turnout large enough to park several pickup trucks is located near the mile post 16.5 marker.

During earlier site reconnaissance visits in 1993 and 1994 this landslide had been considered active. It was reported that remnants of an arc failure were found at the downstream end of the gorge, just upstream from the powerline crossing. Materials exposed in the slide headwall did not show any form of bedding, but rather displayed a heterogeneous mix of silt, sand and predominantly small "fist-size" angular rock fragments, similar to materials seen in a pyroclastic mudflow. The headwall materials were noted as unconsolidated and could be easily excavated with a small hand shovel. Project personnel reported that historically, this area was used as a waste site for landslide debris which had slid onto the railroad tracks and log haul road at a point further upstream. The materials were hauled to the site and end dumped. After the waste area had been filled to capacity the area apparently was leveled. Hundreds of small trees had grown on the surface. The waste pile was estimated to be 300 feet in length, 200 feet in width, and 30 feet thick. During 1994 it was concluded that renewed sliding would not threaten the operation of the project.

The landslide may have renewed activity during a medium-sized rainfall between 28 and 30 November, 1995. The reservoir reached maximum elevation 1,167.98 feet at 2100 hours on 1 December 1995. For the 90 hours (flood event period of record) preceding the high pool, the reservoir was above elevation 1,095 feet, and through the following 90 hours the reservoir was above elevation 1,138 feet. Following the peak elevation, the reservoir was lowered at an average rate of 0.05 feet per hour for the first 10 hours. Through the next 10 hours the reservoir was lowered at an average of 0.15 feet per hour.

Maximum rate of reservoir drop averaged 0.5 feet per hour between 70 and 90 hours after the peak elevation. The rapid rate of reservoir drop may have been responsible for failure of the already unstable slope. Turbidity levels increased sharply for 2 days and decreased to normal levels 5 to 7 days following the slide. The Corps concluded that the landslide mass which still partially blocked the Green River would not produce further adverse turbidity in the reservoir. Early in 1996, the City of Tacoma reshaped the slope to avert additional slippage.

## 2.5 ADDITIONAL WATER STORAGE EFFECT ON RESERVOIR SLOPES

Data collected during the numerous reconnaissance boat trips have been summarized. For descriptive purposes in this document the reservoir rim was divided into topographical distinct segments A through L. See Figure E-2. Each segment is briefly discussed below.

Segment A extends from the dam northward up the North Fork Valley. This segment is characterized by steep relief. A thin veneer of glaciofluvial/lacustrine deposits consisting of silt, sand, gravel, and occasional boulders overlie andesite and basalt rock. These materials may experience minor raveling with increase pool height.

Segment B occupies the flood plain of the North Fork Green River. This area has low relief, containing river deposited sand, gravel, cobbles and boulders. Bank calving should be anticipated, but is of no threat to operation of the project.

Segment C extends from the North Fork floodplain southward to Piling Creek. Relief varies from low to steep. Here, the terraces are composed of silt, clay, sand and gravel. Multiple slumping episodes should be anticipated within the bedded silts and clays. Movement in these materials should pose no threat to operation of the project.

Segment D extends from Piling Creek southward for approximately one mile. Relief varies from low to moderate. Terraces and delta deposits are common. Paragraph 2.3 mentions slump features experienced in this area during the initial pool raise. This segment has a high potential for renewed slumping activity, but as before does not threaten operation of the project.

Segment E relief is predominantly steep. Alluvial sand fills low areas within the massive rock outcrop. Fallout of small rock blocks may occur in the canyon wall. Significant landsliding is not expected.

Segment F is generally low relief. Delta sands and gravels underlie the area. Minor toe calving and slumping are anticipated. Potentially massive slide areas above elevation

1,210 feet along the north side of the valley are considerable horizontal distances from the river, and therefore, do threaten operation of the project.

Segment G extends upstream from the mouth of Gale Creek to the elevation 1,210-foot contour crossing the Green River. Relief ranges from moderate to steep. Alluvial sand and gravel deposits and laminated clay beds conceal much of the tuffaceous bedrock. Even though the terrain is steep, landslides of significant magnitude are not anticipated. Earth and rock slippage throughout this segment should pose no threat to operation of the project.

Segment H extends from the elevation 1,210-foot contour crossing the Green River downstream to the narrow gorge discussed in segment E. Relief ranges from low to moderately steep. Alluvial sand and gravel and laminated lake beds mantle much of the andesitic rock surface. Numerous scars from old slump failures are evident. A higher pool may cause renewed slumps, but these should pose no threat to operation of the project.

Segment I occupies the opposite (south) side of the gorge across from segment E. Relief is very steep. The slope at the upstream end of the gorge is well protected with riprap. A flume on the slope discharges a significant amount of water from the railroad grade above. Further downstream the slope is predominantly rock and is not protected with riprap. Continually raveling sand and gravel should be expected. At the end of the gorge, near the powerline crossing, failure of the wasted materials should be anticipated. Landsliding related to this waste pile can be expected well into the future, but should not pose a threat to operation of the project.

Segment J extends downstream from the rock gorge to the mouth of Charley Creek. Relief throughout this area is moderately steep to very steep. Generally, the reservoir slopes are composed of alluvial sand and gravel deposits overlying laminated silt and clay beds. Bare slopes caused by slip-off slides should be expected. Also, massive shoreline slumping may occur in the initial phases of the pool raise. Both types of slide activity should have no effect on operation of the project.

Segment K comprises Charley Creek and adjacent banks. Relief is steep. Banks are composed of sand and gravel deposits and laminated silt and clay beds. The west side of Charley Creek is characterized by numerous springs. Historically, the area has experienced large slides and slumps resulting from soil saturation during rainstorms. At the same time the sediment load entering the reservoir from the upstream area has been so high that it has masked any turbidity originating in the Charley Creek slide area. As such, sliding at Charley Creek has not impacted turbidity. With an increased pool adjacent slopes will be affected. During initial inundation the temporary suspension of materials is likely, however, the material will settle out and will be diluted as water is exchanged. Charley Creek slopes are not expected to slide routinely during the dry season when water is impounded.

Segment L extends from the mouth of Charley Creek downstream to the left abutment of the dam. Relief is steep. Sand, gravel and rock rubble partially obscure the numerous outcroppings of basalt and andesite. Potential for landsliding appears low.

## 2.6 RAILROAD BRIDGE NO. 1 (STATION 10602+47), UPPER CROSSING OF GREEN RIVER NEAR HUMPHREY

The upper crossing is located approximately 1 mile from the beginning of the relocated railroad near Humphrey. Preconstruction boring logs are shown on Plate E-5.

## 2.7 RAILROAD BRIDGE NO. 2 (STATION 10757+40), CHARLEY CREEK CROSSING

Supplement No. 2 to Design Memorandum No. 4 discusses preconstruction design of the Charley Creek crossing. Preconstruction boring logs are shown on Plate E-6. The railroad is located far enough away from the reservoir as to not be considered threatened by any sloughing to occur from the proposed pool raise

# SECTION 3 EFFECT OF PROPOSED 1,177-FOOT CONSERVATION POOL ON RIGHT ABUTMENT

## 3.1 GENERAL

The complex geologic conditions in the right abutment create a complicated reservoir seepage problem which is not totally understood from the standpoint of hydrogeology. Basically, at least two major aquifers are present with the possibility that others exist. The lower aquifer with base elevation at approximately 1,000 feet is found within the buried valley's alluvial materials. Pervious zones in the overlying glacial and slide materials form the upper aquifer. Neither the lower boundary of, nor the material making up the upper aquifer are as well defined as in the lower aquifer. This is particularly true of the slope downstream of the abutment. The lower boundary of the upper aquifer is estimated to be near elevation 1,065 feet.

Stability analyses during design for the upstream and downstream slopes were performed using the slide circle analysis. These analyses showed a minimum factor of safety of 1.41 and 1.25 for two sections through the downstream slope. The upstream slope in the blanketed area had a minimum factor of safety of 1.91 with a pool at elevation 1,080, and a minimum factor of safety of 1.6 under assumed draw-down conditions. The upstream slope in the random fill area had a minimum factor of safety of 1.67 with a pool at elevation 1,120 and a minimum factor of safety under draw-down conditions of 1.30.

## 3.2 SEEPAGE OBSERVATIONS

Seepage through the right abutment of the dam and its effect on the stability of the downstream right bank slope of the dam have been a basis for continued exploration and studies since the dam became operational in December 1961 (see Exhibit A for logs of wells, piezometers, and horizontal drains, and Plates E-2 and E-4 for locations). The last formal document addressing these issues was a report titled "Right Abutment Seepage", dated 15 June 1992. Initially, seepage in the right abutment was monitored using single stage piezometers. Multiple staged piezometers were introduced in June 1966. Since that time the following modifications and new installations have been completed:

- Multiple stages were installed in single staged piezometers 7, 8, 14, 16, 17, 20, 53, and 54 in 1979.

- Four new wells, 38, 39, 40, and 41, each with 3 piezometers, were installed in 1979.

- In 1986 two multi-stage piezometers (102 and 105) were installed in the right abutment, three multi-stage piezometers (101, 103, and 104) were installed in the dam embankment, and three single stage piezometers (107, 108, and 109) were installed in the downstream toe of the embankment. In addition, an old seismic instrument hole (106) in the dam embankment was converted into a single stage piezometer.

- Twelve new piezometers located in eight wells (110, 111, 112, 113, 114, 115, 117, and 118) were installed in 1993 to provide additional coverage of seepage and to replace non-functional piezometers.

- All piezometers have been automated.

In February 1965, when the pool briefly reached elevation 1,161.8 feet, a spring appeared 460 feet downstream of the dam axis on the right abutment at elevation 1,134 feet. The spring area was blanketed with gravel fill and a crib wall was constructed to support the gravel. In 1968, a 640-foot-long concrete lined drainage tunnel (adit) was constructed into the right abutment at elevation 1,100 feet to improve seepage control. The tunnel is located 200 feet downstream of the dam axis.

During the flood events of December 1995 and February 1996 significant seepage was observed along the downstream right abutment (reference Post Flood Report, Howard A. Hanson Dam Post Flood Report, dated 8 April 1997). During these events seepage was observed further downstream and lower on the slope than reported in 1965. Seepage occurred from a zone extending from weir 1 to 250 feet upstream, and from the slopes behind the two gabion walls, see Plate E-2. Flow quantities were measured from five individual locations for the February 1996 flood. Flows peaked from these locations shortly after the initiation of data collection on 11 February. Weir 1 peaked at nearly 1,000 gallon per minute (gpm) on 9 and 10 February 1996. Based on visual observations of flows running overland and seepage exiting the abutment slope, it is estimated that about 80 percent of the flow through weir 1 was due to seepage and 20 percent due to surface runoff. Weir 2, located farther downstream, peaked at about 550 gpm on 8 and 9 February 1996 with nearly 100 percent of the flow due to surface runoff.

Flows from the drainage tunnel peaked at about 1,150 gpm for the February 1996 flood. Flows measured at well 37 were about 200 gpm, at well 25 were about 11 gpm, at well 34 were about 120 gpm, and at well 35 were about 60 gpm Approximately 800 gpm of the total 1,150 gpm were transmitted through the tunnel gravel floor drain. Water was also observed flowing from the concrete joint just upstream of the tunnel bend and well 25. This water was carrying fines (classified as ML by NPD Laboratory) and had a turbidity of 819 NTU. The data for well 25 exhibits a distinct double peak; the first occurring midday on 10 February and the second at midday on 11 February. It is believed that the first peak is a precipitation response due to infiltration along the rock slope just above the tunnel, and that the second peak is a pool response.

An area of special concern exists between well 25 (elbow of drainage tunnel) and the right abutment/embankment contact. Monitoring of piezometers and wells in the upper aquifer of this area during the February 1996 flood (peak pool elevation of 1,183.2 feet) confirmed the assumption that initial flows through this portion of the abutment are precipitation related. This assumption is validated by the fact that piezometers peak 14 to 18 hours before the flood pool peaks and well 25 peaked 10 hours and again 34.5 hours after the pool peaked. These conclusions are based on the fact that the flows initially are high during the rain storm and infiltration and then once the precipitation stops they reverse direction and flow from the pool towards the drainage tunnel. Precipitation appears to be infiltrating through the rock slope downstream of the administration building parking lot.

## 3.3 SEEPAGE ANALYSES

Plate E-7 shows phreatic contours for 2 summer conservation pools (reservoirs filled to 1,141 feet), one prior to the installation of the drainage tunnel (6 July 1966) and the other after the tunnel was constructed (19 May 1981). A comparison of these phreatic contours readily shows the effect of the tunnel on the abutment groundwater table. This effect is most evident when the 1,130 foot elevation contours are compared. In the outer (riverward) 600 feet of the abutment, the 1,130 foot contour for the 6 July 1966 pool is about 150 feet downstream of the present tunnel location while for the 19 May 1981 pool this contour is about 250 feet upstream of the tunnel. In the inner (upslope) portion of the abutment the 1,130 foot contour as drawn is very nearly at the same location for both pools. For summer conservation pools to elevation 1,141 feet the tunnel is apparently effective in lowering the groundwater table in the outer, more critical, portion of the abutment but has little effect on the inner part of the abutment.

A summer conservation pool to maximum elevation 1,177 feet (elevation 1,180 feet was used for this analysis) has been proposed. In order to assess the effect of storing this pool on the abutment phreatic levels, the geotechnical staff reviewed the piezometer data for previous summer pools and selected the 1987 and 1989 data as the base from which to model a theoretical projection of the effect of an elevation 1,180 foot conservation pool (reference report titled "Right Abutment Seepage" dated 15 June 1992). The phreatic contours for the upper aquifer for an elevation 1,180 foot conservation pool are shown on Plate E-8. These contours indicate that, at least, some of the pool related seepage will actually pass around the end of the drainage tunnel and some may also pass over the tunnel.

Phreatic contours of the lower aquifer for the February 1996 flood event (1,183.2 feet peak elevation) exhibit no distinct channels. Groundwater flow from the lower aquifer appears to exit into the river channel below elevation 1,025 feet, through the riprap bank

or directly into the river. The groundwater flow through the lower aquifer is not considered to be a concern for a conservation pool of 1,177 feet.

The effects of an elevation 1,206 feet flood pool were analyzed in 1992 and found to present no apparent threat to this facility (reference report titled "Right Abutment Seepage", dated 15 June 1992). The results of data analysis from the December 1995 and February 1996 floods made no appreciable changes to this conclusion.

The quantity of water flowing through the abutment for the elevation 1,180 foot conservation pool was calculated to be about 42.8 cubic feet per second (cfs) which is equivalent to about 19,200 gpm; see Figure E-2.

Engineering Pamphlet, EP 1130-2-500 was reviewed to determine the appropriateness of applying the contained criteria to this project for a Risk-based analysis. The following Chapters and Appendixes referenced confirm that a Risk-based analysis for this project is not appropriate.

a. Chapter 3: The proposed seepage control work for the right abutment should not be considered rehabilitation because it would be unnecessary without the additional water storage project. The dam and right abutment are reliable and efficient in their present condition with the current conservation pool level.

b. Appendix B (B-3. d. (1) (d)): The proposed seepage control work is not due to deterioration or degradation in service level.

c. Appendix B (B-3. e. (3) (a)): Alternatives have been developed, but are totally dependent on the reaction of the right abutment to a sustained pool raise.

d. Appendix B (B-3. F. (1) (b)): Failure scenario for this project poses an imminent threat to public safety with a complete dam failure being the worst case.

e. Appendix H: This appendix refers specifically to Hydropower rehabilitation. Howard Hanson dam is a flood control/water supply dam.

The test pool must be accomplished during construction for two reasons: (1) The test pool will be preceded by grouting the area between the drainage tunnel and the embankment. (2) The reservoir may need to be cleared. See paragraph 3.7 for test pool requirements.

## 3.4 STABILITY ANALYSIS

Stability analyses were performed using the "UTEXAS3 Slope-Stability Program." Parameters for the native slide/abutment materials were:

- Dry unit weight = 120 pounds per cubic foot (pcf)
- Moist unit weight = 134.9 pcf
- Saturated unit weight = 138.5 pcf
- Buoyant unit weight = 76.1 pcf
- Angle of internal friction = 38 degrees
- Cohesion = 0 pounds per square foot (psf)

Parameters for the upstream slope and slope treatment materials were:

- Dry unit weight = 135 pcf
- Moist unit weight = 145 pcf
- Saturated unit weight = 147.6 pcf
- Buoyant unit weight = 85.2 pcf
- Angle of internal friction = 38 degrees
- Cohesion = 0 psf

**TABLE E-3-1. CRITICAL ARC FACTORS OF SAFETY**

| Slope | Pool Condition | Seepage Condition | Critical Arc Factor of Safety |
|---|---|---|---|
| Downstream | 1141 Conservation | Steady State | 1.113 |
| Downstream | 1180 Projected Conservation | Steady State | 1.111 |
| Upstream | 1141 Conservation | Steady State | 2.060 |
| Upstream | 1180 Projected Conservation | Steady State | 2.215 |
| Upstream | 1141 Conservation | Rapid Drawdown | 2.060 |
| Upstream | 1180 Projected Conservation | Rapid Drawdown | 2.215 |
| Upstream | 1206 Projected Flood Pool | Steady State | 2.308 |
| Upstream | 1206 Projected Flood Pool | Rapid Drawdown | 2.308 |

Note: The assumed angle of internal friction (Phi) of 38 degrees and cohesion ( c ) = 0 are conservative strength parameters for the materials comprising the right abutment of Howard Hanson Dam. These materials are predominately slide debris consisting of large angular rock blocks, boulders, cobbles, and gravel with a matrix of silts, sands, and clays. Historically, a small amount of cohesion has been recognized to be associated with this material, however, because it is practically impossible to accurately sample and test in-

situ or in a laboratory, the cohesion has been ignored. Instead the upper range of internal friction for gravel has been chosen as the preferred strength parameter for analysis.

## 3.5 POSSIBLE CORRECTIVE ACTIONS TO DECREASE SEEPAGE AND INCREASE STABILITY OF RIGHT ABUTMENT

As evidenced by the relatively low Factors of Safety derived from this study and the previous seepage studies performed to date, it is apparent that some form of corrective actions must be incorporated into the design of the Additional Storage contract. Several alternatives have been developed and analyzed to address reduction of seepage through the right abutment. The alternatives are briefly described in the following paragraphs.

### 3.5.1 Drainage Tunnel Extension

This alternative includes extending the existing tunnel approximately 200 lineal feet or more beyond the current end of the tunnel and installing 5 additional relief wells (see Figure E-3 and Plate E-9). Wells would be 10-inch-diameter perforated steel casings spaced at about 40 feet, for a total length of casing of about 1,150 feet.

### 3.5.2 Additional Feeder Wells at End of Existing Tunnel

This alternative would involve installation of five additional wells at the end of the existing drainage tunnel (see Figure E-4) for drawing down the abutment seepage expected to pass around the end of the tunnel. These would be 10-inch-diameter perforated wells drilled from the ground surface and connected within the drainage tunnel through new feeder pipes and tee connections. Approximately 1,100 feet of drilling and casing will be needed for this option.

### 3.5.3 Horizontal and Inclined Drains

This alternative would consist of a series of perforated pipes drilled into the abutment from the end of the existing drainage tunnel (see Figure E-5) for an average length of about 150 feet per drain. These drains would be arrayed at various angles from near horizontal to as much as 50 degrees from horizontal. There may be as many as three drain sets each with up to 10 drains.

### 3.5.4 Cutoff Wall

A positive seepage cutoff wall would be constructed along the top of the impervious blanket (see Figures E-6 and E-7) using a slurry trench method similar to the cutoff wall constructed at Mud Mountain Dam. A temporary fill (approximately 230,000 cubic yards) would be required to provide a working platform (see Figure E-8). Total wall area would be about 250,000 square feet with a maximum depth of 285 feet. The wall would extend to the right canyon wall about 1,400 lineal feet where it would tie into bedrock at approximately elevation 1,190 feet. The bottom of the wall would need to extend at least down to elevation 1,040 feet.

### 3.5.5 Injection Grouting

This alternative would consist of a series of borings (assumed to be on 3-foot centers and two rows at this time) drilled approximately ten feet into bedrock for a total length of drilling of about 25,500 feet to facilitate placement of grout tubes (see Figures E-9, E-10, and E-11). Casings would be pulled and re-used once grout tubes are in place. Grouting (estimated at about 7,420 cubic yards) would be performed under very low pressures to reduce the chance of hydrofracturing the abutment materials. A work platform will require a temporary fill of approximately 56,000 cubic yards (see Figure E-12).

## 3.6 RECOMMENDATIONS

It is recommended that the "Injection Grouting" option be incorporated as a work item in the proposed pool raise contract. This option could be further refined during PED. The grouting work would reduce known seepage problems through the abutment adjacent to the dam embankment. If the abutment is left in its present condition serious slope stability problems may occur.

The "Alternatives in paragraphs 3.5.1, 3.5.2, and 3.5.3" are recommended for inclusion as options in the future construction contract. These options would be exercised only if conditions warrant based on results of a test pool raise during the early construction phase. Following test pool analyses it will be possible to determine whether the tunnel extension or a lesser option such as "Horizontal and Inclined Drains" or "Additional Feeder Wells" will be adequate to control additional seepage. It must be recognized that because of the highly variable nature of the right abutment slide materials, an unsuspected anomaly may occur during pool raise that will require development of other remedial measures.

Two additional work items are essential to complete the upgrades to this facility: (1) Three water pressure gauges are recommended, one at the elbow, one at the end, and one

at mid point in the existing drainage tunnel. Multiple gauges will be needed for comparison purposes; and (2) since the upstream rock blanket is deteriorating, new rock is recommended to withstand increased erosion caused by a higher wave fetch. Approximately 69,000 cubic yards of rock will be required for this work based on a 3-foot-thick blanket placed directly on the existing rock surface.

## 3.7 TEST POOL REQUIREMENTS

The test pool is needed in order to monitor groundwater conditions in the right abutment and to design and construct an appropriate modification to the seepage control measures currently in existence, if necessary. Requirements for a test pool are as follows:

1) It is known that precipitation effects the groundwater regime of the upper aquifer, therefore, the test pool will be conducted under conditions of a normal summer conservation pool.

2) The test pool will be conducted in a staged manner; i.e. the pool will be raised in approximately 10-foot increments, allowing time for instruments to stabilize before the initiation step. It is estimated that the test pool will take about three months to accomplish.

3) A complete analysis of the data will follow the completion of the test pool, which is expected to take approximately two months to complete. The design of any new seepage control feature or modification to the existing seepage control features will commence after completion of the analysis.

# SECTION 4 INVESTIGATIONS

## 4.1 PRE-DAM EXPLORATIONS

Exploratory drilling for the damsite consisted of core and cable tool borings. Borings were drilled in the spillway, intake channel, stilling basin, tunnel, right and left abutments, and riverbed. A total of 65 borings were drilled between 1947 and 1958. In addition, five observation wells, four test pits, and two adits, 38 and 55 feet in length, were completed on the right abutment to determine foundation conditions. Exploratory boring locations are shown on Plate E-4. A single core boring (56-DD-27) was drilled in February 1956 at the downstream end of the spillway chute. The boring terminated in rock at elevation 1,068.7 feet. Boring DD-27 is located on/in a 50-foot-wide tabular body of poor rock quality. The body trends northwest on the ground and shows a steep relative dip. Other zones of decomposed rock are present below the spillway chute and in the left bank upstream of the gate tower.

## 4.2 RECENT INVESTIGATIONS

During March and April 1994, five NQ wireline (3-inch-diameter) core borings numbered 94-DD-80 through 94-DD-84 were drilled to determine subsurface site conditions for the unchosen alternative No. 1 intake tower and tunnel alignment discussed in Exhibit D. Later, during the study, this alternative was redesignated as Alternative 9A7. Following completion of the alternative investigations and after a tentative fish facility tower location was selected in January 1995, the tower site and tunnel configuration were significantly scaled back to reduce costs. The fish facility tower site was moved to the right side of the existing gate tower. The right side of tower alternatives were designated A1, A2, A3, and A4. In December 1995 the site was moved again to the left side of the existing gate tower because of poor foundation conditions on the right side. A single HQ wireline (3.8-inch-diameter) core boring, 96-DD-87, was drilled during May 1996 to affirm the feasibility of the newest site. In late June 1996, the proposed tunnel transition alignment was changed because the local geology indicated probable roof failure while excavating the left wall of the existing diversion tunnel. Loss of the left sluiceway would be a serious dam safety problem, therefore, the new tunnel conduit alignment was redesigned to enter the existing left sluiceway at a higher angle. In January, 1998 the footprint was moved again this time 25 feet south to provide room for a cofferdam next to the existing outlet works. The recommended site has been designated alternative 9A8.

Two core borings located immediately downstream of the existing gate tower, numbered 94-DD-85 and 94-DD-86, were drilled for the gate tower retrofit program. Laboratory test

results on rock cores from these and DD-87 are available in Exhibit C. Summary drill logs and hydraulic pressure test data are available in Exhibits A and B, respectively.

## 4.3 RECOMMENDED FUTURE INVESTIGATIONS

### 4.3.1 Right Abutment Drainage Tunnel

During feasibility a borehole camera was used to check condition of the perforations in existing drainage tunnel wells. Most were found to be plugged. During PED each of the 10-inch diameter wells will be perforated between elevation 1,090 feet and 1,200 feet. This work coupled with collection of field data during high flood pools will contribute to a better understanding of ground water movement. Approximately 1,100 lineal feet of perforating will be accomplished.

### 4.3.2 Cofferdam, Fish Passage Facility Footprint, and Entrance Channel

The contact zone between soft pyroclastic rock and a hard porphyritic meta-basalt dike is schematically shown on plate E-3. (Plate 3 is a reproduction of Plate 12 which found in the construction foundation report). The dike appears to be striking east west with a 75° southward dip. Plate 3 illustrates the contact zone at about 25 feet upstream of the existing gate tower. This contact may extend through the proposed wet well/fish lock excavation, see Plate E-10. A important element during initial explorations will be to locate the contact zone and collect representative cores for rock strength tests. The proposed cofferdam appears to straddle the contact zone with one abutment in soft andesite pyroclastics and the other in hard basalt. Recommended sites for exploration borings are shown on Plate E-11. The borings will range in depth from 160 to 215 feet. Purpose of the borings will be to determine overburden thickness, rock type, weathering, hardness, discontinuities, joint spacing, groundwater, and other subsurface characteristics. Hydraulic pressure tests will be conducted to measure joint tightness. Downhole photography will be employed to determine joint condition and orientation. Representative rock cores will be sent to the laboratory for rock strength testing. At least two exploratory relief wells will drilled in the vicinity of the footprint and pumping tests will be accomplished.

### 4.3.3 Proposed Tunnels

Only a few of the existing exploratory borings are near, within 100 feet, of the proposed tunnel alignment. None extend down to the proposed tunnel grade, therefore additional field explorations are necessary prior to feature design work. A variety of igneous rock types were encountered in 1960 during mining excavation of the present diversion tunnel,

Plate E-12. The construction foundation report provides a brief description of each rock type, but no rock strengths are given. Three of the five reported rock units extend into the fish facility tunnel alignment. One area of concern involves a 25-foot-wide zone of poor quality andesitic pyroclastic rock bounded on both sides by basalt dike rock in the vicinity of the transition to the existing diversion tunnel. This segment of diversion tunnel was strengthened using closely spaced steel supports on 4-foot centers and a collar grouting program to stop build-up of high water pressures outside the concrete lining. An inventory on the number of drain holes and flow from each within the first 200 linear feet of the existing tunnel is planned during feature design.

A minimum of four vertical core borings, varying in depth from 160 to 190 feet, are planned along the proposed tunnel alignment to determine condition of the rock located within two tunnel diameters above the crown of the highest proposed tunnel grade and to one diameter below the invert of the lowest proposed grade. Hydraulic pressure testing will accompany drilling to determine the degree of fracturing. Downhole photography will be used to determine joint orientation. Representative rock cores will be tested in the laboratory to determine rock strengths.

### 4.3.4 Slope Stability Exploration for Charley Creek Slide

Two slope inclinometer borings, each 200 feet in depth, are proposed for the Charley Creek landslide to evaluate slope stability. The Charley Creek Slide is mentioned in paragraphs 2.3 and 2.5.

## 4.4 LABORATORY TESTS

Laboratory testing was performed on rock core selected from the core borings referred to in Paragraph 4.2. Most tests were run to obtain rock strengths, including direct tensile strength, grout/rock biaxial direct shear strength and uniaxial (unconfined) compressive strength. Special tests to obtain rock properties particularly related to rock bolting were performed on selected pieces of core from each of the borings; DD-85, DD-86, and DD-87. The most recent test results, dated 22 August 1996, were performed on rock core from boring DD-87. These tests include biaxial direct shear strength tests on 10 sawn rock-grouted joints, 4 samples for dynamic modulus of elasticity, 4 samples for unconfined compressive strength and rock density, and 3 samples for direct tensile strength. Rock samples were tested at NPD Materials Laboratory in Troutdale, Oregon. No laboratory testing was performed on overburden materials. See Exhibit C for laboratory test results on selected rock cores.

# SECTION 5 AS-BUILT FOUNDATION TREATMENT FOR EXISTING APPURTENANCES RELEVANT TO PROPOSED FISH FACILITY

## 5.1 INTAKE CHANNEL

The 460-foot-long intake channel is an open rock cut, leading to the gate tower and diversion tunnel. Rock surface on the high side of the cut ranges in elevation from 1,140 feet to 1,160 feet. At the gate tower the finished floor of the channel is at elevation 1,035 feet with a bottom width of 40 feet. The channel widens upstream. Rock slopes on the left wall of the intake channel are 2 vertical (V) on 1 horizontal (H) while the right wall is 1V on 1H. The right side was revised during construction from 2V on 1H because of the poor quality of the rock. Both slopes were systematically rock-bolted as the excavation proceeded downward from the surface.

Intake channel rock is generally soft. The andesite stays mostly compositionally basic having an agglomerate texture interspersed with tuff seams and dense basaltic sills and dikes. Alteration of the rock is prominent; chloritization of the magnesium minerals and kaolinization of the silicates has softened the entire rock mass. Jointing is prominent on the rock surfaces while the degree of fracture varies from intensely shattered rock to moderately fractured or blocky type rock. Major rock joints and faults are shown on Plates E-13 and E-14. The foundation rock is highly variable, changing from soft, poorly indurated mass, to hard, dense zones. The basalt dikes and sills exposed in open cut slopes are all dense, brittle and sound and constitute the most durable rock found in the intake area.

All intake channel areas were shot in 20-foot lifts except when approaching design grade then lifts were reduced to 5 feet high. Millisecond delays were used extensively in all blasts to maintain neat lines and to control breakage. Powder factors used in the various types of rock ranged from one-half pound in the dense hard rock to three quarters of a pound in the softer rock per cubic yard of rock removal. The shots ranged from 4,000 to 10,000 cubic yards of rock per blast on mass excavation, with minor shots of 100 to 500 cubic yards of rock per blast to complete the required excavation. Five-inch-diameter drill holes on 6-foot centers were drilled an average of 20 feet deep. Holes were generally loaded with ANFO. All neat lines were drilled on 3-foot centers and shot with a light charge to keep overbreak to a minimum. Satisfactory results were obtained in all areas of excavation.

Drain holes were drilled into the exposed rock walls to relieve seepage pressures in the rock. The amount of seepage varied with season of the year. All holes were diamond drilled 20 feet deep from a drilling cage as the excavation proceeded downslope. After the

intake channel was essentially complete, holes were drilled to check rock condition in the left wall. Five holes were drilled, 45 feet deep on a 10 percent upward slope at each of the elevations: 1,045 feet, 1,070 feet, and 1,100 feet . The exploration holes were left open to serve as drains. Rock in the left wall varied from hard brittle basalt to soft pyroclastics that could be readily excavated with a shovel.

Rock bolts were used to reinforce the rock cut slopes. Slotted rock bolts of high strength steel varied from 10 feet to 30 feet in length. Plate 14 in the 1963 Foundation Report shows locations and orientations of more than 500 rock bolts installed in the left intake channel wall. Bolts were installed in the direction of maximum compression to reduce fallout due to slip planes, jointing, and shattered rock. Safety netting to alleviate danger from falling rock covered the entire wall of the intake channel and were anchored to the rock bolts or with anchor pins as required. Over the years the slope has held up well, except for minor fallout zones. Most of the netting has deteriorated and has been removed by the project forces.

## 5.2 GATE TOWER

The gate tower is 40 feet by 50 feet in size with vertical rock slopes of 125 feet on the portal face and left wall. According to the construction foundation report the right wall was to have been vertical, but because of the presence of poor rock, the slope was laid back to a stable angle (degrees not provided) and covered with safety netting to catch raveling from the surface of the slope. In this case the redesign by slope layback allowed the wall rock to stand without support. The right wall, one-half of the gate tower floor, and a section of portal face were composed of soft andesite pyroclastic rock containing relatively hard inclusions, enclosed in a fine, granular, altered matrix. The matrix deteriorated rapidly when exposed to the atmosphere. The soft rock had to be covered with a thin layer of concrete immediately upon excavation to limit air slaking deterioration of the foundation. The zone varies from 20 to 30 feet wide, and is flanked upstream by a dike of dense black basalt. Blocky andesite rock forms a cap over the exposed pyroclastic zone at higher elevations of the gate tower.

The left wall of the portal within the gate tower excavation is firm, dense basalt, moderately hard, with blocky structure. Weathering is very pronounced and the rock is somewhat altered. The poor condition of the rock and excavation geometry made overbreak on the outside corners difficult to avoid. Numerous fracture planes dip into the open cut at angles 45° to 80°. Some fractures were observed to carry groundwater the year round and a definite zone of water seepage from the adjacent hillside was exposed on the left wall of the gate tower. Gate tower excavation was completed in conjunction with the intake channel as one operation.

## 5.3 UPSTREAM DIVERSION TUNNEL PORTAL AND TRANSITION SECTION

The tunnel portal is 40 feet by 40 feet in size, with a flat roof section through the 35-foot-long transition. This design required an elaborate support structure to hold the flat roof consisting of 24-inch I-beams on 18-inch centers. The soft zone of pyroclastic andesite on the right wall of the gate tower carries into the right side of the upstream transition section and across the floor section of the tunnel, disappearing into the left wall at the downstream end of the transition. The left wall in the transition section, when opened, revealed water bearing faults and three main joint sets all with steeply dipping angles ranging from 50° to 90° toward the east. During tunnel advancement considerable ground water seepage also occurred on the left wall of the tunnel. After placing the concrete lining, seepage built-up substantial pressure and the flow had to be sealed with a grout collar. Grouting for the diversion tunnel collar was done after completion of the tunnel concrete work. The grout collar extended into the foundation rock for a depth of 20 feet and was carried 90 feet downstream from the upstream portal area. Holes were placed in a circular pattern around each of the two water passages (sluices) on 10-foot centers. Grouting was done on a split spacing method in two stages starting at the downstream edge of the collar and progressing upstream to the gate tower. Grout takes ranged from part of a sack to a maximum of 2,046 sacks taken by one of the holes in the right waterway. That particular hole carried grout across the back of the gate tower over the two waterways and up the rock contact on the back side of the gate tower to the 1,141 feet elevation. The collar grouting program successfully sealed the void behind the concrete liner. Drain holes, both upstream and downstream of the grout collar, showed only minor seepage.

## 5.4 DIVERSION TUNNEL

Water passage is through a concrete-lined 19-foot-diameter tunnel, 900 feet in length in the left abutment rock. A 4-foot-diameter low-flow by-pass tunnel is located beneath the diversion tunnel. The tunnel was driven through volcanics composed of andesite, andesite tuffs, pyroclastics, and dikes of hard, dense basalt and felsite. Extremely variable and abrupt changes of rock types were very common in the exposed tunnel walls. The diversion tunnel was driven full face by conventional drilling and blasting methods employing 10-foot delayed rounds, utilizing a "standard pyramid cut." Progress rate was 10 feet per day. Overbreak was minimal when using a powder factor of 1 pound per cubic yard. The diversion tunnel has vertical sides and a horseshoe shaped crown. One-third of the tunnel was self-supporting where it was driven through moderately hard, irregularly jointed andesite. Two consequential and several minor faults were encountered during excavation of the diversion tunnel. The faults had 2 to 12 inches of gouge and abundant slickensides and almost all were water bearing. One significant fault trends northeast to southwest and dips 75° to 85° northwest and the other strikes N10°E with near vertical dip. The latter was mapped near the left wall of the stilling basin and was encountered in the existing diversion tunnel about 200 feet downstream of the spillway weir. It produced considerable

groundwater. Most minor faults were found to strike roughly east-west with dips varying from 70° to 80° south. Nearly 100 feet of tunnel length near the upstream portal and 50 feet near the downstream portal were supported with steel ribs on 4-foot centers. The majority of rib supports were on 6-foot centers. Light loads were experienced, even though the supported sections were in interstratified soft andesitic pyroclastic rock and denser basalt and felsite (Galster, 1989).

Groundwater was encountered in the gate tower excavation, upstream transition section, and at the mid point in the tunnel. Contact grouting was performed during August 1960 beginning at the downstream transition and working upstream through a distance of approximately 800 feet. Embedded grout pipes through the concrete lining were located on 10-foot centers, five feet each side of the centerline, in the arch of the tunnel. The design of the tunnel with no water stops at monolith joints and the use of embedded drain holes was considered a detriment to grouting operations because leakage through the two areas necessitated considerable extra expense to prevent grout loss.

# SECTION 6 ENGINEERING CONSIDERATIONS FOR PROPOSED FISH PASSAGE FACILITY SITE

## 6.1 GENERAL

The recommended fish passage facility site (9A8) was opted late in the study (December, 1995), after several alternatives were evaluated, see Exhibit D. Approximately one month after the drilling of boring 96-DD-87 (May, 1996), the fish passage facility footprint was shifted again (late June, 1996) to accommodate a new tunnel transition angle with the existing left sluiceway. In mid January, 1998 the footprint was moved 25 feet south to provide sufficient room for siting the cofferdam within the existing rock slope bordering the intake channel; see Plate E-11. Currently, no explorations are located within the latest fish passage footprint or within footprints for proposed ancillary structures. Subsurface conditions are unknown, except for some information in the 1963 construction foundation report. The proposed facility is shown on Plates E-10 and E-11. Excavation for the tower and tunnels will be accomplished by both surface and underground mining methods. In the area of the fish passage facility footprint the predominant rock type could be brecciated, porphyritic meta-basalt or could be a narrow lower strength meta-basalt dike. Rock types will be determined during a comprehensive exploratory program intended in the early stages of preconstruction engineering and design (PED). Various elements of work necessary for foundation preparation include:

- strengthen abutments for the cofferdam;
- excavate overburden/rock to shape stable back and side slopes for the fish collector entrance, wet well, fish lock, and tower excavations; install back-slope support elements;
- erect steel sets and excavate turn-under for the gate chamber;
- perform mining excavation for the new conduit tunnel, for the 24-inch diameter fish transport pipe, and for the 48-inch diameter bypass pipe; and
- excavate overburden/rock to widen the existing intake channel and install slope support elements.

## 6.2 DESIGN CRITERIA

Designs for the surface excavations and tunnels were based on general design criteria presented in Table E-6-1. This table was initially developed using empirical guidelines in EM 1110-2-2901, dated 15 Sep 1978. As a result of recommendations made in the Alternative Formulation Briefing (AFB) in September 1997, Section 6, including Table 6-1 were revised to reflect the new guidance in EM 1110-2-2901, dated 30 May 1997. New

guidance emphasizes tunnel excavation by mechanical means in lieu of drill and blast methods especially where existing concrete structures are in close proximity. Regarding the fish passage facility neither method can be adequately designed for until the comprehensive exploration program is underway. The alternative for tunnel excavation by mechanical means such as roadheader was added to this appendix as a result of independent technical review. This alternative will require further research during PED studies. The Rock Mass Rating (RMR) system was used for cursory analysis for feasibility. The RMR system is based on a set of case histories of relatively large tunnels excavated using blasting. Early in PED emphasis will be placed on performing essential tests such as thin section analysis, Schmidt hammer hardness tests, and density, porosity, compressive, and tensile strength tests. These tests and others will be helpful in predicting mechanical excavator performance.

Permanent rock cut slopes as steep as 10V on 1H may be attainable within the fish facility footprint, but will not stand in the intake channel where the rock is much poorer quality. Controlled blasting will be used to minimize overbreak and reduce the vibrations acting on existing structures. Rock slopes will require controlled blasting to attain the excavation neatline. Excavation lifts will be 20 feet or less in height. In no case will explosive amount, pattern, or timing of explosive charge per delay be allowed to exceed blasting criteria shown on Table E-6-1. After each excavation lift all hazardous loose rock and debris will be removed by barring and wedging before installing slope treatment elements such as rock bolts, shotcrete, backfill concrete, rock drains, and chain-link mesh. When large fallout areas occur the resulting cavities will be backfilled with either shotcrete or cast-in-place concrete depending on depth of the cavity. Shotcrete and concrete backfill will be penetrated by inclined rock drains to enable equalization of water pressure during reservoir fluctuations. All excavation slopes will be covered with temporary chain link mesh for worker safety.

TABLE E-6-1. ROCK EXCAVATION GEOTECHNICAL DESIGN CRITERIA

| |
|---|
| **INTAKE CHANNEL SURFACE EXCAVATION**<br>•Maximum rock cut slopes (>10 feet) = 4V on 1 H<br>•Five-foot bench for every 20 feet of slope height<br>•Rock bolts, permanent chain link mesh, and drains to provide slope stability and safety |
| **FOOTPRINT EXCAVATION**<br>• Minimize excavation quantities<br>• Maximum cut slopes (>10 feet) = 10V on 1 H<br>• Shotcrete, backfill concrete as needed, tensioned rock bolts and drains<br>• Temporary and permanent chain link mesh |
| **TUNNELS**<br>• Use empirical design criteria in EM 1110-2-2901<br>• Tunnels driven by light load blasting and/or by mechanical means<br>• Pre-grouting and rock bolts to strengthen area of transition to existing diversion tunnel<br>• Pressure grout and drains to control groundwater<br>• Rock reinforcement by tensioned rock bolts and fiber reinforced shotcrete<br>• Steel sets, or steel liner construction in critical areas and in portals<br>• Use spiling as necessary |
| **BLASTING CONTROLS**<br>• Reduced charge weight per delay for low vibration level blasting<br>• Vibration level to be less than 4 inches per second on existing concrete<br>• Vibration level to be 2 inches or less per second on newly placed concrete |

## 6.3 BEDROCK ENGINEERING PROPERTIES

The left abutment bedrock consists of a variety of igneous rock types (Plate E-3) with unit weights ranging from 150 to 172 pounds per cubic foot. Table E-6-2 shows characteristics of several rock varieties found at the Howard Hanson Dam Project. Many engineering problems can be related to joints in the rock. Rock in the upstream left abutment has closely and widely spaced fractures depending on location. Prehistoric movement occurred on many secondary fractures as evidenced by gouge and slickensides in local rock exposures.

Rock core from boring 96-DD-87 was field classified as andesite breccia. Actually, the rock is porphyritic meta-basalt. In August 1996, the Corps' Missouri River Division Laboratory in Omaha, Nebraska, completed a petrographic examination of a sample of core from the depth interval 138.5 to 139 feet (elevation 1,027 feet) in boring 96-DD-87. Their results indicate the rock is composed of well fractured (brecciated), altered meta-volcanic rock identified as porphyritic meta-basalt with the majority of principal original volcanic rock mineral constituents altered to chlorite, calcite and mica. The mineral alteration did not appear to have adversely affected rock matrix density. Fractures associated with brecciation were closely spaced, closed and appeared to be well cemented with secondary minerals that included chlorite, carbonate, and microcrystalline silica. The iron ore

identified in the sample was composed predominantly of iron sulfide (pyrite) and comprised approximately 15 percent of the rock as determined by modal analysis. Chemical analysis indicated the whole rock sulfate content as less than 0.1 percent and the iron sulfide appeared to be chemically inert based on results from sodium and calcium hydroxide immersion tests. Based on these results no chemical reactions are anticipated between the iron sulfides and the constituents in concrete.

**TABLE E-6-2. REPORTED AND OBSERVED ROCK CHARACTERISTICS**

| Rock Type | Description | Weathering Characteristic | Characteristic of Shot Rock | Specific Gravity Bulk Dry | Unconfined Compressive Strength in est. psi | Modulus of Elasticity in est. psi |
|---|---|---|---|---|---|---|
| Basalt | Hard and dense, fine grained, concoidal fracture, color black, no alteration | Very resistant | Blocky and durable | 2.60 to 2.65 | 4,500 to 14,500 | 2,900,000 to 7,100,000 |
| Andesite | Moderately hard and dense, medium to fine grained, irregular fracture, color dark green to dark gray, slight hydrothermal alteration | Resistant to normal atmospheric weathering | Massive disintegrates adjacent to shot | 2.50 to 2.60 | | |
| Basalt Pyroclastics (Tuff) | Matrix. moderately hard and dense, medium grained, color dark gray; Nodules, hard and dense, fine grained, color black hydrothermally altered | Matrix, susceptible to mechanic breakdown Nodules, resistant | Breaks fine to granular particles which weather to a sandy gritty mass | 2.30 to 2.35 | | |
| Andesitic Pyroclastics (Tuff) | Matrix, soft, color light gray, uniform fine grained, and dense; Nodules, moderately hard, variable granular texture, hydrothermally altered. | Very susceptible to atmospheric weathering, abrasion, and mechanical breakdown | Breaks fine to silty clayey mass with larger particles weathering readily to silty clay. Breaks to plastic mud under construction equipment | 2.25 2.33 | 3,500 to 4,000 | 1,600,000 to 2,100,000 |
| Felsite | Light gray, hard and dense, fine grained, irregular fracture, small feldspar phenocrysts | Very resistant | Durable and blocky | not tested | | |

Table E-6-2 modified from Hart Crowser & Assoc., Inc, 1984

### 6.3.1 Rock Quality Designation (RQD)

The RQD is a modified core recovery logging technique developed at the University of Illinois. This technique is more sensitive to the soundness and quality of rock than is the procedure of simply logging the percentage of core recovery. RQD is useful for estimating rock bolt spacing and lengths. The RQD is based indirectly on the number of fractures and the amount of softening or alteration in the rock as observed in cores from 3-inch diameter borings. RQD is expressed as a percentage of the aggregate length of the 4-inch or longer

segments to the total length of the core run. When core is broken by handling or while drilling, the fresh pieces are fitted together and counted as one piece. Table E-6-3 shows RQD percentages used for determining rock quality.

**TABLE E-6-3. ROCK QUALITY DESIGNATION**

| RQD Percentage | Rock Quality |
|---|---|
| 0-25 | Very Poor |
| 26-50 | Poor |
| 51-75 | Fair |
| 76-90 | Good |
| 91-100 | Excellent |

The average RQD for boring 96-DD-87 indicates rock of good quality. Fracture spacing ranges from a tenth of a foot to 18 feet. For feasibility the average RQD was used to characterize the overall quality of rock in boring DD-87. Usually, RQD is used as a measure of rock quality for a particular zone of interest such as a portal cut.

### 6.3.2 Rock Mass Rating (RMR)

RMR is a rock mass classification system used to evaluate ground conditions which a tunnel could encounter and as a means to check initial estimates of tunnel support. This applies to areas with adequate rock cover and strength to develop Terzaghi bridging. Two times the tunnel diameter is needed as adequate cover to fully develop bridging action in jointed rock.

For the fish facility tunnel, ground conditions include the following types of rock: andesite/basalt flow rocks and, andesite pyroclastic rocks. A rating based on historical geologic data, laboratory test results, and drill core logs (RQD, joint spacing and condition, weathering) was developed for these volcanic rock types. Figure E-13 "CSIR Geomechanics Classification of Jointed Rock Masses" was used in generating the values in Table E-6-4. Flow rocks fall into Class II "Good Rock" and pyroclastic rocks are in Class III "Fair Rock."

TABLE E-6-4. ROCK MASS RATING SUMMARY

| RATING CATEGORY | AN/BA* FLOW ROCK | PYROCLASTIC** ROCK |
|---|---|---|
| Strength of Intact Rock | 7 | 7 |
| RQD | 17 | 13 |
| Spacing of Joints | 20 | 20 |
| Condition of Joints | 20 | 12 |
| Groundwater | 4 | 0 |
| Rating adjustment for Orientation of Joints | -5 | -5 |
| Total Rating | 73 | 47 |
| Class | II | III |
| Average Standup Time (10-ft span) | 6 months/12-ft span | 1 week/10-ft span |

*AN/BA = Andesite/Basalt
**Primary thickness of shotcrete applied after muck-out cycle will raise rock to class II.

## 6.4 DEWATERING

Groundwater under moderate pressure will be encountered during excavation of the fish facility footprint and at tunnel grade. In boring 96-DD-87, a significant water bearing fracture, dipping 35° (dip direction and strike are unknown) was encountered at a depth of 143.4 feet (elevation 1,022 feet). For 6 days an estimated 40 gpm flowed from the boring at ground surface (elevation 1,166 feet). In May, 1996, the temperature of the flowing artesian water was 48° F., somewhat warmer than the 40° F. temperature at the reservoir surface. A packer was placed in the boring just below elevation 1,030 feet and the boring was pressure grouted, thereby sealing off the water bearing fracture. More exploration is required to adequately design construction and permanent drainage systems. Two exploratory relief wells are planned during PED to further evaluate water problems. For feasibility purposes rock drains will be 2-inch diameter, inclined 5° above horizontal on 12-foot centers, except within the lowermost 15 feet of the excavation, then drains will be more frequent. Field conditions may dictate deviation of lengths, spacings, and orientations of drains. Seepage dewatering will be maintained during the excavation and construction. Once foundation grade has been achieved and mat placed, drain holes on 7-foot by 7 -foot pattern, drilled at least 20 feet deep into the footprint foundation may be needed for uplift pressure relief. Grouting may be necessary to control seepage, particularly if open or continuous joints are present. In addition to the rock drains, systematic grout hole drilling and pressure grouting may be needed around the bottom of the footprint excavation especially between elevations 1,015 and 1,035 feet.

Numerous water bearing rock joints in the area of the proposed tunnels are anticipated. This condition may be exacerbated by high reservoir pools. Therefore, two-inch diameter drains, drilled 20 to 30 feet into the rock on 5-foot centers to relieve pressure. Following tunnel lining installation, additional grouting will be done to restrict high water pressures and seepage.

**TABLE E-6-5. GEOTECHNICAL DESIGN FEASIBILITY**

| Element | Excavation | Support | Dewatering | Reference | Excavation Design Feasibility |
|---|---|---|---|---|---|
| Intake Channel | 4V:1H | Pattern Rock Bolts 5x2½& Drains, 10x10 | Necessary by rock drains | | Good |
| Footprint | 10V:1H | Pattern Rock Bolts 6x6 Diagonal & Drains, 12x12 | Necessary by rock drains, pumping, and grouting | Plate-E-17 | Good |
| Gate Chamber Portal | Controlled Blasting or Mechanical Means | Steel Sets 5' O.C., Pattern Rock Bolts 5x5 Diagonal, 4" Shotcrete | Necessary by rock drains, pumping, and grouting | Plate-E-18 | Good |
| New Conduit Transition to Existing Diversion | Controlled Blasting by Light Charges, Drilling & Splitting or Mechanical | Steel Sets 4' O.C., Pattern Rock Bolts 5x5, 4" Shotcrete, Drains | Necessary by rock drains, pumping, and grouting | Plate-E-18 | Good |
| New 48" Bypass | Controlled Blasting & Mechanical | None | Necessary by pumping | Plate-E-18 | Good |
| Lock Fish Transport Tunnel | Horizontal Drill small dia. bore | None | None | Plate-E-18 | Very Good |

## 6.5 SOUTH WALL REINFORCEMENT FOR COFFERDAM

The south rock wall of the existing intake channel extending from the gate structure to approximately 100 feet upstream will compose part of the proposed cofferdam system. See Appendix A, Design, for the planned cofferdam configuration and cofferdam abutment reinforcement scheme. Also see Plates E-15 and E-16 for as-built reinforcement in the existing south wall.. The cofferdam abutments will be reinforced with post-tensioned cable tendons extending from the ground surface to approximately 35 feet beneath the base of the cofferdam. The tendons will be installed within a series of closely spaced 6-inch diameter vertical borings and grouted full length. In addition to the tendons the abutments will be strengthened with heavy duty Dywidag bolts embedded in resin. The Dywidag bolts will be installed normal to the rock face. Short rod extensometers or some other form of geotechnical instrumentation will be used to measure rock deformation. The rock between

the cofferdam abutments will also be left intact and will be grouted to ensure a water tight condition. Construction for the cofferdam will involve access and logistics problems as well as being complicated by a confined work area adjacent to the operating outlet works. Also, the proposed cofferdam area is subject to submergence during flood storage.

## 6.6 FISH FACILITY FOOTPRINT EXCAVATION AND SLOPE TREATMENT

The fresh rock is anticipated to stand permanently on a 10V on 1H slope. Conventional drill and blast methods can be used to excavate a deep cut or slot in the rock. For ease of construction the near vertical slopes will have 24-inch setbacks for normal air track drills. Since water conveyance channels require permanent protection against rock falls, all exposed rock surfaces will be permanently covered with chain-link mesh. Concrete retaining walls will contain weep holes on 10-foot centers to prevent buildup of water pressure. Overburden on the up slope (south) side of the wet well/lock varies in thickness from several feet to possibly 40 feet. Boring logs 94-DD-80 and DD-81 show overburden consisting of silty, sandy gravel slopewash with numerous cobbles and boulders. No laboratory tests were run on the overburden. An overburden cut slope of 1V on 2H with toe resting on a rock bench 5 to 10 feet from the neatline excavation should allow sufficient room for construction of a temporary barrier fence to catch debris that might otherwise slough into the excavation.

Bedrock fractures are spaced from a few inches to tens of feet. Occasional brecciated zones, several feet thick, are likely to be encountered. Most fractures appear tight. Some fractures contain clay fillings and some are partially or completely rehealed with secondary mineralization. Water bearing fractures are known to occur at foundation grade, elevation 1,030 feet. Water under moderate artesian pressure was encountered in core boring 96-DD-87 and in pre-dam exploratory boring 56-DD-37, see logs in Exhibit A.

The volcanic stratigraphy is very irregular with soft hydrothermally altered zones of incompetent rock. Geotechnical exploration and laboratory testing during feature design studies will be used to determine strength characteristics of some of the questionable rocks. Hydrothermally altered materials destined for disposal will require testing for leachable metals and other suspect specific compounds.

The following conditions could occur: a) joint planes paralleling the excavation cut slope could result in planar sliding; and b) intersecting joint planes may form wedges capable of sliding out of the slope. The following rock bolt-drain hole patterns were selected to support the excavated rock slopes. Treatment will consist of tensioned and grouted rock bolts in a 6-foot by 6-foot diagonal pattern. See Plate E-17 for typical bolt and drain hole configurations. Bolts will be 1-inch diameter, 15 to 30 feet in length and will be installed normal to the slope face. Actual field conditions may dictate deviation of lengths, spacings, and orientations of bolts in order to achieve maximum compression against slip planes and

jointing cracks. Rock drains will be 25 feet in length, on 12-foot centers, inclined 5° above horizontal.

## 6.7 GATE CHAMBER EXCAVATION AND SUPPORT

Portals contain the most unpredictable rock conditions. Two tunnel diameters of sound rock are available at the site for the development of a ground arch over the opening. Rock removal in the portal area will be by the drilling and blasting method. Untensioned rock bolts, shotcrete, and steel mesh will be installed as the excavation advances. Upon achieving turnunder the cut slope will have been thoroughly protected with 30-foot-long rock bolts (#12) on a 5-foot diagonal pattern between elevation 1,076 and 1,096 feet and 4- to 6-inch thick fiber-reinforced shotcrete and welded wire mesh up to elevation 1,160 feet. The gate chamber crown is located at approximately elevation 1,065 feet on the cutslope, see Plate E-18. The portal will be strengthened with a steel set as mining advances. Three more steel sets will be installed in the gate chamber. In addition the chamber crown will be supported with 4-inch thick fiber reinforced shotcrete and embedded rock bolts, 5 feet on center, angled to develop the arch. From the springline down to approximately elevation 1,040 feet the walls will be supported with 4-inches of shotcrete. Consolidation grouting will be accomplished and drains drilled and installed as needed to control water pressure.

Deformation monitoring will be used to provide early warning of potential instability and as a check on the adequacy of installed support. Instruments for this purpose are tape and multiple position borehole extensometers (MPBX). They are effective, relatively low cost and proven reliable. The instruments will be installed during the early stages of the work to optimize their value.

## 6.8 MINING AND SUPPORT FOR NEW CONDUIT

See Plate E-12 for the existing diversion tunnel geology. Rock quality and hardness vary with rock type and location. Considerable local variation in degree of fracturing is predicted. The rock is anticipated to vary from massive and intact at the proposed tower portal to crushed and altered at the proposed transition. Excessively sheared and/or chemically deteriorated rock could also be encountered. Since rock quality at the tunnel transition is anticipated to be very poor, preconsolidation grouting, rock bolting, and installation of spiling will be installed from within the existing diversion tunnel, between station 16+35 and 16+65, before mining of the new conduit tunnel. The crown and left wall of the existing diversion tunnel will be presupported by consolidation grouting for a distance of 40 feet beyond the existing concrete liner to strengthen the rock. Pattern rock bolts, on 4-foot centers will be drilled and embedded at least 25 feet into the tunnel crown. Bolts will be recessed and holes patched to maintain smoothness of the existing concrete.

Mining for the new conduit and new 48-inch bypass pipe will follow gate chamber excavation and support. The new conduit will start at the rear of the approximately 20-foot-long gate chamber, see Plate E-18. Dimensions of the proposed bore are 15 feet high by 13.5 feet wide with invert at elevation 1,032 feet and crown at approximately 1,047 feet. Rock bolts on 5 feet spacing will be embedded 15 to 25 feet in the crown. Restrictive blasting made up of light loads are necessary within 25 feet (approximately one tunnel diameter) of the existing concrete-lined diversion tunnel. During construction of the existing diversion tunnel the natural state of stress of the rock was affected which resulted in redistribution of stresses and displacements within the surrounding rock. Coincidentally, the 25-foot wide restrictive blasting zone is the reach of soft andesite pyroclastic rocks. Rock load is predicted to change erratically from point to point within this reach, therefore 7 steel sets on 4-foot centers are planned.

## 6.9 MINING AND SUPPORT FOR 48-INCH DIAMETER BYPASS CONDUIT

The new 48-inch-diameter bypass excavation follows an alignment underneath the proposed intake tower, gate chamber, new conduit tunnel, and beneath the existing sluiceways where it transitions into the existing 48-inch bypass. Rock excavation beneath existing sluiceways will require removal of portions of the concrete floor to gain entry for rock excavation. Blasting will not be allowed beneath the sluiceways, so rock removal will be through mechanical methods such as hydrohammer.

## 6.10 DRILLING FOR FISH TRANSPORT PIPE

An approximate 20-foot-long permanent 24-inch-diameter continuous steel lining will join the new conduit tunnel approximately 20 feet downgradient from the fish facility radial gate. A 30-inch-diameter micro bore should afford sufficient room for installation of the fish transport pipe as well as construction of an impermeable grout seal.

## 6.11 INTAKE CHANNEL EXCAVATION AND TREATMENT

An overburden cut slope of 1V on 2H with toe resting on a rock bench 10 feet distance from the neatline will allow ample room for construction of a temporary debris fence. Actual width of the bench will be dependent on the catch points selected during feature design and rock elevations actually encountered during excavation. Overburden removal is planned with common excavation equipment.

In the existing upstream intake channel, rock varies from intensely brecciated to moderately fractured. There are three main joint sets which form the controlling structural feature, see Plates E-13 and E-14. The most critical joint set strikes northeast with easterly dip varying

between 40° and 50°. Another set strikes north and dips 70° to 85° east. The third set is nearly horizontal. Regarding stability of the cut, there appears to be no wedge failure problems associated with these joints. These major joints have slickensides and gouge material which varies from a thin veneer to more than 2 inches wide. Hydrothermal alteration minerals have accumulated on some of the exposed joint faces.

Most of the channel widening excavation will be in rock. Systematic drilling and controlled blasting procedures will be employed to prevent damage to final cut slopes and grades. Rock slopes 2V on 1H or steeper will be presplit. The poor quality and fractured nature of the rock dictated a design slope of 4V on 1H with 5-foot-wide horizontal benches every 20 feet in height. Slope treatment elements consisting of tensioned and grouted rock bolts, chain link wire mesh, and drains will be installed in each lift before excavating the next lower lift. Bolt size will be 1-inch diameter (No. 8), 10 to 30 feet in length, and will be spaced in a pattern of 5-foot centers per row and 2-1/2 feet between rows. Chain link mesh will be attached to the cut slope by anchor pins installed midway between each rock bolt. Rock drains will be spaced on 10-foot centers, each a minimum of 30 feet in length and inclined 5° above horizontal.

## 6.12 DISPOSAL OF EXCAVATED MATERIALS

Materials from excavated areas will be placed in designated areas for disposal or use as borrow. Waste areas will be left reasonably smooth graded and sloped to drain. All of the excavated rock from tunnel mining and from the upstream intake channel widening should be considered waste material.

# SECTION 7 CONSTRUCTION MATERIALS

## 7.1 AGGREGATE SOURCES

Sand and gravel materials for construction of the dam core were borrowed from the Bear Creek Terrace, located one-half mile from the damsite on the left bank, Plate E-1. The Bear Creek gravel was determined unsuitable for concrete aggregate because of the high percentage of soft particles, therefore, concrete aggregate was shipped by railroad from the Glacier Sand and Gravel pit at Steilacoom, WA. The use of existing ready-mix pits in nearby vicinities will require investigation prior to final design.

## 7.2 ROCK SOURCES

During construction of Howard Hanson Dam Project the rocks produced from the excavation of the spillway cut, tunnel, forebay, and intake channel were intended to be used as rock fill for the embankment dam, but because the rock weathered so severely within the stockpile, a new rock source had to be obtained. The rock at Bear Creek quarry, one mile west of the dam (Plate E-1), was better quality and produced a sufficient supply of durable rock for the entire project. The Bear Creek quarry, now private property, may not be accessible for the Fish Facility construction Since rock need is minimal, several commercial rock quarries within 20 road miles southwest of the project, may be available. Rock testing will be required.

# SECTION 8 OTHER EVALUATED TOWER/TUNNEL SITES

## 8.1 GENERAL

Section 6 summarizes geotechnical studies and evaluations of three alternative tower locations and five alternative tunnel alignments. Initially, tower design parameters included a tower base at elevation 1,045 feet, and a 12-foot-diameter finished tunnel having an upstream invert at elevation 1,060 feet, and downstream invert at river level, approximate elevation of 1,005 feet yielding a gradient of 1.6°. A nearly unlimited number of tower/tunnel configurations exist having the above design parameters. The following alternatives sites were thought to be viable by the Seattle District staff and by outside sources. Alternative tower sites Nos. 2 and 3 were studied using the above design parameters. As the feasibility study progressed, design parameters were changed: the upstream tunnel invert was lowered to elevation 1,035 feet; the gradient was flattened to under one degree; and the downstream invert was raised to elevation 1,010 feet. Also, lined 18-foot- and 23-foot-diameter tunnels were considered in order to house multiple conduits and provide for emergency reservoir discharge. For a time alternative tower site No. 1 (now designated as Alternative 9A7) was considered the most suitable location and therefore, minimal field drilling investigations were carried out for that site. Selection of site No. 1 was based on the following factors: favorable to fisheries criteria, favorable rock quality, practicality of tunnel excavation, hydraulically acceptable alignment, favorable proximity to the existing intake structure, availability of surrounding rock for tower stability, natural cofferdam, and overall constructability. See Exhibit A for boring logs, Exhibit C for laboratory test data and Exhibit D for relevant drawings.

## 8.2 LEFT ABUTMENT INTAKE TOWER SITE NO. 1

Intake tower site No. 1 was sited 150 feet upstream (southeast) of the existing gate tower. The intake structure was located to facilitate debris removal and maintain low risk to equipment operators. Tower site No. 1 would require rock excavation in the left (south) wall of the intake channel. In the immediate vicinity of site No. 1 the rock appeared structurally sound with ample strength for the requirements of slope stability.

**8.2.1 Tunnel Alignment No. 1** would be predominantly curved through its 2,000-foot length. It would parallel the existing flood control tunnel at a great separation, therefore, construction controls would be less restrictive than for any of the other alternative tunnel alignment schemes. The formerly proposed 23-foot-diameter tunnel would have been mined in andesitic and basaltic rock types and through a 50-foot-wide zone of very soft pyroclastic rock. Bedrock cover ranges from 30 feet at the diversion portal to a maximum of 150 feet over most of the alignment. The downstream portal and appurtenant structures

were located far enough downstream to be protected from spillway discharge and still provide the design tunnel gradient.

## 8.3 LEFT ABUTMENT INTAKE TOWER SITE NO. 2

Left abutment intake tower site No. 2 (now designated Alternate 9A4) was sited 20 feet northeast (right) of the existing gate tower. Tower site No. 2 would have required excavation into soft pyroclastic rock composing the left abutment of the dam and the right wall of the existing gate tower excavation. During excavation for the existing gate tower special treatment was required due to discovery of a soft hydrothermally altered zone on one side of the excavation. The soft rock had to be covered with a thin layer of concrete immediately upon excavation to limit air slaking deterioration of the foundation. The slope was laid back to a stable angle and covered with safety matting. Based on current knowledge of the area Site No. 2 should be avoided. Should the site be reconsidered at a later date, then an extensive core drilling program together with laboratory analyses will be imperative in order that adequate controls for rock excavation can be instituted to preserve the abutment of the dam. Two tunnel schemes exiting this site were studied and determined to be less feasible than other schemes.

### 8.3.1 Tunnel Alignment No. 2L

Tunnel alignment No. 2L would be approximately 1,300 feet in length and would be driven in rock. The upstream invert would be at elevation 1,060 feet and downstream invert would exit rock at river level, approximately elevation 1,005 feet. The alignment crosses over the existing diversion tunnel in the vicinity of the spillway weir. Mining along this alignment would require special procedures such as consolidation grouting and/or installation of a tunnel liner in order not jeopardize the existing tunnel operation. Also, the downstream tunnel portal would be in soft hydrothermally altered rock. There is some concern about the integrity of this rock. When the spillway chute passes water, extensive erosion is expected. A tunnel located at the toe of the spillway chute, exiting within this rock mass, should be avoided. Operation of the spillway would probably impact the downstream portal.

### 8.3.2 Tunnel Alignment No. 2R

Tunnel alignment No. 2R would be a 1,000-foot-long uniform curve into the left abutment between the existing diversion tunnel and the canyon wall. Construction restrictions during mining are recommended to prevent damage to the existing diversion tunnel. The upstream tunnel invert would be at elevation 1,060 feet and downstream invert would be at elevation 1,020 feet where it exits from rock. The tunnel would then transition to a surface flume which would deliver fish downstream to elevation 1,005 feet. The downstream tunnel

portal would exit within a few feet of the stilling basin making portal construction and access difficult.

## 8.4 RIGHT ABUTMENT INTAKE TOWER SITE NO. 3

Site No. 3 was sited about 200 feet upstream (south) of the project office building. This site would require rock excavation into the right abutment of the dam and would require a cofferdam. The intake tower and shaft would be founded in an outcrop of extensively weathered tuff. Right abutment bedrock consists of basalt and andesite in the form of flow deposits and intrusive dikes, and basaltic and andesitic pyroclastics in the form of tuffs. Rock quality was not thoroughly explored during dam construction because the left abutment rock proved best for all the ancillary structures. A major fault, striking E-W and dipping 85° south, was mapped extending from the left abutment across the river canyon into the large bedrock "notch" in the right abutment (Corps of Engineers, 1963). The notch is situated immediately downstream of the dam axis and has since been covered by the dam embankment. Two pre-dam core borings, D-7 and D-8, were drilled in the right bank notch fault zone. Core recovery for the two borings ranged from 75 to 90 percent indicating rock of fair quality. This E-W fault projected across the canyon to the left abutment was encountered in the diversion tunnel and found to transmit considerable groundwater. Groundwater could be a significant problem for tunnel alignments 3L and 3R since two distinct aquifers are known to exist in the right abutment. Two tunnel schemes exiting tower site no. 3 were evaluated. The first significant flood pool occurred in February, 1965 and attained a brief elevation of 1,161.8 feet. At that time a spring abruptly broke out at elevation 1,134 feet, approximately 350 feet downstream from the downstream right abutment toe. The spring flowed as much as 100 gpm and subsequently was controlled by a gravel blanket supported by a crib wall. A drainage adit was constructed in 1968 at elevation 1,100 feet to control abutment leakage through the landslide debris during flood pools. The adit extends 650 feet into the abutment.

### 8. 4.1 Tunnel Alignment No. 3L

Tunnel Alignment No. 3L would be approximately 500 feet in length, bearing N40°W, and would be driven through 300 feet of volcanic rock, 50 feet of landslide debris, and through 150 feet of rock fill located at the toe of the dam. The upstream tunnel invert would be at elevation 1,060 feet and downstream invert would be at elevation 1,030 feet where it would emerge from the rock fill. The tunnel would transition into a surface flume which would extend downstream along the right bank until reaching river elevation 1,005 feet. Mixed face tunneling is costly and slow. Tunneling into the unconsolidated landslide debris and rockfill may jeopardize the dam and therefore, should be avoided.

### 8.4.2 Tunnel Alignment No. 3R

Tunnel Alignment No. 3R would be a 600-foot-long straight tunnel, bearing N32°W, and would be driven 500 feet through volcanic rock. The upstream tunnel invert would be at elevation 1,060 feet and downstream invert would be at elevation 1,040 feet where it would emerge from bedrock. Cut and cover would be required for a length of 100 feet through slope treatment materials and bedrock. Upon emerging from the cut the invert would be approximately elevation 1,030 feet, still 25 feet above the river. The tunnel would then transition to a surface flume which would be founded along the right bank to the elevation 1,005 foot contour where it would intersect the river. Approximately midway along tunnel alignment No. 3R, just downstream of the large bedrock notch, the rock cover thins over the tunnel crown. Tunneling through unconsolidated landslide debris directly beneath the embankment dam should be avoided.

A similar alignment, but at a lower tunnel invert (inlet at elevation 1,030 feet) was studied by Hart Crowser & Associates for Tudor Engineering Company in 1984, to supplement a preliminary evaluation for hydroelectric development. They concluded that conditions overall are suitable for construction of hydroelectric facilities. They were concerned that there is the possibility of inadequate rock cover over the tunnel alignment since available information indicates considerable variation in the top of bedrock. The height of rock cover as well as condition of the rock could significantly impact design for a permanent tunnel lining. They concluded that seepage in the abutment may affect design of a tunnel lining, depending on the relative difference in hydraulic head inside and outside the tunnel.

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# FIGURES

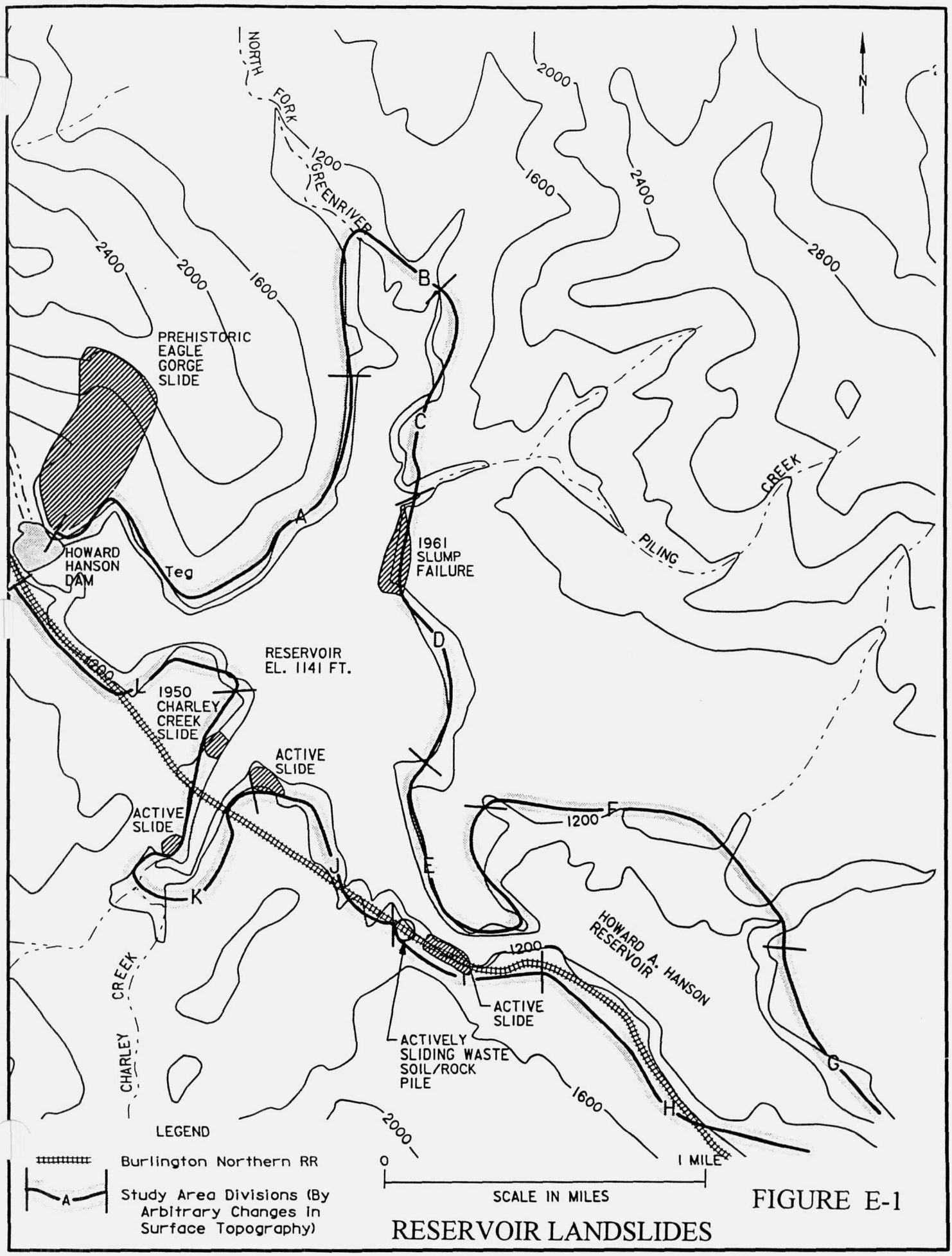



FIGURE E-1

RESERVOIR LANDSLIDES

$H_T$ = TOTAL HEAD LOSS = 1141 − 1085 = 56

$H_T^2 = 56^2 = 3136$

$H_a^2 = \frac{2}{3}(3136) = 2091$ $\quad H_a = \sqrt{2091} = 45.7'$

$H_b^2 = \frac{1}{3}(3136) = 1045$ $\quad H_b = \sqrt{1045} = 32.4'$

$$q_{2A} = K\,\frac{(56.0 - 45.7)}{130}\left(\frac{56.0 + 45.7}{2}\right)$$

$$= K\left(\frac{10.3}{130}\right)\left(\frac{101.7}{2}\right) = 4.02\,K$$

$$Q_{2A} = K\,4.02\,(130) = 522\,K$$

$$\Sigma\, Q_{TUNNEL} = 9(522)K = 4698\,K$$

$Q_{TUNNEL}$ FOR $K = 100{,}000$ FT/YEAR $= .003175$ FT/SEC

$Q = 4698\,(.003175) = 14.9$ FT³/SEC.

POOL AT ELEV. 1160

$H_T$ = TOTAL HEAD LOSS = 1160 − 1085 = 75'

$H_T^2 = 75^2 = 5625$

$H_a^2 = 2/3\,(5625) = 3750$ $\quad H_a = 61.2'$

$H_b^2 = 1/3\,(5625) = 1875$ $\quad H_b = 43.3'$

$$q_{2A} = K\,\frac{(75 - 61.2)}{130}\left(\frac{75 + 61.2}{2}\right)$$

$$= K\left(\frac{13.8}{130}\right)\left(\frac{136.2}{2}\right) = 7.24\,K$$

$$Q_{2A} = 7.24\,K\,(130) = 940\,K$$

$$\Sigma\, Q_{TUNNEL} = 9(940\,K) = 8460\,K$$

$Q_{TUNNEL}$ FOR $K = 100{,}000$ FT/YEAR $= .003175$ FT/SEC

$Q = 8460\,(.003175) = 26.8$ FT³/SEC

POOL AT ELEV. 1180

$H_T$ = TOTAL HEAD LOSS = 1180 − 1085 = 95 $\quad H_T^2 = 9025$

$H_a^2 = 2/3\,(9025) = 6017$ $\quad H_a = 77.6'$

$H_b^2 = 1/3\,(9025) = 3008$ $\quad H_b = 55'$

$$q_{2A} = K\,\frac{(95 - 77.6)}{130}\left(\frac{95 + 77.6}{2}\right) = K\left(\frac{17.4}{130}\right)\left(\frac{172.6}{2}\right) = K\,11.55$$

$$Q_{2A} = K(11.55)(130) = 1500\,K$$

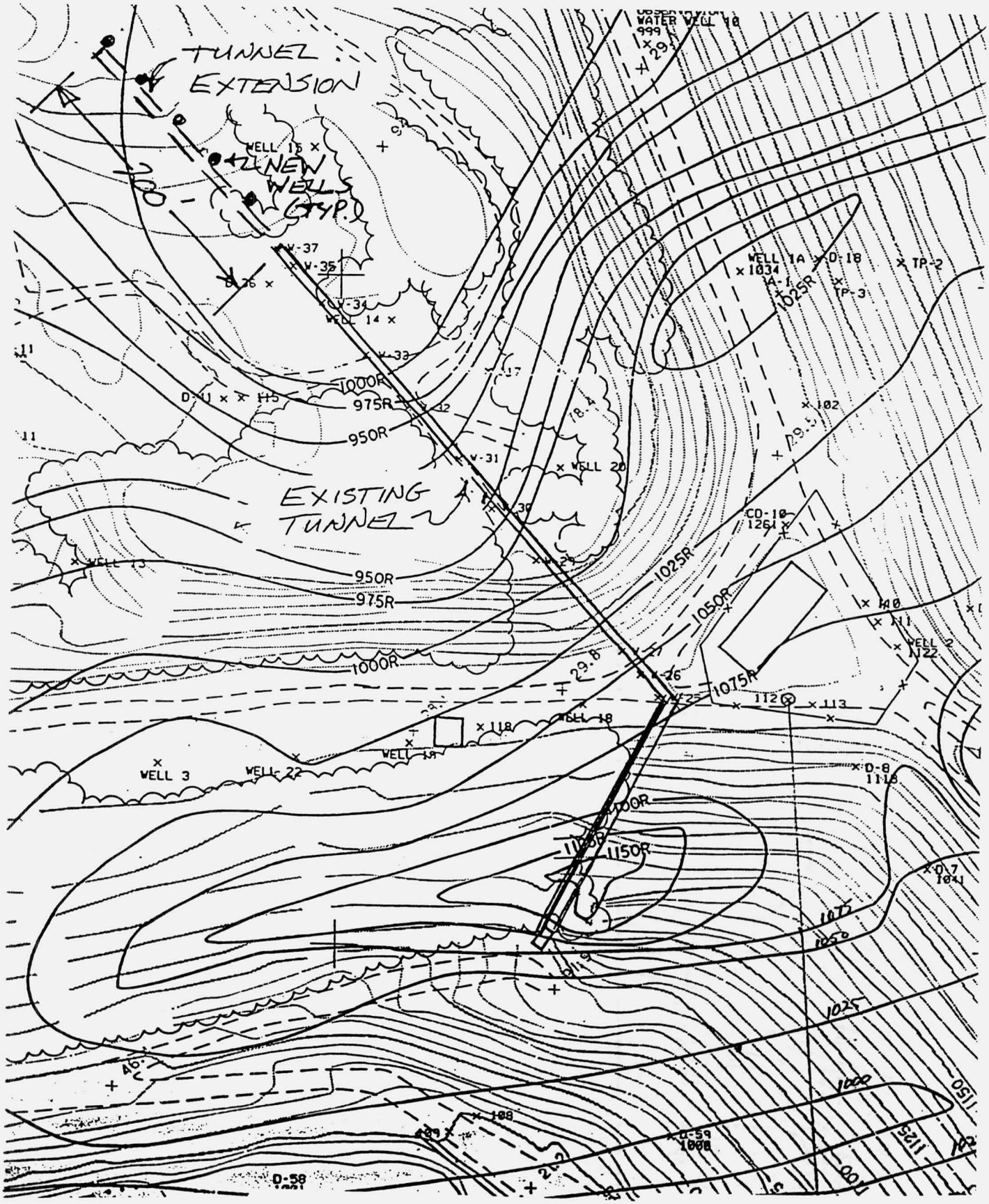
$$\Sigma\, Q_{TUNNEL} = 9(1500\,K) = 13500\,K$$

$Q_{TUNNEL}$ FOR $K = 100{,}000$ FT/YEAR $= .003175$ FT/SEC

$Q = 13500\,(.003175) = 42.8$ FT³/SEC $= 19{,}200$ GPM

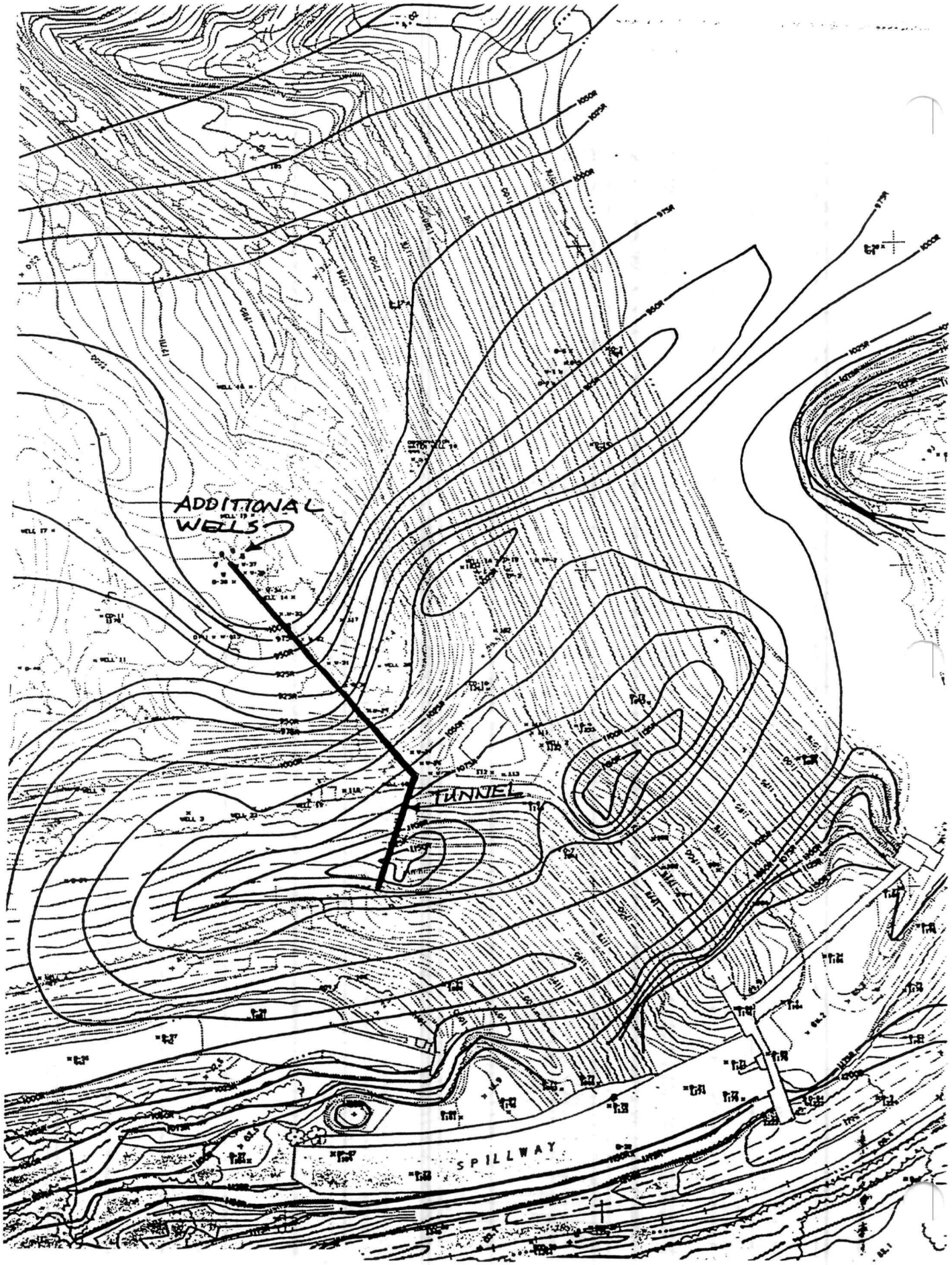
SEEPAGE CALCULATIONS

FIGURE E-2




**TUNNEL EXTENSION**

**FIGURE E-3**

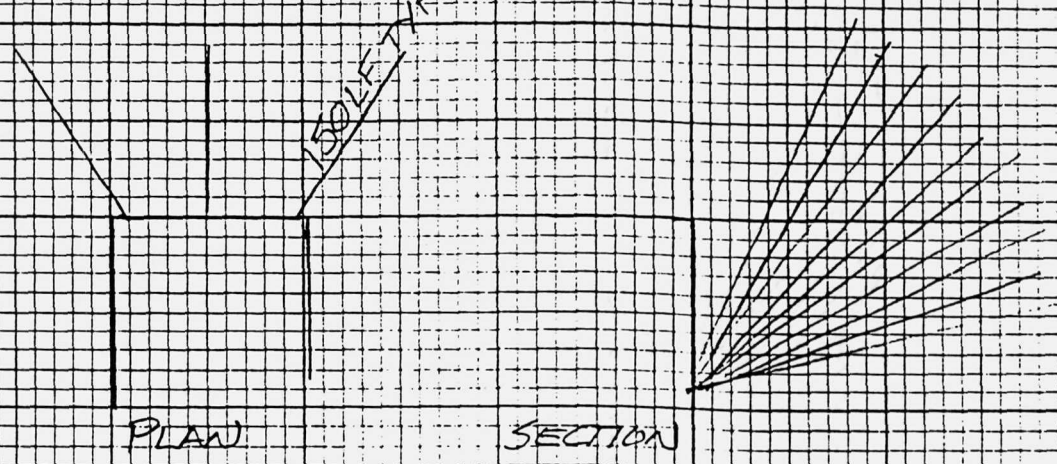



**ADDITIONAL WELLS**

**FIGURE E-4**

HORIZONTAL DRAINS DRILLED THROUGH BACK OF EXISTING TUNNEL.

ASSUME THREE SETS:



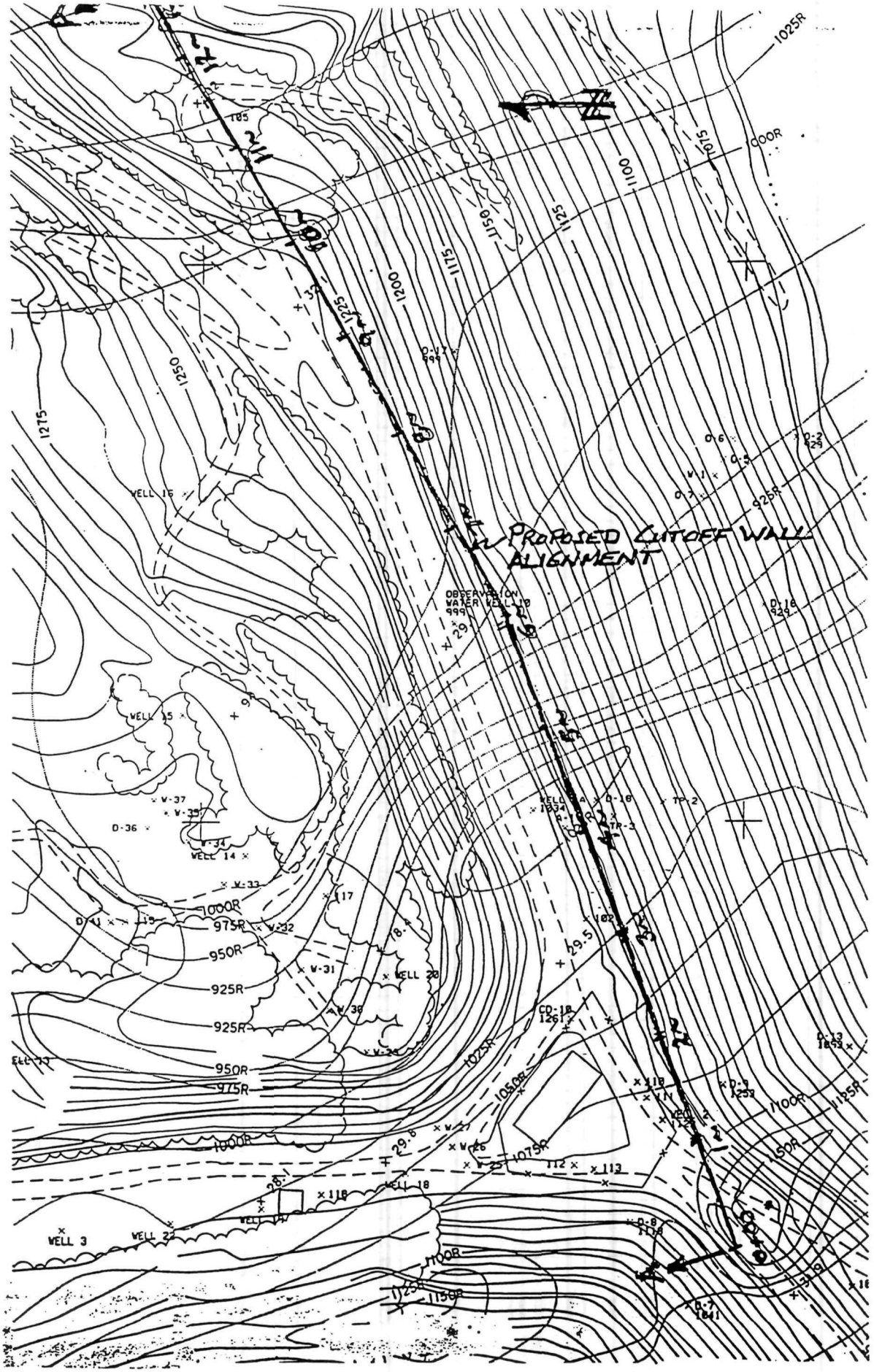

10 DRAINS PER SET @ 150 LF AVERAGE:

30 X 150 = 4500 LF TOTAL

PHILOM-10 X 10 TO 1 INCH
5TH LINE ACCENTED, 10TH HEAVY

**PROPOSED HORIZONTAL WELLS AT BACK OF EXISTING TUNNEL**

**FIGURE E-5**




**PROPOSED CUTOFF WALL ALIGNMENT**

FIGURE F-6

WALL AREA: INCLUDES 10' EMBEDMENT INTO BEDROCK

A) $\frac{1025-1120}{2} \times 125 = 6563\ ft^2$

B) $\frac{1025-1120-1215-1017}{2} \times 300 = 45,450\ ft^2$

C) $\frac{1215-1017-1214-1020}{2} \times 100 = 19,600\ ft^2$

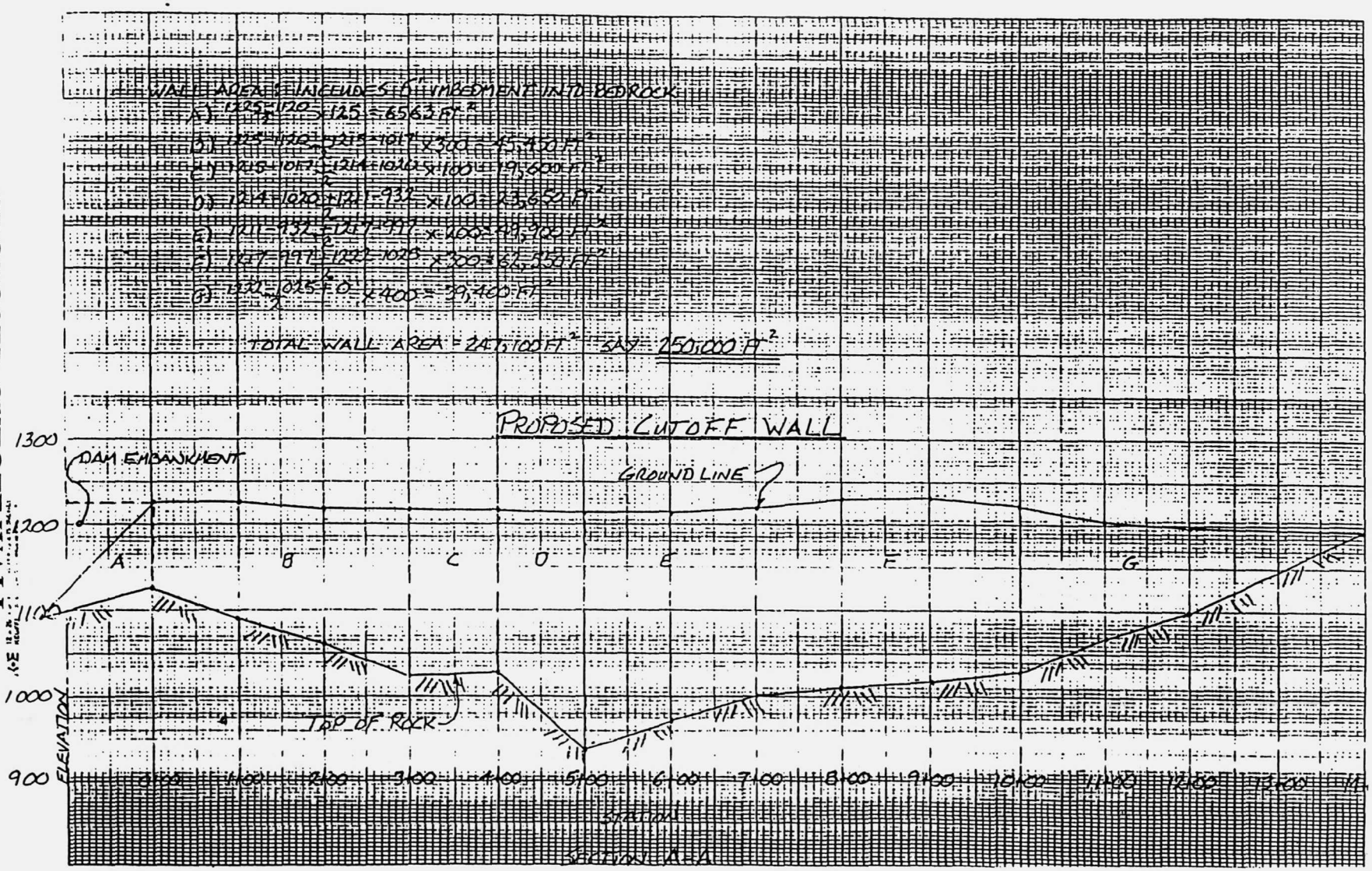
D) $\frac{1214-1020-1211-932}{2} \times 100 = 33,650\ ft^2$

E) $\frac{1211-932-1017-997}{2} \times 400 = 89,900\ ft^2$

F) $\frac{1017-997-1222-1020}{2} \times 300 = 62,250\ ft^2$

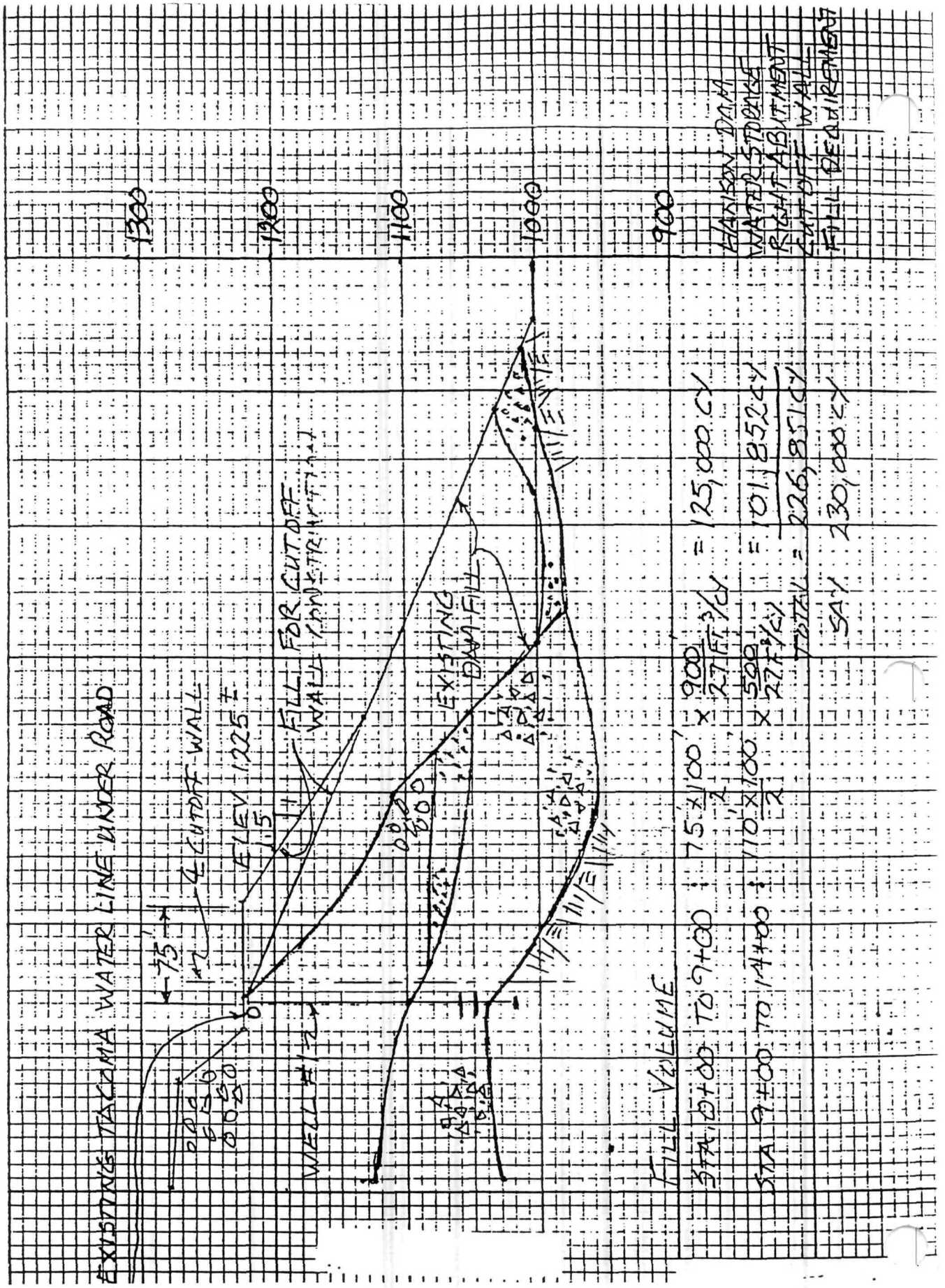
G) $\frac{1222-1025+0}{2} \times 400 = 39,400\ ft^2$

TOTAL WALL AREA = 247,100 $ft^2$ SAY 250,000 $ft^2$



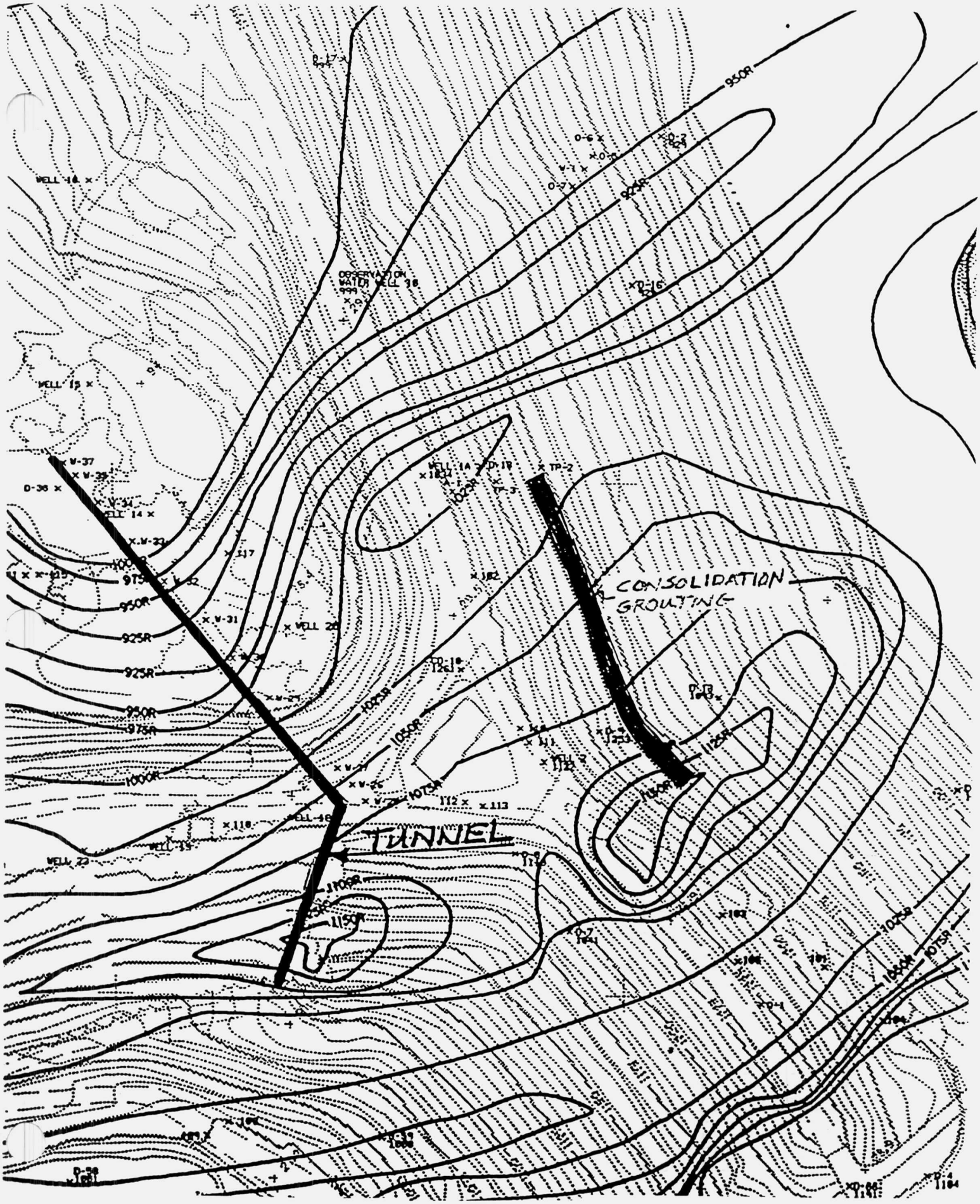

PROPOSED CUTOFF WALL

FIGURE E-7



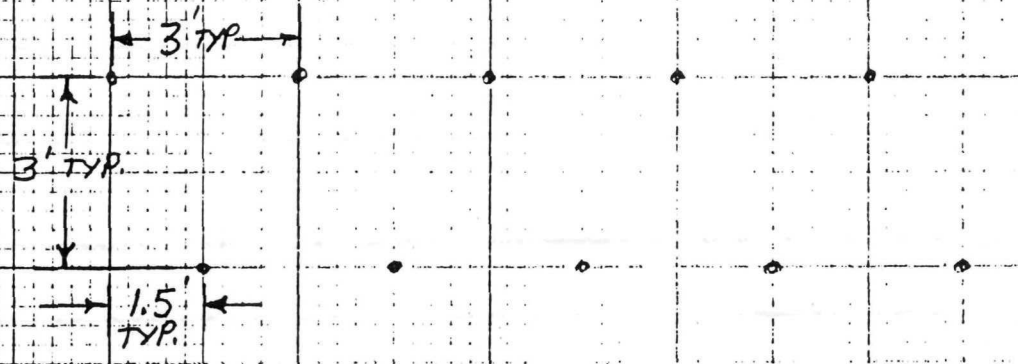

**PAD FOR CUTOFF WALL CONSTRUCTION**

**FIGURE E-8**




**CONSOLIDATION (INJECTION) GROUTING PLAN**

**FIGURE E-9**




BORINGS @ 3' PATTERN x 2 ROWS

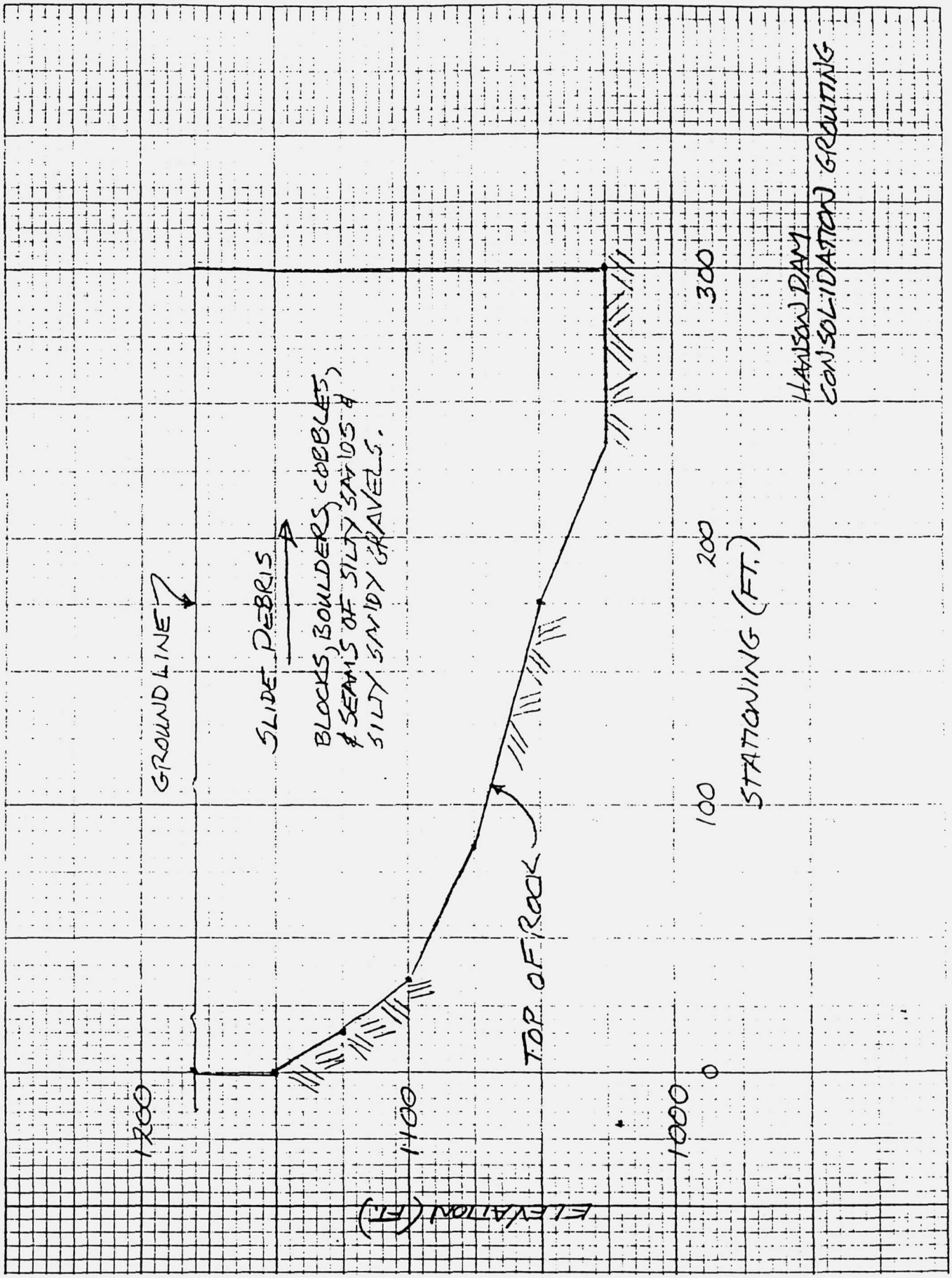
| AVERAGE DEPTH | # BORINGS | | |
|---|---|---|---|
| 60+80÷2 = 70'+10' = 80' | 48 | = | 3840 LF |
| 80+155÷2 = 118'+10' = 128 | 110 | = | 14080 |
| 155+10' = 165' | 46 | = | 7590 |
| TOTAL LF | | = | 25,510 LF |

1) ASSUME 6 INCH DIA. CASED BORINGS.
2) CASING TO BE PULLED & RE-USED ONCE GROUT TUBES ARE INSTALLED.

GROUT QUANTITY:
6" DIA. BORING = 0.7854 $FT^2$
0.7854 x 25510 = 20,035 $FT^3$
20,035 / 27 $\frac{CF}{CY}$ = 742 CY
BY EXPERIENCE @ MUD MOUNTAIN DAM NEED A FACTOR OF 10 TO FILL VOIDS ∴ NEED 7420 CY

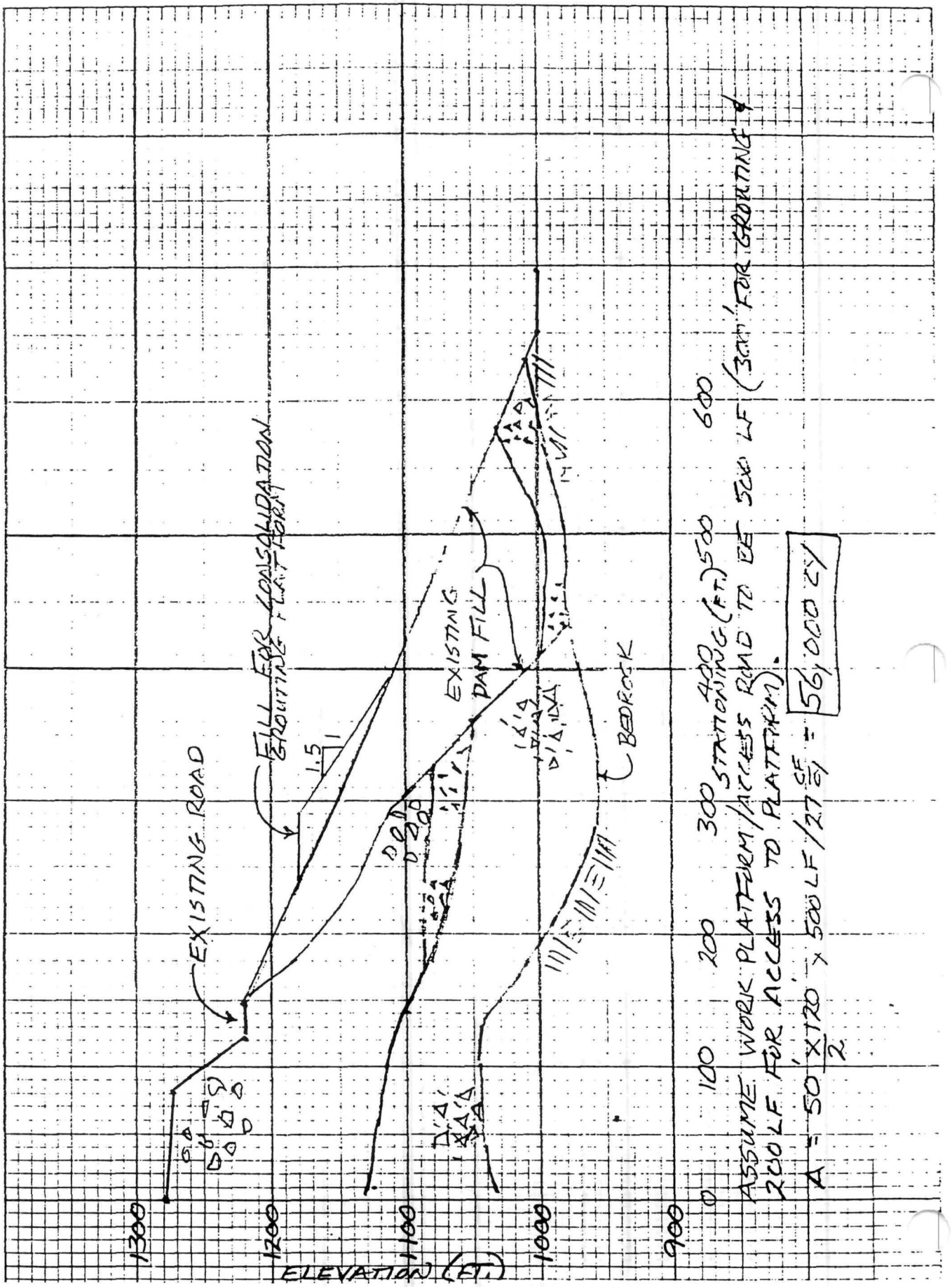
GROUT HOLE PATTERN

FIGURE E-10




**INJECTION GROUT PROFILE**

**FIGURE E-11**




**WORK PLATFORM**

**FIGURE E-12**

# CSIR GEOMECHANICS CLASSIFICATION OF JOINTED ROCK MASSES

## A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

| | PARAMETER | | RANGES OF VALUES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Strength of intact rock material | Point load strength index | > 8 MPa | 4 - 8 MPa | 2 - 4 MPa | 1 - 2 MPa | For this low range - uniaxial compressive test is preferred | | |
| | | Uniaxial compressive strength | > 200 MPa | 100 - 200 MPa | 50 - 100 MPa | 25 - 50 MPa | 10 - 25 MPa | 3 - 10 MPa | 1 - 3 MPa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core quality RQD | | 90% - 100% | 75% - 90% | 50% - 75% | 25% - 50% | < 25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of joints | | > 3 m | 1 - 3 m | 0.3 - 1 m | 50 - 300 mm | < 50 mm | | |
| | Rating | | 30 | 25 | 20 | 10 | 5 | | |
| 4 | Condition of joints | | Very rough surfaces Not continuous No separation Hard joint wall rock | Slightly rough surfaces Separation < 1 mm Hard joint wall rock | Slightly rough surfaces Separation < 1 mm Soft joint wall rock | Slickensided surfaces or Gouge < 5 mm thick or Joints open 1 - 5 mm Continuous joints | Soft gouge > 5 mm thick or Joints open > 5 mm Continuous joints | | |
| | Rating | | 25 | 20 | 12 | 6 | 0 | | |
| 5 | Ground water | Inflow per 10 m tunnel length | None | | < 25 litres/min. | 25 - 125 litres/min. | > 125 litres/min | | |
| | | | OR | | OR | OR | OR | | |
| | | Ratio $\frac{\text{joint water pressure}}{\text{major principal stress}}$ | 0 | | 0.0 - 0.2 | 0.2 - 0.5 | > 0.5 | | |
| | | | OR | | OR | OR | OR | | |
| | | General conditions | Completely dry | | Moist only (interstitial water) | Water under moderate pressure | Severe water problems | | |
| | Rating | | 10 | | 7 | 4 | 0 | | |

## B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

| Strike and dip orientations of joints | | Very favourable | Favourable | Fair | Unfavourable | Very unfavourable |
|---|---|---|---|---|---|---|
| Ratings | Tunnels | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | -60 |

## C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

| Rating | 100 — 81 | 80 — 61 | 60 — 41 | 40 — 21 | < 20 |
|---|---|---|---|---|---|
| Class No. | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

## D. MEANING OF ROCK MASS CLASSES

| Class No. | I | II | III | IV | V |
|---|---|---|---|---|---|
| Average stand-up time | 10 years for 5 m span | 6 months for 4 m span | 1 week for 3 m span | 5 hours for 1.5 m span | 10 min. for 0.5 m span |
| Cohesion of the rock mass | > 300 kPa | 200 - 300 kPa | 150 - 200 kPa | 100 - 150 kPa | < 100 kPa |
| Friction angle of the rock mass | > 45° | 40° - 45° | 35° - 40° | 30° - 35° | < 30° |

**CSIR GEOMECHANICS CLASSIFICATION OF JOINTED ROCK MASSES (1978)**

**FIGURE E-13a**

**Table 7-4**
**Geomechanics Classification of Jointed Rock Masses**

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

| PARAMETER | | | RANGES OF VALUES | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Strength of intact rock material | Point-load strength index | >10 MPa | 4-10 MPa | 2-4 MPa | 1-2 MPa | For this low range - uniaxial compressive test is preferred | | |
| | | | >250 MPa | 100-150 MPa | 50-100 MPa | 25-50 MPa | 5-25 MPa | 1-5 MPa | <1 MPa |
| | Rating | | 15 | 12 | 7 | 4 | 2 | 1 | 0 |
| 2 | Drill core quality RQD | | 90-100% | 75-90% | 50-75% | 25-50% | < 25% | | |
| | Rating | | 20 | 17 | 13 | 8 | 3 | | |
| 3 | Spacing of discontinuities | | >2 m | 0.6-2 m | 200-600 mm | 60-200 mm | <60 mm | | |
| | Rating | | 20 | 15 | 10 | 8 | 5 | | |
| 4 | Condition of discontinuities | | Very rough surfaces. Not continuous. No separation. Unweathered wall rock. | Slightly rough surfaces. Separation <1 mm. Slightly weathered walls. | Slightly rough surfaces. Separation < 1 mm. Highly weathered walls. | Slickensided surfaces OR Gouge < 5 mm thick. Separation 1-5 mm. Continuous. | Soft gouge > 5 mm thick OR Separation > 5 mm. Continuous. | | |
| | Rating | | 30 | 25 | 20 | 10 | 0 | | |
| 5 | Ground-water | Inflow per 10 m tunnel length | None | <10 L/min | 10-25 L/min | 25-125 L/min | >125 L/min | | |
| | | Ratio: joint water pressure major principal stress | OR 0 | OR 0.0-0.1 | OR 0.1-0.2 | OR 0.2-0.5 | OR >0.5 | | |
| | | General conditions | OR Completely dry | OR Damp | OR Wet | OR Dripping | OR Flowing | | |
| | Rating | | 15 | 10 | 7 | 4 | 0 | | |

B. RATING ADJUSTMENT FOR JOINT ORIENTATIONS

| Strike and dip orientations and dips | | Very favorable | Favorable | Fair | Unfavorable | Very unfavorable |
|---|---|---|---|---|---|---|
| Ratings | Tunnels | 0 | -2 | -5 | -10 | -12 |
| | Foundations | 0 | -2 | -7 | -15 | -25 |
| | Slopes | 0 | -5 | -25 | -50 | -60 |

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

| | | | | | |
|---|---|---|---|---|---|
| Rating | 100 ← 81 | 80 ← 61 | 60 ← 41 | 41 ← 21 | <20 |
| Class No. | I | II | III | IV | V |
| Description | Very good rock | Good rock | Fair rock | Poor rock | Very poor rock |

D. MEANING OF ROCK MASS CLASSES

| | | | | | |
|---|---|---|---|---|---|
| Class No. | I | II | III | IV | V |
| Average stand-up time | 10 years for 15-m span | 6 months for 8-m span | 1 week for 5-m span | 10 hr for 2.5-m span | 30 min for 1-m span |
| Cohesion of the rock mass | >400 kPa | 300-400 kPa | 200-300 kPa | 100-200 kPa | <100 kPa |
| Friction angle of the rock mass | >45° | 35-45° | 25-45° | 15-25° | <15° |

**GE0MECHANICS CLASSIFICATION OF JOINTED ROCK MASSES (1997)**

**FIGURE E-13b**

# PLATES

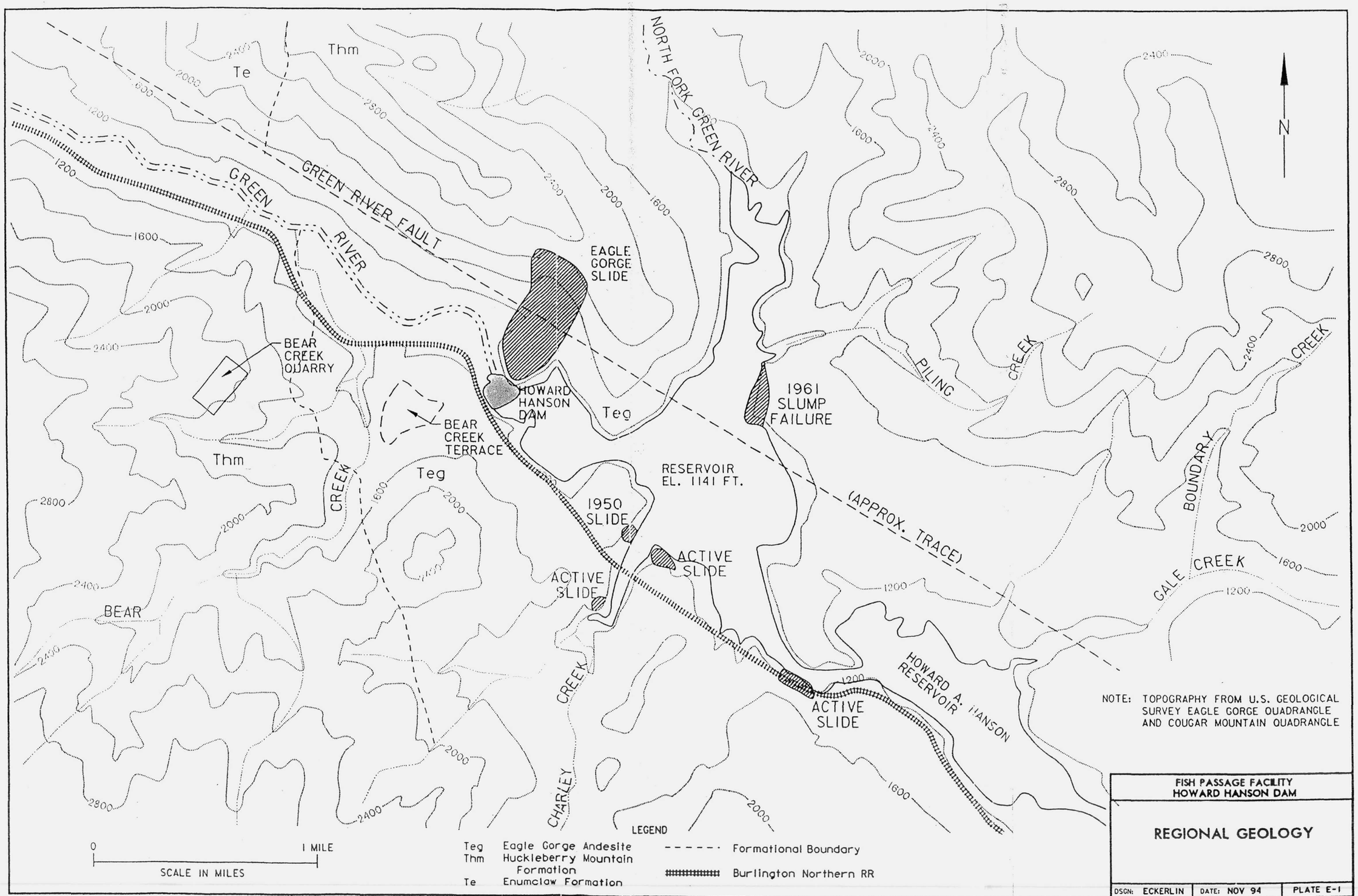
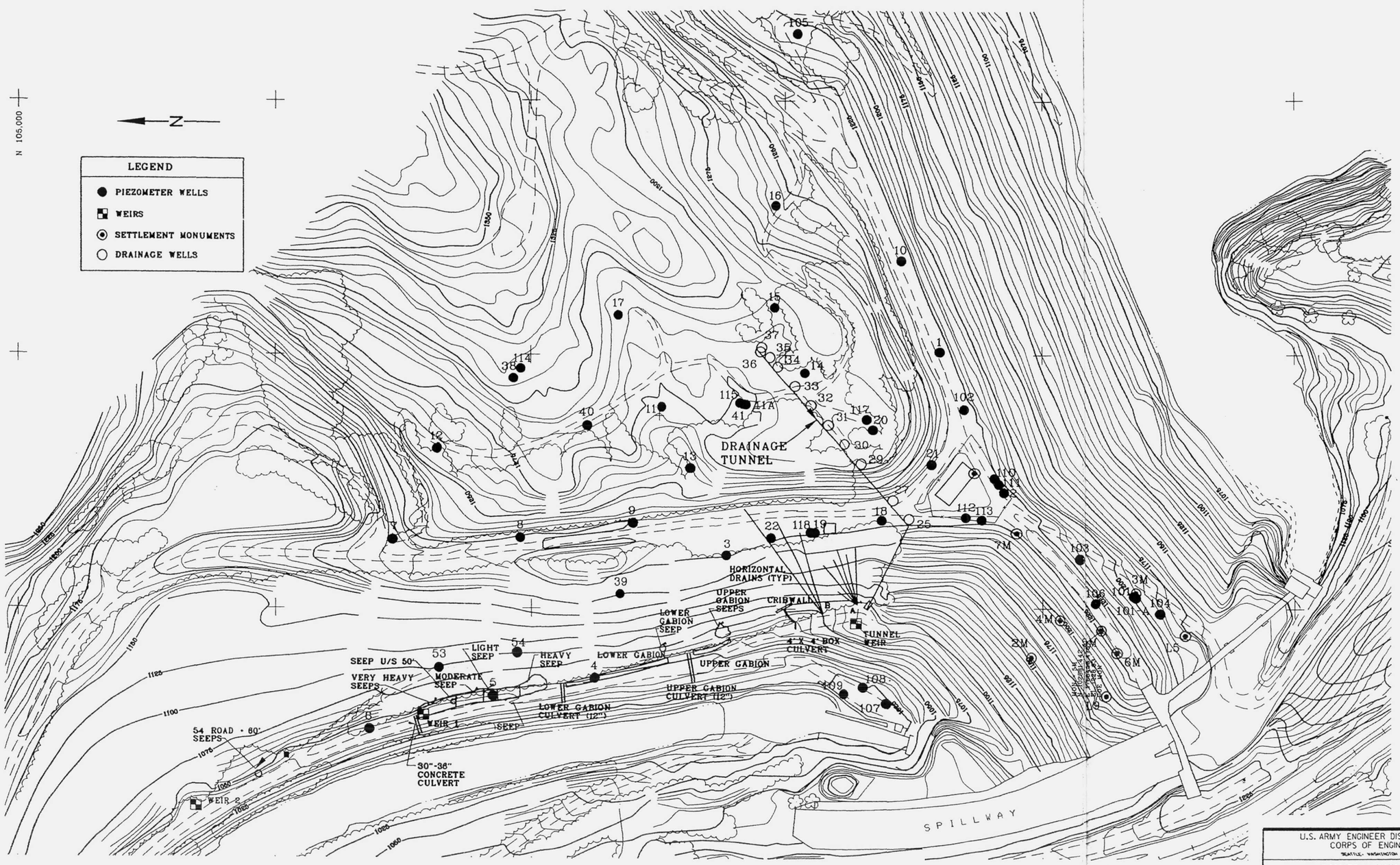

Thm
Te
GREEN RIVER FAULT
GREEN RIVER
NORTH FORK GREEN RIVER
EAGLE GORGE SLIDE
HOWARD HANSON DAM
Teg
BEAR CREEK QUARRY
BEAR CREEK TERRACE
Thm
Teg
BEAR CREEK
1950 SLIDE
ACTIVE SLIDE
ACTIVE SLIDE
RESERVOIR EL. 1141 FT.
1961 SLUMP FAILURE
(APPROX. TRACE)
PILING CREEK
CREEK
BOUNDARY
GALE CREEK
HOWARD A. HANSON RESERVOIR
ACTIVE SLIDE
CHARLEY CREEK
N
NOTE: TOPOGRAPHY FROM U.S. GEOLOGICAL SURVEY EAGLE GORGE QUADRANGLE AND COUGAR MOUNTAIN QUADRANGLE
0
1 MILE
SCALE IN MILES
LEGEND
Teg Eagle Gorge Andesite
Thm Huckleberry Mountain Formation
Te Enumclaw Formation
Formational Boundary
Burlington Northern RR
FISH PASSAGE FACILITY
HOWARD HANSON DAM
REGIONAL GEOLOGY
DSGN: ECKERLIN
DATE: NOV 94
PLATE E-1

PLATE E-1




U.S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

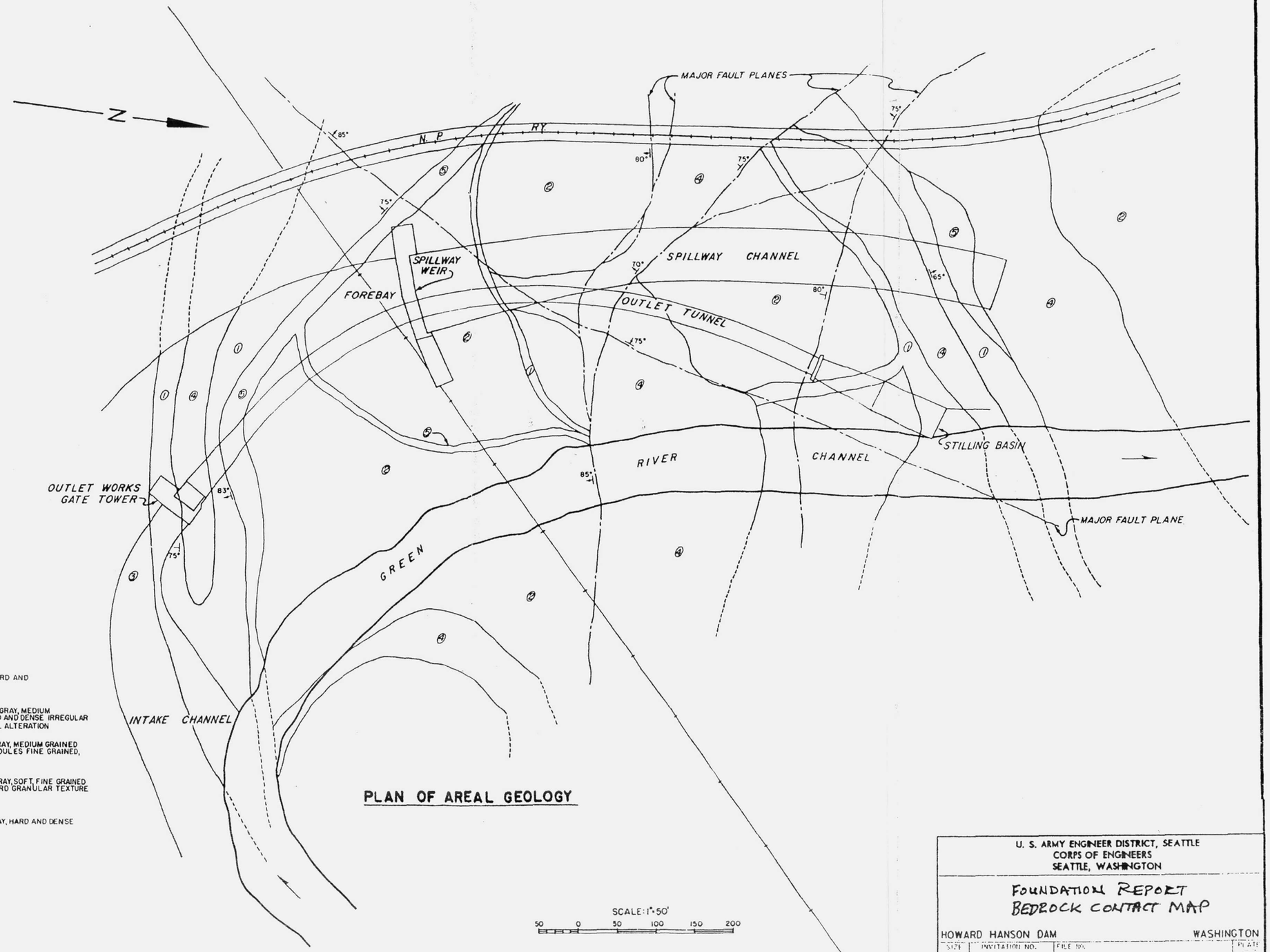
HOWARD A. HANSON DAM

SEEPAGE WELL LOCATIONS

GREEN RIVER WASHINGTON

| SIZE | INVITATION NO. | FILE NO. | DATE | PLATE |
|---|---|---|---|---|
| B | | | | |
| DSGN. MEYERHOLTZ | | CHK. MANN | SHEET | |

PLATE E-2




## LEGEND

| | |
|---|---|
| 1 | BASALT BLACK, FINE GRAINED HARD AND DENSE MODERATELY FRACTURED |
| 2 | ANDESITE DARK GREEN TO DARK GRAY, MEDIUM TO FINE GRAINED, MODERATELY HARD AND DENSE IRREGULAR FRACTURES MINOR HYDROTHERMAL ALTERATION |
| 3 | BASALTIC PYROCLASTICS DARK GRAY, MEDIUM GRAINED MODERATELY HARD AND DENSE NODULES FINE GRAINED, BLACK HARD AND DENSE |
| 4 | ANDESITE PYROCLASTICS LIGHT GRAY, SOFT, FINE GRAINED DENSE NODULES MODERATELY HARD GRANULAR TEXTURE |
| 5 | FELSITE FINE GRAINED, LIGHT GRAY, HARD AND DENSE |

## PLAN OF AREAL GEOLOGY

U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

FOUNDATION REPORT
BEDROCK CONTACT MAP

HOWARD HANSON DAM — WASHINGTON

| SIZE | INVITATION NO. | FILE NO. | PLATE |
|---|---|---|---|
| B | | | |

DSGN: ECKERLIN — CHK: MANN — SHEET

PLATE E-3

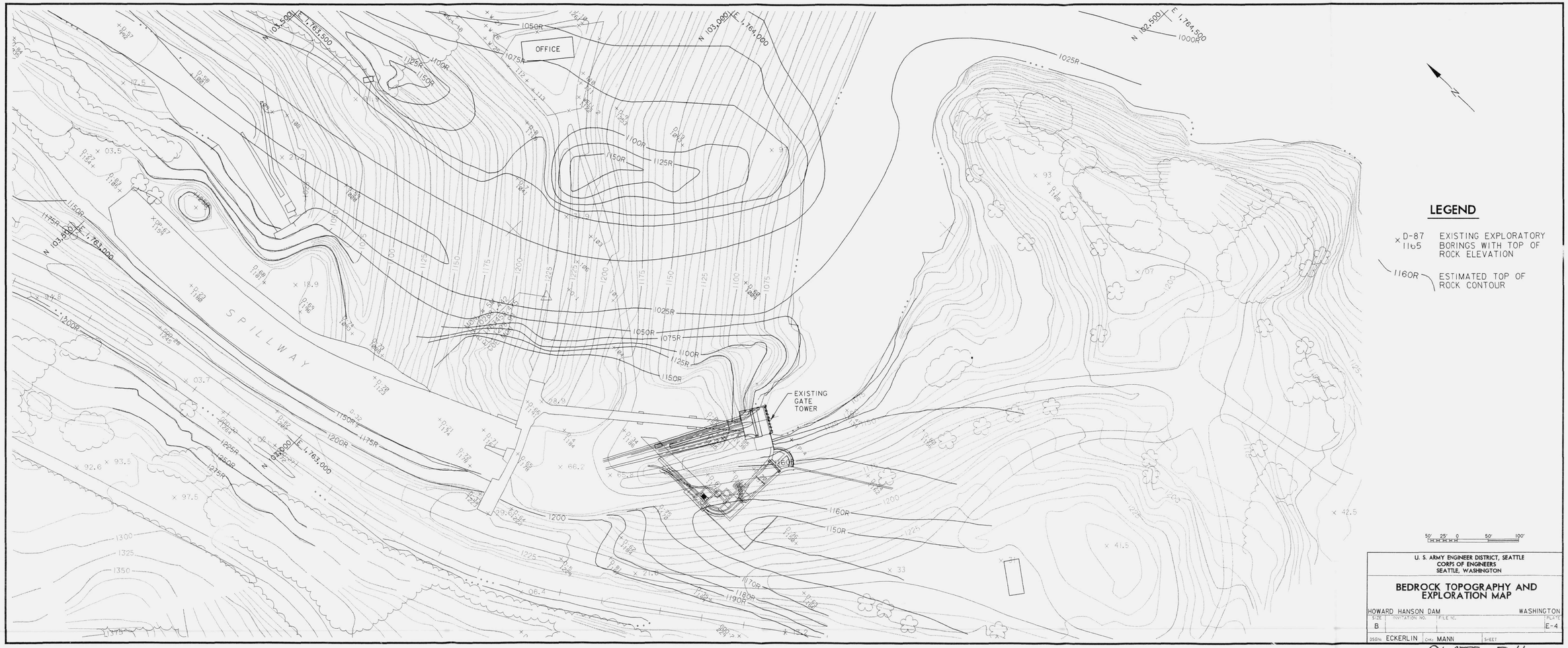
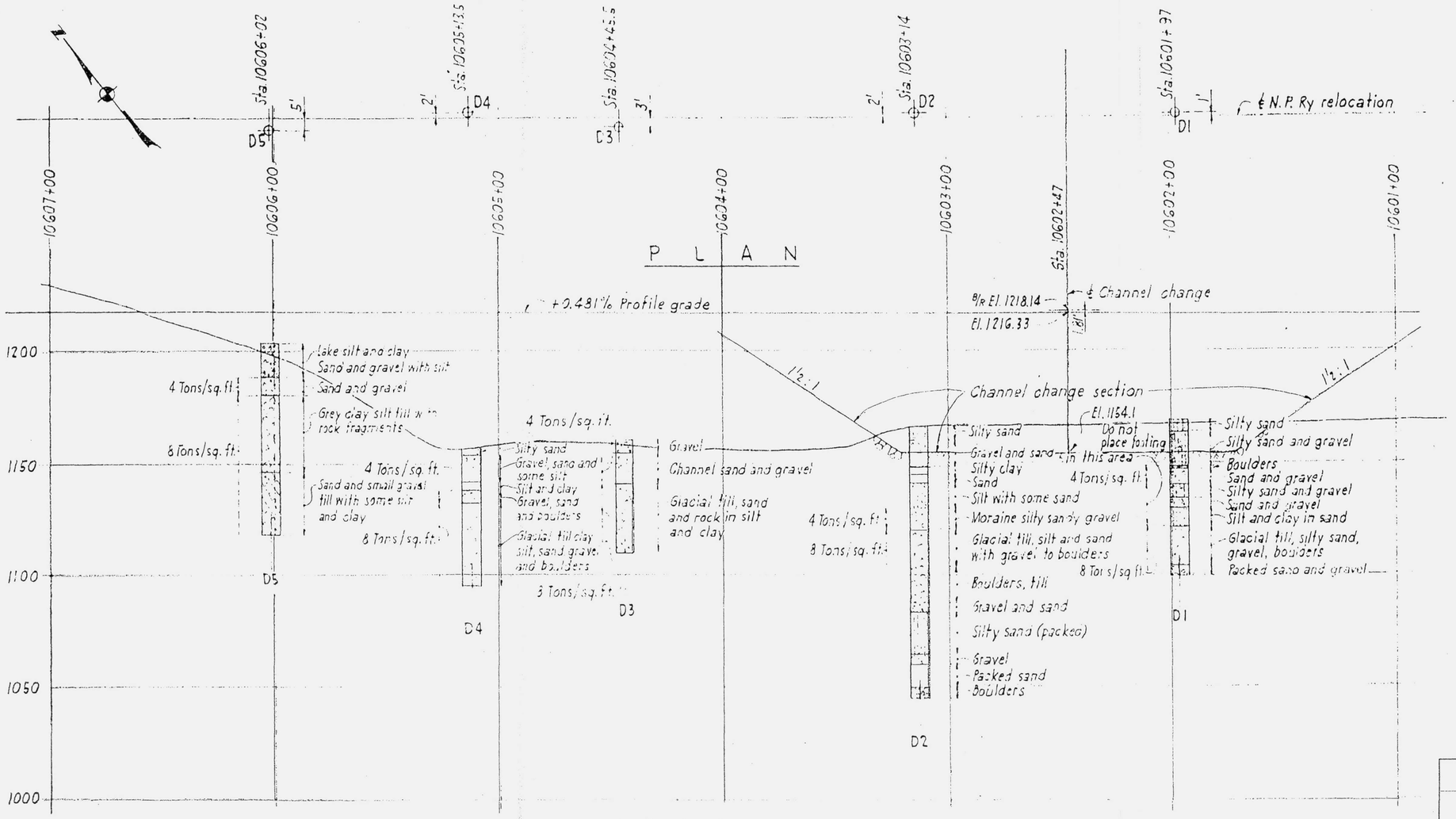

OFFICE
SPILLWAY
EXISTING GATE TOWER
N 103,500 E 1,763,500
N 103,000 E 1,764,000
N 102,500 E 1,764,500
N 103,500 E 1,763,000
N 103,000 E 1,763,000
1050R
1075R
1100R
1125R
1150R
1175R
1200R
1025R
1000R
1160R
1170R
1180R
1190R
1200
1225
1300
1325
1350
1375
LEGEND
D-87 1165 EXISTING EXPLORATORY BORINGS WITH TOP OF ROCK ELEVATION
1160R ESTIMATED TOP OF ROCK CONTOUR
50' 25' 0 50' 100'
U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON
BEDROCK TOPOGRAPHY AND EXPLORATION MAP
HOWARD HANSON DAM
WASHINGTON
SIZE B
INVITATION NO.
FILE NO.
PLATE E-4
DSGN. ECKERLIN
CHK. MANN
SHEET

PLATE E-4




U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

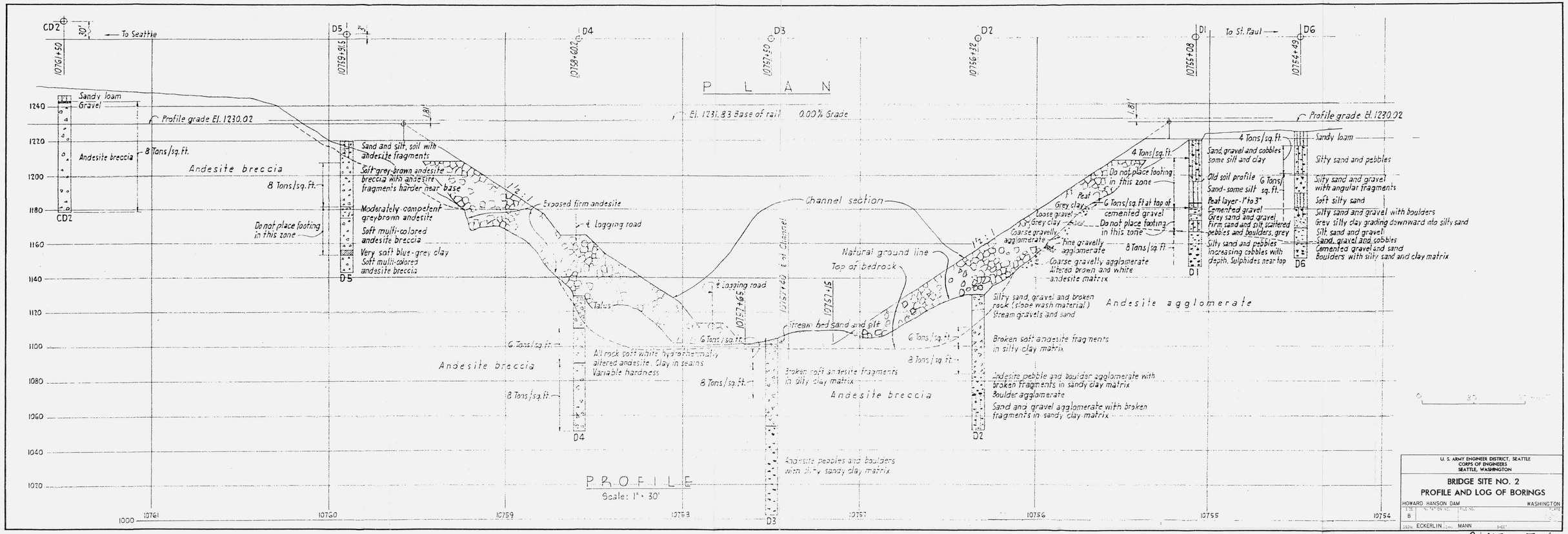
**BRIDGE SITE NO. 1**
**PROFILE AND LOG OF BORINGS**

HOWARD HANSON DAM — WASHINGTON

| SIZE | INVITATION NO. | FILE NO. | PLATE |
|---|---|---|---|
| B | | | |

DSGN ECKERLIN | CHK. MANN | SHEET

PLATE E-5




U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

**BRIDGE SITE NO. 2**
**PROFILE AND LOG OF BORINGS**

HOWARD HANSON DAM — WASHINGTON

B

DRAWN ECKERLIN — MANN

PLATE - E-6

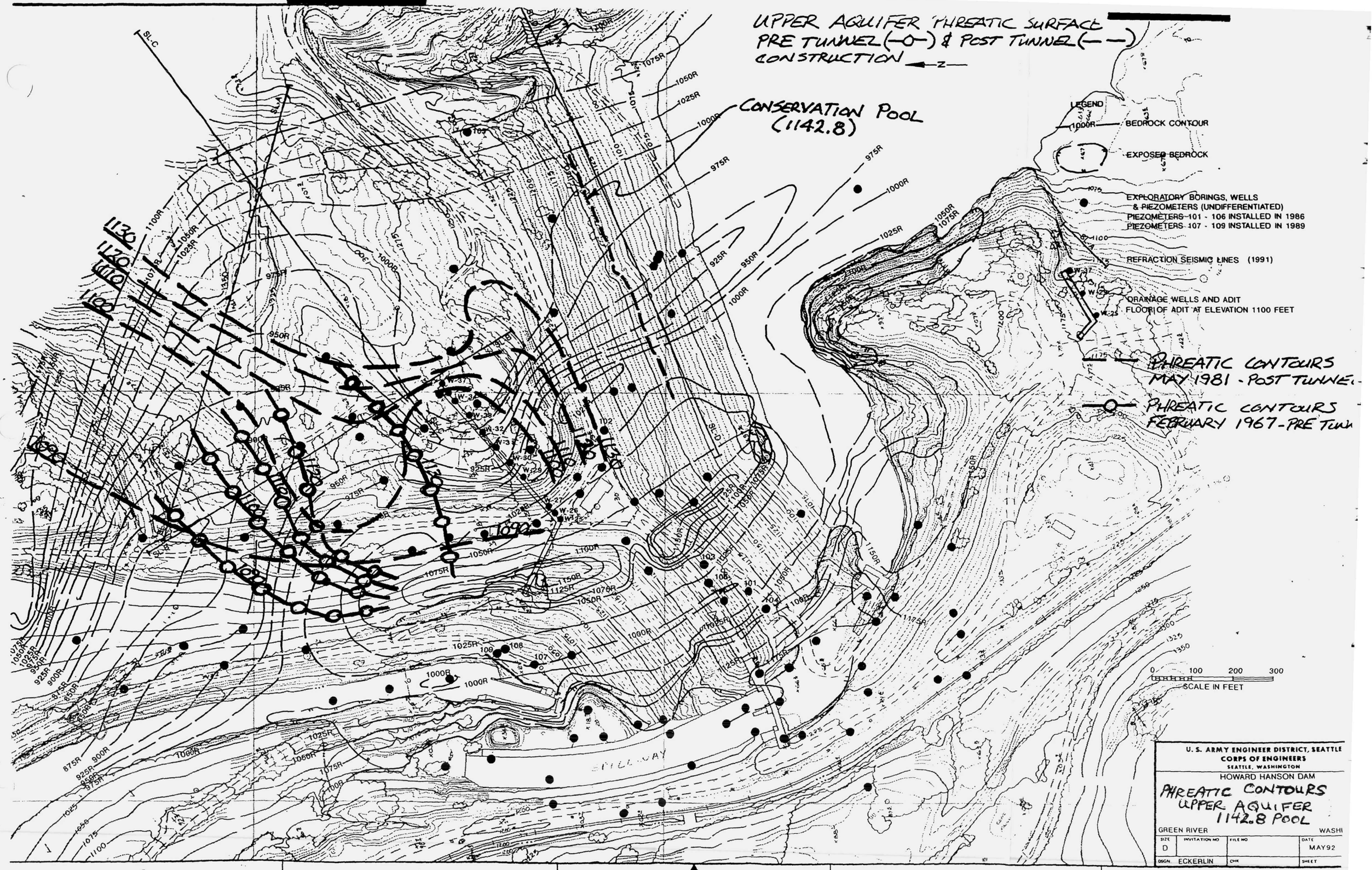
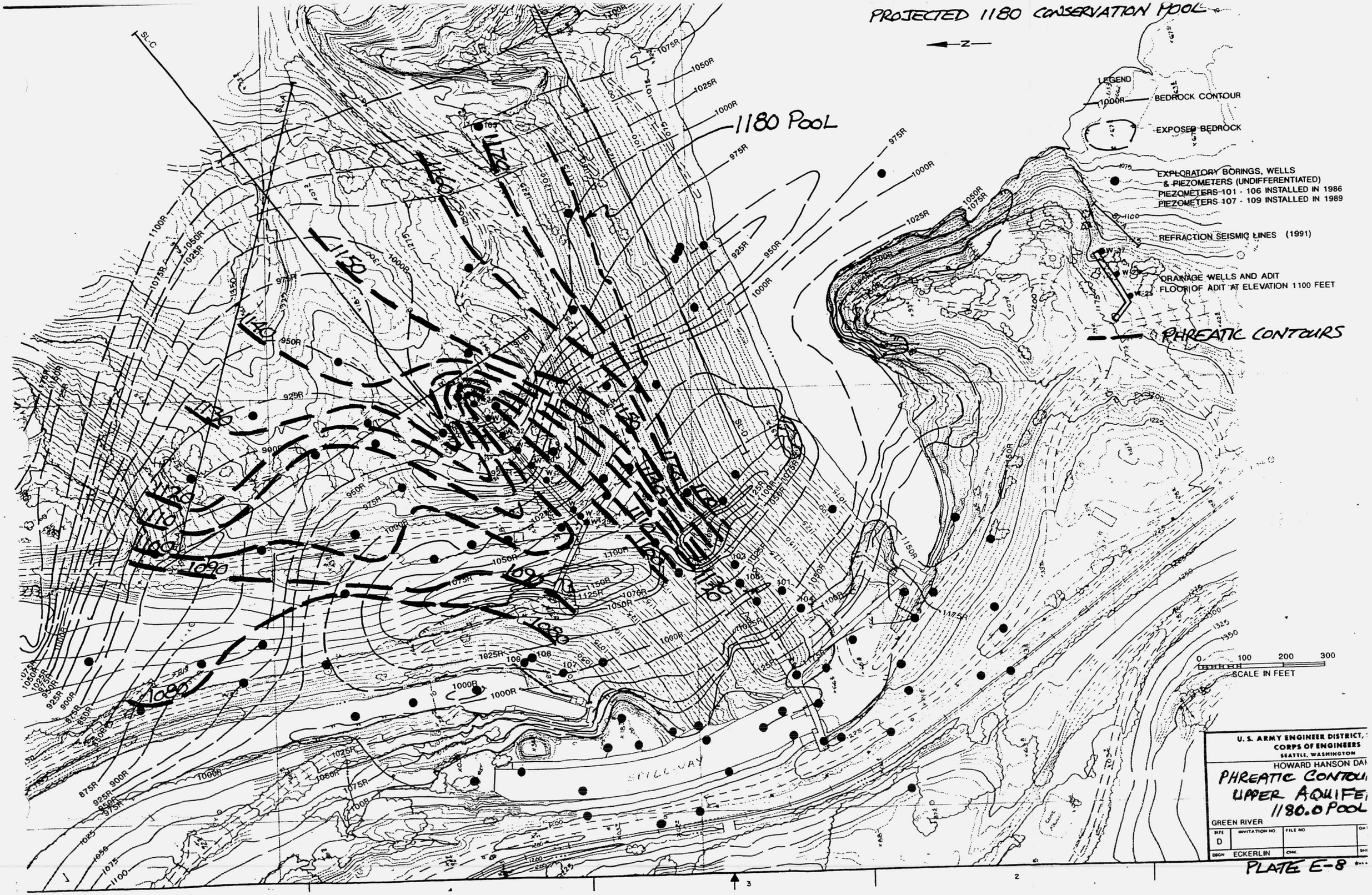
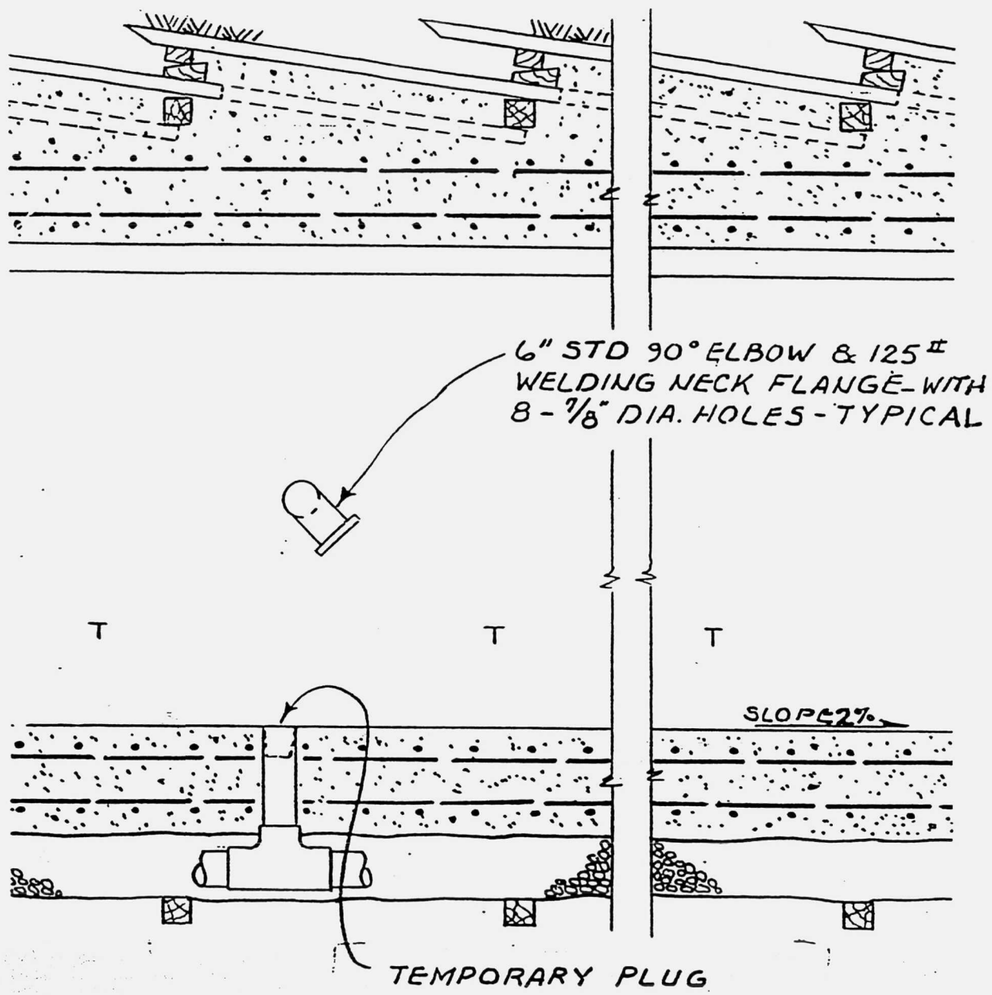
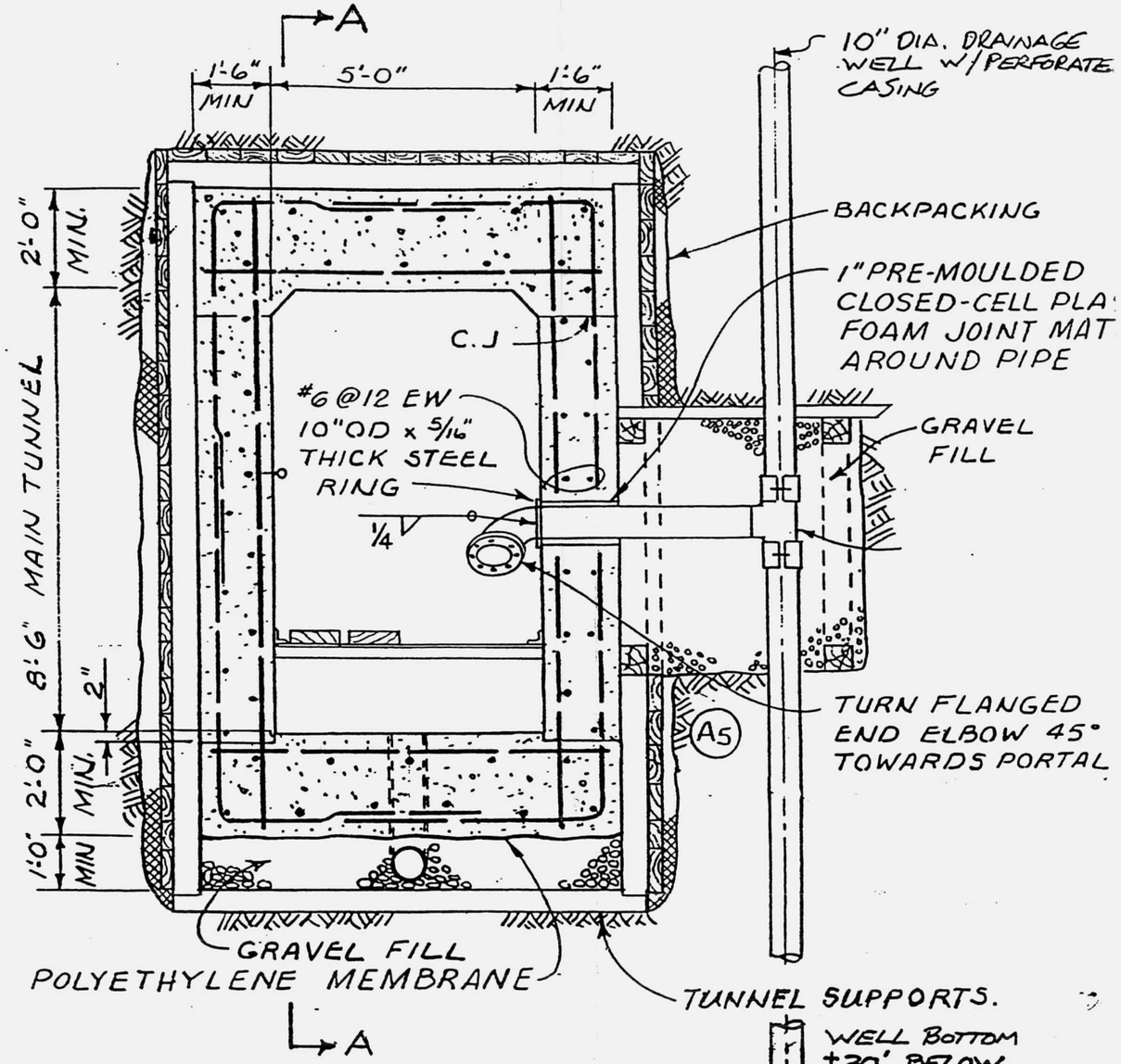

UPPER AQUIFER PHREATIC SURFACE
PRE TUNNEL (—o—) & POST TUNNEL (— —)
CONSTRUCTION —z—
CONSERVATION POOL
(1142.8)
LEGEND
1000R BEDROCK CONTOUR
EXPOSED BEDROCK
EXPLORATORY BORINGS, WELLS
& PIEZOMETERS (UNDIFFERENTIATED)
PIEZOMETERS 101 - 106 INSTALLED IN 1986
PIEZOMETERS 107 - 109 INSTALLED IN 1989
REFRACTION SEISMIC LINES (1991)
DRAINAGE WELLS AND ADIT
FLOOR OF ADIT AT ELEVATION 1100 FEET
PHREATIC CONTOURS
MAY 1981 - POST TUNNEL
PHREATIC CONTOURS
FEBRUARY 1967 - PRE TUNNEL
0 100 200 300
SCALE IN FEET
SPILLWAY
U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON
HOWARD HANSON DAM
PHREATIC CONTOURS
UPPER AQUIFER
1142.8 POOL
GREEN RIVER
WASHI
SIZE D
INVITATION NO
FILE NO
DATE MAY92
DSGN ECKERLIN
CHK
SHEET

PLATE E-7


PROJECTED 1180 CONSERVATION POOL
N
LEGEND
BEDROCK CONTOUR
EXPOSED BEDROCK
EXPLORATORY BORINGS, WELLS & PIEZOMETERS (UNDIFFERENTIATED)
PIEZOMETERS 101 - 106 INSTALLED IN 1986
PIEZOMETERS 107 - 109 INSTALLED IN 1989
REFRACTION SEISMIC LINES (1991)
DRAINAGE WELLS AND ADIT
FLOOR OF ADIT AT ELEVATION 1100 FEET
PHREATIC CONTOURS
1180 POOL
SCALE IN FEET
0
100
200
300
SPILLWAY
SL-C
SL-D
U. S. ARMY ENGINEER DISTRICT,
CORPS OF ENGINEERS
SEATTLE, WASHINGTON
HOWARD HANSON DAM
PHREATIC CONTOUR
UPPER AQUIFER
1180.0 POOL
GREEN RIVER
SIZE D
INVITATION NO.
FILE NO.
DSGN ECKERLIN
CHK.
PLATE E-8




SECTION A-A

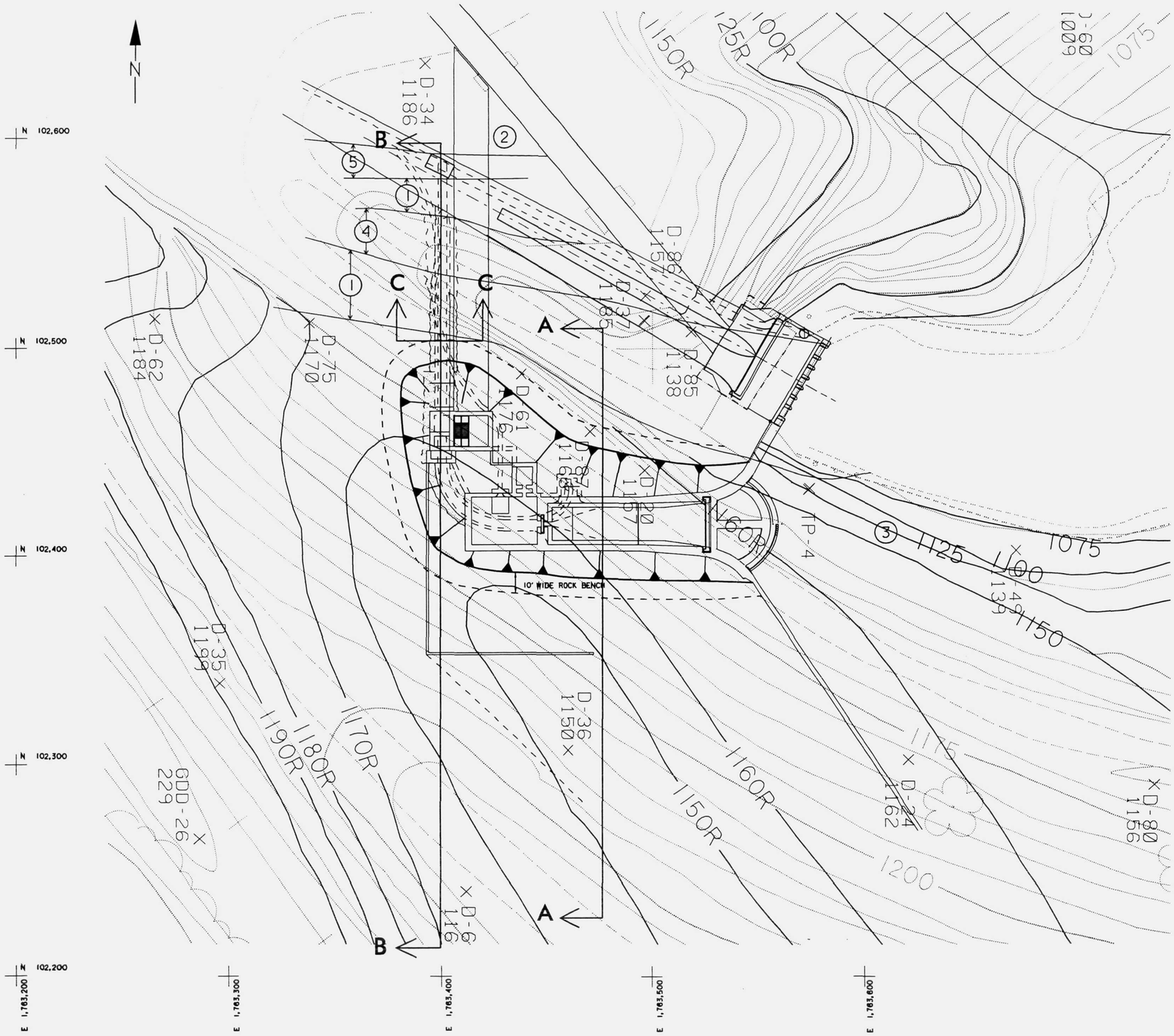



TYPICAL TUNNEL SECTION
(REFERENCE - AS BUILT DRAWING FOR EXISTING TUNNEL - E-56-11-53)

ASSUME WELL SPACING OF 40 FT. ∴ 5 WEL @ 238', 235', 230', 223' & 217'
TOTAL = 1143' SAY 11

WORK PLATFORM

PLATE E-9




## LEGEND

1 - BASALT
2 - ANDESITE
3 - BASALT PYROCLASTICS
4 - ANDESITE PYROCLASTICS
5 - FELSITE

1160R - APPROXIMATE BEDROCK CONTOUR

NOTES:

1. ROCK CONTACTS ARE ESTIMATED USING FOUNDATION REPORT PLATES. THESE ESTIMATED CONTACTS ARE AT THE ELEVATION OF THE DIVERSION TUNNEL.
2. ROCK TYPES FOR THE FISH PASSAGE FACILITY EXCAVATION WILL BE EXPLORED DURING FUTURE EXPLORATORY DRILLING CONTRACTS.
3. SECTION A-A SHOWN ON PLATE E-17 AND SECTIONS B-B AND C-C ARE SHOWN ON PLATE E-18.
4. TUNNEL ALIGNMENT AND TRANSITION TO BE REORIENTED DURING PED.

50' 25' 0 50' 100'

U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

# BEDROCK EXCAVATION

HOWARD HANSON DAM — WASHINGTON

| SIZE | INVITATION NO. | FILE NO. | PLATE |
|---|---|---|---|
| B | | | E-10 |

DSGN: ECKERLIN CHK: MANN SHEET

PLATE E-10

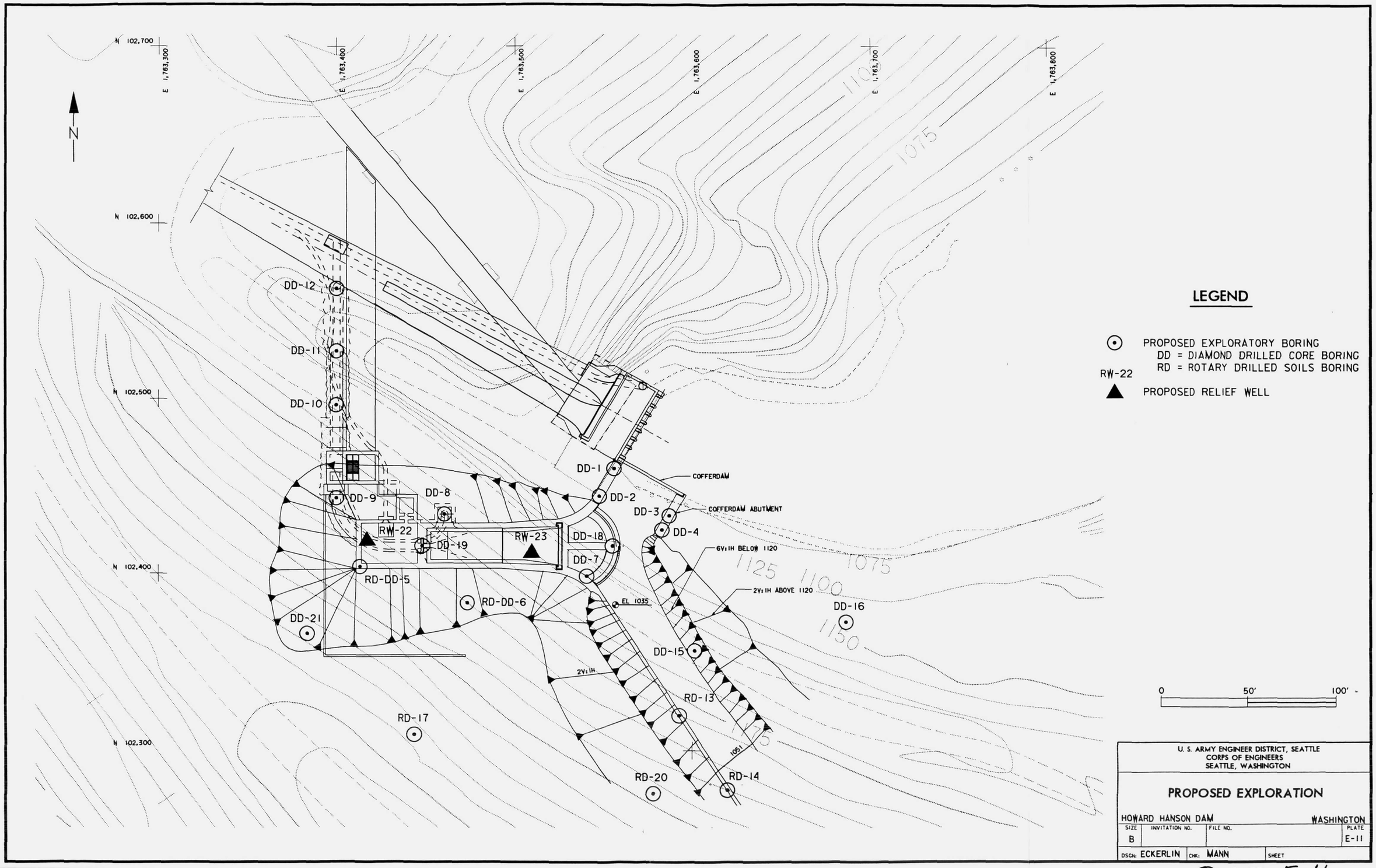
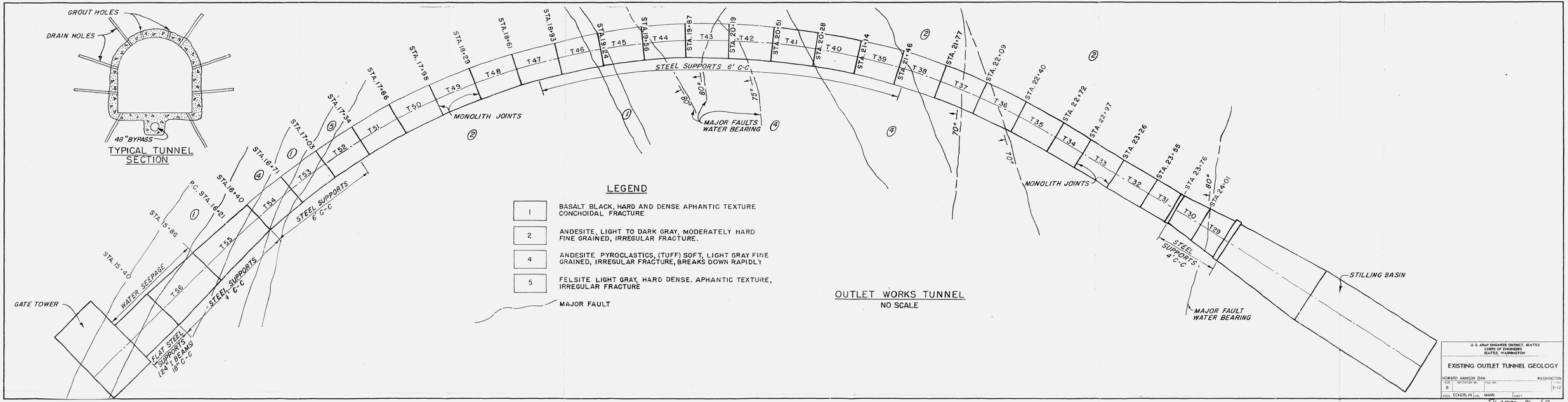

N
N 102,700
N 102,600
N 102,500
N 102,400
N 102,300
E 1,763,300
E 1,763,400
E 1,763,500
E 1,763,600
E 1,763,700
E 1,763,800
1075
1100
1125
1150
DD-12
DD-11
DD-10
DD-9
DD-8
RW-22
DD-19
RW-23
DD-18
DD-7
DD-1
DD-2
DD-3
DD-4
COFFERDAM
COFFERDAM ABUTMENT
6V:1H BELOW 1120
2V:1H ABOVE 1120
EL 1035
RD-DD-5
RD-DD-6
DD-21
DD-16
DD-15
2V:1H
RD-13
RD-17
RD-20
RD-14
LEGEND
PROPOSED EXPLORATORY BORING
DD = DIAMOND DRILLED CORE BORING
RD = ROTARY DRILLED SOILS BORING
RW-22
PROPOSED RELIEF WELL
0
50'
100'
U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON
PROPOSED EXPLORATION
HOWARD HANSON DAM
WASHINGTON
SIZE
B
INVITATION NO.
FILE NO.
PLATE
E-11
DSGN: ECKERLIN
CHK: MANN
SHEET

PLATE E-11


GROUT HOLES
DRAIN HOLES
48" BYPASS
TYPICAL TUNNEL SECTION
GATE TOWER
WATER SEEPAGE
STA. 15+40
STA. 15+86
P.C. STA. 16+21
STA. 16+40
STA. 16+71
STA. 17+03
STA. 17+34
STA. 17+66
STA. 17+98
STA. 18+29
STA. 18+61
STA. 18+93
STA. 19+24
STA. 19+56
STA. 19+87
STA. 20+19
STA. 20+51
STA. 20+28
STA. 21+14
STA. 21+46
STA. 21+77
STA. 22+09
STA. 22+40
STA. 22+72
STA. 22+97
STA. 23+26
STA. 23+55
STA. 23+76
STA. 24+01
T56
T55
T54
T53
T52
T51
T50
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T48
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T43
T42
T41
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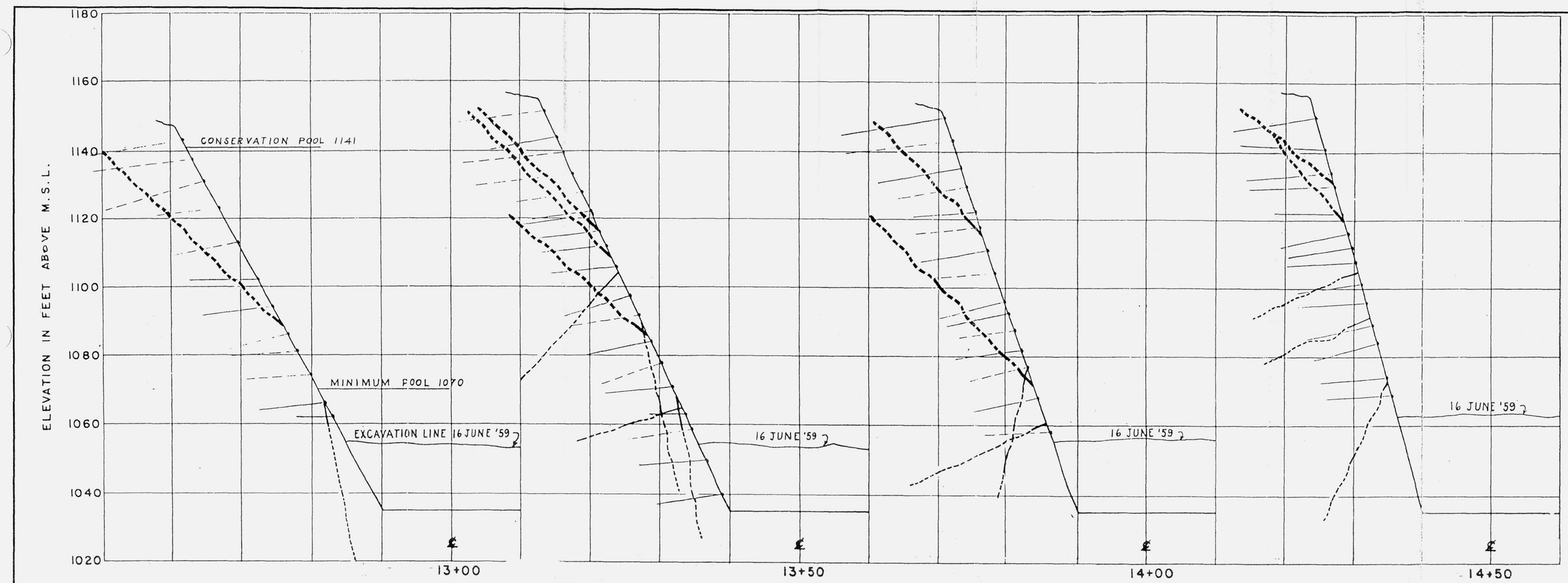
T37
T36
T35
T34
T33
T32
T31
T30
T29
STEEL SUPPORTS 4' C-C
STEEL SUPPORTS 6' C-C
FLAT STEEL I-SUPPORTS (24" I BEAMS) 18" C-C
MONOLITH JOINTS
MAJOR FAULTS WATER BEARING
MAJOR FAULT WATER BEARING
STILLING BASIN
80°
75°
70°
LEGEND
1 BASALT BLACK, HARD AND DENSE APHANTIC TEXTURE CONCHOIDAL FRACTURE
2 ANDESITE, LIGHT TO DARK GRAY, MODERATELY HARD FINE GRAINED, IRREGULAR FRACTURE.
4 ANDESITE PYROCLASTICS, (TUFF) SOFT, LIGHT GRAY FINE GRAINED, IRREGULAR FRACTURE, BREAKS DOWN RAPIDLY
5 FELSITE LIGHT GRAY, HARD DENSE. APHANTIC TEXTURE, IRREGULAR FRACTURE
MAJOR FAULT
OUTLET WORKS TUNNEL
NO SCALE
U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON
EXISTING OUTLET TUNNEL GEOLOGY
HOWARD HANSON DAM
WASHINGTON
SIZE B
DESIGN ECKERLIN
DR. MANN
E-12
PLATE E-12




U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

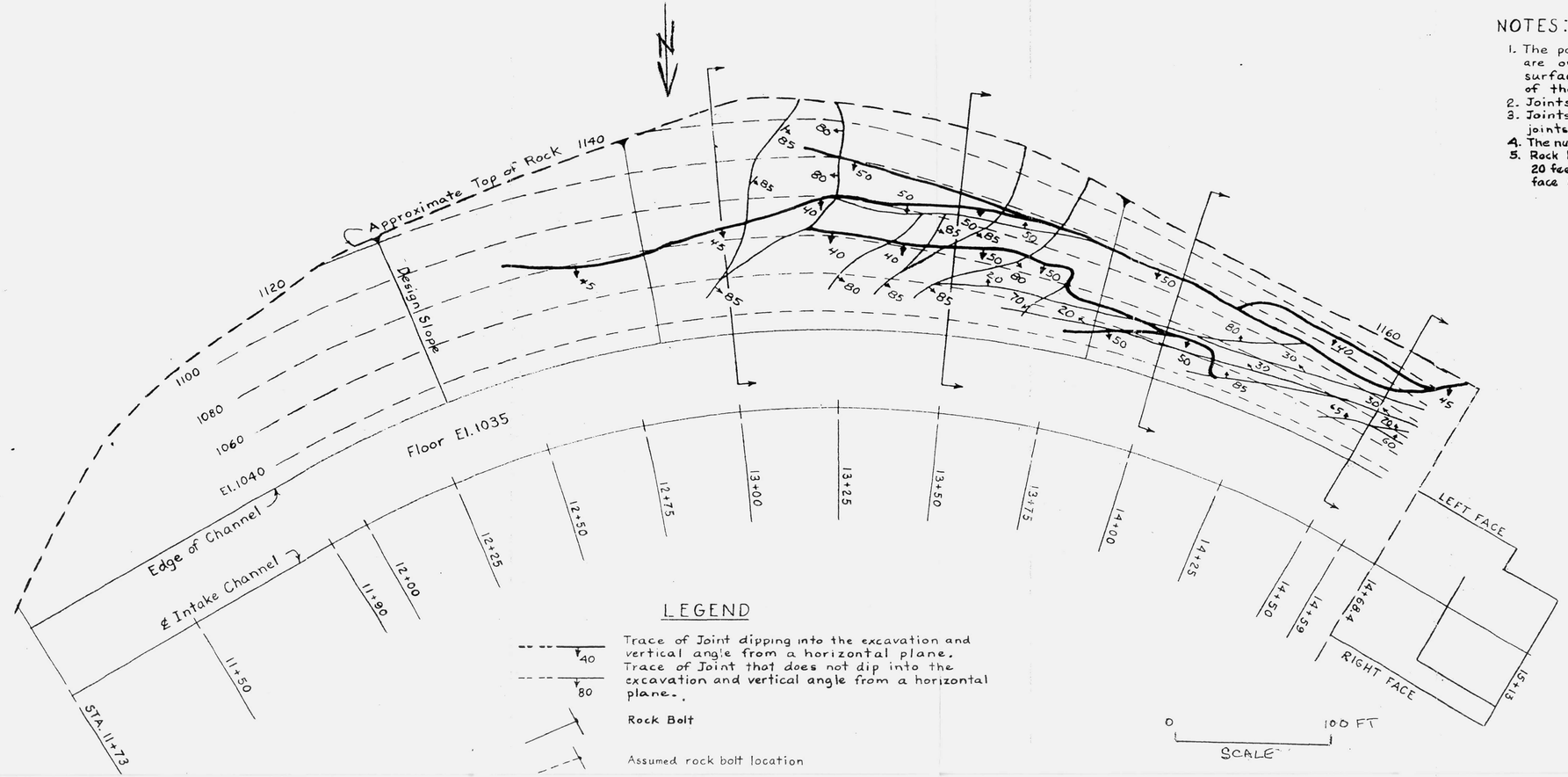
MAJOR JOINTS ON LEFT ROCKWALL OF EXISTING INTAKE CHANNEL

HOWARD HANSON DAM WASHINGTON

| SIZE | INVITATION NO. | FILE NO. | PLATE |
|---|---|---|---|
| B | | | |

DSGN: ECKERLIN CHK: MANN SHEET

PLATE E-13




## LEGEND

Trace of Joint dipping into the excavation and vertical angle from a horizontal plane. (40)

Trace of Joint that does not dip into the excavation and vertical angle from a horizontal plane. (80)

Rock Bolt

Assumed rock bolt location

## NOTES:

1. The potential slippage surfaces shown on the plan and sections are overemphasized for purposes of illustration. These surfaces, however, can be located by careful observation of the excavation.
2. Joints and faults are not differentiated.
3. Joints are shown in approximate position and attitude of joints is estimated from bottom of excavation.
4. The numerous minor fractures and joints are not shown.
5. Rock bolts are placed on about five (5) foot centers. The bolts in the upper 20 feet of the face are 30 feet long and the lower portion of the face is secured by rock bolts 20 feet long.

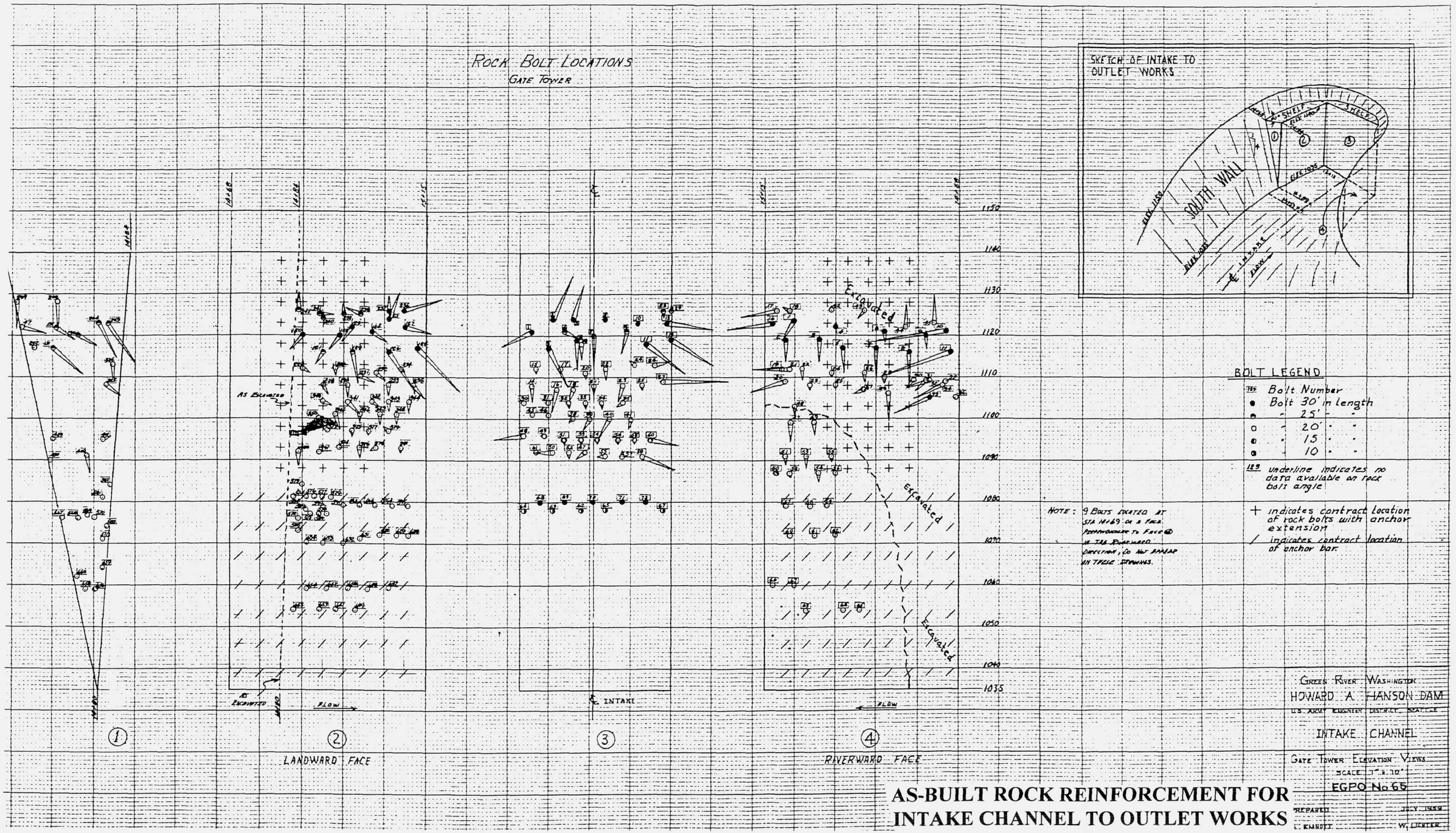
U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

**GEOLOGIC SECTIONS ALONG LEFT ROCKWALL OF EXISTING INTAKE CHANNEL**

HOWARD HANSON DAM — WASHINGTON

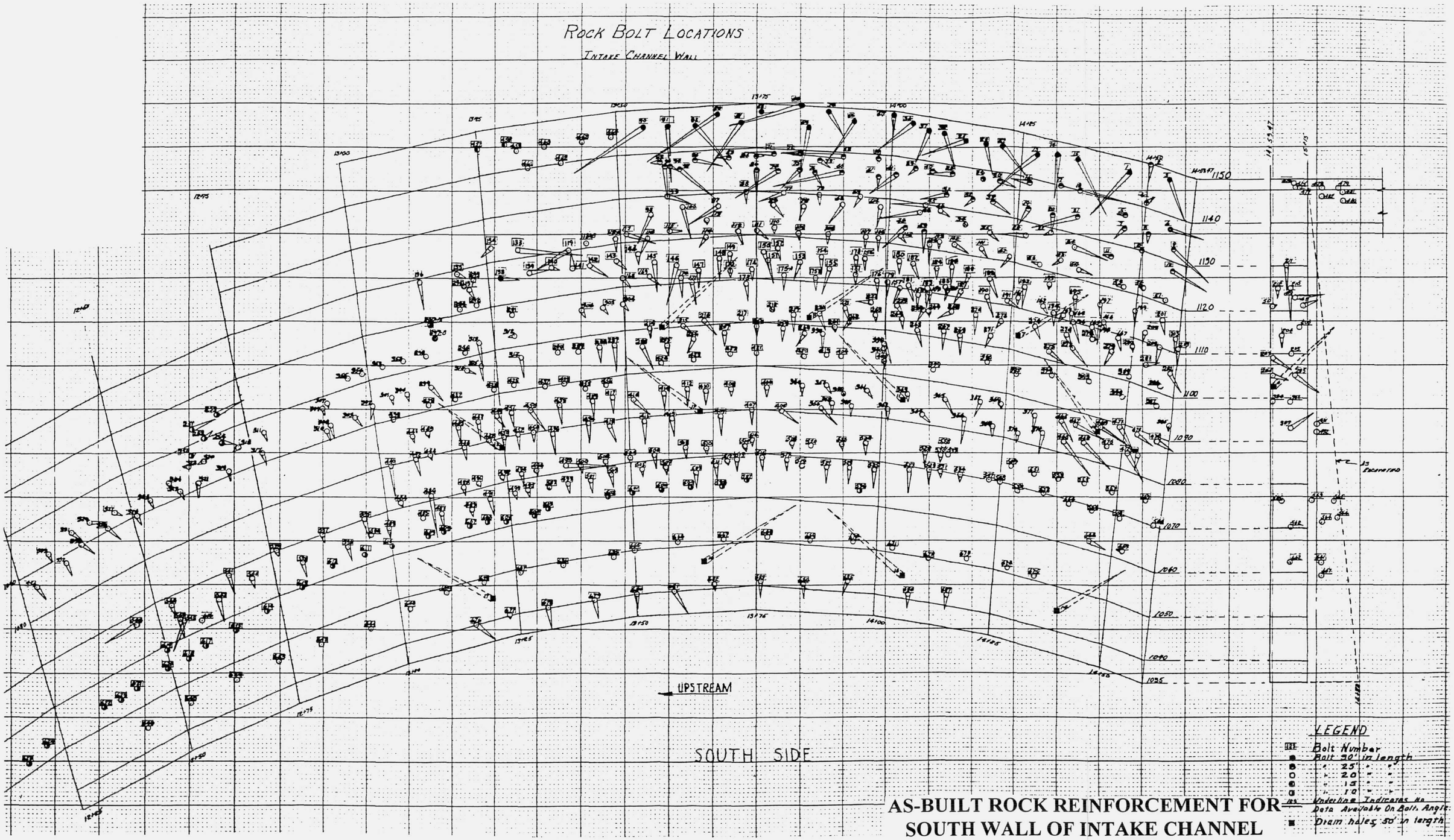
| SIZE | INVITATION NO. | TITLE NO. | PLATE |
|---|---|---|---|
| B | | | |
| DSGN. ECKERLIN | CHK. MANN | SHEET | |

PLATE E-14



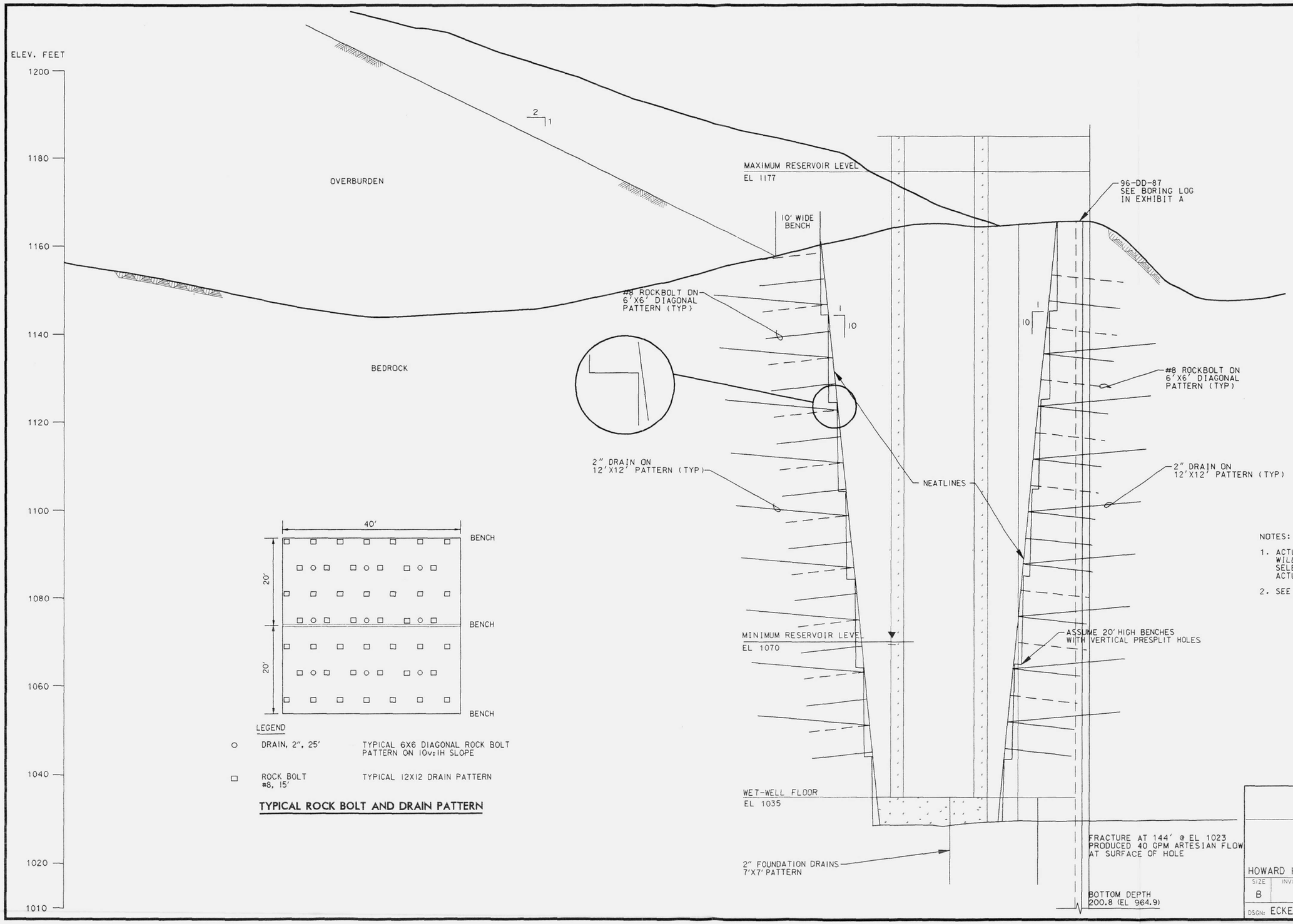

**AS-BUILT ROCK REINFORCEMENT FOR INTAKE CHANNEL TO OUTLET WORKS**

PLATE E-15




**AS-BUILT ROCK REINFORCEMENT FOR SOUTH WALL OF INTAKE CHANNEL**

PLATE E-16




NOTES:

1. ACTUAL WIDTH OF BENCH AT TOP OF ROCK CUT SLOPE WILL BE DEPENDENT ON THE CATCH POINTS SELECTED DURING DESIGN AND ROCK ELEVATIONS ACTUALLY ENCOUNTERED DURING EXCAVATION.
2. SEE PLATE E-10 FOR PLAN.

U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

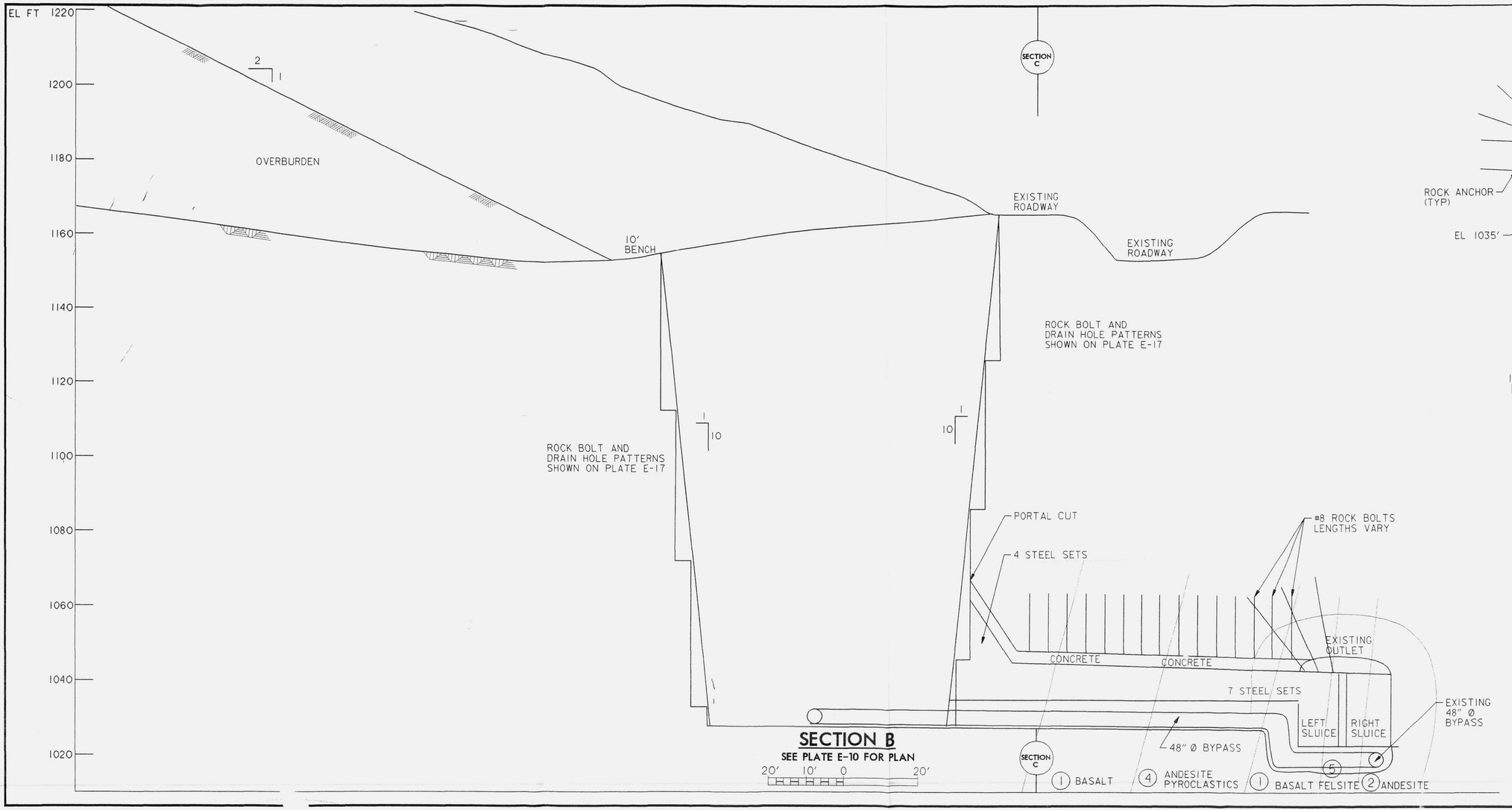
# FISH FACILITY
# GEOLOGIC SECTION A

HOWARD HANSON DAM — WASHINGTON

| SIZE | INVITATION NO. | FILE NO. | PLATE |
|---|---|---|---|
| B | | | E-17 |

DSGN: ECKERLIN | CHK: MANN | SHEET

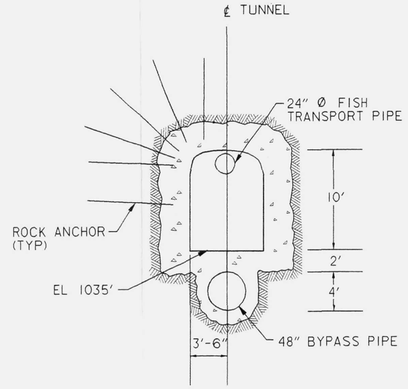
PLATE E-17




## SECTION B

SEE PLATE E-10 FOR PLAN

20′ 10′ 0 20′




## SECTION C

SEE PLATE E-10 FOR PLAN

10′ 5′ 0 10′

1 - BASALT

2 - ANDESITE

3 - BASALT PYROCLASTICS

4 - ANDESITE PYROCLASTICS

5 - FELSITE

NOTES:

1. ROCK CONTACTS ARE ESTIMATED USING FOUNDATION REPORT PLATES.
2. ACTUAL WIDTH OF BENCH CUT AT TOP OF ROCK CUTSLOPE WILL BE DEPENDENT ON THE CATCH POINTS SELECTED DURING DESIGN AND ROCK ELEVATIONS ACTUALLY ENCOUNTERED DURING EXCAVATION.

U. S. ARMY ENGINEER DISTRICT, SEATTLE
CORPS OF ENGINEERS
SEATTLE, WASHINGTON

**FISH FACILITY**
**GEOLOGIC SECTIONS B AND C**

HOWARD HANSON DAM — WASHINGTON

| SIZE | INVITATION NO. | FILE NO. | PLATE |
|---|---|---|---|
| B | | | E-18 |

DSGN: ECKERLIN | CHK: MANN | SHEET

PLATE E-18

# EXHIBIT A

## SUMMARY DRILL LOGS

| DRILLING LOG | DIVISION NPD | INSTALLATION NPS | SHEET 1 OF 2 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT HHD Fish Passage Study | 10. SIZE AND TYPE OF BIT NWCJ Wireline |
| 2. LOCATION (Coordinates or Station) N 102,291.016 E 1,763,737.800 | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929 |
| 3. DRILLING AGENCY Ruen Drilling (Clark Fork, Idaho) | 12. MANUFACTURER'S DESIGNATION OF DRILL Longyear 44 |
| 4. HOLE NO. (As shown on drawing title and file number) 94-DD-80 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED – ; UNDISTURBED – |
| 5. NAME OF DRILLER LYLE BALLINGER | 14. TOTAL NUMBER CORE BOXES 12 |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER 1153.3 |
| 7. THICKNESS OF OVERBURDEN 8.4 FT. | 16. DATE HOLE STARTED 4/5/94 COMPLETED 4/8/94 |
| 8. DEPTH DRILLED INTO ROCK 156.6 FT. | 17. ELEVATION TOP OF HOLE 1164.767 |
| 9. TOTAL DEPTH OF HOLE 165.0 FT. | 18. TOTAL CORE RECOVERY FOR BORING 98.3% % |
| | 19. SIGNATURE OF INSPECTOR |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY 0 - 100 | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1164.8 | | | GM, Silty Sandy GRAVEL with boulders. | | | NWCJ - OD = 2.980" ID = 1.875" SPLIT INNER TUBE 4/5/94 |
| 1156.4 | | | TOP OF ROCK @ 8.4 FT | RQD % | | |
| 1153.8 | 10 | | ANDESITE, soft, weathered, rusty-red to gray in color. | 75.0 | A | 4/6/94 |
| 1149.8 | | | | 80.8 | B | |
| | 20 | | ANDESITE BRECCIA, moderately hard, dense, weathered, rusty-red. | 96.1 | C | 1 — 40 psig/6.7 gpm/15 min 40-21/5 sec 21-7/120 sec. |
| | | | | 100 | D | |
| 1139.7 | | | Color change to gray-green | 84.4 | E | |
| | 30 | | | 98.4 | F | 2 — 40 psig/15.5 gpm/15 min 40-17/5 sec 17-4/120 sec. |
| | | | | 100 | G | |
| | 40 | | | 80.0 | H | |
| | | | | 84.4 | I | 3 — 40 psig/8.1 gpm/15 min 40-22/5 sec 22-8/120 sec. |
| | 50 | | From 47.4 to 57 core is soft, slicken sides on joints 47.4 to 48.4 clay gouge, soft, gray | 64.5 | J | 4/6/94 |
| | | | | 77.8 | K | 4/7/94 |
| 1107.7 | 60 | | ANDESITE BRECCIA, moderately hard, dense, dark gray to black | 88.3 | L | 4 — 80 psig/8.0 gpm/15 min 80-58/5 sec 58-33/120 sec. |
| | | | | 90.0 | M | |
| | | | | 97.0 | N | |
| 1091.9 | 70 | | Color change to light gray-green @ 71.0', with slickensides on joints: 75.0' to 76.0', clayey gouge. | 87.6 | O | 5 — 80 psig/9.7 gpm/15 min 80-47/5 sec 47-13/120 sec. |
| | | | | 86.1 | P | |
| | | | | 88.0 | Q | |
| | 80 | | | 98.4 | R | 80 psig/1.5 gpm/15 min 80-25/5 sec 25-0/120 sec. |
| | | | | 92.0 | S | 6 |
| | 90 | | | 98.4 | T | 80 psig/0 gpm/15 min 80-49/5 sec 49-21/120 sec. |
| | | | | 90.0 | U | 7 |
| 1064.8 | 100 | | | | | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT FISH PASSAGE STUDY | HOLE NO. 94-DD-80

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1164.76 | Hole No. 94-00-80 |
|---|---|---|
| PROJECT HHD Fish Passage Study | INSTALLATION | SHEET 2 OF 2 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1064.8 | 100 | | ANDESITE BRECCIA, soft to hard, green to gray, slickensides on joint surfaces. | 65.8 | V 7 | |
| | 105 | | | 50.0 | W | 4/7/94 |
| | 110 | | | 93.2 | X 8 | 80 psig/0 gpm/15 min 80-40/5 sec 40-19/120 sec. |
| | 115 | | | 100 | Y | |
| | 120 | | | 100 | Z | 80 psig/0 gpm/15 min 80-43/5 sec 43-21/120 sec. |
| | 125 | | | 96.6 | AA | |
| | 130 | | | 100 | AB 9 | |
| | 135 | | NPD laboratory test, conducted on core 139.3 - 140.3'. Results reported 7/13/94: Specific Gravity 2.42 unit Weight 150.8 pcf Absorption 6.6% Unconfined Compressive Strength = 5,410 psi | 91.2 | AC | 80 psig/0 gpm/15 min 80-70/5 sec 70-50/120 sec. |
| | 140 | | | 100 | AD | |
| | | | | 100 | 10 AE | |
| 1020.4 | 145 | | | 51 | AF | |
| | 150 | | ANDESITE BRECCIA, clayey, soft, altered gray to green, slickensides on joints. | 62.5 | AG | 80 psig/5.3 gpm/ 80-75/5 sec 75-60/120 sec. |
| | 155 | | | 77.1 | 11 AH | |
| | 160 | | hard @ 163 ft | 86.2 | AI 12 | 80 psig/5.7 gpm/ 80-70/5 sec 70-51/120 sec. |
| 999.8 | 165 | | | 94.8 | AJ | 4/8/94 |

Bottom of boring @ 165 ft

NOTE: Ruen Drilling Company is subcontractor to Andrew Drilling Co., Idaho Falls, Idaho under contrat DACA 67-93-0-1012 Delivery Order No. 9

*NOTE

Water test data corresponds to interval shown.

Abbreviations used:
80 psig/9.7 gpm/15 min
80-40/5 sec
40-19/120 sec

80 psig = 80 pounds water pressure per inch measured by a gauge at ground level

9.7 gpm/15 min = 9.7 gallons of water per minute measured with a flow meter for the stated period

80-40 /5sec = water pressre drop in system from 80 to 40 psig in 5 seconds.

40-19/120 sec = water pressure drop in system from 40 to 19 psig in 2 minutes

| ORILLING LOG | DIVISION NPD | INSTALLATION NPS | SHEET 1 OF 2 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT HHD FISH PASSAGE STUDY | 10. SIZE AND TYPE OF BIT NWCJ (WIRELINE) |
| 2. LOCATION (Coordinates or Station) N 102,503.562 E 1,763,228.777 | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929 |
| 3. DRILLING AGENCY RUEN DRILLING (CLARK FORK, IDAHO) | 12. MANUFACTURER'S DESIGNATION OF DRILL LONGYEAR 44 |
| 4. HOLE NO. (As shown on drawing title and file number) 94-DD-81 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED - ; UNDISTURBED - |
| 5. NAME OF DRILLER LYLE BALLINGER | 14. TOTAL NUMBER CORE BOXES 13 |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER 1189.7 |
| 7. THICKNESS OF OVERBURDEN 23.0 FT. | 16. DATE HOLE: STARTED 4/21/94; COMPLETED 4/234/94 |
| 8. DEPTH DRILLED INTO ROCK 167.0 FT. | 17. ELEVATION TOP OF HOLE 1220.307 |
| 9. TOTAL DEPTH OF HOLE 190.0 FT. | 18. TOTAL CORE RECOVERY FOR BORING 99 % |
| | 19. SIGNATURE OF INSPECTOR |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| 1220.3 | | | GM, Silty sandy gravel | | | |
| | 10 | | | | | Legend for joint spacing: widely >1.5 ft; moderately 0.5 to 1.5 ft; closely 0.1 to 0.5 ft; highly fractured=brecciated |
| | 20 | | Top of rock @ 23.0 ft | RQD % | | |
| 1197.3 | | | ANDESITE BRECCIA: altered dark green to gray, soft zones, calcite | 87 | A | |
| 1189.7 | 30 | | FeO | 89 | B | 1 |
| | | | | 91 | C | |
| | | | | 97 | D | |
| | 40 | | | 96 | E | 2 |
| | | | | 100 | F | |
| | 50 | | | 91 | G | |
| | | | | 88 | H | 3 |
| | 60 | | | 92 | I | 4/21/94 SWL 23.6 bgs |
| | | | | 100 | J | 4/22/94 7.1 bgs; 4 |
| | 70 | | | 96 | K | |
| | | | | 96 | L | |
| | 80 | | | 100 | M | 5 |
| | | | | 86 | N | |
| | | | | 100 | O | |
| | 90 | | Clayey joints | 96 | P | |
| 1126.5 | | | ANDESITE BRECCIA, altered FeO, Pyrite, CaCo on joints | | | 6 |
| 1120.3 | 100 | | | 91 | Q | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT HHD FISH PASSAGE

HOLE NO. 94-DD-81 X-3

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1220.307 | Hole No. 94-00-81 |
|---|---|---|
| PROJECT HHD FISH PASSAGE | INSTALLATION NPS | SHEET 2 OF 2 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY 0 - 100 | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1120.3 | 100 | | ANDESITE BREDCCIA, altered, clayey zones, FeO, Pyrite, Calcite, slickensides. | RQD % 54 | R 6 | |
| | | | | 88 | S 7 | |
| | 110 | | | 100 | T | |
| | | | | 100 | U | |
| | 120 | | | 100 | V 8 | SEE NOTE ON SHEET 2 LOG 94-00-80 |
| | | | | 94 | W | |
| | 130 | | @ 130' Slickensides on joint surfaces | 71 | X | 80 psi/0 gpm/15 min 80-61 psi/120 sec |
| | | | | 89 | Y 9 | |
| | 140 | | | 88 | Z | |
| | | | | 100 | AA | 80 psi/27.8 gpm/13.5 min 80-0 psi/5 sec |
| | 150 | | | 71 | AB 10 | |
| 1085.3 | | | | 61 | AC | |
| | | | ANDESITE BRECCIA, highly altered, intact | 60 | AD | 80 psi/30.7 gpm/15 min 80-0 psi/5 sec |
| | 160 | | | | | |
| 1054.1 | | | | 58 | AE 11 | |
| | | | ANDESITE BRECCIA, altered - soft, broken, discolored, local, clay, FeO, Calcite | 74 | AF | |
| | 170 | | | 74 | AG | 80 psi/25.7 gpm/15 min 80-17 psi/5 sec 17 - 0 psi /60 sec |
| | | | | 98 | AH 12 | |
| | 180 | | | 98 | AI | 80 psi /12.9 gpm/15min 80-40 psi/5 sec 40-13psi/120 sec |
| | | | | 91 | AJ 13 | |
| 1030.3 | 190 | | | 100 | AK | |
| | | | Bottom of boring at 190.0' | | | |
| | | | NPD lab results 7/13/94 conducted on core 175.2-175.8 | | | |
| | | | Sp. Gravity 2.81<br>Unit Weight 162.6 pcf<br>Absorption 2.0%<br>Unconfined CompStr 8,790 psi | | | |
| | | | Conducted on core 187.5 - 188.0<br>Sp. Gravity 2.85<br>Unit Weight 165.1 pcf<br>Absorption 1.6%<br>Unconfined CompStr 9,170 psi | | | NOTES: End of shift 4/22 cored to 170.1 SWL 23.8' Began Shift 4/23 SWL 30.6' |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HHD FISH PASSAGE | HOLE NO. 94-00-81

X-4

| DRILLING LOG | DIVISION NPD | INSTALLATION NPS | SHEET 1 OF 2 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT HHD FISH PASSAGE | 10. SIZE AND TYPE OF BIT NWCJ (WIRELINE) |
| 2. LOCATION (Coordinates or Station) N 103,055.429 E 1,763,015.934 | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD, 1929 |
| 3. DRILLING AGENCY RUEN DRILLING (CLARK FORK, IDAHO) | 12. MANUFACTURER'S DESIGNATION OF DRILL LONGYEAR 44 |
| 4. HOLE NO. (As shown on drawing title and file number) 94-00-82 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED: UNDISTURBED: |
| 5. NAME OF DRILLER LYLE BALLINGER | 14. TOTAL NUMBER CORE BOXES 16 |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER 1170.8 FT |
| 7. THICKNESS OF OVERBURDEN 4.2' | 16. DATE HOLE STARTED 4/18/94 COMPLETED 4/20/94 |
| 8. DEPTH DRILLED INTO ROCK 205.8' | 17. ELEVATION TOP OF HOLE 1206.396 ft |
| 9. TOTAL DEPTH OF HOLE 210.0' | 18. TOTAL CORE RECOVERY FOR BORING 97.2 % |
| | 19. SIGNATURE OF INSPECTOR |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY 0 to 100 | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) e |
|---|---|---|---|---|---|---|
| 1206.4 | | | GM, Silty Sandy Gravel | | | |
| | | | Top of rock @ 4.2 ft | RQD | | |
| 1202.2 | | | ANDESITE BRECCIA, Altered, maroon to green-gray, broken, clay in places, FeO, $CaCO_3$ | 21 | A | |
| | 10 | | | 80 | B | |
| | | | | 80 | C | |
| | | | | 23 | D | Legend for Joint Spacing |
| | 20 | | | 42 | E | Widely >1.5 ft<br>Moderately 0.5 to 1.5 ft<br>Closely 0.1 to 0.5 ft<br>Highly Fractured = brecciated |
| | | | 0.4' Loss | 47 | F | |
| | 30 | | | 90 | G | |
| 1170.3 ▼ | | | | 100 | H | |
| 1168.9 | | | ANDESITE BRECCIA, Highly altered, clayey, gouge, discoloration, slickensides, $CaCO_3$, FeO | 60 | I | |
| | 40 | | | 76 | J | |
| | 50 | | 1.3' loss | 47 | K | |
| | | | 2.0' loss | 0 | L | |
| | 60 | | 2.1' loss | 0 | M | |
| 1143.5 | | | ANDESITE BRECCIA, Altered but intact, with zones of heavy alteration, green to gray, calcite, and pyrite mineralization | 74 | N | |
| | 70 | | | 65 | O | |
| | | | | 91 | P | |
| | | | | 89 | Q | |
| | 80 | | Slickensides on joints | 80 | R | |
| 1112.0 | 90 | | | 89 | S | |
| | | | ANDESITE/ANDESITE BRECCIA, hard, dark green | 99 | T | |
| 1106.4 | 100 | | | 100 | U | |

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT HH FISH PASSAGE

HOLE NO. 94-00-82

X-5

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1206.396 | Hole No. 94-DD-82

PROJECT: HHD FISH PASSAGE | INSTALLATION: NPS | SHEET 2 OF 2 SHEETS

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1106.4 | 100 | | ANDESITE/ANDESITE BRECCIA, hard, dark green, minor alteration FeO and slickensides on joints | 99 | V | |
| | | | | 100 | W 8 | |
| | 110 | | | 92 | X | |
| | | | | 96 | Y | |
| | 120 | | | 90 | Z 9 | |
| | | | | 100 | AA | SEE NOTE ON SHEET 2 LOG 94-DD-80 |
| | 130 | | | 100 | AB 10 | |
| | | | | 96 | AC | |
| | 140 | | | 100 | AD | 80 psig/0 gpm/15 min 80-46 psig/120 sec |
| | | | | 100 | AE 11 | |
| | 150 | | | 100 | AF | |
| | | | | 100 | AG | 80 psig/0 gpm/15 min 80 - 48 psig/5 sec 48 - 18 psi /120 sec |
| | | | | 100 | AH | |
| | 160 | | | 100 | AI 12 | |
| | | | | 100 | AJ | |
| | | | | 100 | AK | 80 psig/0 gpm/15 min 80-40 psig/5 sec 40 - 26 psig/120 sec |
| | 170 | | NPD lab results 7/13/94 conducted on core 179.9' - 180.7' | 98 | AL 13 | |
| | | | | 100 | AM | 80 psig/0 gpm/15 min 80-59 psig/120 sec |
| | 180 | | Sp. Gravity 2.59<br>Unit Weight 181.4 pcf<br>Absorption 2.1%<br>Unconfined CompStr 21,920 psi | 100 | AN | |
| | | | | 100 | AO 14 | |
| | 190 | | | 91 | AP | |
| | | | | 98 | AQ | 80 psig/0 gpm/15 min 80-49 psig/120 sec |
| | 200 | | | 96 | AR 15 | |
| | | | | 100 | AS 16 | 80 psig/0 gpm/15 min 80-40 psig/5 sec 40 - 30 psig/120 sec |
| 996.4 | 210 | | Bottom of Boring @ 210' | 100 | AT | Hole cemented |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT: HHD FISH PASSAGE | HOLE NO. 94-DD-82

X-6

| DRILLING LOG | DIVISION NPD | INSTALLATION NPS | SHEET 1 OF 2 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT HHD FISH PASSAGE STUDY | 10. SIZE AND TYPE OF BIT NWCJ (Wireline) |
| 2. LOCATION (Coordinates or Station) N 103,494.837 E 1,763,093.729 | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD 1929 |
| 3. DRILLING AGENCY RUEN DRILLING (CLARK FORK, IDAHO) | 12. MANUFACTURER'S DESIGNATION OF DRILL LONGYEAR 44 |
| 4. HOLE NO. (As shown on drawing title and file number) 94-DD-83 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED - ; UNDISTURBED - |
| 5. NAME OF DRILLER LYLE BALLINGER | 14. TOTAL NUMBER CORE BOXES 17 |
| | 15. ELEVATION GROUND WATER 1051.8 |
| 6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 20° DOWN DEG. FROM VERT. | 16. DATE HOLE STARTED 3/29/94 COMPLETED 4/2/94 |
| | 17. ELEVATION TOP OF HOLE 1104.810 |
| 7. THICKNESS OF OVERBURDEN 0 | 18. TOTAL CORE RECOVERY FOR BORING 96.6 % |
| 8. DEPTH DRILLED INTO ROCK 220 ft | 19. SIGNATURE OF INSPECTOR |
| 9. TOTAL DEPTH OF HOLE 220 ft | |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY 0 @ 100 e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| 1104.8 | | | ANDESITE, hard, black | RQD% 16.7 | A | NWCJ |
| | | | | 63.0 | B | OD = 2.980" |
| 1101.0 | | | ANDESITE BRECCIA, clayey, altered, soft, gray, closely to moderately spaced joints | 30.0 | C 1 | ID = 1.875" SOLID INNER TUBE TYPE WIRELINE BARREL |
| | 10 | | | 0 | D | |
| | | | | 0 | E | 3/29/94 |
| | | | | 15.4 | F | Legend for Joint Spacing: |
| | 20 | | | 41.7 | G 2 | Widely = >1.5 ft; Moderately = 0.5 - 1.5 ft; Closely = 0.1 -0.5 ft; Highly Fractured = Brecciated |
| | | | | 84.6 | H | |
| | | | | 81.1 | I | |
| | 30 | | | 52.4 | J 3 | |
| | | | | 24.8 | K | |
| | 40 | | | 32.7 | L 4 | |
| | | | | 50.0 | M | |
| | 50 | | | 35.0 | N | |
| ▼ 1051.8 | | | | 15.0 | O 5 | |
| | 60 | | | 23.3 | P | |
| | | | | 0.0 | Q | |
| | 70 | | | 79.2 | R 6 | |
| | | | | 80.0 | S | |
| | 80 | | | 19.2 | T 7 | |
| 1026.8 | | | ANDESITE BRECCIA, altered with clayey gouge, FeO at 86'-87'. Joints closely spaced to highly fractured. | 0.0 | U | |
| | 90 | | | 25.0 | V | |
| 1017.9 | | | ANDESITE BRECCIA, dark green, altered highly fractured to closely spaced joints | 31.5 | W 8 | |
| 1010.8 | 100 | | | 44.4 | X | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT HHD FISH PASSAGE | HOLE NO. 94-DD-83

X-1

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1104.810 | Hole No. 94-DD-83 |
|---|---|---|
| PROJECT HHD FISH PASSAGE | INSTALLATION NPS | SHEET 2 OF 2 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1010.8 | 100 | | ANDESITE, hard, gray, closely to moderately spaced joints | 7.7 | X Y 8 | |
| | | | | 23.5 | Z | SEE NOTE ON SHEET 2 LOG 94-DD-80 |
| | 110 | | | 56 .1 | 9 AA | 3/30/94 |
| | | | | 85.2 | AB | |
| | 120 | | | 76.2 | AC | |
| | | | | 38.0 | AD 10 | 80 psig/12.5gm/15 min 80-60/5 sec 60 - 30/120 sec |
| | 130 | | | 47.4 | AE | |
| | | | | 78.2 | AF | |
| | 140 | | | 91.2 | AG 11 | 80 psig/0.9 gpm/15 min 80-50 /5 sec 50 - 0/120 sec |
| 970.4 | | | ANDESITE BRECCIA, altered, light gray to green, soft, crumbles NPO lab results 7/13/94 on core 147.5 to 148.0 ft So. Gravity 2.42 UnitWgt 150.8 pcf Absorption 6.1% Unconf. Comostr 13,510 psi | 76.2 | AH | 3/31/94 |
| | 150 | | | 62.1 | AI | |
| | | | | 51.0 | AJ 12 | 80 psig/8.8 gpm/15 mi 80-60 /5 sec 60 - 0 /60 sec |
| | | | On core 150.2 to 1510.0 ft So. Gravity 2.39 Unit Wgt 148.9 pcf Absorption 6.5% Unconf. Comostr 8,900 psi | 22.2 | AK | |
| | 160 | | | 47.6 | AL | |
| 949.8 | | | ANDESITE BRECCA, hard, dark green, some clayey zones, moderately to widely spaced joints | 96.5 | AM 13 | 80 psig/9.3 gpm/15 min 80-75 /5 sec 75 - 32 /120 sec |
| | 170 | | | 100.0 | AN | |
| | | | | 78.3 | AO | |
| | 180 | | | 85.0 | AP 14 | 80 psig/3.0 gpm/15 min 80-65 /5 sec 65 - 12 /120 sec |
| | | | | 93.0 | AQ | |
| | 190 | | | 40.7 | AR | 4/1/94 |
| | | | FeO on joint | 61.9 | AS 15 | 80 psig/11.5gpm/15 min 80-58/5 sec 58-34/120 sec |
| | | | | 92.2 | AT | |
| | 200 | | | 93.1 | AU | 80 psig/5 gpm/10 min 80-60 /5 sec 63- 18/120 sec |
| | | | | 94.8 | AV 16 | |
| | 210 | | | 88.7 | AW | |
| | | | | 92.9 | AX 17 | 80 psig/0.1 gpm/5 min 80-63 /5 sec 63- 9/120 sec |
| 898.1 | 220 | | | 92.0 | AY | Hole Cemented |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71

PROJECT HHD FISH PASSAGE | HOLE NO. 94-DD-83

X-8

| DRILLING LOG | DIVISION NPD | INSTALLATION NPS | SHEET 1 OF 1 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT HHD FISH PASSAGE STUDY | 10. SIZE AND TYPE OF BIT NWCJ (WIRELINE) |
| 2. LOCATION (Coordinates or Station) N 103,792.632 E 1,763,150.124 | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) NGVD, 1929 — SOLID INNER TUBE |
| 3. DRILLING AGENCY RUEN DRILLING (CLARK FORK, IDAHO) | 12. MANUFACTURER'S DESIGNATION OF DRILL LONGYEAR 44 |
| 4. HOLE NO. (As shown on drawing title and file number) 94-DD-84 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED |
| 5. NAME OF DRILLER LYLE BALLENGER | 14. TOTAL NUMBER CORE BOXES 8 |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER 1026.0 FT |
| 7. THICKNESS OF OVERBURDEN 0 | 16. DATE HOLE STARTED 4/3/94 COMPLETED 4/5/94 |
| 8. DEPTH DRILLED INTO ROCK 100 FT | 17. ELEVATION TOP OF HOLE 1035.044 FT |
| 9. TOTAL DEPTH OF HOLE 100 FT | 18. TOTAL CORE RECOVERY FOR BORING 97.6 % |
| | 19. SIGNATURE OF INSPECTOR |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY 0 - 100 | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1035.0 | | | ANDESITE BRECCIA, altered with clayey gouge on joint surfaces, soft, gray green, closely spaced joints to highly brecciated (0-30 ft). | RQD 54 | A | Core Bite = NWCJ<br>OD= 2.980 - inch<br>ID = 1.875 - inch |
| | | | | 10.8 | B 1 | SEE NOTE ON SHEET 2 LOG 94-DD-80 |
| | | | | 0 | C | |
| 1026.0 | 10 | | | 33 | D | |
| | | | | 0 | E | |
| | | | | 33.7 | F | 40 PSIG/4.6 GPM/15 MIN<br>40-19/5 SEC<br>19-8/120 SEC |
| | | | | 48.7 | G | |
| | 20 | | | 48.1 | H 2 | |
| | | | | 25.4 | I | |
| | | | | 0 | J | |
| | | | | 33.9 | K | 40 PSIG/7 GPM/15 MIN<br>40-8/5 SEC<br>8-0/30 SEC |
| | 30 | | @30 ft joint spacing close to moderate | 77.7 | L 3 | |
| | | | | 48.7 | M | |
| | 40 | | | 30.6 | N | 80 PSIG/23.7 GPM/15 MIN<br>80-10/5 SEC<br>10-0/60 SEC |
| | | | | 31.7 | O 4 | |
| | | | FeO on jt surfaces | 42.7 | P | |
| | 50 | | Brecciated | 0 | Q | |
| | | | | 91.2 | R | 80 PSIG/17.7 GPM/15 MIN<br>80-0/ 5 SEC |
| | | | Brecciated, FeO on jts | 0 | S 5 | |
| | 60 | | | 62.5 | T | |
| | | | | | U | |
| | | | | 39.2 | | |
| | | | Brecciated, FeO on jt surfaces | | | 80 PSIG/20 GPM/15 MIN<br>80-0/5 SEC |
| | 70 | | | 94 | V | |
| | | | | 89.8 | W 6 | |
| | | | NPD lab results 7/13/94 on core 35-35.4 | 94.0 | X | |
| | 80 | | Sp. Gravity 2.72<br>Unit Wgt 169.5 pcf<br>Absorption 0.8% | 51.1 | Y | 80 PSIG/26 GPM/17 MIN<br>80-0/5 SEC |
| | | | Unconf. Comp. Str. 18,010 on core 53.1 - 53.5 | 60.2 | Z 7 | |
| | 90 | | Sp. Gravity 2.76<br>Unit Wgt 171.9 pcf<br>Absorption 0.9%<br>Unconf. Comp. Str. 8,320 psi | 94.5 | AA | |
| | | | | 99.7 | AB 8 | 80 PSIG/24.7 GPM/15 MIN<br>80-10/5 SEC<br>10-0/60 SEC |
| 935.0 | 100 | | | 88.7 | AC | Hole Cemented |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT HH FISH PASSAGE STUDY | HOLE NO. 94-DD084

X-9

| DRILLING LOG | DIVISION NPD | INSTALLATION SEATLE DISTRICT | SHEET 1 OF 3 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT HOWARD HANSEN DAM INTAKE TOWER | 10. SIZE AND TYPE OF BIT HQ DIAMOND |
| 2. LOCATION (Coordinates or Station) N102,508.19 E 1,763,518.22 | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) NGVD 1929 |
| 3. DRILLING AGENCY KERR DRILLING CO. | 12. MANUFACTURER'S DESIGNATION OF DRILL MOBILE B-53 |
| 4. HOLE NO. (As shown on drawing title and file number) 94-DD-85 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0 |
| 5. NAME OF DRILLER RANDY PAINTER | 14. TOTAL NUMBER CORE BOXES 6 |
| 6. DIRECTION OF HOLE VERTICAL ☒ INCLINED ☐ _____ DEG. FROM VERT | 15. ELEVATION GROUND WATER 1133 |
| | 16. DATE HOLE: STARTED 09-18-94; COMPLETED 09-20-94 |
| 7. THICKNESS OF OVERBURDEN 2.0 | 17. ELEVATION TOP OF HOLE 1140.1 |
| 8. DEPTH DRILLED INTO ROCK 54.0 | 18. TOTAL CORE RECOVERY FOR BORING 96 |
| 9. TOTAL DEPTH OF HOLE 56 | 19. SIGNATURE OF INSPECTOR [signature] |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g |
|---|---|---|---|---|---|---|
| 1140.1 | 0 | | ROCK FILL | 63 | 1 | RUN A TO 4.0' D 4.0: C2.5: L1.5 RQD 12.. 5% |
| 1138.1 | 2.0 | | ANDESITE, breccia, gray, hard broken w/qtz and pyrite mineralization | | | |
| 1137.1 | 3.0 | | high angle joint 70 degree 3.5 to 4.9 ft broken zone | 100 | | RUN B TO 6.0' D 2.0: C 2.0: L 0.0 RQD 55 % |
| 1135.2 | 4.9 | | 50 degree 45 degree 40 degree 65 degree, pyrite mineralizaton, some slickensides 45 degree | 100 | | RUN C TO 11.0' D 5.0:C 5.0:L 0 RQD 85% w.t. 9/18 9/19 |
| 1130.1 | 10 | | ANDESITE, breccia, hard 70 degree, pyrite fill flat joint, fresh hard rock 10 degree 45 degree 30 degree | 100 | 1 / 2 | BOX 1 Fm 0.0 to 11.0' RUN D TO 16.0 D5.0:C5.0:L0.0 RQD 96% |
| 1124.1 | 16.0 | | broken zone to 18 ft. 20 degree group of 3 | 90 | | RUN E TO 21.0 D5.0:C4.5:L0.5 RQD 63% |
| 1123.1 | 17 | | Andesite lapallie tuff, | | | |

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1140.1 | Hole No. 94-DD-85 |
|---|---|---|
| 1. PROJECT HOWARD HANSEN DAM INTAKE TOWER | INSTALLATION SEATLE DISTRICT | SHEET 2 OF 3 SHEETS |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g |
|---|---|---|---|---|---|---|
| | | | 30 degree thin calcite crust rock is crumbly | | | |
| | | | 30 degree, calcite fill | | | lost return water, water exiting slope drain at elev 1132 ft. |
| | | | 60 degree, calcite | | | |
| 1120.1 | 20 | | 35 degree, thick calcite infill, crumbly rock | | 2 | |
| | | | Andesite, brecia, gray, hard | | ----- | BOX 2 Fm 11.0 TO 21 FT |
| | | | 45 degree | 100 | 3 | RUN F TO 26.0' DS.0:CS.0:L0.0 RQD 60% |
| | | | 70 degree | | | |
| | | | 22.4 to 24.0 ft, broken zone | | | |
| | | | flat joint | | | RUN G TO 31.0' |
| | | | 26.3 to 26.8 ft., broken zone | 100 | | DS.0:CS.0:L0.0 RQD 86% |
| | | | 5 degree | | | |
| | | | 27.8 to 28.4 ft., broken zone | | | |
| | | | 10 degree | | | |
| | | | 30 degree, some slickensides | | | |
| 1110.1 | 30.00 | | Andesite, breccia, gray, hard | | 3 | |
| | | | 5 degree, several close fractures | | ----- 4 | BOX 3 TO 30.6' RUN H TO 36.0' |
| | | | 35 degree | | | DS.0:CS.0:L0.0 RQD 96% |
| | | | same | 100 | | |
| | | | 5 degree | | | |
| | | | 6 & 20 degree | | | |
| | | | 5 degree, minor calcite | | | |
| | | | soft zone | | | |
| | | | 50 degree, soft infill | | | |
| | | | 35.9 to 36.7 ft., broken, crumbly rock, slicks present | | | RUN I TO 41.0' DS.0:CS.0:L0.0 RQD 80% |
| | | | 50 degree, pyrite, qtz infill | 100 | 4 | |
| | | | | | ----- | BOX 4 Fm 30.6 To 39.6 FT. |
| 1100.1 | 40.0 | | 30 degree, soft | | 5 | |

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1140.1 | Hole No. 94-DD-85 |
|---|---|---|

| 1. PROJECT HOWARD HANSEN DAM INTAKE TOWER | INSTALLATION SEATLE DISTRICT | SHEET 3 OF 3 SHEETS |
|---|---|---|

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g |
|---|---|---|---|---|---|---|
| 1099.6 | 40.5 | | 40.5 to 42.0 ft., broken zone, rock is soft, crumbly with silickensides | | | RUN J TO 46.0' D5.0:C5.0:L0.0 RQD 90% |
| 1098.1 | 42 | | Andesite Lapallie tuff, hardcompetent rock 30 degree, Qtz, pyrite soft infill | 100 | | |
| | | | 30 degree | | 5 | |
| | | | | 100 | ----- | BOX 5 Fm 39.6 To 48.5 FT. |
| 1090.1 | 50 | | | | 6 | |
| | | | 30 degree | | | |
| | | | 40 degree | 100 | | RUN L TO 56.0 D5.0:C5.0:L0.0 RQD 84% |
| | | | shallow joint set | | | |
| | | | 30 & 35 degree conjugate set | | | |
| | | | 40 degree, slight broken zone | | | |
| | | | 20 degree | | 6 | |
| 1084.1 | 56.0 | | btm of hole@ 56 ft. | | ----- | BOX 6 Fm 48.5 To 56.0 FT. |

| DRILLING LOG | DIVISION NPD | INSTALLATION SEATLE DISTRICT | SHEET 1 OF 3 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT HOWARD HANSEN DAM INTAKE TOWER | 10. SIZE AND TYPE OF BIT 6" DIAMOND |
| TION (Coordinates or Station) N102,525.236 E1,763496.572 | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) NGVD 1929 |
| 3. ..ING AGENCY KERR DRILLING CO. | 12. MANUFACTURER'S DESIGNATION OF DRILL MOBILE B-53 |
| 4. HOLE NO. (As shown on drawing title and file number) 94-DD-86 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 0 |
| 5. NAME OF DRILLER R. PAINTER | 14. TOTAL NUMBER CORE BOXES 6 |
| | 15. ELEVATION GROUND WATER 1146.3 |
| 6. DIRECTION OF HOLE VERTICAL ☒ INCLINED ☐ _____ DEG. FROM VERT | 16. DATE HOLE: STARTED 09/16/94; COMPLETED 09/17/94 |
| 7. THICKNESS OF OVERBURDEN 2.6 | 17. ELEVATION TOP OF HOLE 1159.7 |
| 8. DEPTH DRILLED INTO ROCK 38.4 | 18. TOTAL CORE RECOVERY FOR BORING 92 |
| 9. TOTAL DEPTH OF HOLE 41.1 | 19. SIGNATURE OF INSPECTOR [illegible] |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g |
|---|---|---|---|---|---|---|
| 1159.7 | 0 | | CONCRETE | 66 | 1 | RUN A TO 3.0'<br>D3.0:C2.0:L1.0:RQD N/A<br>Initial advance w/HQ bit |
| 1157.7 | 2.0 | | SUBGRADE, (1/4"-) gravels | | | |
| 1157.1 | 2.6 | | ANDESITE, gray-green, Mod.hard<br>core highly broken, crumbly<br>crumbly | 71 | | RUN B TO 6.5'<br>D3.5:C2.5:L1.0 RQD 0%<br>Return water leaking to pool in subsurface |
| | | | rock highly broken<br>vertical joint w/slickensides<br>40 degrees<br>20 degrees<br>70 degrees | 100<br>72 | | RUN C TO 8.0'<br>D1.5:C1.5:L0 RQD 25%<br>reamed HQ pilot hole to 6" dia for next run.<br>RUN D TO 13.0<br>D5.0:C3.6:L1.4 RQD 19<br>% water return 80% 0- |
| | | | | | 1 | BOX 1 FM 0.0 TO 9.7 FT. |
| 1149.7 | 10 | | ANDESITE, gray, hard<br>calcite infill, soft, highly broken to 15.1 Ft.<br>0 degres | | 2 | |
| | | | watertable<br>flat jointed | 100 | | RUN E TO 18.0'<br>D5.0:C5.0:L0 RQD 54%<br>w.t 9/17 |
| 5 | 15.1 | | Andesite, gray, hard<br>10 degree<br>flat joint<br>45 degree joint | | 2 | BOX 2 Fm 9.7'To 17.0' |

FORM ... PREVIOUS EDITIONS ARE OBSOLETE | PROJECT | HOLE NO.

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1159.7 | Hole No. 94-DD-86 |
|---|---|---|
| 1. PROJECT HOWARD HANSEN DAM INTAKE TOWER | INSTALLATION SEATLE DISTRICT | SHEET 2 OF 3 SHEETS |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g |
|---|---|---|---|---|---|---|
| | | | | | 3 | |
| 1141.7 | 18.0 | | ANDESITE BRECCIA, gray, amgdules pink/maroon | 100 | | RUN F TO 23.0' D5.0:C5.0:10 RQD 64% |
| | | | broken, crumbly, soft breccia. 1/8 to 4 " pieces. Pyrite and calcite | | 3 | |
| 1138.7 | 21 | | highly breciated and broken to 23 ft. | | ----- | BOX 3 Fm 17.0' To 22.5' |
| 1136.7 | 23.0 | | 40 degree | 100 | 4 | RUN G TO 28.0 D 5.0:C5.0:L0 RQD 86% |
| | | | 70 degree rehealed fracture, qts filling | | | |
| | | | 70 degree dark coating | | | |
| | | | flat pocket of qtz | | | |
| | | | 50 degree | | 4 | |
| | | | soft zone | | ----- | BOX 4 Fm 22.5' To 28.0' |
| | | | 90 degree, qts infill | 100 | 5 | RUN H TO 34.5 |
| | | | 30 degree, Qtz. and pyrite mineralizaton | | | D 6.5:C 6.5:L 0 RQD 28% |
| | | | 40 degree, thin qtz infill | | | |
| 1129.7 | 30 | | Andesite, breccia, hard broken, crumbly, soft clayey grouge | | | |
| | | | high angle jointing | | | |
| | | | high angle jointing | | | |
| | | | high angle jointing | | 5 | |
| | | | broken zone 1 to 2" pieces | | ----- | BOX 5 To 34.5 FT. RUN I TO 41.0' D 6.5:C6.5:L0.0 RQD 20% |
| | | | high angle and flat jnt. | 100 | 6 | |
| 1123.7 | 36.0 | | clay gouge zone, clay, grey, soft | | | |
| 1122.2 | 37.5 | | Andesite breccia, hard | | | |
| 121.3 | 38.4 | | 60 degree, broken to 38.5 ft. Andesite, lapillie tuff | | | |
| | | | 70 degree | | 6 | |

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1159.7 | Hole No. 94-DD-86 |
|---|---|---|

| 1. PROJECT HOWARD HANSEN DAM INTAKE TOWER | INSTALLATION SEATLE DISTRICT | SHEET 3 OF 3 SHEETS |
|---|---|---|

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc. if significant) g |
|---|---|---|---|---|---|---|
| 1118.6 | 41.1 | | 40-41 ft. high angle joint zone rock highly broken<br>BTM of HOLE | | ----- | BOX 6 TO 41.0 ft. |

PROJECT

HOLE NO.

DRILLING LOG | NPD | NPS | OF 2 SHEETS

| | |
|---|---|
| 1. PROJECT<br>HHD FISH PASSAGE STUDY | 10. SIZE AND TYPE OF BIT HQ WIRELINE |
| 2. LOCATION (Coordinates or Station)<br>N102,462 E1,763,470 (TOPO) | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) |
| 3. DRILLING AGENCY<br>JOHNSON DRILLING for R&R DRILLING | 12. MANUFACTURER'S DESIGNATION OF DRILL<br>JOY 22 |
| 4. HOLE NO. (As shown on drawing title and file number) 96-DD-87 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED N/A UNDISTURBED N/A |
| 5. NAME OF DRILLER<br>BOB JOHNSON | 14. TOTAL NUMBER CORE BOXES 20 |
| 6. DIRECTION OF HOLE<br>☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER FLOWING ARTESIAN |
| 7. THICKNESS OF OVERBURDEN 1.0' | 16. DATE HOLE STARTED 29 APR 96 COMPLETED 3 MAY 96 |
| 8. DEPTH DRILLED INTO ROCK 199.8' | 17. ELEVATION TOP OF HOLE 1165.7 |
| 9. TOTAL DEPTH OF HOLE 200.8' | 18. TOTAL CORE RECOVERY FOR BORING 99.9 % |
| | 19. SIGNATURE OF INSPECTOR RICHARD ECKERLIN |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | RQD | RUN/BOX | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1165.7 | | | GW Silty Sandy Gravel | | | |
| 1164.7 | | | TOP OF ROCK<br>ANDESITE BRECCIA, mod hard to hard, black to green to reddish green, closely to widely fractured | 0 | A | Drilled to 5.3 in 3 runs, then reamed 4"-I.D. (HW) casing to 4.8". Removed 4" casing and took off diamond reaming shoe, then set back in hole so that top is 3" bgs. Top is threaded for cap. |
| | | | | | B | |
| | | | | 100 | C 1 | |
| | | | | 35 | D | NOTE: Petrographic Examination of core by WRD Lab - see 10 Oct 96 Memorandum in Exhibit C |
| | | | 80°, with calcite | 35 | E | |
| | | | 55° | | | |
| | 10 | | | 51 | F | |
| 1152.9 | | | 35°, FeO, water course (12.8-13.0)<br>50°, FeO | | | |
| | | | 75°, FeO, Calcite<br>at 16" vesicules filled with zeolites to 1/8" dia. | 71 | G 2 | |
| | | | 55° | | | 11 — 27 gpm/10 minutes<br>15 - 0 psi/instantaneous |
| 1145.4 | 20 | | 75°<br>75°, possible water course (20.3)<br>FeO, silt | 77 | H | |
| | | | FeO<br>Green Gouge, pyrite vein, calcite | 70 | I 3 | |
| | | | | 84 | J | 10 — 26.1 gpm/10 minutes<br>20 - 2 psi/30 sec |
| | 30 | | | 100 | K | |
| | | | 34-38"<br>Core is mottled red, green black with calcite, vesicules filled with zeolites (1/8")<br>at 37" chlorite on jt., fault gouge | 90 | L 4 | |
| | 40 | | 75° traces, 50°<br>Intensely fractured 39.8-43.3" | 0 | M | 9 — 0.23 gpm/10 minutes<br>52 - 20 psi/2 min |
| | | | | 57 | N 5 | |
| | 50 | | 45° | 96 | O | |
| | | | 45°<br>0.2" loss<br>25° | 44 | P | 8 — 0.19 gpm/10 minutes<br>50 - 20 psi/2 min<br>4/30 1730 |
| | | | | 96 | Q 6 | 5/1 0700<br>SWL 18.5' bgs |
| | 60 | | 25°<br>59.7-70.3" core sent to NPD Lab. | 100 | R | 7 — 0.58 gpm/10 minutes<br>52 - 14 psi/2 min |
| | | | 55° 55°, 60° | 100 | S | |
| | | | 65°<br>45°<br>No joints 67.3-65.2" | 96 | T 7 | |
| | 70 | | | 100 | U | 6 — 0.65 gpm/10 minutes<br>55 - 16 psi/2 min |
| | | | | 100 | V 8 | |
| | 80 | | | 96 | W | 5 — 2.4 gpm/10 minutes<br>65 - 40 psi/2 min |
| | | | 40° | | | |
| 1078.8 | | | FeO Taking Jt, Water Course | 98 | X 9 | |
| | 90 | | | | | 4 — 3.1 gpm/10 minutes<br>64 - 36 psi/2 min |
| | | | 30°, FeO, Clay<br>40° | 98 | Y | |
| | | | 30°, FeO<br>65°<br>15° | 96 | Z 10 | J |
| 1065.7 | 100 | | | | | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HHD FISH PASSAGE STUDY HOLE NO. 96-DD-87

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 1165.7 | Hole No. 96-DD-87 |
|---|---|---|
| PROJECT HHD FISH PASSAGE STUDY | INSTALLATION NPS | SHEET 2 OF 2 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | RQD | RUN/BOX | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1065.7 | 100 | | ANDESITE BRECCIA, moderately hard to hard, black to green to reddish green, medium to widely fractured | 100 | AA 11 | 2.6 gpm/5 mi. 50 - 10 psi/2 min |
| | | | 20° | 81 | AB | |
| | 110 | | 111.7-117.5' core tested at NPO Lab | 100 | AC 12 | 4.1 gpm/5 mi. 45 - 10 psi/2 min |
| | | | 50° | 96 | AD | |
| | 120 | | | | | 5/1 1730 SWL 9.0 bgs |
| | | | 75° | 96 | AE 13 | SWL 14.5 bgs 5/2 0700 |
| 1040.0 | | | 35° | | | 1.3 gpm/5 mi. 45 - 12 psi/2 min |
| | | | 45° | 100 | AF | |
| | 130 | | 65° 50° 45° | | | |
| 1030.0 | | | 135.1-139.7' core tested at NPO Lab | 100 | AG 14 | BASE OF PROPOSED EXCAVATION At 137' Set Grout Packer |
| | 140 | | 35° | 100 | AH | |
| 1022.9 | | | 35° FeO, Water Course at 142.8 | | | |
| 1022.0 | | | 30°, 35°, FeO Artesian Zone 143.4-143.7 | 82 | AI 15 | On 8 May, grouted hole 137-200 ± using 10 sacks cement grout. |
| | | | 60° | | | NOTE: Core from interval 138.5-139' classified as porphyritic metabasalt (see 10 Oct 96 Memorandum in Exhibit C) |
| | | | 40° | 76 | AJ | |
| | 150 | | 30° 30° 30° 45° | 76 | AK | |
| 1009.8 | | | 155.9-156.4 Fault at 156.1 green gouge on 1'.. pyrite vein | 92 | AL 16 | |
| | 160 | | 70° | 100 | AM | |
| | | | 65° 85° | 33 | AN 17 | |
| | 170 | | 65° 65° 35° 0° at 174.5' possibly fault | 78 | AO | |
| | | | 55° | 100 | AP 18 | |
| | 180 | | 40°, 45° 45° | 75 | AQ | |
| | | | | | | 5/2 1730 Artesian 40 gpm |
| | | | 50° 45° 35° 0° | 68 | AR 19 | 5/3 0700 Artesian Pool 40° F, Artesian 48° F |
| | 190 | | 20° | 94 | AS | |
| | | | 50° 60° 80° | 81 | AT 20 | |
| 964.9 | 200 | | | 96 | AU | |
| | | | Bottom of Hole at 200.8' | | | |

LEGEND FOR JOINT SPACING

| | | |
|---|---|---|
| Widely | : | >1.5 ft |
| Moderately | : | 0.5 to 1.5 ft |
| Closely | : | 0.1 to 0.5 ft |
| Highly Fractured | : | brecciated |

## UNIFIED SOIL CLASSIFICATION SYSTEM

### GRAVELS

| | |
|---|---|
| GW | WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES. |
| GP | POORLY GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES. |
| GM | SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURE. |
| GC | CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES. |

### SANDS

| | |
|---|---|
| SW | WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES. |
| SP | POORLY GRADED SANDS OR GRAVELLY SNADS, LITTLE OR NO FINES. |
| SM | SILTY SANDS, SAND-SILT MIXTURES. |
| SC | CLAYEY SANDS, SAND-CLAY MIXTURES. |

### FINES

| | |
|---|---|
| ML | INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTIC PLASTICITY. |
| CL | INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS. |
| OL | ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY. |
| MH | INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS. |
| CH | INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS. |
| OH | ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS. |
| PT | PEAT AND OTHER HIGHLY ORGANIC SOILS. |

BOUNDARY CLASSIFICATIONS: SOILS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE DESIGNATED BY COMBINATIONS OF GROUP SYMBOLS. FOR EXAMPLE GW-GC, WELL-GRADED GRAVEL-SAND MIXTURE WITH CLAY BINDER.

| | |
|---|---|
| \|* | LOCATION OF PERFORATED ZONES IN WELL CASING. |
| WL | WATER LEVEL AT COMPLETION OF HOLE . |
| S \| | LOCATION OF SEAL. |
| T ▶ | LOCATION OF PIEZOMETER TIP. |

| HOLE NUMBER | WELL 1 |
|---|---|
| PROJECT | HANSON DAM SEEPAGE STUDIES |
| LOCATION | N 103,199 E 1,764,00[illegible] |
| DATE STARTED | 18 November 1961 |
| DATE COMPLETED | 17 January, 1962 |

2 STAGE PIEZ COMP 25 MAY 66

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS<br>TOP OF CASING EL 229.23' |
|---|---|---|
| 1227.3 | | SAND AND GRAVEL FILL |
| 1212.3 | 20 | |
| | 40 | COARSE, ANGULAR ROCK FRAGMENTS w/sand, gravel and clay |
| | 60 | |
| [illegible].3 | | |
| | 80 | LARGE, ANGULAR ROCK BLOCKS w/sand and clay |
| | 100 | |
| 1122.3 | | |
| | 120 | LARGE, ANGULAR ROCK BLOCKS w/interstitial silt |
| 1087.3 | 140 | |
| | | COARSE, ANGULAR ROCK FRAGMENTS w/silt and clay |
| | 160 | |
| 1057.3 | | W. L., Jan. 1962 |
| [illegible].3 | | |
| | 180 | COARSE, ANGULAR ROCK FRAGMENTS w/minor gravel, water bearing |
| 1034.7 | | |
| 1034.3 | | Top of Bedrock |
| 1027.3 | 200 | ANDESITE: soft |

| HOLE NUMBER | WELL 2 |
|---|---|
| PROJECT | HANSON DAM SEEPAGE STUDIES |
| LOCATION | N 103,076 E 1,763,729 |
| DATE STARTED | 19 January 1962<br>25 July 1963 |
| DATE COMPLETED | 1 February 1962<br>1 August 1963 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS<br>TOP OF CASING EL 1230.70 |
|---|---|---|
| 1228.2 | | SAND AND GRAVEL FILL |
| 1210.2 | | |
| | | COARSE, ANGULAR ROCK FRAGMENTS w/sand, gravel and silt |
| 1195.2 | | |
| | 40 | LARGE, ANGULAR ROCK FRAGMENTS w/sand, gravel and silt |
| 1180.2 | | |
| | 60 | ANGULAR ROCK FRAGMENTS w/interstitial sand, silt and clay, minor gravel and intercalated lenticular sand and silt |
| 1158.2 | | W. L., Feb. 1962 |
| | 80 | |
| | 100 | |
| | 120 | Bottom of boring, Feb. 1962 |
| 1102.2 | | |
| | | SANDY GRAVEL w/boulders |
| 1091.2 | | |
| | 140 | SILTY SAND w/gravel |
| 1077.2 | | |
| 1076.2 | | CLAY |
| | | Top of bedrock |
| 1064.2 | | ANDESITE BRECCIA |

NOTE: Bottom perforation is to pick up water in void between 4" casing and 6" hole.

HOLE NUMBER WELL 3

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,617 E 1,763,606

| DATE STARTED | DATE COMPLETED |
|---|---|
| 1 March 1962<br>8 July 1963 | 16 March 1962<br>24 July 1963 |

2 STAGE PIEZ COMP 24 MAY 66

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS<br>TOP OF CASING EL 1225.70 |
|---|---|---|
| 1223.3 | | |
| 1213.3 | | FILL MATERIAL |
| 1193.3 | 20 | |
| 1190.3 | | BOULDER |
| 1143.3 | 40<br>60<br>80 | COARSE TO LARGE ANGULAR ROCK FRAGMENTS w/interstitial sand, silt, clay and minor gravel |
| 1126.3 | | LARGE ANGULAR ROCK FRAGMENTS |
| 1123.3 | 100 | VOLCANIC ASH, lt. gray |
| 1110.3 | | LARGE, ANGULAR ROCK FRAGMENTS |
| 1103.3 | | COARSE, ANGULAR ROCK FRAGMENTS AND GRAVEL |
| 1071.3 | 130<br>150 | COARSE, ANGULAR ROCK FRAGMENTS w/minor sand, gravel and silt<br>Bottom of boring, Mar. 1962 |
| 1063.3 | | SILTY SANDY GRAVEL |
| 1060.3 | | SANDY GRAVEL, water |
| 1054.3 | 170 | COARSE TO FINE ANGULAR ROCK FRAGMENTS and clay |
| 1052.3 | | SANDY GRAVEL, water |
| | | SILTY SANDY GRAVEL |
| 1036.3 | 180 | Top of bedrock<br>HIGHLY FRACTURED BRECCIA |
| 1028.3 | | BRECCIA |

HOLE NUMBER WELL 4

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,878 E 1,763,366

| DATE STARTED | DATE COMPLETED |
|---|---|
| 6 February 1962 | 9 February 1962 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS<br>TOP OF CASING EL 1047.70 |
|---|---|---|
| 1044.7 | | |
| 1038.7 | | COARSE, ANGULAR ROCK FRAGMENTS w/silt and sand |
| 1031.7 | | SAND AND GRAVEL w/trace clay |
| 1022.7 | 20 | SANDY SILTY GRAVEL |
| 1009.7 | 30 | SILTY GRAVEL<br>W. L. Feb 1962 |
| 1005.7 | | |
| 1002.7 | | GRAVEL, water bearing |
| 997.7 | | SILT w/gravel |
| 989.7 | 50 | Top of bedrock<br>ANDESITE: soft, blue gray, pyrochastic |

X-2

HOLE NUMBER WELL 5

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,074 E 1,763,329

| DATE STARTED | DATE COMPLETED |
|---|---|
| 18 January 1962 | 5 February 1962 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS<br>TOP OF CASING EL 1046.38 |
|---|---|---|
| 1042.6 | | |
| 1030.6 | | SAND AND GRAVEL w/minor clay, water bearing |
| | 20 | SILTY GRAVEL, fine w/sand, compact, minor rock fragments |
| 1011.4 | | W.L. Feb. 1962 |
| 1000.6 | 40 | |
| | | SANDY GRAVEL, coarse, w/cobbles and sand lenses, water bearing |
| | 60 | |
| 964.5 | | SILTY CLAY w/gravel |
| 962.6 | | SANDY CLAY |
| | | INTERBEDDED FINE SAND AND SILT |
| 948.6 | | |
| 942.6 | 100 | SAND |
| | | SILT w/sand and gravel lenses |
| 930.6 | | |
| 924.6 | | SILT w/decomposed rock and gravel |
| 922.6 | | BEDROCK |

HOLE NUMBER WELL 6

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,315 E 1,763,265

| DATE STARTED | DATE COMPLETED |
|---|---|
| 2 February 1962 | 9 February 1962 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS<br>TOP OF CASING EL 1043.29 |
|---|---|---|
| 1040.0 | | |
| | | SANDY, CLAYEY SILT w/rock fragments |
| 1020.0 | 20 | |
| | | SANDY, SILTY, CLAYEY GRAVEL w/rock fragments |
| 1011.0 | | |
| 1005.0 | | BOULDER |
| | 40 | SILTY, SANDY GRAVEL, water bearing |
| 994.0 | | |
| | | GRAVEL: water bearing |
| 985.0 | | |
| | 60 | SAND AND GRAVEL w/silt and clay lenses |
| 965.0 | | |
| 960.0 | | CLEAN SAND AND GRAVEL |
| | | SAND AND GRAVEL w/minor silt |
| 940.0 | | |
| | | INTERBEDDED SANDS, GRAVEL, SILT AND ROCK FRAGMENTS |
| | 120 | |
| | 140 | |
| 894.0 | | |

HOLE NUMBER WELL 7

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,271 E 1,763,636

| DATE STARTED | DATE COMPLETED |
|---|---|
| 26 August 1963 | 18 September 1963 |

2 STAGE PIEZ COMP 20 JUN 66

TOP OF CASING EL 1213.10

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1210.6 | | ANGULAR ROCK FRAGMENTS AND CLAY |
| | 20 | |
| | 40 | |
| 1161.6 | | ANGULAR ROCK FRAGMENTS, occasional boulders w/interstitial clay |
| | 60 | |
| .6 | | |
| | 80 | SANDY CLAYEY ANGULAR ROCK FRAGMENTS w/occasional boulders |
| | 100 | |
| 1094.6 | | |
| | 120 | GRAVELLY CLAYEY SAND |
| 1076.6 | | |
| 1075.6 | | CLEAN SAND |
| 1072.6 | | SANDY CLAY |
| 1060.6 | | GRAVEL AND BROKEN ROCK, water bearing |
| 1050.6 | 160 | ROCK FRAGMENTS |
| 1042.6 | | CLAYEY SANDY GRAVEL |
| 1039.6 | | CLEAN GRAVEL, water |
| | 180 | CLAYEY SANDY GRAVEL |
| 1024.6 | | CLEAN SAND |
| | | SANDY GRAVEL, water bearing |

HOLE NUMBER WELL 7

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1000.6 | | SANDY GRAVEL |
| 1001.6 | | |
| 999 | | BROKEN ROCK & GRAVEL |
| 990.6 | 220 | ROCK FRAGMENTS AND CLAY |
| 989.6 | | CLEAN SAND |
| | 240 | ROCK FRAGMENTS w/interstitial clay |
| 952.6 | | |
| 930.6 | 280 | CLAY, SAND AND GRAVEL |
| 913.6 | | CLAY |
| 904.6 | 300 | SANDY CLAY |
| | 320 | SANDY GRAVEL w/boulders |
| | 340 | |
| 858.6 | | |
| 855.6 | | SAND, GRAVEL AND ROCK FRAGMENTS |

HOLE NUMBER WELL 8

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,022 E1,763,640

| DATE STARTED | DATE COMPLETED |
|---|---|
| 20 September 1963 | 1 October 1963 |

2 STAGE PIEZ COMP 18 MAY 66

TOP OF CASING EL 1227.59

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1225.4 | | |
| 1208.4 | | BROKEN ROCK AND CLAY |
| 1184.4 | 20 | CLAY AND BROKEN ROCK |
| 1175.4 | 40 | BLOCKY ROCK W/CLAY |
| 1152.4 | 60 | CLAY AND BROKEN ROCK |
| 1139.4 | 80 | BLOCKY ROCK W/CLAY |
| 1126.4 | | CLAY W/BROKEN ROCK |
| 1100.4 | 120 | SANDY CLAYEY GRAVEL AND ROCK FRAGMENTS (T, S) |
| 1062.4 | 140, 160 | SILTY SANDY GRAVEL AND ROCK FRAGMENTS (T, S) |
| 1039.4 | 180 | BROKEN ROCK, water bearing; BROKEN ROCK w/clay; SAND, water bearing |
| | 200 | SANDY GRAVEL w/cobbles |

HOLE NUMBER WELL 8

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1005.4 | 220 | SANDY GRAVEL w/cobbles, water bearing at depth 206 ft. |
| 1000.0 (T) 995.4 | | SAND w/gravel and silt |
| 975.4 | 240 | SANDY GRAVEL, water bearing |
| 974.4 | | CLAY AND BROKEN ROCK |

X-2E

HOLE NUMBER WELL 9

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,803 E 1,763,669

| DATE STARTED | DATE COMPLETED |
|---|---|
| 2 August 1963 | 23 August 1963 |

2 STAGE PIEZ COMP 28 APR 66

TOP OF CASING EL 1230.01

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1227.5 | | ANGULAR ROCK FRAGMENTS w/sand and clay |
| | 20 | |
| 1197.5 | | BROKEN ROCK w/clay, scattered large blocks |
| | 40 | |
| | 60 | |
| | 80 | |
| 1139.5 | | BROKEN ROCK |
| | 100 | |
| 1117.5 | | BROKEN ROCK w/clay and sand |
| 1107.5 | | |
| 1102.5 | | SANDY, BROKEN ROCK |
| | | BROKEN ROCK w/sand and clay |
| | 140 | |
| | 160 | |
| | 180 | GRAVELLY CLAY |
| 1033.5 | | |
| 1032.5 | | GRAVEL, water bearing |
| | 200 | CLAYEY GRAVEL |

HOLE NUMBER WELL 9

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | CLAYEY GRAVEL |
| 1005.5 | 220 | |
| 997.5 | | SANDY GRAVEL AND broken rock |
| 991.5 | | GRAVEL w/sand, water |
| 987.0 | 240 | |
| 982.5 | | CLAY |
| | | BEDROCK |
| | 260 | |
| 963.5 | | |

X-2

HOLE NUMBER WELL 10

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,275 E 1,764,190

| DATE STARTED | DATE COMPLETED |
|---|---|
| 15 October 1961 | 14 November 1961 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 228.6 | | TOP OF CASING EL 1223.51 |
| | | BROKEN ROCK w/sand, gravel and fines |
| 210.6 | | |
| | | BROKEN ROCK w/sand and gravel |
| | 80 | |
| 1178.6 | | |
| | 60 | BLOCKY ROCK w/sand, gravel and clay |
| 1150.6 | | |
| | | BOULDERS in a sand, clay and gravel matrix |
| | 100 | |
| | 120 | |
| 1099.6 | | |
| | | SILT, SAND AND GRAVEL w/broken rock |
| | 140 | |
| 1074.6 | | |
| | 160 | LARGE FRAGMENTS OF BROKEN ROCK (clean) |
| 1063.6 | | W L., Nov. 1961 |
| | | COARSE SAND AND GRAVEL w/broken rock |
| | 180 | |
| 1044.6 | | |
| | | CLEAN COARSE SAND AND GRAVEL |
| | 200 | |

HOLE NUMBER WELL 10

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | CLEAN COARSE SAND AND GRAVEL |
| 1013.6 | | (Well screen) |
| | 220 | SAND, GRAVEL, CLAY AND SILT |
| 1001.6 | | |
| 998.6 | | SILT AND CLAY |
| 992.6 | | BEDROCK |

HOLE NUMBER WELL II

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,748 E 1,763,881

| DATE STARTED | DATE COMPLETED |
|---|---|
| 29 August 1963 | 17 September 1963 |

2 STAGE PIEZ COMP 2 JUN 66

TOP OF CASING EL 1274.26

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1271.7 | | |
| 1268.7 | | GRAVELLY SILTY SAND |
| | | ANGULAR BROKEN ROCK w/sand, gravel & clay |
| | 20 | |
| | 40 | |
| | 60 | |
| | 80 | |
| | 100 | |
| | 120 | |
| | 140 | |
| | 160 | |
| 1101.7 | | BROKEN ROCK (water seepage) |
| 1081.7 | | SANDY CLAYEY GRAVEL w/occasional boulders |
| | 200 | |

HOLE NUMBER WELL II

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | SANDY CLAYEY GRAVEL w/occasional boulders |
| | 220 | |
| 1033.7 | | |
| 1026.7 | | CLEAN GRAVEL, water |
| | | SAND AND GRAVEL |
| 1010.7 | 260 | |
| 1006.7 | | CLEAN GRAVEL, water |
| 1004.7 | | CLAYEY GRAVEL |
| 1001.7 | | CEMENTED GRAVEL |
| 997.7 | | |
| | 280 | BROKEN ROCK w/clay |
| 981.7 | | |

X-26

HOLE NUMBER CD-12

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,184 E 1,763,816

| DATE STARTED | DATE COMPLETED |
|---|---|
| | June 1953 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1256.6 | | TOP OF CASING 1260.1 |
| 1255.6 | | SANDY ORGANIC SILT |
| | | BROKEN ROCK and sandy silt |
| | 20 | |
| | 40 | |
| 1211.6 | | BROKEN ROCK w/interstitial sandy silt |
| | 60 | |
| | 80 | |
| | 100 | |
| | 120 | |
| | 140 | |
| 1100.6 | | |
| | 160 | BROKEN ROCK, gravel size, in matrix of sandy clay and silt |
| 1085.6 | | BROKEN ROCK |
| | 180 | |
| | 200 | |

HOLE NUMBER CD-12

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | BROKEN ROCK |
| | 220 | |
| 1024.6 | | |
| 1019.6 | | SANDY GRAVEL |
| 1018.6 | | GRAVELLY SAND |
| | | SANDY GRAVEL |
| | 260 | |
| 991.6 | | |
| | | SANDY GRAVEL w/boulders |
| 976.6 | 280 | |
| | | CLAYEY SANDY GRAVEL w/boulders |
| 963.6 | | |
| 954.6 | 300 | CLAYEY SAND w/boulders |
| 951.6 | | CLAYEY SANDY GRAVEL w/boulders |

HOLE NUMBER WELL 13

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,689 E 1,763,778

| DATE STARTED | DATE COMPLETED |
|---|---|
| 14 September 1963 | 28 September 1963 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1253.2 | | TOP OF CASING 1255.7 |
| | | BROKEN ROCK w/sand, gravel and silt |
| | 20 | |
| | 40 | |
| | 60 | |
| | 80 | |
| 1162.2 | | |
| 1155.2 | | BROKEN ROCK |
| | | BROKEN ROCK w/sand and silt |
| T | | |
| S | 120 | |
| 1128.2 | | |
| | | BROKEN ROCK |
| | 140 | |
| 1102.2 | | |
| | 160 | |
| | 180 | SILTY SANDY GRAVEL AND BROKEN ROCK, water at 155 & 173-185 ft |
| T | | |
| S | 200 | |

HOLE NUMBER WELL 13

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1047.2 | | SILTY SANDY GRAVEL AND BROKEN ROCK |
| 1040.2 | | CLAY |
| 1034.2 | | SILTY SANDY GRAVEL |
| 1032.2 | | SANDY GRAVEL, WATER |
| 1026.2 | | SILTY SANDY GRAVEL |
| | | SANDY GRAVEL |
| | 240 | |
| 1009.2 | | |
| | | SILTY SANDY GRAVEL |
| | 260 | |
| 974.2 | | |
| | | BEDROCK |
| 958.2 | | |

X-29

HOLE NUMBER WELL 14

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,462 E 1,763,965

| DATE STARTED | DATE COMPLETED |
|---|---|
| 10 July 1963 | 31 July 1963 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1284.1 | | TOP OF CASING 1286.8 |
| | | SILTY CLAYEY GRAVEL w/boulders and sand |
| | 20 | |
| 1253.1 | | |
| | 40 | BROKEN ROCK w/clay |
| | 60 | |
| | 80 | |
| | 100 | |
| | 120 | |
| | 140 | |
| T 1124.1 | 160 | * |
| S | | SANDY CLAYEY GRAVEL, water at 169 feet |
| | 180 | * |
| 1096.1 | | |
| | | SANDY CLAYEY GRAVEL, w/boulders |
| | | * |

HOLE NUMBER WELL 14

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| T | | * |
| S | 220 | SANDY CLAYEY GRAVEL w/boulders |
| T 1037.1 | 240 | * |
| | | BROKEN ROCK |
| 1020.1 | 260 | |
| 1019.1 | | CLAY |
| | | BEDROCK |
| 1009.1 | | |

X-2a

HOLE NUMBER WELL 15

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,521 E 1,764,095

| DATE STARTED | DATE COMPLETED |
|---|---|
| 24 June 1963 | 9 July 1963 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1287.4 | | TOP OF CASING 1290.0 |
| | | SILTY SAND w/gravel |
| | 20 | |
| | 40 | |
| 1237.4 | | |
| | 60 | BROKEN ROCK w/clayey sand |
| | 80 | |
| 1187.4 | 100 | |
| | | BROKEN ROCK w/clay |
| | 120 | |
| 1157.4 | | |
| | | BROKEN ROCK w/sand |
| | 140 | |
| 1137.4 | | |
| | | BROKEN ROCK w/sandy clay |
| | 160 | |
| 1123.9 | | W. L. 10 July 1963 |
| | * | SILTY SANDY GRAVEL, water bearing |
| | 180 | |
| | | SANDY CLAYEY GRAVEL |
| 1087.4 | * | |

HOLE NUMBER WELL 15

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | SANDY CLAYEY GRAVEL |
| | 220 | |
| S | | |
| | 240 | |
| 1037.4 | | |
| | | SANDY GRAVEL water bearing |
| | 260 | |
| 1021.4 | * | |
| 1017.4 | | GRAVELLY SANDY CLAY |
| 1014.4 | * | SANDY GRAVEL, water |
| T | 280 | BROKEN ROCK w/clay |
| 1002.4 | | |
| | | BEDROCK |
| 988.4 | | |

X-30

HOLE NUMBER WELL 16

JECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,518 E 1,764,296

| DATE STARTED | DATE COMPLETED |
|---|---|
| 5 June 1963 | 21 June 1963 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1257.0 | | TOP OF CASING 1259.3 |
| | | ANGULAR ROCK FRAGMENTS w/clay and sand |
| | 20 | |
| | 40 | |
| 1212.0 | | |
| | | BROKEN ROCK w/clay |
| | 60 | |
| S | | |
| 1177.0 | 80 | |
| | | BROKEN ROCK w/clay and sand |
| 1167.0 | | |
| 1157.0 | 100 | BROKEN ROCK w/clay, silt and sand |
| | | CLAYEY SANDY BROKEN ROCK |
| T | 120 | |
| S | | |
| | | Water at 140 - 142 feet |
| | 160 | Water at 162 - 163 feet |
| | 180 | |
| S | 200 | |

HOLE NUMBER WELL 16

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1049.0 | | CLAYEY SANDY BROKEN ROCK |
| 1046.0 | | SANDY GRAVEL, water |
| 1037.0 | 220 | CLAYEY SANDY ANGULAR GRAVEL |
| T | | SANDY GRAVEL w/clay lenses, water bearing |
| 1011.0 | | |
| | | BEDROCK |
| 995.0 | 260 | |

| HOLE NUMBER | WELL 17 |
|---|---|
| PROJECT | HANSON DAM SEEPAGE STUDIES |
| LOCATION | N 103,833 E 1,764,080 |
| DATE STARTED | 5 August 1963 |
| DATE COMPLETED | 28 August 1963 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1288.2 | | TOP OF CASING 1290.7 |
| | | SANDY CLAYEY BROKEN ROCK |
| 1270.2 | 20 | BROKEN ROCK w/clay |
| | 40 | |
| | 60 | |
| | 80 | * |
| | 100 | S |
| | 120 | |
| 1161.2 | | * CLAYEY GRAVEL w/broken rock |
| | 140 | T |
| | | S |
| | 160 | |
| | | Water bearing at 168 feet |
| | 180 | |
| | 200 | |

| HOLE NUMBER | WELL 17 |
|---|---|

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | T |
| | | S |
| | 220 | CLAYEY GRAVEL w/broken rock |
| | 240 | |
| | 260 | |
| 1023.2 | | |
| | | * |
| | 280 | SANDY GRAVEL, water bearing |
| 1000.2 | | * |
| | | T |
| | 300 | GRAVELLY SAND water bearing |
| 980.2 | | |
| | 320 | GRAVELLY SILTY SAND |
| 956.2 | | |
| 951.2 | | GRAVELLY CLAY |
| | 340 | BEDROCK |
| 933.2 | | |

HOLE NUMBER WELL 18

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,314 E 1,763,675

| DATE STARTED | DATE COMPLETED |
|---|---|
| 11 May 1965 | 3 June 1965 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1228.1 | | TOP OF CASING 1230.7 |
| 1210.1 | | CLAYEY ANGULAR GRAVEL AND ROCK FRAGMENTS |
| 1206.1 | 20 | SILTY SANDY GRAVEL |
| 1175.1 | 40 | CLAYEY ANGULAR GRAVEL AND ROCK FRAGMENTS |
| 1142.1 | 60, 80 | SILTY SANDY ANGULAR GRAVEL AND ROCK FRAGMENTS<br>* Lost drill water, 76 to 86' |
| S 1131.1 | | CLAYEY SANDY GRAVEL w/broken rock |
| 1112.1 | 100 | SILTY SANDY GRAVEL w/broken rock |
| 1083.1 | 120, 140 | SILTY SANDY GRAVEL w/broken rock. Water bearing zones at 133' - 134' and 139' - 140'.<br>S.W.L. 130' |
| 1072.1 | | CLAY |
| 1071.1 | | SANDY GRAVEL, water S.W.L. 135' |
| 1068.1 | 160 | CLAY |
| 1062.1 | | SILTY SANDY GRAVEL & boulder |
| 1058.1 | | CLAY |
| T 1041.1 | 180 | BEDROCK ANDESITE |

X-33

HOLE NUMBER WELL 19

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 103,444 E 1,763,650

| DATE STARTED | DATE COMPLETED |
|---|---|
| 4 June 1965 | 16 July 1965 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1226.9 | | TOP OF CASING 1229.5 |
| 1224.9 | | FILL MATERIAL |
| 1195.9 | 20 | CLAYEY ANGULAR GRAVEL AND ROCK FRAGMENTS |
| .9 | 40, 60 | SILTY SANDY ANGULAR GRAVEL AND ROCK FRAGMENTS<br>Lost drill water, 63 - 64' |
| 1128.9 | 80, 100 | BROKEN ROCK w/clay. Lost drill water |
| 1116.9 | | SANDY SILTY GRAVEL AND ROCK FRAGMENTS |
| 1065.9 | 120, 140, 160 | SANDY SILTY GRAVEL w/cobbles, boulders and broken rock<br>Lost drill water, 123 - 124'<br>Water bearing zones intermittent between 133 and 153'. S.W.L. 128' |
| 1060.9 | | SANDY CLAYEY GRAVEL w/broken rock |
| S .9 | 180 | CLAY |
| T 1026.9 | | SANDY GRAVEL AND SANDY SILTY GRAVEL, interbedded, water bearing to 197'. S.W.L. 182' |

HOLE NUMBER WELL 19

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1016.9 | | SANDY GRAVEL w/ broken rock |
| 1011.9 | | SANDY SILTY GRAVEL |
| 1001.9 | | BEDROCK |

X-34

HOLE NUMBER WELL 20

PROJECT HANSON DAM DRAINAGE TUNNEL

LOCATION

N 103,330 E 1,763,854

| DATE STARTED | DATE COMPLETED |
|---|---|
| 15 June 1965 | 2 Aug 1965 |

2 Stage piez. comp. 25 Mar. 1966

Top of Casing El. 1280.0

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1277.4 | | |
| 1275.4 | | SILT |
| | 20 | SANDY SILTY ANGULAR GRAVEL AND ROCK FRAGMENTS |
| | 40 | |
| | 60 | |
| | S 80 | |
| | * 100 | |
| | 120 | |
| | * T 140 | |
| | S 160 | |
| 1105.4 | | |
| | 180 | BROKEN ROCK SAND, 1' thick @ 176-7' Water 172' - 188' S.W.L. 168' |
| 1089.4 | | |
| 1083.4 | | SANDY SILTY GRAVEL |
| 1078.4 | | *FINE SAND & BROKEN ROCK water |
| | 200 | SANDY SILTY GRAVEL |

HOLE NUMBER WELL 20

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1075.4 | | SANDY SILTY GRAVEL |
| 1064.4 | | BROKEN ROCK, * water |
| 1062.4 | | SAND, water, S.W.L. 169' |
| 1057.4 | 220 | BROKEN ROCK, water |
| S 1050.4 | | BOULDER |
| 1041.4 | | SILT |
| 1037.4 | 240 | *SAND, water, S.W.L. 204' |
| 1034.4 | | SANDY GRAVEL |
| 1027.4 | | BROKEN ROCK |
| 1024.4 | | CLAYEY GRAVELLY SAND |
| 1016.4 | 260 | *GRAVELLY SAND, water, S.W.L. 204' |
| 1013.0 T | | CLAY w/sand lenses |
| | 280 | |
| 987.4 | | |
| 979.4 | | SANDY GRAVELLY CLAY |
| | 300 | BEDROCK |
| 967.4 | | |
| | 320 | |

X-35

HOLE NUMBER WELL 21

PROJECT HANSON DAM
DRAINAGE TUNNEL

LOCATION

N 103,215 E 1,763,786

| DATE STARTED | DATE COMPLETED |
|---|---|
| 16 July 1965 | 19 Aug 1965 |

2 Stage piez. comp. 28 March 1966
Top of Casing El. 1230.8

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1228.0 | | |
| | 20 | CLAYEY SANDY ANGULAR GRAVEL AND ROCK FRAGMENTS |
| | 40 | |
| | 60 | |
| 1150.0 | | |
| | 80 | SILTY SANDY ANGULAR GRAVEL AND ROCK FRAGMENTS |
| | 100 | |
| 1119.0 | | |
| | 120 | BROKEN ROCK w/ clayey sandy gravel |
| | | * Water bearing zone 131' to 139' |
| | 140 | S.W.L. 123 to 126' during drilling to depth 216' |
| 1069.0 | | |
| | 160 | SILT |
| .0 S | 180 | SANDY GRAVELLY CLAY |
| 1032.0 | | |
| | 200 | * BROKEN ROCK |

HOLE NUMBER WELL 21

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1027.0 | | BEDROCK VOLCANIC BRECCIA |
| | 220 | |
| 999.0 | | |
| | 240 | |

X-36

HOLE NUMBER WELL 22

PROJECT HANSON DAM
DRAINAGE TUNNEL

LOCATION

N 103,529 E 1,763,640

| DATE STARTED | DATE COMPLETED |
|---|---|
| 11 May 1965 | 2 June 1965 |

2 Stage piez. comp. 10 May 1966
Top of Casing El. 1227.6

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1225.4 | | |
| | 20 | CLAYEY ANGULAR GRAVEL AND ROCK FRAGMENTS |
| | 40 | |
| | 60 | |
| | 80 | SILTY SANDY ROCK FRAGMENTS AND GRAVEL |
| 1124.4 | 100 | |
| 1109.4 | | BOULDERS AND BROKEN ROCK w/sandy clay |
| 1101.4 | 120 | SILTY SANDY GRAVEL |
| 1091.4 | | SANDY GRAVELLY CLAY |
| 1085.4 | 140 | SILTY SANDY GRAVEL, water bearing. S.W.L. 124' |
| | | SILT & CLAY |
| | 160 | |
| 1055.4 | | |
| | 180 | SILT & FINE SAND |
| 1036.4 | | |
| 1026.4 | | SILTY SANDY GRAVEL |

HOLE NUMBER WELL 22

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1020.4 | | GRAVELLY SAND, water S.W.L. 193' |
| 1015.4 | | BEDROCK ANDESITE |
| 1006.2 | 220 | Water in open joint at depth 219' S.W.L. 189' |

X-27

| HOLE NUMBER | HORIZ. DRAIN A-1 |
|---|---|
| PROJECT | HANSON DAM DRAINAGE TUNNEL |
| LOCATION | N 103,360 E 1,763,510 |
| DATE STARTED | 16 August 1967 |
| DATE COMPLETED | 17 August 1967 |

| ELEVATION 1107.2 | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | 20 | BEDROCK |
| | 40 | |
| | 60 | |
| 1113.8 | 80 | |
| 1115.2 | 100 | FINE SAND |
| | | NOTE: Material from 82 to 100 feet depth caved and bound the drill bit, creating refusal to further penetration. |

| HOLE NUMBER | HORIZ. DRAIN A-2 |
|---|---|
| PROJECT | HANSON DAM DRAINAGE TUNNEL |
| LOCATION | N 103,360 E 1,763,510 |
| DATE STARTED | 14 August 1967 |
| DATE COMPLETED | 16 August 1967 |

| ELEVATION 1107.0 | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | 20 | |
| | 40 | BEDROCK |
| | 60 | |
| | 80 | |
| | 100 | |
| 1113.3 | 120 | |
| 1113.7 | | SILTY FINE SAND |
| | 140 | NOTE: Material from 125 to 133 feet depth binds around drill rods, creating refusal to further penetration. |

X-39

| HOLE NUMBER | HORIZ. DRAIN A-3 |
|---|---|
| PROJECT | HANSON DAM<br>DRAINAGE TUNNEL |
| LOCATION | N 103,360 E 1,763,510 |
| DATE STARTED | 14 August 1967 |
| DATE COMPLETED | 14 August 1967 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1107.2 | | |
| | 20 | BROKEN ROCK |
| 1108.0 | | |
| | 40 | |
| | 60 | BEDROCK: Jointed w/clay seams |
| | 80 | |
| 1110.2 | 100 | |
| 1110.5 | | SAND & BROKEN ROCK |
| | 120 | BORING MADE 90 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1133 FT. |

| HOLE NUMBER | HORIZ. DRAIN A-4 |
|---|---|
| PROJECT | HANSON DAM<br>DRAINAGE TUNNEL |
| LOCATION | N 103,360 E 1,763,510 |
| DATE STARTED | 9 August 1967 |
| DATE COMPLETED | 14 August 1967 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1107.8 | | |
| | 20 | |
| | 40 | BEDROCK: Fractured w/clay seams |
| | 60 | |
| | 80 | |
| 1120.9 | | |
| | 100 | BEDROCK: Sound |
| 1122.9 | | |
| 1124.0 | 120 | SILTY SAND |
| 1125.4 | | SILTY SANDY GRAVEL w/ rock fragments |
| | 140 | BORING MADE 30 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1133 FT. |

| HOLE NUMBER HORIZ. DRAIN A-5 | | |
|---|---|---|
| PROJECT HANSON DAM DRAINAGE TUNNEL | | |
| LOCATION N 103,360 E 1,763,510 | | |
| DATE STARTED 8 August 1967 | DATE COMPLETED 8 August 1967 | |
| ELEVATION 1107.0 | DEPTH | DESCRIPTION OF MATERIALS |
| 1107.4 | | BEDROCK: Sound |
| 1108.7 | 20 | BROKEN BEDROCK w/seams of silty & clayey sand |
| 1112.7 | 40<br>60<br>80 | SILTY SANDY FINE GRAVEL w/rock fragments<br>- BORING MAKING 1.2 GPM FROM DEPTH OF 70 FT. |
| 1114.4 | 100<br>120 | SILTY SANDY COARSE GRAVEL & BROKEN ROCK<br>BORING MADE 60 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1137 FT. |

| HOLE NUMBER HORIZ. DRAIN A-6 | | |
|---|---|---|
| PROJECT HANSON DAM DRAINAGE TUNNEL | | |
| LOCATION N 103,360 E 1,763,510 | | |
| DATE STARTED 17 August 1967 | DATE COMPLETED 18 August 1967 | |
| ELEVATION 1107.6 | DEPTH | DESCRIPTION OF MATERIALS |
| 1109.4 | 20 | BEDROCK: Sound |
| 1115.0 | 40<br>60<br>80<br>100 | BROKEN BEDROCK w/ seams of silty and clayey sand |
| 1115.3 | | FINE SAND |
| 1116.0 | 120 | SILTY SANDY GRAVEL. w/rock fragments<br>BORING MADE 37 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1130 FT. |

HOLE NUMBER HORIZ. DRAIN B-1A

PROJECT HANSON DAM DRAINAGE TUNNEL

LOCATION

N 103,425 E 1,763,498

| DATE STARTED | DATE COMPLETED |
|---|---|
| 6 Sept. 1967 | 11 Sept. 1967 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1081.3 | | |
| | 20 | |
| | 40 | BEDROCK |
| | 60 | |
| | 80 | |
| 1094.4 | | |
| | | BORING MAKING WATER BELOW DEPTH 82 FT. |
| | 100 | CLAYEY SANDY GRAVEL |
| 1099.8 | 120 | |
| | 140 | |
| | 160 | BROKEN ROCK: Weathered w/clay & silt filled seams. HARD BETWEEN DEPTH 160 & 180 FT. |
| | 180 | |
| | 200 | |

HOLE NUMBER HORIZ. DRAIN B-1A

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | 220 | BROKEN ROCK: Weathered w/clay and silt filled seams. |
| | 240 | BORING MADE 60 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1121 FT. |
| 1120.8 | 260 | |

| HOLE NUMBER | HORIZ. DRAIN 3-2 |
|---|---|
| PROJECT | HANSON DAM DRAINAGE TUNNEL |
| LOCATION | N 103,425 E 1,763,498 |
| DATE STARTED | 11 Sept. 1967 |
| DATE COMPLETED | 13 Sept. 1967 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1082.4 | 20, 40, 60 | BEDROCK |
| | 80, 100, 120 | CLAYEY SANDY GRAVEL |
| 1100.4 | 140 | CLAYEY SANDY GRAVEL AND BROKEN ROCK w/ sand lenses |
| 1105.7 | 160, 180 | BROKEN ROCK w/interstitial clay, silt and sand |
| 1110.9 | 200 | CLAYEY & SILTY GRAVEL & ROCK FRAGMENTS w/ sand lenses |
| 1112.4 | | |

| HOLE NUMBER | HORIZ. DRAIN 3-3 |
|---|---|
| PROJECT | HANSON DAM DRAINAGE TUNNEL |
| LOCATION | N 103,425 E 1,763,498 |
| DATE STARTED | 15 Sept. 1967 |
| DATE COMPLETED | 17 Sept. 1967 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1081.3 | 20, 40, 60 | BEDROCK |
| 1085.9 | 80, 100, 120 | BROKEN ROCK w/interstitial clayey and silty sandy gravel and occasional sand lenses |
| | 140 | BORING MADE 90 GPM UPON COMPLETION w/ RESERVOIR AT ELEV. 1120 FT. |
| 1092.9 | 160, 180 | |

BORING MADE 70 GPM UPON COMPLETION WITH RESERVOIR AT ELEV. 1121 FT.

X-46

HOLE NUMBER 79-CD-38

PROJECT Howard Hanson Dam
1979 Piezometer installation

LOCATION Right Abutment

N 104,036.28 E. 763,956.34

| DATE STARTED | DATE COMPLETED |
|---|---|
| 23 Aug 1979 | 27 Oct 1979 |

| ELEVATION 1308 | DEPTH | DESCRIPTION OF MATERIALS<br>Top of Casing -1311.3 |
|---|---|---|
| | | Boulders & broken rock - all angular - w/silt & sand. |
| | 10 | GM, Silty Sandy GRAVEL (ang.) w/boulders (ang.) & minor clay or decomposed rock, medium w/dense zones, brown w/minor gray. |
| | 20 | BOULDER |
| | 30 | GM, Cemented Sands & Gravels w/silt, clay & broken rock, medium, brownish gray. |
| | 40 | GM, Cemented Sands & Gravels w/silt, clay, broken rock & occ. boulders (ang.), medium, brownish gray. |
| | 50 | Lost Drill Water from -55 to -64 |
| | 60 | |
| | 70 | |
| | 80 | |
| | 90 | GM, Cemented Sands & Gravels w/clay, medium to dense, gray. |
| S | | |

HOLE NUMBER 79-CD-38

| ELEVATION 1208 | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | Lost Drill Water from -95 to -107 |
| | 110 | Water Bearing Zone from -113.5 to -114 |
| | | BOULDER |
| | 120 | GM, Cemented Sands & Gravels w/clay, broken rock & boulders (ang.), dense, gray |
| | 130 | Boulders (nest of) w/clay & minor sand & silt between boulders & broken rock. |
| | 140 | SP-SM, Gravelly SAND w/silt, very dense, NP, moist, gray. |
| | 150 | GM, Clayey GRAVEL w/sand, silt & broken rock, very dense, moist, gray. |
| | | SM, Clayey Silty SAND (med. to fine), dense, gray. |
| | 160 | Rock Slab (Lost Drill Water from -152 to -153.5) |
| | 170 | GM, Silty Sandy GRAVEL (coarse to fine, ang.) w/boulders & clay, dense, gray w/traces of brown. Less boulders w/depth. * |
| T | 180 | W.L. (Hit Ground Water, Did Not Seal Off Until Casing Reached -320±) |
| S | 190 | → 9/24/79 p.m. : hole 187', W.L. 176'<br>→ 9/25/79 a.m. : hole 187', W.L. 173' |
| | 200 | GM, Broken rock w/silt, sand, gravel (ang.) & minor clay, dense, gray w/brown. * |
| | | → 9/25/79 p.m. : hole 193', W.L. 181'<br>→ 9/26/79 a.m. : hole 193', W.L. 181' |
| 1098 | 210 | → 9/26/79 p.m. : hole 205', W.L. 176.5'<br>→ 9/27/79 a.m. : hole 205', W.L. 176.5' |

X-43

HOLE NUMBER 79-CD-38

| ELEVATION 988 | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | → 10/4/79 p.m. : hole : 220', W.L. : 180 |
| | | → 10/5/79 a.m. : hole : 220', W.L. : 181 |
| T | 220 | |
| | | GM, Broken Rock w/silt, sand, gravel (ang.), decomposed rock & boulders (ang.), dense, gray w/brown. |
| | 230 | |
| S | | NOTE: W.L. STATIC : -181' until 10/17/79 |
| | 240 | |
| | 250 | |
| | 260 | |
| | | SM, Silty SAND (med. to fine) [w/minor gravel (fine) to -264'], medium to dense, grayish brown. |
| | 270 | |
| T | | GM, Broken Rock w/silt, sand & gravel (ang.), dense, gray w/ brown. |
| | 280 | |
| | 290 | |
| | | STATIC WATER LEVEL |
| | 300 | |
| | 310 | GM, Silty Sandy GRAVEL (coarse to fine, ang.) w/ boulders & clay, dense, gray w/brown. |
| 988 | 320 | → 10/17/79 p.m. : hole : 321.5', W.L. : 295.5' |
| | | → 10/18/79 a.m. : hole : 321.5', W.L. : 295.5' |

HOLE NUMBER 79-CD-38

| ELEVATION 988 | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | Less Boulders w/depth. |
| | 330 | Hit possible water bearing zone -330' to -340'. |
| | | → 10/18/79 p.m. : hole : 340', W.L. : 280' |
| | 340 | |
| | | → 10/19/79 a.m. : hole : 340', W.L. : 320' |
| | | → 10/20/79 p.m. : hole : 351', W.L. : 320' |
| | 350 | BOULDER |
| | | → 10/24/79 a.m. : hole : 351', W.L. : 288' |
| | | SP-GP, Gravelly (coarse to fine) SAND (coarse to fine) w/ minor silt & num. boulders (rounded), medium to dense, brownish gray. |
| | 360 | |
| | | GP-GM, Silty Sandy GRAVEL w/boulders, medium to dense, brownish gray. |
| | 370 | |
| | | → 10/26/79 p.m. : hole : 365', W.L. : 302.5' |
| 923 | | |
| | 380 | Bottom : -375' |
| | | → 10/27/79 p.m. : hole : 380', W.L. : 295.5' |
| | | NOTE: Casing : -361.5 |

HOLE NUMBER 79-CD-39

PROJECT Howard Hanson Dam
1979 Piezometer Installation

LOCATION Right Abutment

N 103,829.63 E 1,753,329.97

| DATE STARTED | DATE COMPLETED |
|---|---|
| 29 Aug. 1979 | 25 Sept. 1979 |

| ELEVATION 1176.4 | DEPTH | DESCRIPTION OF MATERIALS<br>Top of casing = 1178.9 |
|---|---|---|
| | | CASING STICKUP = 2.5'<br>BACKFILL MATERIAL PLACED AUGUST 1981 |
| | 10<br>20<br>30 | GM, Silty Sandy GRAVEL (ang.) BROKEN ROCK-w/occ. boulders, med. to loose w/dense zones, brown. |
| | 40 | GM, Silty Sandy GRAVEL (a[illegible]) w/occ. boulders, broken [illegible] & minor organic debris, m[illegible] dium, brown. |
| | 50 | BROKEN ROCK w/silt, sand & Gravel, med. to dense, brown to brownish gray. |
| | 60 | BROKEN ROCK & boulders (ang.) w/silt, sand, gravel & minor clay, dense, brownish gray to tan. |
| | 70 | * |
| | 80 | BROKEN ROCK & boulders (ang.) w/silt, sand, clay & gravel, dense, grayish brown. |
| T | | |
| | 90 | water bearing zone from 90.1 to 91.1 |
| | 100 | BROKEN ROCK & boulders (ang.) w/silt, sand, clay & decomposed rock, dense, blue-gray |

HOLE NUMBER 79-CD-39

| ELEVATION 1176.4 | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| | | water level @ -101.1 until sealed by casing into clay zone below.<br>* |
| T | 110 | CL, CLAY, very stiff, moist, gray. |
| S | 120 | |
| | 130 | SP, SAND (med. to fine, clean) w/minor gravel (fine), medium to dense, gray. |
| | 140 | GP-GM, Silty Sandy (coa[illegible] to fine) GRAVEL (1½"-), dense, brownish gray. |
| | 150 | BOULDER |
| | | GM, Silty Sandy (coars[illegible] to fine) GRAVEL (coars[illegible] fine, ang.) w/num. boulders, dense, gray w/min[illegible] brown & reddish gravel. |
| | 160 | * |
| | | GM, Silty Sandy GRAVEL (ang.) to sub-round) w/0cc[illegible] bldrs., dense, brown. |
| | 170 | |
| T | | GP, Sandy GRAVEL (med. to coarse, sub-round) clean, loose to medium, wet, gray<br>HIT WATER @ - 165.1<br>STATIC LEVEL @ - 152.1 |
| | 180 | ROCK - SOLID w/possible fracture zones. |
| | 190 | |
| | 200 | |
| 973.3 | | Bottom @ - 203' in bedrock. |
| | 210 | |

X-45

HOLE NUMBER 79-CD-40

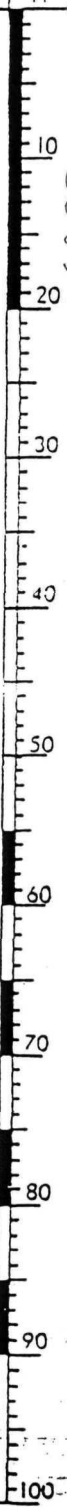
PROJECT Howard Hanson Dam
1979 Piezometer Installations

LOCATION Right Abutment

N 103,891.20 E 1,763,861.25

| DATE STARTED | DATE COMPLETED |
|---|---|
| 31 Aug 1979 | 27 Sep 1979 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1236.4 | | Top of Casing = 1289.4 |




Broken and decomposing ROCK (angular) with GM, Silty Sandy GRAVEL w/some clay, occ. cobbles & boulders, NP, med to very dense, moist, gray & tan (landslide debris)

1186.4

HOLE NUMBER 79-CD-40

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1186.4 | | |

dense @ 110'

med. @ 115'

Broken ROCK w/SM, Clayey SAND, dense, moist, gray.

med. @ 126'

dense @ 145'

med. @ 150' - 200'

(landslide debris)

hit water: hole @ 191.0', W.L. @ 188.5' (9/18/79)

hole caved from 193' to 187'

minor sand @ 200.0'

water 183.0' with hole 208.5'

1076.4

X-46

HOLE NUMBER 79-CD-40

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 5.4 | | 9/19/79 a.m. : hole : 208.5', W.L. : 189.3' |
| | | 9/21/79 a.m. : hole : 226.5', W.L. : 189.3' |
| | 220 | * very dense 225' |
| | 220 | dense : 230' |
| | | 9/24/79 a.m. : hole : 231.5', W.L. : 188.8' |
| T | | |
| S | | CL, CLAY, medium, moist gray |
| | 240 | |
| | | GP, Sandy GRAVEL (rounded) w/minor silt, NP, med. to dense, moist to wet, gray |
| | 250 | |
| | | GM, Silty Sandy GRAVEL w/some clay, NP, med. to dense, wet, brown & gray. (rounded gravels) |
| | 260 | |
| | | 9/24/79 1200 hrs : hole : 242.0', W.L. : 195.0' |
| | 270 | |
| | | 9/25/79 a.m. : hole : 251.5', W.L. 192.5' |
| | | GP, Sandy GRAVEL w/occ. cobbles, NP, loose, saturated, gray. |
| | 280 | |
| | | * 9/26/79, a.m. : hole 271.5', W.L. 191.5' |
| | 290 | |
| | | 9/27/79, a.m. : hole 285.0', W.L. 264.3' |
| T | | |
| | | 10/1/79, a.m. : hole 300.0', W.L. 264.5' |
| 986.4 | 300 | |
| | | Bottom of Hole : 300.0' |

HOLE NUMBER 79-CD-41A

PROJECT Howard Hanson Dam
1979 Piezometer Installation

LOCATION Right Abutment

N 103,586.77 E 1,7[illegible],904.70

| DATE STARTED | DATE COMPLETED |
|---|---|
| 4 Sep 1979 | 31 Oct 1979 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1274.2 | | Top of Casing =1277.0 |
| | | GM, Silty Sandy GRAVEL w/ cobbles & boulders (all ang.), medium, brown. |
| | 10 | GM, Silty Sandy GRAVEL w/ clay & occ. boulders, medium to dense, tan. |
| | 20 | LOST DRILL WATER FROM -9 to -11 & FROM -15 to -17. |
| | 30 | |
| | | BOULDER |
| | 40 | GM, Silty Sandy GRAVEL w/ clay & occ. boulders, dense, tan. |
| | 50 | |
| | | GM, Clayey Sandy GRAVEL w/silt, occ. boulders & cobbles, dense, tan. |
| | 60 | |
| | 70 | |
| S | 80 | |
| | | very dense w depth. |
| | 90 | * |
| | 100 | |

HOLE NUMBER 79-CD-41A

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1174.2 | | |
| T | | GM, Clayey Sandy GRAVEL w/ silt, broken rock, occ. boulders & cobbles, medium to very dense, moist, brown & gray w/reddish brown in clayey material. |
| | 110 | |
| S | | |
| | 120 | * |
| | | LOST DRILL WATER FROM -121' to - 135'. |
| | 130 | GM, Silty Sandy GRAVEL w/clay occ. cobbles &/or boulders & broken rock, medium to dense, moist, gray & reddish brown. |
| | 140 | NOTE: reddish brown material appears to be decomposed rock. |
| T | | |
| | 150 | medium to very dense w/depth. |
| S | | |
| | 160 | |
| T | 170 | * |
| S | | |

Bottom @ 176' Lost Bailer

HOLE NUMBER 79-CD-41

PROJECT Howard Hanson Dam
1979 Piezometer Installation

LOCATION Right Abutment

N 103,586.77 E 1,763,904.70

| DATE STARTED | DATE COMPLETED |
|---|---|
| 4 Sep 1979 | 31 Oct 1979 |

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1274.2 | | Top of Casing =1277.0 |
| | | GM, Silty Sandy GRAVEL w/ cobbles & boulders (all ang.), medium, brown. |
| | 10 | GM, Silty Sandy GRAVEL w/ clay & acc. boulders, medium to dense, tan. |
| | 20 | LOST DRILL WATER FROM -9 to -11 & FROM -15 to -17. |
| | 30 | |
| | | BOULDER |
| | 40 | GM, Silty Sandy GRAVEL w/ clay & acc. boulders, dense, tan. |
| | 50 | |
| | | GM, Clayey Sandy GRAVEL w/silt, acc. boulders & cobbles, dense, tan. |
| | 60 | |
| | 70 | |
| | 80 | |
| | | very dense w/depth. |
| | 90 | |
| | 100 | |

HOLE NUMBER 79-CD-41

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1174.2 | | GM, Clayey Sandy GRAVEL w/ silt, broken rock, acc. boulders & cobbles, medium to very dense, moist, brown & gray w/reddish brown in clayey material. |
| | 110 | |
| | 120 | |
| | | LOST DRILL WATER FROM -121' to - 135'. |
| | 130 | GM, Silty Sandy GRAVEL w/clay acc. cobbles &/or boulders & broken rock, medium to dense, moist, gray & reddish brown. |
| | | NOTE: reddish brown material appears to be decomposed rock. |
| | 140 | |
| | 150 | medium to very dense w/depth. |
| | 160 | |
| S | 170 | |
| | | POSSIBLE SAND SEAM |
| | 180 | GM, Silty Sandy GRAVEL (ang.) &/or broken rock w/clay, num. boulders & cobbles, medium to dense, grayish brown. |
| | ▽190 | |
| | | More cobbles & gravel & less clay w/depth. |
| T | 200 | |
| | | ROCK SLAB |
| | | Hit Ground Water @ -205' |
| | | Static Water Level @ -190'. |
| 1064.2 | 210 | |
| | | Bottom @ -210 |

X-49

HOLE NUMBER CD-53

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,180 E 1,763,385

DATE STARTED | DATE COMPLETED 1955

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1086.6 | | TOP OF CASING 1087.5 |
| | | SANDY SILT w/broken rock |
| 1069.6 | | |
| | | SANDY SILTY CLAY w/rock fragments |
| T 1052.6 | | |
| S 1050.6 | | SANDY CLAY w/rock fragments |
| | 40 | SANDY GRAVEL w/clay and silt |
| 1035.6 | | |
| | | GRAVELLY SAND w/broken rock |
| | 60 | |
| 1006.6 | 80 | W. L. |
| 989.6 | | |
| | | SILTY CLAY w/broken rock |
| 975.6 | | |
| | | SAND w/rock fragments |
| 961.1 | 120 | |
| T 955.6 | | SILTY SANDY GRAVEL |
| 948.1 | | SAND |
| | | SAND, GRAVEL, SILT AND CLAY, interbedded |
| 925.6 | 160 | |
| | | SAND, SILT AND CLAY, interbedded |
| | 180 | |
| 894.6 | | |
| 886.6 | 200 | BEDROCK |

HOLE NUMBER CD-54

PROJECT HANSON DAM SEEPAGE STUDIES

LOCATION

N 104,029 E 1,763,414

DATE STARTED | DATE COMPLETED 1955

| ELEVATION | DEPTH | DESCRIPTION OF MATERIALS |
|---|---|---|
| 1093.3 | | TOP OF CASING 1094.6 |
| | | BROKEN ROCK w/sandy silt |
| | 20 | |
| 1064.3 | | |
| | | BOULDER |
| T 1048.8 | 40 | |
| S 1046.8 | | CLAY |
| 1045.3 | | BOULDER |
| 1038.3 | | SANDY SILTY GRAVEL |
| 1032.8 | 60 | SAND |
| 1026.8 | | SANDY SILTY GRAVEL |
| | | SANDY SILTY GRAVEL w/broken rock |
| | 80 | |
| 992.3 | 100 | GRAVEL w broken rock, some sand and silt |
| 986.3 | | |
| 981.8 | | SANDY GRAVEL |
| 979.3 | | SAND |
| 974.3 | | SILTY SANDY GRAVEL |
| | 140 | INTERBEDDED SANDS, GRAVELS, SILTY GRAVELS, AND GRAVELLY SANDS w occasional rock fragments |
| | 160 | |
| T | 180 | |
| 903.3 | | |
| 900.3 | | WEATHERED ROCK |
| 893.3 | 200 | BEDROCK |

X-50

DRILLING LOG | NPD | NPS | SHEET 1 OF 3 SHEETS

| | |
|---|---|
| 1. PROJECT HOWARD HANSON DAM | 10. SIZE AND TYPE OF BIT 0-10'[8"] 10'-198'[6"] |
| 2. LOCATION (Coordinates or Station) N102,795 E1763,510 [TOPO] | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) |
| 3. DRILLING AGENCY JENSEN DRILLING CO. | 12. MANUFACTURER'S DESIGNATION OF DRILL BUCYRUS ERIE 22W CABLE TOOL |
| 4. HOLE NO. (As shown on drawing title and file number) 86-CD-101/101A | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 2 UNDISTURBED 19 |
| 5. NAME OF DRILLER ART GWIN | 14. TOTAL NUMBER CORE BOXES 0 |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| | 16. DATE HOLE STARTED 10/30/86 COMPLETED |
| 7. THICKNESS OF OVERBURDEN 192' | 17. ELEVATION TOP OF HOLE 1194 [TOPO] |
| 8. DEPTH DRILLED INTO ROCK 6' | 18. TOTAL CORE RECOVERY FOR BORING % |
| 9. TOTAL DEPTH OF HOLE 198' | 19. SIGNATURE OF INSPECTOR R. ECKERLIN |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1194 | | | GM GRAVEL LOOSE | | | DRILLED WITH BUCYRUS ERIE CABLE TOOL. 6" BIT 4" ID SAMPLER WITH 2,000 LB. WT 15' LONG N=# BLOWS TO DRIVE SAMPLER 6" |
| | | | APPROX. CORE OF DAM | | | |
| | 10 | | GM. SILTY SANDY GRAVEL WITH COBBLES [6"]. DENSE | | A | SAMPLE A REFUSAL, 0% REC. |
| | | | SANDY AT 18' | | | |
| | 20 | | GM. SILTY SANDY GRAVEL WITH COBBLES. DENSE BROWN WITH MOTTLED GRAY | | B | N=48,36,50 70% REC. 10/30/86 10/31/86 |
| | 30 | | | | C | N=65,69,50 60% REC. 10/31/86 11/3/86 |
| | 40 | | GM. SILTY SANDY GRAVEL WITH COBBLES [6"] DENSE MOIST, BROWN | | D | N=43,42,33 100% REC. 11/3/86 11/4/86 |
| | 50 | | | | E | N=20,24,30 100% REC |
| | 60 | | LARGE COBBLE AT 62.5' | | F | N=49,28,28 100% REC. 11/4/86 11/5/86 |
| | 70 | | | | G | N=37,40,36 75% REC. |
| | 80 | | | | H | N=63,67,75 50% REC. 11/5/86 11/6/86 |
| | 90 | | | | I | N=38,66,60 75% REC 11/6/86 11/18/86 |
| | 100 | | | | J | 11/18/86 11/18/86 |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT HHD HOLE NO. 86-CD-101/101A

X-51

PROJECT HOWARD HANSON DAM | INSTALLATION NPSEN-GT | HOLE NO. 86-CD-101/101A | SHEET 2 OF 3 SHEETS

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1094' | 100 | | GM. SILTY SANDY GRAVEL. COBBLES. MOIST. BROWN | | J | N=31.42.38 100% REC. |
| | | | | | | SWL 105.7 11/19/86 |
| | 110 | | LOOSE GRAVELS [SOME CAVING]. MOIST TO WET | | | SWL 104.9 11/20/86 |
| | | | | | K | N=34.40.63 100% REC. |
| | | | | | | SWL 104.9 11/20/86 |
| | 120 | | | | | SWL 104.9 11/21/86 |
| | | | | | L | |
| | | | AT 124' CASING BENT | | | SWL 120 11/21/86 |
| | | | MOVE TO NEW LOCATION 5' TOWARD LEFT ABUTMENT FROM 101 11/25/86 START NEW HOLE 86-CD-101A | | | SWL 118.5 11/24/86 101 101A |
| | 130 | | | | | 12/18/86 |
| | | | | | | N= 42.43.39 |
| | | | | | M | SWL 129.6 12/18/86 |
| | | | GP-GM, SILTY SANDY GRAVEL. WITH COBBLES DENSE.MOIST.BROWN | | | SWL 129.3 12/19/86 |
| | 140 | | | | | |
| | | | | | N | N= 42.43.47 100% REC. |
| | 150 | | COBBLE @ 152 | | | SWL 145.2 12/19/86 |
| | | | | | | SWL 146.2 1/6/87 |
| | | | | | O | N=45.45.REFUSAL 100% REC., 2 JARS |
| | 160 | | | | | |
| | | | | | P | N= 24.55.39 60% REC. 1/6/87 |
| | | | | | | SWL 161 1/7/87 |
| | 170 | | GP-GM. LESS SILT THAN PREVIOUS SAMPLE | | | |
| | | | | | | N= 41.43.68 90% REC. 1/7/87 |
| | | | | | Q | SWL 163.6 1/8/87 |
| | 180 | | GM. SILTY SANDY GRAVEL WITH COBBLES. VERY DENSE.MOIST.BROWN | | | |
| | | | | | R | N= 32.60.44 75% REC. 1/8/87 |
| | | | | | | SWL 165.5 1/9/87 |
| | | | FINE GRNED. WITH COARSE SAND TO GM | | S | BAILER SAMPLE |
| | 190 | | | | T | N= 40.56.REFUSAL 100% REC. 2 JARS SWL-BAIL DRY 1/9/87 |
| 1002' | | | TOP ROCK | | | SWL 183.4 1/13/87 |
| | | | SOFT-HARD | | | |
| | | | HARD | | | |
| 996' | | | ANDESITE. BLACK | | | |
| | 200 | | TD 198'[ELV. 996'] | | | |
| | | | | | | TD 198' |
| | | | | | | CASING TO 192.5' [6"ID] |

ENG FORM 1836-A MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HHD HOLE NO. 86-CD-101/101A

X-52

DRILLING LOG | NPD | NPS | SHEET ___ OF ___ SHEETS

| | |
|---|---|
| 1. PROJECT HOWARD HANSON DAM | 10. SIZE AND TYPE OF BIT 6" ODEX |
| 2. LOCATION (Coordinates or Station) N103,150 E1,763,905 [TOPO] | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) |
| 3. DRILLING AGENCY JENSEN DRILLING CO. | 12. MANUFACTURER'S DESIGNATION OF DRILL CP 650 AIR ROTARY DRILL |
| 4. HOLE NO. (As shown on drawing title and file number) 87-RD-102 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 22 UNDISTURBED 10 |
| 5. NAME OF DRILLER TED MERYDITH | 14. TOTAL NUMBER CORE BOXES |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| 7. THICKNESS OF OVERBURDEN 208' | 16. DATE HOLE STARTED JAN. 21, 1987 COMPLETED JAN. 29, 1987 |
| 8. DEPTH DRILLED INTO ROCK 12' | 17. ELEVATION TOP OF HOLE APPROX. 1225 [TOPO] |
| 9. TOTAL DEPTH OF HOLE 220' | 18. TOTAL CORE RECOVERY FOR BORING ___ % |
| | 19. SIGNATURE OF INSPECTOR RICK ECKERLIN |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (Description) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g |
|---|---|---|---|---|---|---|
| 1225 | | | CLAYEY-SILTY CRUSHED ROCK, WET, TAN-BROWN [FILL?] | | | DRILLED WITH AIR USING ODEX HAMMER CASING CONCURRENT WITH DRLG. USED OVERHEAD CASING DRIVE THRU HAMMER TO DRIVE SAMPLER |
| | 10 | | | | | |
| | 20 | | | 75% | A | DRIVE SAMPLE A N= 8,10,12 |
| 1223 | | | GM, SILTY SANDY GRAVEL WITH COBBLES AND BOULDERS | | | |
| | 30 | | | 75% | B | 1/21/87 1/22/87 DRIVE SAMPLE B N= 8,10,10 |
| 1191 | | | ANDESITE BLOCK, HARD, LIGHT GREEN [34-42'] | | | |
| | 40 | | | | C | CHIP SAMPLE |
| | | | SILT | | | |
| | | | ANDESITE BLOCK, HARD, LIGHT GREEN [43-65'] | | | |
| | 50 | | | | D | CHIP SAMPLE |
| | 60 | | | | E | CHIP SAMPLE |
| | | | SILT AND COBBLES, LOOSE, BROWN | | F | CHIP SAMPLE |
| | | | | | G | CHIP SAMPLE |
| | 70 | | | 0% | H | DRIVE SAMPLE H N= 20/2, REFUSAL |
| | | | ANDESITE BLOCK, HARD, GREEN 70-78' | | | |
| | | | SAND AND COBBLES | | I | CHIP SAMPLE |
| | 80 | | | | J | CHIP SAMPLE |
| | | | ANDESITE BLOCK, HARD GREEN 79-99' | | | |
| | | | | | K | CHIP SAMPLE |
| | 90 | | | | L | CHIP SAMPLE |
| 1125 | 100 | | | | N | CHIP SAMPLE JAN 22, 1730 HRS |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT HHD | HOLE NO. 87-RD-102

X-53

Hole No. 87-RD-102

PROJECT: HOWARD HANSON DAM | INSTALLATION: NPS | SHEET 2 OF 3 SHEETS

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) | |
|---|---|---|---|---|---|---|---|
| 1125 | | | 99', SILTY SANDY ROCK FRAGMENTS [1'- 1, MED SOFT, MOIST, GREEN | 100% | O | DRIVE SAMPLE O N= 11,14,15 | 1/23/87 |
| 1117 | | | | | | | |
| | 110 | | ANDESITE BLOCK, HARD, GREEN 108-113' | | P | CHIP SAMPLE | |
| 1112 | | | SILTY SAND AND ROCK FRAGMENTS | | | | |
| 1108 | | | | | | | |
| | 120 | | ANDESITE BLOCK, 113-124 | | Q | CHIP SAMPLE | |
| 1101 | | | | | | | |
| | | | | | R | CHIP SAMPLE | |
| | 130 | | | 100% | S | DRIVE SAMPLE S N= 4,6,6 | |
| | | | ROCK FRAGMENTS IN SILTY SAND MATRIX, MOIST, GREEN | | T | CHIP SAMPLE | 1/23/87 |
| | 140 | | | 75% | U | DRIVE SAMPLE U N= 10,8,9 | 1/27/87 |
| | 150 | | | | V | CHIP SAMPLE | |
| | | | | | W | CHIP SAMPLE | |
| | | | | | X | CHIP SAMPLE | |
| 1065 | 160 | | GC, CLAYEY SANDY GRAVEL, WITH COBBLES, DENSE, MOIST, BROWN, OCCASIONAL BOULDER | 100% | Y | DRIVE SAMPLE Y N= 10,12,15 | |
| 1057 | | | | | | | |
| | 170 | | GC, CLAYEY GRAVEL, MOIST, CHARCOAL GRAY | | | | |
| 1053 | | | CL, SANDY CLAY, SOFT, MOIST, CHARCOAL GRAY [VARVED] SM, SILTY SAND [FINE], WITH OCCASIONAL GRAVEL, SOFT, MOIST, BROWN | | | | 1/27/87 |
| | 180 | | | 100% | Z | SWL=171.6 DRIVE SAMPLE Z N= 2,4,10 | 1/28/87 |
| 1043 | | | | | | | |
| | 190 | | GP, SANDY GRAVEL WITH COBBLES AND BOULDERS | | AA | CHIP SAMPLE | |
| | | | | | AB | CHIP SAMPLE | |
| | 200 | | | 100% | AC | DRIVE SAMPLE AC N= 12,12 | |
| | | | | | | SWL=181.0 | 1/28/87 |
| | | | | | | SWL=182.3 | 1/29/87 |
| 1017 | | | TOP OF BEDROCK @ 208 | | | | |
| | 210 | | RESIDUUM 208-209 | 0% | AD | DRIVE SAMPLE AD N=15/3 REFUSAL | |
| | | | ANDESITE, MED. SOFT, GRAY | | | | |
| 1005 | 220 | | TD 220' | | AE | CHIP SAMPLE | 1/29/87 |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT: HID | HOLE NO. 87-RD-102

X-54

| | |
|---|---|
| 1. PROJECT: HOWARD HANSON DAM | 10. SIZE AND TYPE OF BIT: 8"-12' ; 6"-178' |
| 2. LOCATION (Coordinates or Station): N 102,905 E1,763,905 | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL): |
| 3. DRILLING AGENCY: JENSEN DRILLING CO. | 12. MANUFACTURER'S DESIGNATION OF DRILL: BUCYRUS ERIE 22W CABLE TOOL |
| 4. HOLE NO. (As shown on drawing title and file number): 87-CD-103 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0 ; UNDISTURBED 15 |
| 5. NAME OF DRILLER: ART GWIN | 14. TOTAL NUMBER CORE BOXES: |
| 6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER: |
| | 16. DATE HOLE: STARTED JAN. 14. 1987 ; COMPLETED FEB. 3. 1987 |
| 7. THICKNESS OF OVERBURDEN: 173' | 17. ELEVATION TOP OF HOLE: 1217' |
| 8. DEPTH DRILLED INTO ROCK: 5' | 18. TOTAL CORE RECOVERY FOR BORING: x |
| 9. TOTAL DEPTH OF HOLE: 178' | 19. SIGNATURE OF INSPECTOR: RICK ECKERLIN |

| ELEVATION (a) | DEPTH (b) | LEGEND (c) | CLASSIFICATION OF MATERIALS (Description) (d) | % CORE RECOVERY (e) | BOX OR SAMPLE NO. (f) | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g) |
|---|---|---|---|---|---|---|
| 1217 | | | FILL FOR DRILLING PAD [CRUSHED GRAVEL] | | | PAD PREPARED. RIG-UP DRILLED 8' AND SET 8" CASING 2,000 LB. TOOL WT. FOR SAMPLING; 4" ID- LS' LONG 1/14/87 |
| | | | GM. SILTY SANDY GRAVEL WITH COBBLES. LOOSE TO MEDIUM., MOIST BROWN | | | 1/15/87 |
| | 10 | | | | | N= * BLOWS TO DRIVE SAMPLER 6' |
| | | | | | | 1/15/87 |
| | | | | | | 1/16/87 |
| | 20 | | | 50% | A | N= 14.17.23 |
| | | | | 100% | B | N= 20.21.33 |
| | 30 | | | | | 1/16/87 |
| | | | | | | 1/20/87 |
| | 40 | | | 100% | C | N= 18.23.32 |
| | | | | | | 1/20/87 |
| | 50 | | GP-GM | 100% | D | 1/21/87 N= 20.15 88 |
| | 60 | | | 100% | E | N= 20.20.32 |
| | | | | | | 1/21/87 |
| | | | | | | 1/22/87 |
| | 70 | | | 100% | F | N= 30.30.18 |
| | 80 | | | 90% | G | N= 20.30.36 |
| | 90 | | | 75% | H | N= 39.+50 REFUSAL 1/22/87 |
| | | | | | | 1/23/87 |
| 1117 | 100 | | | | | |

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: HHD | HOLE NO. 87-CD-103

X-55

PROJECT: HOWARD_HANSON_DAM

INSTALLATION: NPS

Hole No. 87-CD-103

SHEET 2 OF 3 SHEETS

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling Time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| | 100 | | GP-GM, SILTY SANDY GRAVEL WITH COBBLES, MEDIUM, MOIST, BROWN | | I | N= 34,50,53 100% RECOVERY 1/23/87 |
| | | | | | | 1/27/87 |
| | 110 | | | | | |
| | | | | | J | N= 35,46,71 100% RECOVERY 1/27/87 |
| | 120 | | | | | SWL= 111 1/28/87 |
| | | | | | K | N= 50,60, REFUSAL |
| | 130 | | | | | |
| | | | | | | SWL= 135.5 1/28/87 |
| | | | | | | SWL= 129.9 1/29/87 |
| | 140 | | | | L | N= 37,53,57 90% RECOVERY |
| | 150 | | GP-GM, SILTY SANDY GRAVEL WITH COBBLES, LIGHT BRN. AND WET | | | SWL 1/29/87 |
| | | | | | | SWL= 141.3 1/30/87 |
| | | | | | M | N= 32,50,42 100% RECOVERY |
| | 160 | | | | | SWL= BAILED DRY 1/30/87 |
| | | | | | N | SWL= 152 2/2/87 N= 33,31,33 60% RECOVERY |
| | | | | | | SWL= BAILED DRY 2/2/87 |
| | 170 | | | | | SWL= DRY 2/3/87 |
| 1044 | | | BEDROCK | | | |
| | | | ANDESITE, GREEN, HARD | | O | N= 50/1" REFUSAL 1 JAR SAMPLE |
| 1039 | | | | | | TD= 178' 2/3/87 |
| | 180 | | BOTTOM OF HOLE AT 178' [ELV. 1039] | | | HOLE DRY DURING DRILLING |
| | | | | | | 6" CASING TO 172.5' |
| | 190 | | | | | |
| | 200 | | | | | |

ENG FORM 1836-A MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: HHD

HOLE NO. 87-CD-103

X-56

| DRILLING LOG | NPD | INSTALLATION NPS | SHEET 1 OF 3 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT HOWARD HANSON DAM | 10. SIZE AND TYPE OF BIT 6" CABLE TOOL |
| 2. LOCATION (Coordinates or Station) N 102,750 E 1,763,470 | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) |
| 3. DRILLING AGENCY JENSEN DRILLING CO. | 12. MANUFACTURER'S DESIGNATION OF DRILL BUCYRUS ERIE 22W |
| 4. HOLE NO. (As shown on drawing title and file number) 87-CD-104 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 0; UNDISTURBED 8 |
| 5. NAME OF DRILLER GLEN WHITE | 14. TOTAL NUMBER CORE BOXES |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| 7. THICKNESS OF OVERBURDEN 121' | 16. DATE HOLE: STARTED 2/4/87; COMPLETED 2/20/87 |
| 8. DEPTH DRILLED INTO ROCK 6' | 17. ELEVATION TOP OF HOLE 1185 [TOPO] |
| 9. TOTAL DEPTH OF HOLE 127' | 18. TOTAL CORE RECOVERY FOR BORING % |
| | 19. SIGNATURE OF INSPECTOR BILL GOSS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| | | | FILL [CRUSHED GRAVEL] FOR DRILLING PAD | | | DRILLED WITH BUCYRUS ERIE 22W CABLE DRILL USING 2,000 LB. TOOL WEIGHT FOR DRIVE SAMPLING. SAMPLER= 15' LONG, 4" ID. 2/4/87 |
| | 10 | | GP-GM: SANDY GRAVEL WITH SILT AND COBBLES | | | 2/5/87 N= # OF BLOWS TO DRIVE SAMPLER 6". |
| | 20 | | | | A | N= 44,34,50 66% RECOVERY 2/5/87 |
| | 30 | | | | | 2/9/87 |
| | | | GM: SILTY SANDY GRAVEL DENSE, BROWN, MOIST | | B | N= 8,6,16 100% RECOVERY 2/9/87 |
| | 40 | | | | | 2/10/87 |
| | 50 | | | | C | N= 40,29,29 80% RECOVERY 2/10/87 |
| | 60 | | | | | 2/11/87 |
| | | | | | D | N= 26,25,33 66% RECOVERY 2/11/87 |
| | 70 | | GM: SILTY SANDY GRAVEL WITH COBBLES, DENSE, BROWN, MOIST | | | 2/12/87 |
| | | | | | E | N= 24,56,62 80% RECOVERY 2/12/87 |
| | 80 | | | | | 2/17/87 |
| | 90 | | | | F | N= 31,35,50 90% RECOVERY 2/17/87 |
| | 100 | | | | | 2/18/87 |

1185' [TOPO]

Hole No. 87-CD-104

| PROJECT | INSTALLATION | SHEET 2 OF 3 SHEETS |
|---|---|---|
| HOWARD HANSON DAM | NPS | |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| 1085 | 100 | | GM: SILTY SANDY GRAVEL DENSE, BROWN, MOIST | | | 2/18/87 |
| | | | | | G | N= 20,34,50 |
| | | | | | | 95% RECOVERY |
| | | | | | | 2/18/87 |
| | 110 | | | | | SWL 105 2/19/87 |
| | | | | | | N= 16,24,30 |
| | | | | | H | 70% RECOVERY |
| | 120 | | | | | BAILER SAMPLE |
| | | | | | I | SWL 119.5 2/19/87 |
| 1064 | | | ANDESITE- GREEN, HARD | | | SWL 119.5 2/20/87 |
| | | | | | | SAMPLE I- BAILER SAMPLE |
| 1058 | | | | | | 1 JAR ANDESITE AND GRAVEL |
| TD | 130 | | | | | TD 127' |
| | | | | | | 125' OF 6" CASING |
| | | | | | | CASING SEATED IN BEDROCK |
| | | | | | | AT 123.5' |
| | | | | | | HOLE DRY DURING DRILLING |

B1

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT HOWARD HANSON DAM

HOLE NO. 87-CD-104

X-58

USCS _____ NPS _____ SHEET 1 OF 3 SHEETS

| | |
|---|---|
| 1. PROJECT HOWARD_HANSON_DAM | 10. SIZE AND TYPE OF BIT 6" ODEX |
| 2. LOCATION (Coordinates or Station) N_103,485 E_1,764,630 | 11. DATUM FOR ELEVATION SHOWN (TBM or MSL) |
| 3. DRILLING AGENCY JENSEN_DRILLING_CO | 12. MANUFACTURER'S DESIGNATION OF DRILL CP_650_AIR_ROTARY_DRILL |
| 4. HOLE NO. (As shown on drawing title and file number) 87-BD-105 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED ____ UNDISTURBED ____ |
| 5. NAME OF DRILLER TED_WERYDITH | 14. TOTAL NUMBER CORE BOXES ____ |
| 6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER ____ |
| | 16. DATE HOLE STARTED 3/17/87 COMPLETED 3/25/87 |
| 7. THICKNESS OF OVERBURDEN 132' | 17. ELEVATION TOP OF HOLE 1205_GROUND |
| 8. DEPTH DRILLED INTO ROCK 54' | 18. TOTAL CORE RECOVERY FOR BORING ____ % |
| 9. TOTAL DEPTH OF HOLE 186' | 19. SIGNATURE OF INSPECTOR BILL GOSS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| | | | GM: SILTY SANDY GRAVEL | | | DRILLED WITH AIR USING ODEX HAMMER |
| | | | BOULDER 8-10' | | | CASING CONCURRENT WITH DRILLING |
| | 10 | | | | | USED OVERHEAD CASING DRIVE THRU HAMMER TO DRIVE SAMPLER |
| | | | GM | | | FIRST LENGTH OF 6" CASING 21' WITH SHOE AT 21.2' |
| | 20 | | | | A | BIT 6' AHEAD OF CASING SHOE |
| | | | BOULDER 20-25' | | | 3/18/87 |
| | | | | | | CHIP SAMPLE A 1 JAR |
| | | | GM | | | |
| | 30 | | | | B | DRIVE SAMPLE B N= 5,5,8 90% REC |
| | | | BOULDER 33'-36' | | | |
| | 40 | | | | C | CHIP SAMPLE C 1 JAR |
| | | | GM: SILTY SANDY GRAVEL, WET, ANGULAR, RUST BRN.-WEATHERED GRAYISH GRN.-FRESH SMALL AMOUNT OF WATER ENCOUNTERED | | | DRIVE SAMPLE D N= 4,9,3 70% REC |
| | 50 | | | | D | 3/18/87 |
| | | | BOULDER 52'-55' | | | 3/18/87 |
| | 60 | | | | E | DRIVE SAMPLE E N= 2,5,7 60% REC |
| | | | GM | | | |
| | 70 | | | | F | DRIVE SAMPLE F N= 2,2,4 65% REC |
| | 80 | | | | G | DRIVE SAMPLE N= 11,15, REFUSAL 50% REC |
| | 90 | | | | H | DRIVE SAMPLE H N= 15/4", REFUSAL 30% REC |
| | | | | | | 3/19/87 |
| | | | | | | 3/23/87 |
| | 100 | | | | I | DRIVE SAMPLE N= 20,20/4", REFUSAL 50%REC |

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT HOWARD_HANSON_DAM HOLE NO. 87-BD-105

X-59

1 1205_(1080)

Hole No. 87-RD-105

| PROJECT | INSTALLATION | SHEET 2 OF 3 SHEETS |
|---|---|---|
| HOWARD_HANSON_DAM | NDS | |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (Description) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) |
|---|---|---|---|---|---|---|
| | | | GM: SANDY SILTY GRAVEL | | | |
| | 110 | | | | J | DRIVE SAMPLE J<br>N= 3,8,10 100% REC |
| | 120 | | | | K | CHIP SAMPLE |
| | 130 | | GM | | L | DRIVE SAMPLE L<br>N= 4,3,5 70% REC<br>3/23/87 |
| 1073 | | | ANDESITE: BLACK, FRESH, SHARP ANGULAR DRILL CUTTINGS | | | 3/24/87 |
| | 140 | | | | M | CHIP SAMPLE |
| | 150 | | | | N | CHIP SAMPLE |
| | 160 | | | | O | CHIP SAMPLE |
| | | | DRILLING ON GROUND WATER | | | 3/24/87<br>3/25/87 |
| | 170 | | | | P | CHIP SAMPLE<br>WATER IN HOLE--<br>DRILLING ON GRNDWATER |
| | 180 | | | | Q | CHIP SAMPLE |
| | | | | | R | CHIP SAMPLE |
| | | | TD=186' | | | |
| | 190 | | | | | |
| 1005 | 200 | | | | | |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT HOWARD_HANSON_DAM

HOLE NO. 87-RD-105

X-60

DATE AND TIME PLOTTED: 28-SEP-1993 18:07

Hole No. 92-RD-110

| ORILLING LOG | DIVISION CENPS-EN-GT | INSTALLATION HOWARD HANSON DAM | SHEET 1 OF 2 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT PIEZOMETER INSTALLATION | 10. SIZE AND TYPE OF BIT 8" ODEX |
| 2. LOCATION (COORDINATES OR STATION) | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) |
| 3. DRILLING AGENCY ANDREW WELL DRILLING | 12. MANUFACTURER'S DESIGNATION OF DRILL |
| 4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED: UNDISTURBED |
| 5. NAME OF DRILLER ROBERT DEWILD | 14. TOTAL NUMBER CORE BOXES |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| 7. THICKNESS OF OVERBURDEN | 16. DATE HOLE: STARTED: COMPLETED |
| 8. DEPTH DRILLED INTO ROCK 16' | 17. ELEVATION TOP OF HOLE |
| 9. TOTAL DEPTH OF HOLE 199' | 18. TOTAL CORE RECOVERY FOR BORING % |
| | 19. NAME AND SIGNATURE OF INSPECTOR |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | | | ROCK SPALLS (3") W/GRAVEL & SANDY CLAY, BROWN | | | |
| | 5 | | RIP RAP (3") AND LOOSE BOULDERS | | | |
| | 10 | | | | | |
| | 15 | | SILTY SAND, FINE, DRY, BROWN | | | 5 NOV 92 |
| | 20 | | | | | |
| | 25 | | | | | |
| | 30 | | SILTY SAND, MED.- FINE, DRY, GREY. | | | |
| | 35 | | SILTY SAND W/ OCC GRAVELS, MED, DRY-MOIST, BROWN | | | |
| | | | SILTY SAND W/ OCC GRAVELS MED., DRY, GREY | | | |
| | 40 | | SILTY SAND, MED.-COARSE, DRY, BROWNISH GREY | | | |
| | 45 | | | | | |
| | 50 | | SILTY SAND, FINE, DRY, BROWN | | | |
| | 55 | | | | | |
| | 60 | | | | | |
| | 65 | | SAND (COARSE, MED) W/ SOME SILT, DRY-MOIST, GREY, (GRANULES ARE UNIFORM W/ FRACTURED FACES, PROBABLY BOULDERS) | | | |
| | 70 | | SILTY SAND, FINE, DRY BROWN | | | |
| | 75 | | ANDESITE BOULDERS W/ INTERSTITIAL SAND, SILT, AND CLAY WITH MINOR GRAVEL, DRY, GREEN ROCK FRAGMENTS W/ BROWN CLAY AND SILT. (CONT.) | | | 6 NOV 92 |
| | 80 | | | | | |
| | 85 | | | | | |
| | 90 | | | | | |
| | 95 | | | | | |
| | 100 | | | | | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT: PIEZOMETER INSTALLATION

HOLE NO. 92-RD-110

X-41

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 92-RD-110 |
|---|---|---|
| PROJECT | INSTALLATION HOWARD HANSON DAM | SHEET 2 OF 2 SHEETS |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | 100 | | (CONT.) ANDESITE BOULDERS W/ INTERSTITIAL SAND, SILT, AND CLAY WITH MINOR GRAVEL. DRY. GREEN ROCK FRAGMENTS W/ BROWN CLAY AND SILT | | | |
| | 105 | | | | | |
| | 110 | | | | | |
| | 115 | | | | | 7 NOV 92 |
| | 120 | | | | | |
| | 125 | | | | | |
| | 130 | | FRACTURED ANDESITE W/ INTERSTITIAL SILT & CLAY. GROUNDWATER AT 127' | | | |
| | 135 | | | | | |
| | 140 | | BOULDERS | | | 8 NOV 92 |
| | 145 | | | | | |
| | 150 | | | | | |
| | 155 | | CLAY/SOME SANDS | | | |
| | 160 | | ANDESITE BRECCIA - BLUE/GREEN FLAKES | | | |
| | 165 | | COARSE, ANGULAR ROCK FRAGMENTS. BLUE/GREEN CHIPS W/ BROWN FLAKES | | | 9 NOV 92 |
| | 170 | | | | | |
| | 175 | | | | | |
| | 180 | | ANDESITE - SOFT | | | |
| | 185 | | | | | |
| | 190 | | | | | |
| | 195 | | | | | 10 NOV 92 |
| | 200 | | | | | |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT

HOLE NO. 92-RD-110

X-62

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

# WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 12-18-92
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector BEN LAZO
Depth 199' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 199 ft.
in. to ft.

CASING
Type STEEL (SEE COMMENTS)
Mfr.
Ht. above gnd. surf.
Drive shoe
Size: 8 ¼ in. to 199 ft.

SCREEN
Type SCH 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

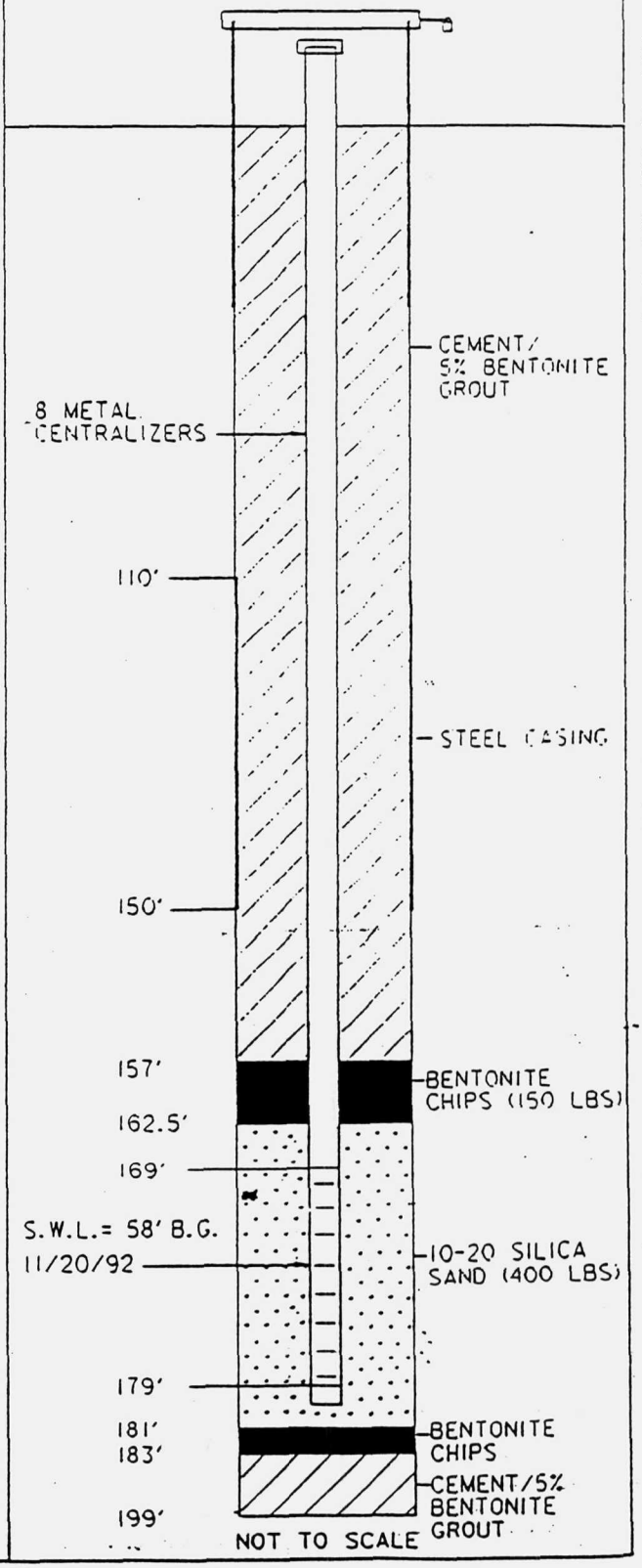
| Fittings: | Length | Dia. |
|---|---|---|
| Riser | | |
| Tailpipe | | |

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used 4 FT³
Depth 162.5 to 181 ft.
to ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used
Inst. method TREMMIE
Depth 0.0 to 157 ft.
183 to 199 ft.

REMARKS: 40 FEET OF CASING (WITH DRIVE SHOE) LEFT IN HOLE FROM 110 FEET TO 150 FEET. ALL OTHER CASING REMOVED FROM HOLE.

## WELL DETAIL (AS BUILT)
## 92-RD-110
## NOT TO SCALE




DESIGN FILE:

Hole No. 92-RD-111

| DRILLING LOG | DIVISION CENPS-EN-GT | INSTALLATION HOWARD HANSON DAM | SHEET 1 OF 2 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT PIEZOMETER INSTALLATION | 10. SIZE AND TYPE OF BIT 8" ODEX |
| 2. LOCATION (COORDINATES OR STATION) | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) |
| 3. DRILLING AGENCY ANDREW WELL DRILLING | 12. MANUFACTURER'S DESIGNATION OF DRILL |
| 4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED: UNDISTURBED |
| 5. NAME OF DRILLER ROBERT DEWILD | 14. TOTAL NUMBER CORE BOXES |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| 7. THICKNESS OF OVERBURDEN | 16. DATE HOLE: STARTED: COMPLETED |
| 8. DEPTH DRILLED INTO ROCK | 17. ELEVATION TOP OF HOLE |
| 9. TOTAL DEPTH OF HOLE 150' | 18. TOTAL CORE RECOVERY FOR BORING % |
| | 19. NAME AND SIGNATURE OF INSPECTOR |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | | | ROCK SPALLS (3") W/GRAVEL | | | |
| | 5 | | RIP RAP (3") AND LOOSE BOULDERS | | | |
| | 10 | | | | | |
| | 15 | | SILTY SAND, FINE, BROWN | | | |
| | 20 | | | | | |
| | 25 | | SILTY SAND, FINE W/GRAVELS, TAN<br>BOULDERS 1-2' D | | | |
| | 30 | | | | | |
| | 35 | | | | | |
| | 40 | | CLAYEY SAND W/GRAVEL (1/2") AND COBBLES (3") TAN | | | |
| | 45 | | | | | |
| | 50 | | SILTY SAND W/GRAVELS (1/2"), BROWN | | | |
| | 55 | | | | | |
| | 60 | | FRACTURED ROCK AND GRAVELS, GREEN, W/SILT | | | |
| | 65 | | | | | |
| | 70 | | | | | |
| | 75 | | | | | |
| | 80 | | | | | |
| | 85 | | | | | |
| | 90 | | | | | |
| | 95 | | | | | |
| | 100 | | | | | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION

HOLE NO. 92-RD-111

X-6

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 92-RD-111 |
|---|---|---|
| PROJECT: PIEZOMETER INSTALLATION | INSTALLATION: HOWARD HANSON DAM | SHEET 2 OF 2 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (DESCRIPTION) | | BOX OR SAMPLE NO. | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) |
|---|---|---|---|---|---|---|
| | 100 | | ANDESITE BOULDERS W/INTERSTITIAL SAND, SILT, AND CLAY. OCCASIONAL GRAVELS. DRY, GREEN ROCK FRAGMENTS WITH BROWN-TAN SILT AND CLAY | | | |
| | 105 | | | | | |
| | 110 | | | | | |
| | 115 | | | | | |
| | 120 | | | | | |
| | 125 | | | | | |
| | 130 | | FRACTURED ANDESITE W/INTERSTITIAL SILT AND CLAY LAYERS. WATER GENERATED AT 127 FEET | | | |
| | 135 | | | | | |
| | 140 | | FRACTURED ANDESITE ROCK FRAGMENTS APPEAR UNIFORM IN SIZE | | | |
| | 145 | | | | | |
| | 150 | | | | | |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT

HOLE NO. 92-RD-111

X-165

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

# WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 12/18/93
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector BEN LAZO, CHARLES IFFT
Depth 150' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 150' ft.
in. to ft.

CASING
Type STEEL (REMOVED)
Mfr.
Ht. above gnd. surf.
Drive shoe
Size: 8 1/4 in. to 150' ft.

SCREEN
Type SCH 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

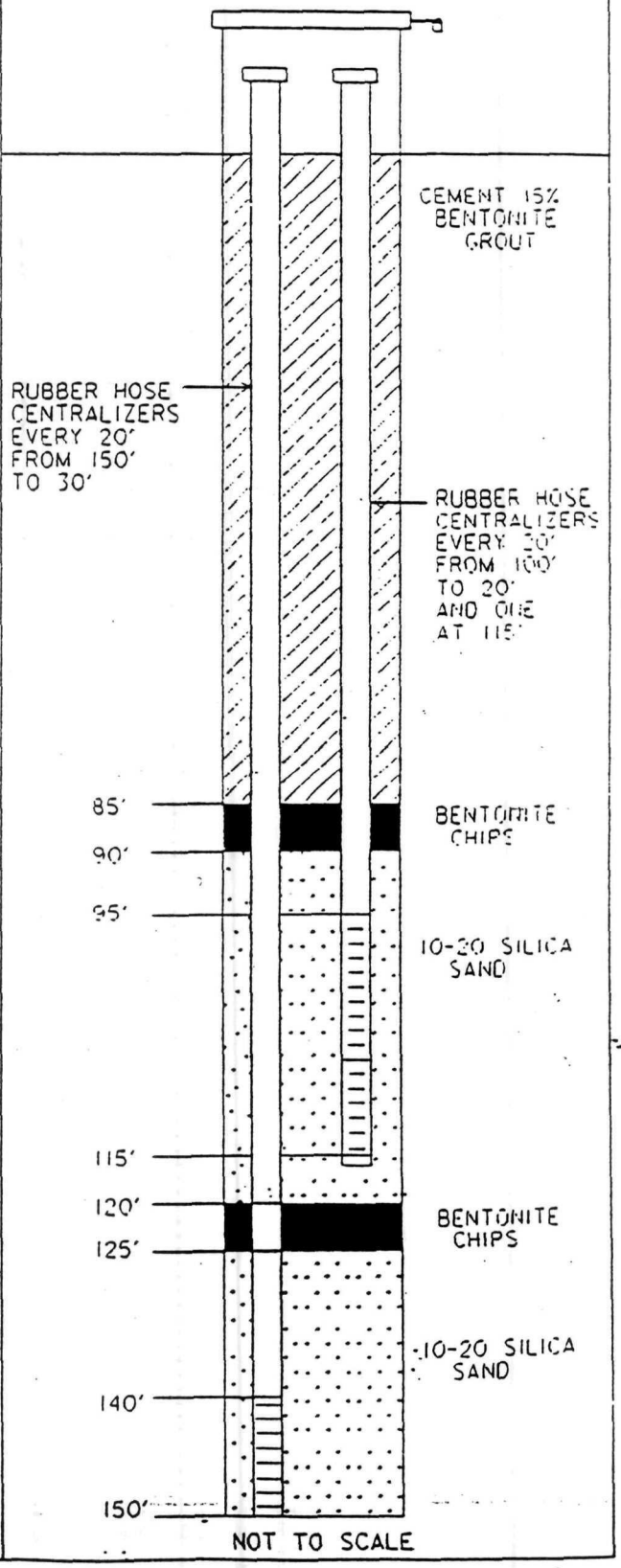
| Fittings: | Length | Dia. |
|---|---|---|
| Riser | | |
| Tailpipe | | |

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used
Depth 90 to 120 ft.
125' to 150' ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used
Inst. method TREMMIE
Depth 0.0 to 85 ft.
to ft.

REMARKS:

## WELL DETAIL (AS BUILT)
## 92-RD-111
## NOT TO SCALE




DATE AND TIME PLOTTED: 28-SEP-1994

/ceaps projects cw hn geotech hanson.dgn

DESIGN FILE

X-66

| DRILLING LOG | DIVISION CENPS-EN-GT | INSTALLATION HOWARD HANSON DAM | SHEET 1 OF 2 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT PIEZOMETER INSTALLATION | 10. SIZE AND TYPE OF BIT 8" ODEX |
| 2. LOCATION (COORDINATES OR STATION) | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) |
| 3. DRILLING AGENCY ANDREW WELL DRILLING | 12. MANUFACTURER'S DESIGNATION OF DRILL IR AIR ROTARY - T4W |
| 4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) 92-RD-112 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED |
| 5. NAME OF DRILLER ROBERT DEWILD | 14. TOTAL NUMBER CORE BOXES |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| 7. THICKNESS OF OVERBURDEN 138 | 16. DATE HOLE STARTED 7 OCT 92 / COMPLETED |
| 8. DEPTH DRILLED INTO ROCK 22 | 17. ELEVATION TOP OF HOLE |
| 9. TOTAL DEPTH OF HOLE 160 | 18. TOTAL CORE RECOVERY FOR BORING % |
| | 19. NAME AND SIGNATURE OF INSPECTOR |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | | | GRAVEL WEARING COURSE (3/4" MINUS) | | | |
| | 5, 10, 15, 20, 25 | | SILTY SAND, DRY, TAN | | | 7 OCT 92 |
| | 30 | | SANDY CLAY W/GRAVEL, MOIST, BROWN | | | |
| | 35, 40 | | SANDY SILT, DRY, TAN | | | |
| | 45 | | SILTY SAND, DRY, TAN-LT GREY | | | |
| | 50, 55 | | SILT W/SAND, DRY LT GREY (ASH-LIKE) | | | |
| | 60, 65, 70 | | GRAVELLY SAND W/SILT, TAN-LT GREY, DRY | | | |
| | 75 | | SILTY SAND W/GRAVEL TAN-LT GREY, DRY | | | |
| | 80 | | GRAVEL W/SILT, LT GREY, DRY, (POSSIBLE BOULDER) | | | |
| | 85, 90, 95, 100 | | SILTY SAND W/GRAVEL, DRY, TAN-LT GREY (CONT.) | | | 8 OCT 92 |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT: PIEZOMETER INSTALLATION

HOLE NO. 92-RD-112

X-6

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 92-RD-112 |
|---|---|---|
| PROJECT PIEZOMETER INSTALLATION | INSTALLATION HANSON DAM | SHEET 2 OF 2 SHEETS |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | 100 | | (CONT.) SILTY SAND W/GRAVEL, DRY, TAN-LT GREY | | | |
| | 105 | | | | | |
| | 110 | | LOSS OF CUTTINGS IN THIS ZONE, LARGE VOID OR FRACTURE, CASING DROVE EASILY. | | | |
| | 115 | | | | | 9 OCT 92 |
| | 120 | | FRACTURED ANDESITE WATER GENERATED BETWEEN ZONES (1 GALLON/MINUTE) | | | |
| | 125 | | | | | |
| | 130 | | SANDY GRAVEL W/SILT MOIST, TAN-LT GREY | | | |
| | | | | | | 18 OCT 92 |
| | 135 | | CLAY, MOIST, GREY | | | 19 OCT 92 |
| | 140 | | | | | |
| | 145 | | BEDROCK (ANDESITE CUTTINGS BECAME UNIFORM IN SIZE AND COLOR) | | | |
| | 150 | | | | | |
| | 155 | | | | | |
| | 160 | | | | | 20 OCT 92 |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER

HOLE NO. 92-RD-112

X-67

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

# WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 10/23/92
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector
Depth 160' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 160' ft.
in. to ft.

CASING
Type STEEL (REMOVED)
Mfr.
Ht. above gnd. surf.
Drive shoe
Size: 8 1/4 in. to 160' ft.

SCREEN
Type SCH 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

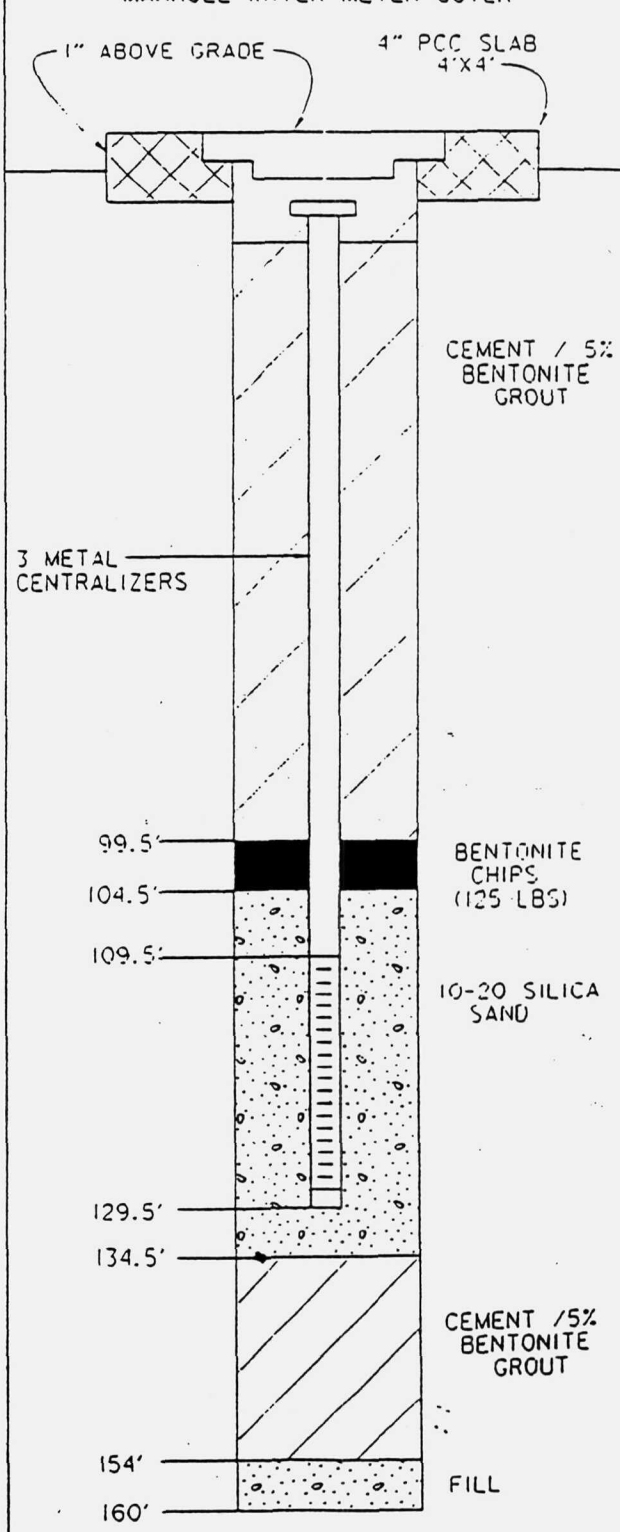
| Fittings: | Length | Dia. |
|---|---|---|
| Riser | | |
| Tailpipe | | |

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used 9 $FT^3$
Depth 104.5 to 134.5 ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used
Inst. method TREMMIE
Depth 0.0 to 99.5 ft.
134.5 to 154 ft.

REMARKS:

## WELL DETAIL (AS BUILT)
## 92-RD-112
## NOT TO SCALE




NOT TO SCALE

DESIGN FILE: /cenps/projects cw hh/geotech hr gill.dgn DATE AND TIME PLOTTED: 28-SEP-19

X-6

DATE AND TIME PLOTTED: 06-OCT-1993 12:46

Hole No. 92-RD-113

| DRILLING LOG | DIVISION CENPS-EN-GT | INSTALLATION 92-RD-113 | SHEET 1 OF 1 SHEETS |
|---|---|---|---|
| 1. PROJECT PIEZOMETER INSTALLATION | | 10. SIZE AND TYPE OF BIT 8" ODEX | |
| 2. LOCATION (COORDINATES OR STATION) HOWARD HANSON DAM | | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) | |
| 3. DRILLING AGENCY ANDREW WELL DRILLING | | 12. MANUFACTURER'S DESIGNATION OF DRILL IR AIR ROTARY - T4W | |
| 4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) 92-RD-113 | | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED / UNDISTURBED |
| 5. NAME OF DRILLER ROBERT DEWILD | | 14. TOTAL NUMBER CORE BOXES | |
| | | 15. ELEVATION GROUND WATER | |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | | 16. DATE HOLE | STARTED 26 OCT 92 / COMPLETED 4 NOV 92 |
| | | 17. ELEVATION TOP OF HOLE | |
| 7. THICKNESS OF OVERBURDEN 97 | | 18. TOTAL CORE RECOVERY FOR BORING % | |
| 8. DEPTH DRILLED INTO ROCK 0 | | 19. NAME AND SIGNATURE OF INSPECTOR | |
| 9. TOTAL DEPTH OF HOLE 97 | | | |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | | | GRAVEL WEARING COURSE FOR PARKING LOT (3/4") | | | |
| | 5 | | SILTY SAND, FINE, DRY, BROWN | | | |
| | 10 | | | | | |
| | 15 | | | | | 26 OCT 92 |
| | 20 | | | | | |
| | 25 | | | | | |
| | 30 | | | | | |
| | 35 | | | | | |
| | 40 | | | | | |
| | 45 | | SANDY CLAY W/GRAVEL, MOIST, BROWN | | | |
| | 50 | | SAND W/GRAVELS (1/2") SILT AND CLAY (COURSE) MOIST-DRY, BROWN | | | |
| | 55 | | | | | |
| | 60 | | | | | |
| | 65 | | | | | |
| | 70 | | | | | |
| | 75 | | | | | 27 OCT 92 |
| | 80 | | | | | |
| | 85 | | SANDY SILT, DRY, REDDISH BROWN (RUST) | | | |
| | 90 | | SAND W/SILT (MED-COURSE) DRY, TAN-LT GREY (UNIFORM, POSSIBLE BOULDER) | | | |
| | 95 | | SILTY SAND (MED-FINE), DRY LT-GREY TAN | | | 2 NOV 92 |
| | 100 | | BOTTOM OF HOLE | | | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT: PIEZOMETER INSTALLATION

HOLE NO. 92-RD-112

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

# WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 11/04/92
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector BEN LAZO, STEVE MYERHOLTZ
Depth 97' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 97' ft.
in. to ft.

CASING
Type STEEL (ALL BUT 10' REMOVED)
Mfr.
Ht. above gnd. surf.
Drive shoe YES - LEFT IN HOLE
Size: 8 ½ in. to 97' ft.

SCREEN
Type SCH 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

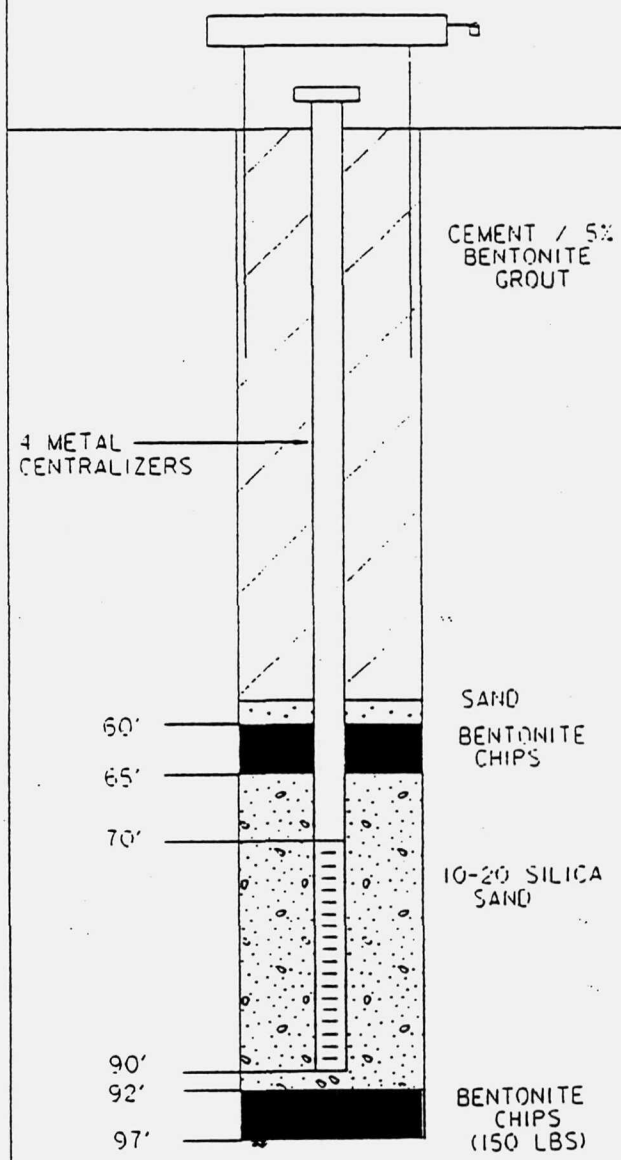
| Fittings: | Length | Dia. |
|---|---|---|
| Riser | | |
| Tailpipe | | |

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used
Depth 65 to 92 ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used
Inst. method TREMMIE
Depth to ft.
to ft.

REMARKS: GROUT LOSS @ 30' STOPPED BY ADDING SAND AND BENTONITE CHIIPS TO GROUT

## WELL DETAIL (AS BUILT)
## 92-RD-113
## NOT TO SCALE




NOT TO SCALE

DESIGN FILE: /cenps/projects/cw/hh geotech/hgl113.dgn DATE AND TIME PLOTTED: 28-SEP-19

X-11

| ORILLING LOG | DIVISION CENPS-EN-GT-GE | INSTALLATION HOWARD HANSON DAM | SHEET 1 OF 3 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT PIEZOMETER INSTALLATION | 10. SIZE AND TYPE OF BIT 8" ODEX |
| 2. LOCATION (COORDINATES OR STATION) | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) |
| 3. DRILLING AGENCY ANDREW WELL DRILLING | 12. MANUFACTURER'S DESIGNATION OF DRILL I R AIR ROTARY-T4W |
| 4. HOLE NO. (AS SHOWN ON DRAWING TITLE AND FILE NUMBER) 93-RD-114 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 8; UNDISTURBED |
| 5. NAME OF DRILLER ROBERT DEWILD | 14. TOTAL NUMBER CORE BOXES - |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER - |
| 7. THICKNESS OF OVERBURDEN 336.5 | 16. DATE HOLE: STARTED 6-7-93; COMPLETED 7-3-93 |
| 8. DEPTH DRILLED INTO ROCK 0 | 17. ELEVATION TOP OF HOLE |
| 9. TOTAL DEPTH OF HOLE 336.5 | 18. TOTAL CORE RECOVERY FOR BORING - % |
| | 19. NAME AND SIGNATURE OF INSPECTOR RICHARD E. SMITH |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (DESCRIPTION) | SAMPLE INTERVAL | BOX OR SAMPLE NO. | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT) |
|---|---|---|---|---|---|---|
| | | | BROWN CLAY/SILT AND CLAYEY GRAVEL CONSISTING OF WEATHERED ANGULAR ANDESITE PEBBLES AND ROCK CUTTINGS; LOOSE, MOIST | | | DRILLED WITH 8" ODEX BIT CONCURRENT WITH 8 1/4" ID STEEL CASING BY DOWN-THE-HOLE HAMMER |
| | | | GREY/BROWN SILT/CLAY AND SILTY, CLAYEY GRAVEL AS ABOVE; LOOSE AND DRY | | | DRILLING FLUID RETURN SUMMARY<br>0-19 FT: AIR ONLY<br>19-31 FT: NO RETURN<br>31-37 FT: 25-50% RETURN<br>37-42 FT: NO RETURN<br>42-115 FT: 100% RETURN<br>115-120 FT: NO RETURN<br>120-150 FT: 100% RETURN<br>150-159.5 FT: NO RETURN<br>159.5-170 FT: 100% RETURN<br>170-172 FT: NO RETURN<br>172-193 FT: 100% RETURN<br>193-195 FT: NO RETURN<br>195-260 FT: 100% RETURN<br>260-277 FT: <20% RETURN<br>277-336.5 FT: 100% RETURN |
| | 10 | | ANDESITE BOULDER | | | |
| | 20 | | LARGE COBBLES OF FRACTURED ANDESITE, LOOSE | | | |
| | 30 | | | | | |
| | 40 | | | | | |
| | | | CUTTINGS OF ANDESITE COBBLES, GRAVELS AND BOULDERS WITH GREY/BROWN TO BROWN SILT/CLAY, LOOSE TO DENSE | | | |
| | 50 | | | | ① | |
| | 60 | | | | | |
| | 70 | | | | | S.W.L. - DRY 6/7/93 (277 FT) |
| | 80 | | | | | S.W.L. - DRY 6/8/93 (277 FT) |
| | 90 | | | | | |
| | 100 | | CUTTINGS OF ANDESITE COBBLES AND BOULDERS WITH SOME GREY CLAY/SILT, DENSE | | ② | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION | HOLE NO. 93-RD-114

DATE AND TIME PLOTTED: 16-AUG-1993 12:38

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 93-RD-114 |
|---|---|---|
| PROJECT: PIEZOMETER INSTALLATION | INSTALLATION: HOWARD HANSON DAM | SHEET 2 OF 3 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (DESCRIPTION) | SAMPLE INTERVAL | BOX OR SAMPLE NO. | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT) |
|---|---|---|---|---|---|---|
| | 100 | | | | | |
| | 110 | | | | | |
| | | | CUTTINGS OF ANDESITE W/ NO SILT OR CLAY. LOOSE | | | |
| | 120 | | BOULDER OR ROCK SLAB | | | |
| | 130 | | CUTTINGS OF LARGER ANDESITE COBBLES WITH VARYING AMOUNTS OF CLAY AND SILT (GREY/BROWN); OCCASIONAL LOOSE OPEN ZONES WHERE FLUID LOSS OCCURED; ALSO, SUB-ANGULAR, WEATHERED ANDESITE PEBBLES UP TO 1" BELOW 157'. DENSE. | | | |
| | 140 | | | | | |
| | 150 | | | | | |
| | | | | | | S.W.L. = DRT 6/8/93 (@ 157') |
| | | | | | | S.W.L. = DRT 6/9/93 (@ 157') |
| | 160 | | | | | |
| WATER LEVEL UPPER STAGE (7-6-93) | | | | | | |
| | 170 | | | | | |
| 171.3' B.G. | | | CUTTINGS OF LARGE ANDESITE COBBLES/BOULDERS AND SUB-ANGULAR WEATHERED ANDESITE PEBBLES AS ABOVE WITH MORE CLAY/SILT AND THIN LENSES OF SANDY, BROWN CLAY/SILT. DENSE | | | |
| | 180 | | ANDESITE BOULDER | | | |
| | | | CONTINUED | | | |
| | 190 | | | | | |
| | 200 | | | | | FORMATION WATER @ 200'-205.5' |
| | 210 | | | | | FORMATION WATER @ 210.5'-214.5' |
| | | | | | | S.W.L. = 179.0' 6/16/93 (@216.5') |
| | 220 | | | | | |

DATE AND TIME PLOTTED: 16-AUG-1993 13:13

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 93-RD-114 |
|---|---|---|
| PROJECT: PIEZOMETER INSTALLATION | INSTALLATION: HOWARD HANSON DAM | SHEET 3 OF 3 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (DESCRIPTION) | SAMPLE INTERVAL | BOX OR SAMPLE NO. | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT) |
|---|---|---|---|---|---|---|
| | 220 | | FRACTURED SLAB OR BOULDERS OF GREEN, PINK AND WHITE ANDESITE. VERY HARD AND DENSE, WITH COBBLES OF THE SAME ROCK AT THE TOP AND BOTTOM OF THIS INTERVAL. | | ③ | ZONE 218-256 MAY OR MAY NOT BE WATER BEARING |
| | 230 | | | | | |
| | 240 | | | | | |
| | | | | | | 6/18/93 |
| | 250 | | | | | |
| | | | CLAYEY, VERY SILTY (BROWN) SANDY, ANGULAR GRAVEL (ANDESITE) AND ROUNDED GRAVEL (MIXED VOLCANICS) WITH NUMEROUS BROWN AND GREY SILT/CLAY BALLS | | ④ ⑤ | S.W.L. = DRY 6/18/93 (@258') |
| | 260 | | SLIGHTLY (?) SILTY (BROWN) WELL-ROUNDED GRAVELS OF MIXED IGNEOUS ORIGIN UP TO 2" ACROSS, AND CUTTINGS OF POSSIBLY LARGER GRAVELS, AND THIN LAYERS OF MEDIUM SAND; MEDIUM TO LOOSE, POSSIBLY DRY TO 277'. ALSO SOME THIN SILT/CLAY LENSES, AND CLAYEY GRAVEL NEAR BOTTOM. | | ⑥ | |
| | 270 | | | | | |
| WATER LEVEL LOWER STAGE (7/6/93) ▼ 280.85' B.G. | | | | | | S.W.L. = DRY 6/18/93 (@ 278') |
| | 280 | | | | ⑦ | |
| | | | | | ⑧ | |
| | 290 | | | | | |
| | | | | | | S.W.L. = 280.0' 6/18/93 (@ 295') |
| | | | | | | S.W.L. = 279.3' 6/19/93 (@ 295') |
| | 300 | | | | | |
| | 310 | | | | | |
| | | | | | | S.W.L. = 280.1' 6/19/93 (@ 317') |
| | 320 | | | | | |
| | 330 | | | | | |
| | | | BOTTOM = 336.5' B.G. | | | S.W.L. = DRY 6/19/93 (ABOVE 300') |
| | | | | | | S.W.L. = 282.3' 6/20/93 (@ 336.5') |
| | 340 | | | | | |

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PROJECT: PIEZOMETER INSTALLATION | HOLE NO. 93-RD-114

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

# WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 7-3-93
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector RICHARD E. SMITH
Depth 336.5' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 336.5 ft.
in. to ft.

CASING
Type STEEL (REMOVED ALL BUT 10')
Mfr.
Ht. above gnd. surf.
Drive shoe YES (REMOVED DURING COMPLETION)
Size: 8 1/4 in. to 336.2 ft.

SCREEN
Type SCH 80 MONOFLEX
Mfr. CAMPBELL
Composition PVC Dia. 2"

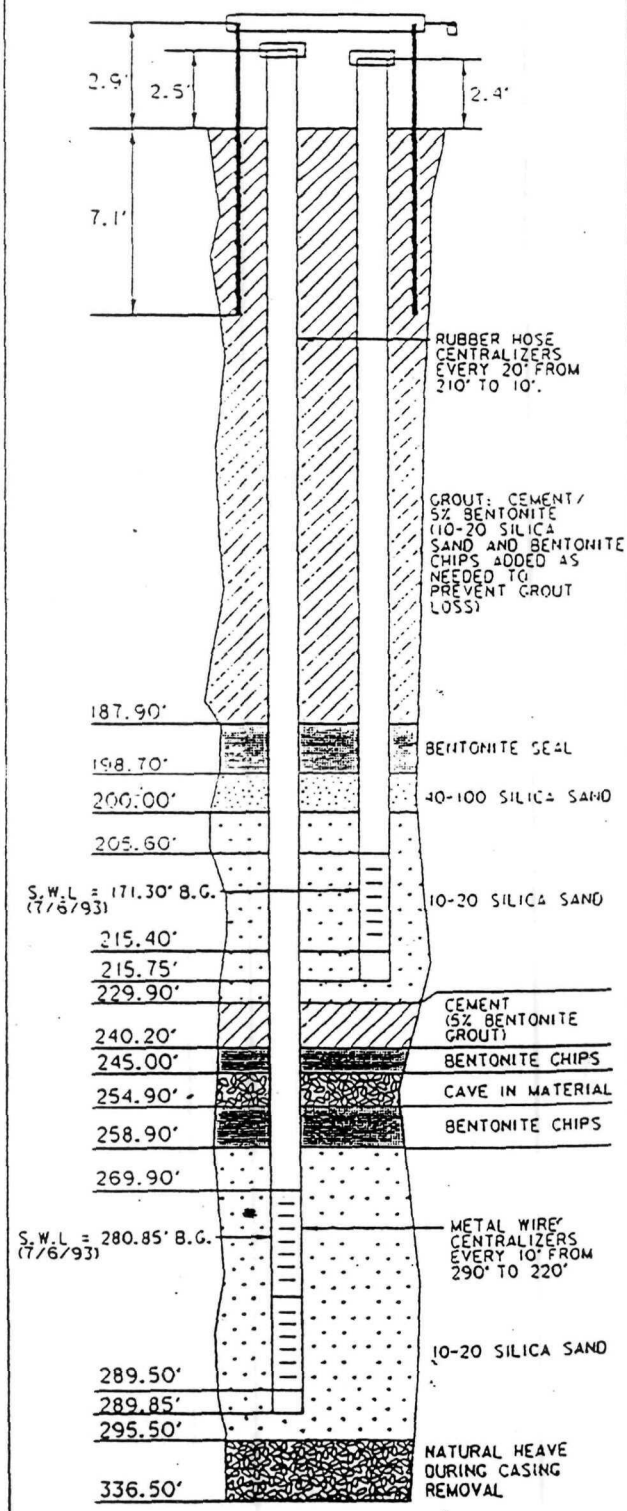
| Fittings: | Length | Dia. |
|---|---|---|
| Riser | | 2" |
| Tailpipe | 0.35' | 2" |

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used 20.5 FT³ / 18 FT³
Depth 200 to 229.9 ft.
259 to 295.5 ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used 600 GALLONS/50 GALLONS
Inst. method TREMMIE
Depth 0.0 to 187.9 ft.
229.9 to 240.2 ft.

REMARKS: PULLING CASING WAS VERY DIFFICULT AND COULD NOT ADD GROUT AT BOTTOM UNTIL CASING PULLED, BUT FORMATION COLLAPSED INTO THE HOLE AS FAST AS CASING WAS REMOVED. 270' OF WIRE LOST IN HOLE AT 257' AND WIRE BUNCHED AROUND STABILIZER AT 220'. 281.5' OF WIRE AND 1.5' OF REBAR LOST IN HOLE AT 271' B.G.

## WELL DETAIL (AS BUILT)
## 93-RD-114
## NOT TO SCALE




DESIGN FILE /cenps/projects/cw/nh/geotech DATE AND TIME PLOTTED: 30-JUL-1995

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DATE AND TIME PLOTTED 16-AUG-1993 13:41

Hole No. 93-RD-115

| DRILLING LOG | DIVISION CENPS-EN-GT-GE | INSTALLATION HOWARD HANSON DAM | SHEET 1 OF 4 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT PIEZOMETER INSTALLATION | 10. SIZE AND TYPE OF BIT 8" ODEX/6 5/8" TRICONE |
| 2. LOCATION (COORDINATES OR STATION) | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) |
| 3. DRILLING AGENCY ANDREW WELL DRILLING | 12. MANUFACTURER'S DESIGNATION OF DRILL IR AIR ROTARY - T4W |
| 4. HOLE NO. (AS SHOWN ON DRAWING AND FILE NUMBER) TITLE 93-RD-115 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 12 UNDISTURBED |
| 5. NAME OF DRILLER ROBERT DEWILD | 14. TOTAL NUMBER CORE BOXES |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| 7. THICKNESS OF OVERBURDEN 251' | 16. DATE HOLE STARTED 5-18-93 COMPLETED 6-5-93 |
| 8. DEPTH DRILLED INTO ROCK 143' | 17. ELEVATION TOP OF HOLE |
| 9. TOTAL DEPTH OF HOLE 394' | 18. TOTAL CORE RECOVERY FOR BORING % |
| | 19. NAME AND SIGNATURE OF INSPECTOR RICHARD E. SMITH |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | 10, 20, 30 | | SILTY, SLIGHTLY CLAYEY, SLIGHTLY SANDY GRAVEL, MOIST TO DRY, BECOMING DRY WITH DEPTH, LOOSE, BROWN TO TAN, OCCASIONAL ZONES OF LARGE COBBLES. | | | DRILLED WITH ODEX BUTTON BIT DRIVEN BY DOWN-THE-HOLE HAMMER CONCURRENT WITH 8 1/4" ID STEEL CASING<br><br>DRILLING FLUID RETURN SUMMARY<br>0-48 FT: AIR CIRCULATION<br>48-70 FT: 50-60% RETURN<br>70-217FT: 100% RETURN<br>217-230FT: AIR CIRCULATION<br>230-242FT: 100% RETURN<br>242-248FT: AIR CIRCULATION<br>248-394FT: 100% RETURN |
| | 40, 50 | | GRAVEL WITH A LITTLE SAND, SOME SILT AND CLAY, DRY CHANGING TO MOIST WITH DEPTH, GREY-BROWN; MAY BE WET AT 48'; GRAVEL ARE ANGULAR PEBBLES AND CUTTINGS OF ANDESITE AND OTHER VOLCANIC ROCKS. | | | |
| | 60 | | ANGULAR GRAVEL (PEBBLES AND CUTTINGS OF ANDESITE AND OTHER VOLCANICS) WITH COARSE SAND AND SOME SILT, TAN.<br><br>POSSIBLE WEATHERED HORIZON | | | |
| | 70, 80 | | SILTY, SANDY GRAVEL AND CLAY, ORANGE-BROWN, GRAVELS ARE WEATHERED ANGULAR ANDESITE AND BASALT CUTTINGS AND PEBBLES. LARGE COBBLES ARE PRESENT NEAR THE BASE OF THIS UNIT. | | 1 | |
| | 90 | | SLIGHTLY SILTY/CLAYEY GRAVEL (AS ABOVE, EXCEPT NUMEROUS SUB-ROUNDED PEBBLES LOCATED NEAR THE TOP OF THIS UNIT). ORANGE-BROWN TO BROWN. CLAY AND SILT CONTENT DECREASES DOWNWARD. | | 2 | |

DATE AND TIME PLOTTED: 16-AUG-1993 13:46

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 93-RD-115 |
|---|---|---|
| PROJECT: PIEZOMETER INSTALLATION | INSTALLATION: HOWARD HANSON DAM | SHEET 2 OF 4 SHEETS |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | | | SILTY, SLIGHTLY SANDY GRAVEL AND CLAY. BROWN. GRAVEL CONSISTS OF ANGULAR PEBBLES AND CUTTINGS OF ANDESITE AND OTHER VOLCANIC ROCKS. LAYERS OF DARK BROWN TO BROWN CLAY/SILT ALSO PRESENT. | | | |
| | 110 | | | | | |
| | 120 | | | | ③ | |
| | 130 | | | | | |
| | | | | | | S.W.L = DRY 5/26/93 @ 137' |
| | 140 | | | | | |
| | 150 | | | | | |
| | | | | | | S.W.L = DRY 5/26/93 @ 157' |
| | | | BOULDER | | | |
| | 160 | | SLIGHTLY SILTY AND SLIGHTY CLAYEY TO CLAYEY ANGULAR GRAVEL AND CUTTINGS OF GRAY-GREEN PYRITE-RICH ANDESITE. BROWN. LARGER GRAVELS POSSIBLE 173'-228.5' | | | |
| WATER LEVEL UPPER STAGE | 170 | | | | | |
| 175.45' B.G. | | | | | | S.W.L = DRY 5/26/93 @ 177' |
| | | | SLIGHTLY SILTY CUTTINGS OF LARGER GRAVELS AS DESCRIBED ABOVE. LIGHT BROWN | | | S.W.L = DRY 5/27/93 @ 177' |
| | 180 | | | | | |
| | | | CLAY AND CUTTINGS OF GRAY-GREEN PYRITE-RICH ANDESITE COBBLES. GRAY TO GRAY-BROWN | | ④ | |
| | 190 | | | | | |
| | | | SILT WITH MINOR CLAY AND CUTTINGS OF WEATHERED GRAY-GREEN ANDESITE (PYRITE-RICH) COBBLES. GRAY TO GRAY-BROWN. | | | |
| | 200 | | LESS SILT WITH DEPTH AND COLOR CHANGES TO BROWN AT 202' AND OCCASIONAL GRAY CLAY BALLS AFTER 202'. | | | FORMATION WATER AFTER 202'<br>DENSE DRILLING PAST 206' |
| | 210 | | COLOR OF SILT CHANGES BACK TO GRAY-BROWN AT 212' AND TO GRAY AT 215' | | | |
| | | | | | | S.W.L = 175' 5/28/93 @ 217' |

DESIGN FILE: /CONPS/PROJECTS/CVAN/DESTRCOV.MNG
DATE AND TIME PLOTTED: 16-AUG-1993 13:52

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 93-RD-115 |
|---|---|---|
| PROJECT: PIEZOMETER INSTALLATION | INSTALLATION: HOWARD HANSON DAM | SHEET 3 OF 4 SHEETS |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| WATER LEVEL LOWER STAGE 225.00' B.G. | | | | | | |
| | 230 | | DENSE, DRY TO MOIST, SILT/CLAY, DARK GRAY. | | 5 | NO FORMATION WATER 228.5'-238' |
| | | | CLAY/SILT AS ABOVE AND ROUNDED FINE TO COARSE PEBBLE GRAVEL OF MIXED IGNEOUS ORIGIN, DRY AND DENSE. | | | |
| | 240 | | CLEAN RIVER GRAVELS (ROUNDED MIXED IGNEOUS AND CUTTINGS OF SAME), MINOR GRAY-BROWN SILT, LOOSE. | | 6 | WATER 238'-245' |
| | | | LARGE COBBLES OF DARK GREEN ANDESITE AND RED-ORANGE CLAY/SILT BALLS, DENSE. | | 7 | NO FORMATION WATER 245'-294' |
| | 250 | | CUTTINGS OF DARK GREEN ANDESITE BOULDER/ROCK SLAB. | | | |
| | 260 | | | | 8 | S.W.L = 220.4' 5-29-93 @ 2517<br>DRILLED WITH 6 ¾"-TRICONE BIT W/O NO CASING ADVANCED PAST 257.6' |
| | 270 | | | | | |
| | 280 | | | | | |
| | 290 | | MEDIUM TO VERY FINE GRAINED GREY, GREEN, WHITE, AND RED SAND AND GRAY SILT. OCCASIONAL CUTTINGS OF DECOMPOSED GRAY ROCK WITH DECAYED RED AND GREEN MINERALS. VARYING AMOUNTS OF CLAY AND SILT WITH OCCASIONAL THIN CLAY/SILT LAYERS. ROCK IS DENSE AND CEMENTED. POSSIBLE GLACIAL TILL. | | 9 | |
| | 300 | | | | | |
| | 310 | | | | 10 | |
| | 320 | | | | | |
| | 330 | | | | | S.W.L. = 225.5' 5/29/93 @ 3347 |
| | 340 | | | | | |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
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PROJECT: PIEZOMETER INSTALLATION | HOLE NO. 93-RD-115

X-7

DESIGN FILE: /CENPS/PROJECTS/CV/HH/GEOTECH/HHG
DATE AND TIME PLOTTED: 16-AUG-1993 13:53

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 93-RD-115 |
|---|---|---|
| PROJECT: PIEZOMETER INSTALLATION | INSTALLATION: HOWARD HANSON DAM | SHEET 4 OF 4 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (DESCRIPTION) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC. IF SIGNIFICANT) |
|---|---|---|---|---|---|---|
| | | | CONTINUED | | | |
| | 350 | | | | | |
| | | | | | 11 | |
| | 360 | | | | | |
| | 370 | | FINE TO MEDIUM SAND, GRAY AND WHITE, WITH VARYING AMOUTS OF GRAY SILT AND CLAY AND FLAT ANGULAR CUTTINGS OF GRAY, BRITTLE SILTSTONE (?) WITH OCCASIONAL SAND SIZED GRAINS EMBEDDED WITHIN | | | |
| | 380 | | | | | |
| | 390 | | | | | |
| | | | POSSIBLE ANDESITE BOULDER AT 292'-293.5' | | 12 | |
| | | | BOTTOM OF HOLE = 394' | | | S.W.L = 225.7' 5-30-93 (@ 394') |
| | 400 | | | | | |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT: PIEZOMETER INSTALLATION
HOLE NO. 93-RD-115

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

# WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 6-5-93
Contractor ANDREW WELL DRILLING SERVICE
Rig INGERSOL RAND T-4W
Operator ROBERT DEWILD
Inspector RICHARD E. SMITH
Depth 394' Datum BELOW GROUND

HOLE DATA
Size: 8 in. to 257.6 ft.
7 in. to 394.0 ft.

CASING
Type STEEL
Mfr.
Ht. above gnd. surf. 2.95'
Drive shoe YES (REMOVED DURING COMPLETION)
Size: 8 1/4 in. to 257.6 ft.

SCREEN - 10' THREADED
Type SCH 80 MONOFLEX
Mfr. CAMPBELL
Composition PVC Dia. 2" ID

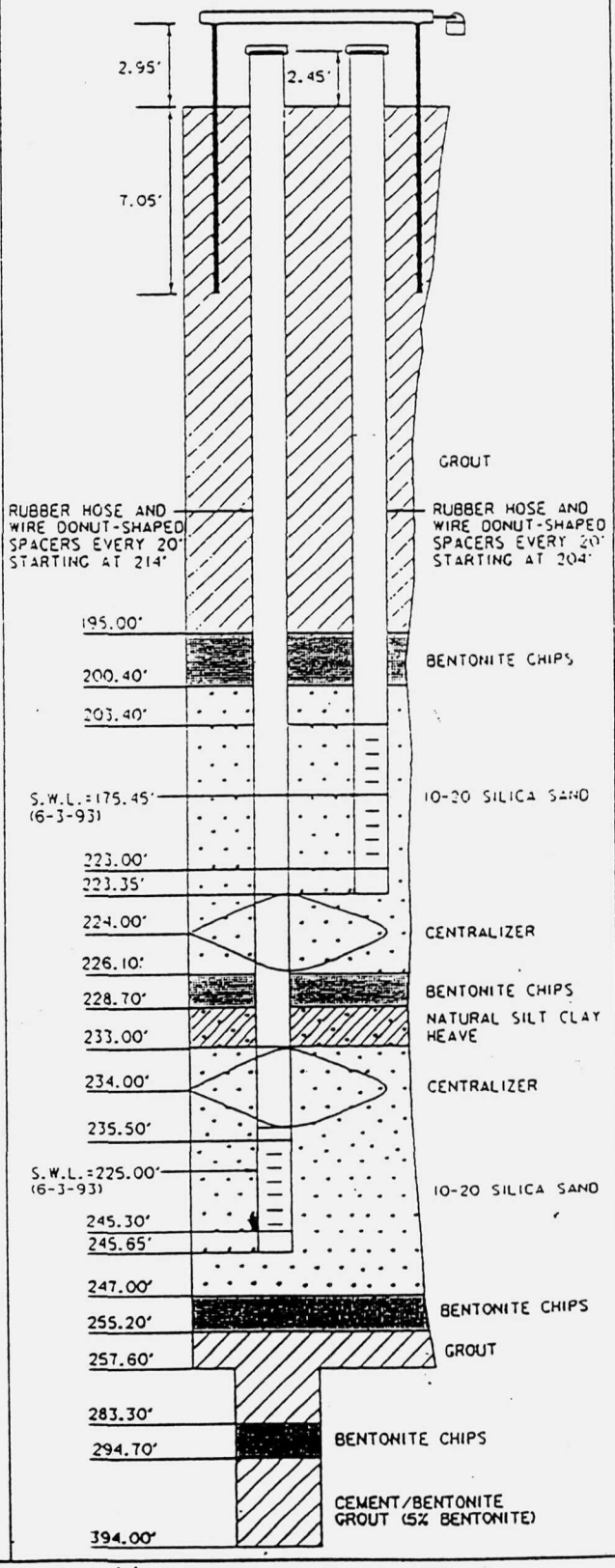
| Fittings: | Length | Dia. |
|---|---|---|
| Riser | | |
| Tailpipe | 0.35" | 2" ID |

FILTER
Source BAGS (100 LBS) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used 12.5 FT$^3$ / 5.5 FT$^3$
Depth 200.4 to 226.1 ft.
233.0 to 247.0 ft.

GROUT
Composition CEMENT/BENTONITE (5% BENTONITE)
Volume used 1000 GALLONS/250 GALLONS
Inst. method TREMMIE
Depth 0.0 to 195.0 ft.
255.2 to 394.0 ft.

REMARKS: THE NATURAL SEAL AT 228.5' TO 231.0' (SILT/CLAY) EXPANDED AND FILLED THE VOID LEFT DURING CASING REMOVAL. BENTONITE CHIPS WERE FORCED INTO AND ON TOP OF THIS LAYER BY ADDING 400 GALLONS OF WATER WHILE ADDING BENTONITE. GROUT LOSS AT 80', 55', AND 35' WAS STOPPED BY ADDING SAND AND BENTONITE CHIPS.

WELL DETAIL (AS BUILT)
93-RD-115
NOT TO SCALE




DATE AND TIME PLOTTED: 06-AUG-1993

DESIGN FILE: /cenps/projects/cw/hh/geotech hrg115.dgn

X-81

Hole No. 93-RD-117

| DRILLING LOG | DIVISION CENPS-EN-GT-GE | INSTALLATION HOWARD HANSON DAM | SHEET 1 OF 4 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT PIEZOMETER INSTALLATION | 10. SIZE AND TYPE OF BIT 8" ODEX/6 5/8" TRICONE |
| 2. LOCATION (COORDINATES OR STATION) | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) |
| 3. DRILLING AGENCY ANDREW WELL DRILLING | 12. MANUFACTURER'S DESIGNATION OF DRILL IR AIR ROTARY -T4W |
| 4. HOLE NO. (AS SHOWN ON DRAWING AND FILE NUMBER) TITLE 93-RD-117 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 13 UNDISTURBED |
| 5. NAME OF DRILLER ROBERT DE WILD | 14. TOTAL NUMBER CORE BOXES |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| 7. THICKNESS OF OVERBURDEN 320' | 16. DATE HOLE STARTED 4-16-93 COMPLETED 5-17-93 |
| 8. DEPTH DRILLED INTO ROCK 19' | 17. ELEVATION TOP OF HOLE |
| 9. TOTAL DEPTH OF HOLE 349' | 18. TOTAL CORE RECOVERY FOR BORING % |
| | 19. NAME AND SIGNATURE OF INSPECTOR RICHARD E. SMITH |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (DESCRIPTION) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) |
|---|---|---|---|---|---|---|
| | | | CLAYEY SILT WITH OCCASIONAL PEBBLES. MOIST AND LOOSE. TAN/BROWN | | | DRILLED WITH ODEX BUTTON BIT DRIVEN BY DOWN-THE-HOLE HAMMER CONCURRENT WITH 8 1/4" ID STEEL CASING. SAMPLES SAVED WERE PLACED IN PLASTIC JARS. |
| | | | SILTY SANDY, CLAYEY GRAVEL (FINE TO MEDIUM ROUNDED PEBBLE GRAVEL). DRY AND LOOSE. TAN/LIGHT BROWN | | 1 | DRILLING FLUID RETURN SUMMARY<br>0-17FT: AIR CIRCULATION<br>17-45 FT: 100% RETURN<br>45-47 FT: NO RETURN<br>47-170 FT: 100% RETURN<br>170-175 FT: AIR CIRCULATION<br>175-285 FT: 100% RETURN<br>285-349 FT: AIR CIRCULATION |
| | 10 | | | | | |
| | 20 | | AS ABOVE EXCEPT GRAVELS ARE ANGULAR CUTTINGS OF LARGER GRAVELS (ANDSITE). | | | |
| | 30 | | | | | |
| | | | SLIGHTLY CLAYEY, SLIGHTLY SILTY, SLIGHTLY SANDY GRAVEL CONSISTING OF PEBBLES AND CUTTINGS OF ANDESITE AND BASALT. OCCASIONAL THIN LENSES OF BROWN CLAY/SILT PRESENT, AND OCCASIONAL ZONES OF LARGE COBBLES. | | | |
| | 40 | | | | | |
| | 50 | | | | 2 | |
| | 60 | | | | | |
| | 70 | | | | | |
| | 80 | | | | 3 | |
| | | | AS ABOVE EXCEPT MANY ROCK FRAGMENTS ARE OXIDIZED AND NUMEROUS ORANGISH BROWN CLAY/SILT BALLS ARE PRESENT. | | | POSSIBLE WEATHERED HORIZON @ 85' |
| | 90 | | | | | |
| | | | SAME AS 35'-65' INTERVAL, SILT AND SAND CONTENT VARIES SLIGHTLY THROUGHOUT | | | |
| | 100 | | | | | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION | HOLE NO. 93-RD-117

DESIGN FILE: /CEMPS/PROJECTS/OI/MN/GOTEDCO/MNO
DATE AND TIME PLOTTED: 06-AUG-1993 13:54

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE PIEZOMETER INSTALLATION | Hole No. 93-RD-117 |
|---|---|---|
| PROJECT PIEZOMETER INSTALLATION | INSTALLATION HOWARD HANSON DAM | SHEET 2 OF 4 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (DESCRIPTION) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) |
|---|---|---|---|---|---|---|
| | 100 | | CONTINUED | | | |
| | 110 | | | | | |
| | 120 | | | | | |
| | 130 | | | | | |
| | 140 | | | | 4 | |
| | 150 | | | | | |
| | 160 | | | | | |
| | 170 | | | | | |
| WATER LEVEL UPPER STAGE 5/17/93 ▼ 181.8' B.G. | 180 | | | | | |
| | 190 | | | | | BEGAN MAKING WATER @ 190' |
| | 200 | | | | | S.W.L = 181.8' 5/17/93 (@ 214') |
| WATER LEVEL LOWER STAGE 5/17/93 ▼ 214.1' B.G. | 210 | | | | 5 | |
| | 220 | | | | | |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CEMPS

PROJECT PIEZOMETER INSTALLATION | HOLE NO. 93-RD-117

X-2

DATE AND TIME PLOTTED: 16-AUG-1993 16:28

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE PIEZOMETER INSTALLATION | Hole No. 93-RD-117 |
|---|---|---|
| PROJECT PIEZOMETER INSTALLATION | INSTALLATION HOWARD HANSON DAM | SHEET 3 OF 4 SHEETS |

| ELEVATION | DEPTH | LEGEND | CLASSIFICATION OF MATERIALS (DESCRIPTION) | % CORE RECOVERY | BOX OR SAMPLE NO. | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) |
|---|---|---|---|---|---|---|
| | 220 | | CONTINUED | | | |
| | | | SILTY GRAVEL(SUB-ANGULAR TO SUB ROUNDED ANDESITE AND BASALT) AND CLAY, GREY. | | ⑥ | |
| | 230 | | CLAYEY SILT OR SILTY CLAY, DENSE, DRY TO MOIST, DARK GREY | | ⑦ | |
| | | | CLEAN, ROUNDED GRAVELS OF MIXED INGEOUS ORIGIN AND ANGULAR CUTTINGS OF SAME, MINOR SAND | | ⑧ | |
| | 240 | | | | | |
| | 250 | | SILTY, SLIGHTLY CLAYEY, SANDY GRAVELS (ANGULAR CUTTINGS AND ROUNDED PEBBLES OF MIXED IGNEOUS ORIGIN) AND BROWN CLAYEY SILT OR SILTY CLAY | | ⑨ | |
| | 260 | | SILTY SAND, FINE SUB-ROUNDED GRAVELS OF MIXED IGNEOUS ORIGIN, BROWN. | | | |
| | 270 | | ALTERNATING LAYERS OF SLIGHTLY SILTY, SLIGHTLY SANDY ROUNDED GRAVEL AND ANGULAR GRAVEL OF MIXED IGNEOUS ORIGIN AND SLIGHTLY SILTY GRAVELLY SAND, GREY. | | | |
| | 280 | | CUTTINGS OF LARGER GRAY IGNEOUS ROCK (DESCRIBED AS BEDROCK BELOW ) WITH SOME GREY SILT; DENSE. A FEW ROUNDED PEBBLES OF MIXED IGNEOUS ORIGIN ARE PRESENT THROUGHOUT. INCREASING IN QUANTITY DOWNWARD. | | ⑩ | |
| | 290 | | | | | |
| | 300 | | ALTERNATING LAYERS OF GREY CLAYEY SILT, GREY SILTY SAND AND GREY SILTY GRAVEL CONSISTING OF PEBBLES AND/OR CUTTINGS OF GREY IGNEOUS ROCK DESCRIBED AS BEDROCK BELOW; POSSIBLE GLACIAL TILL | | | |
| | 310 | | | | ⑪ | |
| | | | | | ⑫ | |
| | | | | | ⑬ | |
| | 320 | | BEDROCK: GREY IGNEOUS ROCK (ANDESITE?) WITH ELONGATE GREEN XTLS AND PYRITE IN A GREY MATRIX | | | BEGAN DRILLING WITH A 6⅝" TRICONE BIT WITHOUT ADVANCING CASING @ 320' |
| | 330 | | | | | |
| | 340 | | | | | |

ENG FORM 1836-A PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CEMPR

PROJECT PIEZOMETER INSTALLATION | HOLE NO. 93-RD-117

X-8

DATE AND TIME PLOTTED: 06-AUG-1993 15:37

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 93-RD-117 |
|---|---|---|
| PROJECT: PIEZOMETER INSTALLATION | INSTALLATION: HOWARD HANSON DAM | SHEET 4 OF 4 SHEETS |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | 340 | | BEDROCK CONTINUED | | | |
| | 349 | | | | | SWL = 213' 5/6/93 (@ 349') |
| | | | BOTTOM = 349' BELOW GROUND | | | SWL = 212' 5/7/93 (@ 349') |



X-85

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

# WELL COMPLETION REPORT

## WELL DETAIL (AS BUILT)

93-RD-117

Project HOWARD HANSON DAM PIEZOMETER INSTALLATION
Completion date 5/17/93
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W, 8" ODEX & 6 5/8" TRICONE
Operator ROBERT DEWILD
Inspector RICHARD E. SMITH:CENPS-EN-GT-GE
Depth 349' Datum GROUND SURFACE

HOLE DATA
Size: 8.5 in. to 320 ft.
7 in. to 349 ft.

CASING
Type STEEL
Mfr.
Ht. above gnd. surf. 3.0'
Drive shoe YES - REMOVED
Size: 8 1/4 ID in. to 320' ft.
in. to ft.
in. to ft.

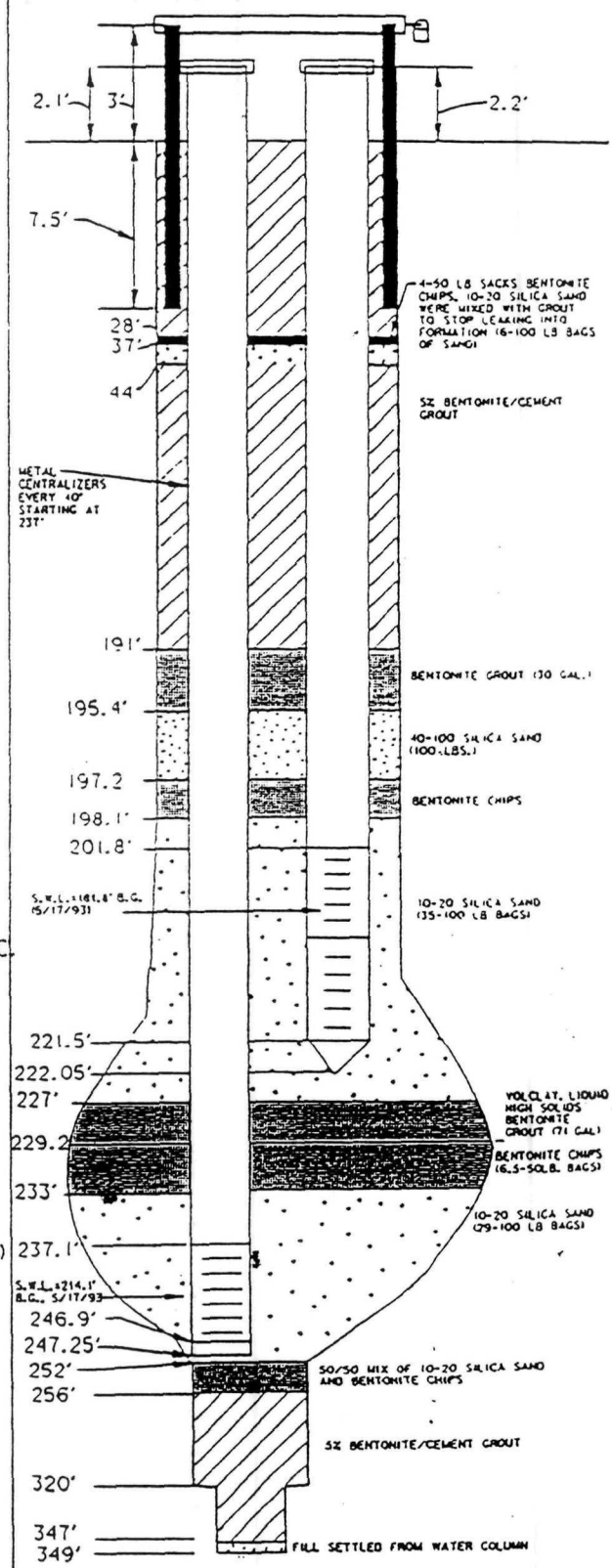
SCREEN
Type MONOFLEX, SCHEDULE 80
Mfr. CAMPBELL
Composition PVC Dia. 2" ID

| Fittings: | Length | Dia. |
|---|---|---|
| Packer | NONE | |
| Riser | | |
| Tailpipe | 0.55"/0.35" | 2" |

FILTER
Source BAGS (100 LBS.) COLORADO SILICA SAND INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POURED DOWN HOLE
Volume used 35 FT$^3$(197-227)/29 FT$^3$(233-252)
Depth 197.2 to 227 ft.
233 252

GROUT
Composition 5% BENTONITE CEMENT
Volume used 1200 GAL (0-191)/210 GAL (256-347)
Inst. method TREMMIE
Depth 0 to 191 ft.
256 to 347 ft.

REMARKS: ALL STEEL CASING REMOVED DURING WELL COMPLETION. LARGE CAVITY SUSPECTED AROUND LOWER SCREEN FROM CASING REMOVAL AND SUBSEQUENT REDRILLING (SEE DRILLING LOG). CENTRALIZERS INSTALLED ON LOWER STAGE EVERY 40' BEGINNING AT 197'. 10.5' OF STEEL CASING ADDED DURING SURFACE COMPLETION AS WELL PROTECTION.




NOT DRAWN TO SCALE

DATE AND TIME PLOTTED: 19-AUG-1993

/cenps/projects/cw/hh/geotech/hh93117.dgn

DESIGN FI

X-8

Hole No. 92-RD-118

| DRILLING LOG | DIVISION CENPS-EN-GT | INSTALLATION HOWARD HANSON DAM | SHEET 1 OF 2 SHEETS |
|---|---|---|---|

| | |
|---|---|
| 1. PROJECT PIEZOMETER INSTALLATION | 10. SIZE AND TYPE OF BIT 8" ODEX |
| 2. LOCATION (COORDINATES OR STATION) | 11. DATUM FOR ELEVATION SHOWN (TBM OR MSL) |
| 3. DRILLING AGENCY ANDREW WELL DRILLING | 12. MANUFACTURER'S DESIGNATION OF DRILL AIR ROTARY |
| 4. HOLE NO. (AS SHOWN ON DRAWING AND FILE NUMBER) TITLE 92-RD-118 | 13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED UNDISTURBED |
| 5. NAME OF DRILLER ROBERT DEWILD | 14. TOTAL NUMBER CORE BOXES |
| 6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT. | 15. ELEVATION GROUND WATER |
| | 16. DATE HOLE STARTED 12/3/92 COMPLETED |
| 7. THICKNESS OF OVERBURDEN | 17. ELEVATION TOP OF HOLE 1227 |
| 8. DEPTH DRILLED INTO ROCK 15' | 18. TOTAL CORE RECOVERY FOR BORING % |
| 9. TOTAL DEPTH OF HOLE 216' | 19. NAME AND SIGNATURE OF INSPECTOR |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | % CORE RECOVERY e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | 5, 10, 15, 20 | | SILTY SAND, COARSE, DRY, BROWN | | | 12/3/92 SET-UP<br>12/4/92 0-50' |
| | 25, 30 | | SANDY GRAVELS (2"), DRY, GREY | | | |
| | 35 | | BOULDER 2', GREY/GREEN | | | |
| | 35, 40 | | SANDY GRAVELS (2"), DRY, GREY | | | |
| | 45 | | | | | 11 HRS. DRILL TIME |
| | 50 | | | | | 12/4/92 END |
| | 55 | | | | | 12/5/92 START |
| | 60, 65 | | SILTY SAND, MED., DRY, LT. BROWN | | | |
| | 70 | | SILTY SAND, MED. COARSE, DRY, LT. GREY | | | |
| | 75 | | | | | 4 HRS. DRILL TIME<br>6 HRS. DOWN TIME (3PM)<br>BROKE HYDRAULIC LINE |
| | 80, 85 | | | | | 12/5/92 END |
| | 90 | | | | | 12/6/92 START (2 PM)<br>SLOW DRILLING BIT LOCKS UP |
| | 95, 100 | | | | | |

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
SEP 90 MODIFIED FOR CADD BY CENPS

PROJECT PIEZOMETER INSTALLATION

HOLE NO. 92-RD-118

A-8

| DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 92-RD-118 |
|---|---|---|
| PROJECT: PIEZOMETER INSTALLATION | INSTALLATION: HOWARD HANSON DAM | SHEET 2 OF 2 SHEETS |

| ELEVATION a | DEPTH b | LEGEND c | CLASSIFICATION OF MATERIALS (DESCRIPTION) d | e | BOX OR SAMPLE NO. f | REMARKS (DRILLING TIME, WATER LOSS, DEPTH OF WEATHERING, ETC., IF SIGNIFICANT) g |
|---|---|---|---|---|---|---|
| | 100 | | (CONT.) | | | SIX HRS. DRILL TIME<br>THREE HRS. DOWN TIME<br>12/6/92 END |
| | 105 | | SILTY SAND, MED.-COARSE, DRY, GREY W/ INTERMITTENT LARGER ROCK FRAGMENTS LAYERS INDICATING MED.-LARGE BOULDERS | | | 12/7/92 START |
| | 110 | | | | | |
| | 115 | | | | | |
| | 120 | | | | | |
| | 125 | | | | | |
| | 130 | | | | | |
| | 135 | | | | | |
| | 140 | | SILTY SAND INDICATES MOISTURE (VERY LITTLE) | | | |
| | 145 | | SILTY SAND BECOMES DRY AGAIN W/ INTERMITTENT ROCK FRAGMENT LAYERS (BOULDERS) | | | 12/7/92 END |
| | 150 | | | | | 12/8/92 START |
| | 155 | | | | | |
| | 160 | | | | | |
| | 165 | | | | | |
| | 170 | | | | | |
| | 175 | | | | | 12/8/92 END<br>12/9/92 START @ 180'<br>SLOW DRILLING IN CLAY |
| | 180 | | CLAYEY SAND W/ GRAVEL | | | SANDY GRAVEL |
| | 185 | | | | | |
| | 190 | | SILTY, SANDY GRAVEL | | | 12/9/92 END<br>DRILL DOWN 11:30 - BROKEN HYDRAULIC LINE |
| | 195 | | | | | |
| | 200 | | CLAYEY SAND W/ GRAVEL AND ROCK FRAGMENTS (1") | | | 201'-216' DRILLED WITH 6" TRI-CONE. 8" CASING RESTS @ 201' (TOP OF BEDROCK) |
| | 205 | | BEDROCK | | | |
| | 210 | | BEDROCK (VERY FRACTURED) @ 210' | | | WATER WAS PRODUCED @ 210' ROCK DRILLS<br>WATER SOUNDED IN AM ON 12/12/92 @ 200 FT. |
| | 215 | | BOTTOM OF HOLE @ 216' | | | |
| | 220 | | | | | |

U.S. ARMY CORPS OF ENGINEERS, SEATTLE DISTRICT

# WELL COMPLETION REPORT

Project PIEZOMETER INSTALLATION, HANSON DAM
Completion date 12/16/92
Contractor ANDREW WELL DRILLING SERVICE
Rig IR AIR ROTARY - T4W
Operator ROBERT DEWILD
Inspector BEN LAZO, STEVE MEYERHOLTZ
Depth 216' Datum GROUND SURFACE

HOLE DATA
Size: 8 in. to 201 ft.
7 in. to 216 ft.

CASING
Type STEEL (ALL REMOVED BUT 10')
Mfr.
Ht. above gnd. surf.
Drive shoe
Size: 8 ¼ in. to 201 ft.

SCREEN
Type SCHEDULE 80 MONOFLEX -0.020 IN. SLOT
Mfr. CAMPBELL
Composition PVC Dia. 2"

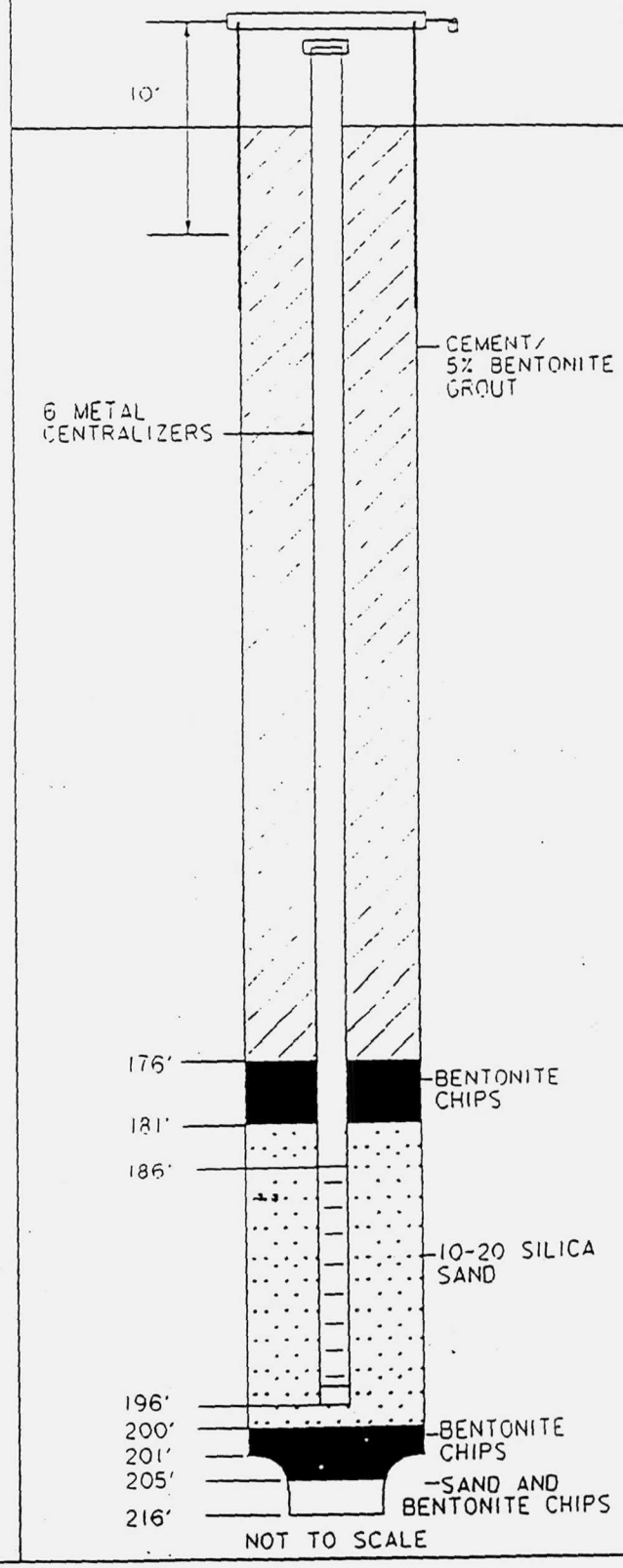
| Fittings: | Length | Dia. |
|---|---|---|
| Riser | | |
| Tailpipe | | |

FILTER
Source BAGS (100LB) COLORADO SILICA SAND, INC.
Composition CLEAN SILICA SAND
Gradation 10-20
Inst. method POUR DOWN HOLE
Volume used
Depth 181 to 200 ft.
to ft.

GROUT
Composition CEMENT /5% BENTONITE
Volume used
Inst. method TREMMIE
Depth 0 to 176 ft.
to ft.

REMARKS: GROUT LOSS AT BOTTOME OF HOLE STOPPED BY ADDING SAND AND BENTONITE CHIPS. VOLUMINOUS GROUT LOSS IN UPPER ZONES STOPPED BY MIXING IN 20 BAGS OF SAND STARTING AT 105' AND INCREASING THE PERCENTAGE BENTONITE IN THE GROUT

## WELL DETAIL (AS BUILT)
## 92-RD-118
## NOT TO SCALE




NOT TO SCALE

DATE AND TIME PLOTTED: 28-SEP-1993

DESIGN FILE: /cenps/projects/cw/hh/geotech/hhg118.dgn

X-8

## D-1

DRILLED 20 - 24 JULY 1947

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1011.0 | | TOP OF ROCK |
| | | 85% TO 100%, 25%, 100%, 85%-90%, 100%, 85%, 100% | BASIC ANDESITE |
| 51.8 | 959.2 | 80%-95% | ANDESITE |
| 56.6 | 954.6 | 100%, 44%, 75%, 80% | TUFF ZONES |
| 72.0 | 939.0 | 100%, 75%, 85% | ANDESITE |
| 79.5 | 931.5 | | |

BOTTOM OF HOLE

## D-2

DRILLED 6 JUNE-17 JULY 1947

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1072.6 | | BOULDERS |
| 13.0 | 1059.6 | ML | |
| 23.0 | 1049.6 | CL | SILTY |
| 38.3 | 1034.3 | GW | SANDY |
| 66.0 | 1006.6 | GW | SANDY W/BOULDERS |
| 143.4 | 929.2 | | TOP OF ROCK |
| | | 100% | ALTERED ANDESITE |
| 220.7 | 851.9 | | |

BOTTOM OF HOLE

## D-3

DRILLED 29 JULY-16 AUGUST 1947

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1093.4 | GW | SANDY |
| 37.5 | 1055.9 | ML | CLAYEY |
| 48.2 | 1045.2 | GW | SANDY |
| 93.0 | 1000.4 | CL | W/GRAVEL & BROKEN ROCK |
| 115.5 | 977.9 | SP | W/GRAVEL & BOULDERS |
| 143.4 | 950.0 | SP | |
| 174.0 | 919.4 | ML | CLAYEY |
| 190.0 | 903.4 | 40%-65% | TOP OF ROCK |
| | | 80%, 100%, 25%, 50% | BROKEN ANDESITE |
| 206.0 | 887.4 | | |

BOTTOM OF HOLE

## D-4

DRILLED 3 - 10 JANUARY 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1189.5 | ML | SANDY (ORGANIC) |
| 2.0 | 1187.5 | | GP - SANDY |
| 5.0 | 1184.5 | | TOP OF ROCK |
| | | 90% TO 100%, 80%, 100%, 85% TO 100%, 50% TO 95%, 85%-100% | ANDESITE |
| 45.5 | 1144.0 | | |

BOTTOM OF HOLE

## D-5

DRILLED 12 - 21 JANUARY 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1236.0 | GM | TALUS |
| 7.0 | 1229.0 | 35%-100% | TOP OF ROCK |
| | | 85%-95%, 100%, 25%-45%, 80% TO 100% | ANDESITE |
| 67.7 | 1168.3 | | |

BOTTOM OF HOLE

## D-6

DRILLED 22 - 31 JANUARY 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1276.5 | GM | TALUS |
| 10.0 | 1266.5 | 10%, 50%-100% | TOP OF ROCK |
| | | 95% TO 100% | ANDESITE |
| 50.2 | 1226.3 | | |

BOTTOM OF HOLE

## D-7

DRILLED 2 FEBRUARY-3 MARCH 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1073.5 | | BROKEN ANDESITE ROCK & SANDY SILT |
| 33.4 | 1040.1 | 95% TO 100% | TOP OF ROCK |
| | | 80% TO 100%, 45%, 80% TO 90%, 75%, 85%, 100% | ANDESITE |
| 76.1 | 997.4 | | |

BOTTOM OF HOLE

## D-8

DRILLED 21 FEBRUARY-2 APRIL 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1162.5 | | BROKEN AGGLOMERATIC ANDESITE FRAGMENTS & SANDY SILT |
| 26.0 | 1136.5 | CL | SANDY W/BROKEN ANDESITIC ROCK |
| 45.0 | 1117.5 | | BROKEN ANDESITIC ROCK W/SANDY SILT |
| 75.0 | 1087.5 | 91% | TOP OF ROCK |
| | | 30%, 35%, 45%, 80%-100%, 55% TO 75%, 80%, 90%, 75%, 100% | ANDESITE |
| 122.5 | 1040.0 | | |

BOTTOM OF HOLE

## D-9

DRILLED 30 MARCH-27 APRIL 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1253.2 | | BROKEN AGGLOMERATIC ANDESITE W/INTERSTITIAL SANDY SILT |
| 80.0 | 1173.2 | CL | SANDY W/BROKEN ANDESITIC ROCK |
| 86.0 | 1167.2 | | ANDESITIC ROCK W/ INTERSTITIAL SANDY SILT |
| 96.0 | 1157.2 | | |

BOTTOM OF HOLE

## CD-10

DRILLED 22 JANUARY-13 MAY 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1292.5 | | SANDY |
| 2.0 | 1290.5 | | BROKEN AGGLOMERATIC ANDESITE & SANDY SILT |
| 32.0 | 1260.5 | | BROKEN AGGLOMERATIC ANDESITE WITH INTERSTITIAL SANDY SILT |
| 161.0 | 1131.5 | | |

BOTTOM OF HOLE

NOTES

1. PERCENT OF CORE RECOVERY BELOW TOP OF ROCK IS SHOWN IN THE 3RD COLUMN.
2. THE OVERBURDEN WAS DRILLED BY CONTINUOUS DRIVE SAMPLING WHERE POSSIBLE.
3. THE ROCK WAS CORED WITH A DIAMOND DRILL. UNDISTURBED SAMPLES WERE OBTAINED WHERE MOISTURE CONTENTS ARE SHOWN IN THE DRILL LOGS.
4. FIELD LOGS & SAMPLES ARE AVAILABLE FOR INSPECTION IN THE SEATTLE DISTRICT OFFICE, CORPS OF ENGINEERS, 4735 E. MARGINAL WAY, SEATTLE, WASHINGTON.
5. ABSENCE OF GROUND WATER DATA ON DRILL LOGS SHALL NOT BE CONSTRUED AS INDICATING THAT NO WATER WILL BE ENCOUNTERED IN CONSTRUCTION OPERATIONS.

## CD-11

DRILLED 6 FEBRUARY-3 JUNE 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1274.5 | | ORGANIC, SANDY |
| 1.0 | 1273.5 | | BROKEN AGGLOMERATIC ANDESITE & SANDY SILT |
| 105.0 | 1169.5 | | BROKEN AGGLOMERATIC ANDESITE W/INTERSTITIAL SANDY SILT |
| 151.0 | 1123.5 | | |

BOTTOM OF HOLE

## CD-12

DRILLED 26 FEBRUARY-26 JUNE 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1255.0 | | ML - ORGANIC, SANDY |
| 1.0 | 1254.0 | | BROKEN AGGLOMERATIC ANDESITE & SANDY SILT |
| 45.0 | 1210.0 | | BROKEN AGGLOMERATIC ANDESITE W/INTERSTITIAL SANDY SILT |
| 156.0 | 1099.0 | | BROKEN AGGLOMERATIC ANDESITE, GRAVEL SIZE IN MATRIX OF SANDY CLAY, CL AND SILT |
| 171.0 | 1084.0 | | BROKEN AGGLOMERATIC ANDESITE |
| 232.0 | 1023.0 | GP | SANDY |
| 237.0 | 1018.0 | | SP - GRAVELLY |
| 238.0 | 1017.0 | GP | SANDY |
| 265.0 | 990.0 | GP | SANDY W/BOULDERS |
| 280.0 | 975.0 | GC | SANDY W/BOULDERS |
| 293.0 | 962.0 | SC | W/BOULDERS |
| 302.0 | 953.0 | GC | SANDY W/BOULDERS |
| 305.0 | 950.0 | | |

BOTTOM OF HOLE

## D-13

DRILLED 16 MAY-13 JUNE 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1189.4 | | BROKEN AGGLOMERATIC ANDESITE W/INTERSTITIAL SANDY SILT |
| 63.0 | 1126.4 | SW | |
| 96.8 | 1092.6 | | TOP OF ROCK |
| | | 100% | ANDESITE |
| 125.8 | 1063.6 | | |

BOTTOM OF HOLE

ANGLE HOLE - HORIZONTAL

## D-14A

NOT DRILLED, BROKE THROUGH ROCK WHICH HAD THICKNESS OF ONLY 1 FOOT.

ANGLE HOLE - 30° BELOW HORIZONTAL

## D-14B

DRILLED 10 - 12 NOVEMBER 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1089.5 | | BROKEN ANDESITE |
| 8.0 | 1085.5 | | SM |
| 10.[illegible] | [illegible] | | |

BOTTOM OF HOLE

ANGLE HOLE - 45° BELOW HORIZONTAL

## D-14C

DRILLED 30 NOVEMBER-1 DECEMBER 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1089.0 | | ANDESITE |
| 15.5 | 1078.0 | | SP |
| 18.0 | 1076.3 | | |

BOTTOM OF HOLE

ANGLE HOLE - HORIZONTAL

## D-15A

DRILLED 12 - 15 NOVEMBER 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1092.1 | | ANDESITE |
| [illegible] | 1092.1 | | GW |
| [illegible] | 1092.1 | | WEATHERED ANDESITE |
| 30.0 | 1092.1 | | |

BOTTOM OF HOLE

ANGLE HOLE - 30° BELOW HORIZONTAL

## D-15B

DRILLED 17 - 27 NOVEMBER 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1089.2 | | ANDESITE |
| 79.0 | 1069.7 | | |

BOTTOM OF HOLE

ANGLE HOLE - 10° BELOW HORIZONTAL

## D-15C

DRILLED 27 - 30 NOVEMBER 1953

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1090.[illegible] | | ANDESITE |
| 18.5 | [illegible] | | SP |
| 19.0 | [illegible] | | |

BOTTOM OF HOLE

## D-16

DRILLED 6 NOVEMBER-2 DECEMBER 1954

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1023.7 | GC | SANDY W/ ROCK FRAGMENTS |
| 17.0 | 1006.7 | GW | SANDY W/ROCK FRAGMENTS |
| 28.0 | 995.7 | | BOULDER |
| 32.0 | 991.7 | GW | SANDY |
| 35.0 | 988.7 | SM | FINE, GRAY |
| 65.0 | 958.7 | ML | SANDY, DARK GRAY |
| 75.0 | 948.7 | ML | SANDY WITH ROCK FRAGMENTS |
| 90.0 | 933.7 | | BOULDER |
| 94.0 | 929.7 | | CL-RED W/ROCK FRAGMENTS |
| 95.0 | 928.7 | | TOP OF ROCK |
| | | | DECOMPOSED TUFF |
| 119.5 | 904.2 | | |

BOTTOM OF HOLE

## D-17

DRILLED 9 NOVEMBER-20 DECEMBER 1954

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1157.0 | | CLAYEY, SILTY SAND IN ROCK FRAGMENTS TO BOULDER SIZE |
| 90.0 | 1067.0 | SM | W/ROCK FRAGMENTS |
| 98.0 | 1059.0 | CL & SP | LAMINATED GRAY SILTY CLAY W/POORLY GRADED MEDIUM SAND |
| 107.0 | 1050.0 | SP | MEDIUM, DRY |
| 125.0 | 1032.0 | GC | SANDY |
| 138.0 | 1019.0 | | GM |
| 140.0 | 1017.0 | GC | SANDY |
| 145.0 | 1012.0 | GP | MEDIUM TO FINE |
| 157.0 | 1000.0 | | BOULDER |
| 158.5 | 998.5 | | TOP OF ROCK |
| | | | ANDESITE |
| 198.1 | 958.9 | | |

BOTTOM OF HOLE

ANGLE HOLE - 40° BELOW HORIZONTAL

## D-18A

DRILLED 20 - 30 DECEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1201.8 | | BROKEN ANDESITE BRECCIA FRAGMENTS TO 6" SIZE, APPROX 25% RECOVERY |
| 25.0 | 1185.7 | | |

BOTTOM OF HOLE

ANGLE HOLE - 40° BELOW HORIZONTAL

## D-18B

DRILLED 30 DEC. 1955-5 JAN. 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1201.8 | | BROKEN ANDESITE BRECCIA FRAGMENTS TO 6" SIZE APPROX. 25% RECOVERY |
| 16.0 | 1190.2 | | |

BOTTOM OF HOLE

### LEGEND

- GW - WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
- GP - POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
- GM - SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
- GC - CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
- SW - WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
- SP - POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
- SM - SILTY SANDS, SAND-SILT MIXTURES
- OL - ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
- CL - INORGANIC CLAYS OF LOW TO MED. PLASTICITY
- CH - INORGANIC CLAYS OF HIGH PLASTICITY
- M - MOISTURE CONTENT
- SC - CLAYEY SANDS, SAND-CLAY MIXTURES.
- ML - INORGANIC SILTS & VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS W/ SLIGHT PLASTICITY.

EXHIBIT AN-1

GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
DRILL LOGS

Sheet of | Scale as shown
U.S. Army Engr. District, Seattle, Wash.

Des: RMW | Date:
Dwn: RMW
Chk'd: | File No. E-56-6-61

## D-20

DRILLED 25 OCTOBER - 2 NOVEMBER 1954

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1211.0 | SM | ORGANIC |
| 3.0 | 1208.0 | SW | SANDY |
| 6.0 | 1205.0 | SP | |
| 9.0 | 1202.0 | CL&GM | |
| 14.0 | 1197.0 | CL&SP | |
| 18.0 | 1193.0 | SM&CL | INTERBEDDED |
| 26.0 | 1185.0 | CL | W/GRAVEL & SAND BOULDERS |
| 29.8 | 1181.2 | | |
| 32.8 | 1177.2 | CL, GP & SP | INTERBEDDED CLAY, GRAVEL & SAND |
| 54.0 | 1157.0 | | TOP OF ROCK |
| | | 100% | |
| | | 95% | GRAY-GREEN & BLUE-GRAY ANDESITE & AGGLOMERATE WITH ANDESITE FRAGMENTS |
| | | 100% | ANDESITE & AGGLOMERATE |
| 100.0 | 1111.0 | | |

BOTTOM OF HOLE

## D-21

DRILLED 18 - 26 NOVEMBER 1954

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1178.7 | SP | W/ ROCK FRAGMENTS |
| 5.0 | 1173.7 | | TOP OF ROCK |
| | | 90% | |
| | | 100% | ANDESITE |
| | | 90% | |
| | | 65% | |
| | | 95% | |
| 67.7 | 1111.0 | | |

BOTTOM OF HOLE

## D-23

DRILLED 15 DEC. 1955 - 20 JAN. 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1247.3 | SM | W/SOFT WEATHERED ROCK |
| 8.0 | 1239.3 | SM | CLAYEY W/SOFT WEATHERED ROCK |
| 16.0 | 1231.3 | | BROKEN ROCK FRAGMENTS |
| 29.0 | 1218.3 | | BOULDERS |
| 36.0 | 1211.3 | SC | SILTY |
| 44.0 | 1203.3 | SC | COARSE & SILTY |
| 48.0 | 1199.3 | SM | FINE |
| 55.0 | 1192.3 | GP | W/BOULDERS |
| 58.0 | 1189.3 | SM | W/BROKEN ROCK |
| 65.0 | 1182.3 | | SP - COARSE |
| 66.0 | 1181.3 | | SM - GRAVELLY |
| 67.0 | 1180.3 | | TOP OF ROCK |
| | | 100% | |
| | | 90% | SOUND, BLUE-GREEN ANDESITE |
| | | 100% | |
| | | 95% | |
| | | 100% | |
| | | 90% | |
| | | 100% | |
| | | 90% | |
| | | 40% | |
| 165.2 | 1082.1 | 90% | |

BOTTOM OF HOLE

## D-24

DRILLED 4 - 15 NOVEMBER 1954

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1214.5 | SM | GRAVELLY W/BOULDERS |
| 8.0 | 1206.5 | SP | FINE & GRAY |
| 17.5 | 1197.0 | CL | BLUISH & SILTY |
| 19.2 | 1195.3 | SP | FINE & GRAY |
| 25.0 | 1189.5 | GW | BOULDER AT 32' |
| 35.0 | 1179.5 | | GRAVELLY |
| 37.0 | 1177.5 | SW | SANDY |
| 40.0 | 1174.5 | | CL - BLUISH & SILTY |
| 41.0 | 1173.5 | GW | SANDY W/SILT & CLAY BOULDER @ 46' |
| 52.8 | 1161.7 | | TOP OF ROCK |
| | | 90% | AGGLOMERATE & ANDESITE |
| | | 80% | |
| 67.3 | 1147.2 | 95% | |

BOTTOM OF HOLE

## CD-25

DRILLED 7 JANUARY - 3 FEBRUARY 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1282.0 | | BOULDERS, COBBLES & SOME CLAY |
| 44.0 | 1238.0 | | COBBLES, SANDY CLAY AND SOME ROCK FRAGMENTS |
| 52.0 | 1230.0 | | SANDY SILTY CLAY W/SMALL ROCK FRAGMENTS |
| 58.0 | 1224.0 | | ROCK FRAGMENTS W/ SANDY SILTY CLAY |
| 77.0 | 1205.0 | | ROCK FRAGMENTS TO COBBLE SIZE W/SAND & SILT PARTICLES, W/TRACES OF CL |
| 92.0 | 1190.0 | | ROCK FRAGMENTS W/ SOME CLAYEY SILT |
| 115.0 | 1167.0 | | ROCK FRAGS. TO COBBLE SIZE W/ SOME CLAYEY SILT |
| 121.0 | 1161.0 | SC | GRAVELLY M=7.8% |
| 130.0 | 1152.0 | CL | SANDY & ROCK FRAGMENTS |
| 164.0 | 1118.0 | | TOP OF ROCK MED. HARD BLUE-GREEN ANDESITE |
| 175.0 | 1107.0 | | |

BOTTOM OF HOLE

## D-26

DRILLED 26 JAN.-9 FEBRUARY 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1140.8 | | TOP OF ROCK |
| | | 100% | GRAY ANDESITE |
| 31.9 | 1108.9 | 100% | GRAY ANDESITE BRECCIA |
| 85.5 | 1055.3 | 95% | |
| | | 90% | GRAY ANDESITE |
| | | 100% | |
| 108.0 | 1032.8 | 95% | |
| | | 100% | GRAY & RED ANDESITE BRECCIA |
| | | 95% | |
| | | 100% | |
| 144.0 | 996.8 | | |

BOTTOM OF HOLE

## D-27

DRILLED 17 FEBRUARY - 22 MARCH 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1168.3 | GM | SANDY W/BROKEN ROCK |
| 14.5 | 1153.8 | | TOP OF ROCK |
| | | 30% | ANDESITE BRECCIA, SEAMY, BROKEN ROCK |
| | | 50% TO 75% | |
| 33.5 | 1134.8 | 40% | ANDESITE |
| 44.0 | 1124.3 | 25% | |
| 49.0 | 1119.3 | 90% | HARD ANDESITE |
| 56.0 | 1112.3 | 15% | ANDESITE BRECCIA |
| | | 30% TO 50% | |
| | | 20% | ANDESITIC TUFF & |
| | | 45% | ANDESITE BRECCIA |
| | | 20%-95% | |
| 99.6 | 1068.7 | 15% TO 25% | |

BOTTOM OF HOLE

## D-32

DRILLED 7 - 28 MARCH 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1260.0 | | ML-SANDY W/ROCK FRAGMENTS |
| 0.5 | 1259.5 | | GP-SANDY, SILTY W/ ROCK FRAGMENTS |
| 2.5 | 1257.5 | 80%-100% | TOP OF ROCK |
| 6.0 | 1252.0 | | DARK GRAY ANDESITE |
| | | 70% | |
| | | 65% | |
| | | 100% | HARD ANDESITE BRECCIA W/FEW SOFT ZONES 1 FOOT THICK. |
| | | 90% | |
| | | 100% | |
| 146.5 | 1113.5 | | |

BOTTOM OF HOLE

## D-33

DRILLED 1 - 6 DECEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1222.5 | | TOP OF ROCK |
| | | 40%-65% | SOFT, BROKEN AGGLOMERATE |
| 9.3 | 1213.2 | 90% | |
| | | 75% | |
| | | 100% | |
| | | 85% | SOUND, GRAY & BLUE-GREEN AGGLOMERATE & ANDESITE |
| | | 70% | |
| | | 100% | |
| | | 85% | |
| | | 95% | |
| | | 55% | |
| 80.0 | 1142.5 | 100% | |

BOTTOM OF HOLE

## D-34

DRILLED 29 - 31 OCTOBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1186.9 | | SW - GRAVELLY |
| 1.0 | 1185.9 | | TOP OF ROCK |
| | | 65%-95% | SOUND ANDESITE |
| | | 80%-95% | |
| | | 100% | |
| 20.2 | 1166.7 | 80% | BROKEN, WELL-JOINTED ANDESITE |
| | | 40% | |
| | | 100% | |
| | | 20% | |
| 36.0 | 1150.9 | 40% | |

BOTTOM OF HOLE

## LEGEND

GW - WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GP - POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES LITTLE OR NO FINES
GM - SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
GC - CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
SW - WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES.
SP - POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SM - SILTY SANDS, SAND-SILT MIXTURES
SC - CLAYEY SANDS, SAND-CLAY MIXTURES
ML - INORGANIC SILTS & VERY FINE SANDS
CL - INORGANIC CLAYS OF LOW TO MED. PLASTICITY
OL - ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
CH - INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
MH - INORGANIC SILTS, ELASTIC SILTS
M - MOISTURE CONTENT

## D-35

DRILLED 18 - 20 OCTOBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.3 | 1229.3 | | SANDY, & GRAVELLY |
| 1.7 | 1228.0 | SC | GRAVELLY M=20.2% |
| 7.6 | 1222.0 | SM | GRAVELLY |
| 10.7 | 1218.9 | GM | FINE M=18.2% |
| 15.5 | 1214.1 | SC | GRAVELLY |
| 18.7 | 1210.9 | SM | BLUE TO BROWN WITH BROKEN ROCK |
| 24.6 | 1205.0 | GM | BROWN & SANDY |
| 30.9 | 1198.7 | | TOP OF ROCK |
| 35.9 | 1193.7 | | BROWN WEATHERED ROCK, ALTERED ANDESITE |
| | | 50% | SOUND, BLUISH-GRAY ANDESITE |
| 60.0 | 1169.6 | 90% | |

BOTTOM OF HOLE

## D-36

DRILLED 6 - 15 OCTOBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1221.8 | OL | ORGANIC & GRAVELLY |
| 3.0 | 1218.8 | SM | ML-SANDY M=21.9% |
| 4.0 | 1217.8 | SM | GC-SANDY M=12.6% |
| 5.0 | 1216.8 | SM | GRAVELLY M=20.7% |
| 13.0 | 1208.8 | SM | SANDY |
| 16.0 | 1205.8 | SM | COARSE |
| 19.0 | 1202.8 | SM | GRAVELLY |
| 22.0 | 1199.8 | SM | M=61.7% |
| 23.0 | 1198.8 | SM | GRAVELLY |
| 35.0 | 1186.8 | | M=16.7% |
| 36.0 | 1185.8 | | GC-SANDY M=48.2% |
| 40.8 | 1180.8 | MH | GRAVELLY M=77.0% |
| 44.2 | 1177.2 | ML | BLUE & SANDY M=38.6% |
| | | SM | GRAVELLY |
| 54.7 | 1166.7 | SM | SANDY & COMPACT |
| 61.0 | 1160.4 | | SM-COARSE |
| 62.0 | 1159.4 | GM | COMPACT, SANDY W/ BOULDERS |
| 71.0 | 1150.4 | | TOP OF ROCK |
| 74.3 | 1147.1 | | SOFT, RED-BROWN ALTERED ANDESITE |
| | | 90% TO 95% | BLUE & PURPLE ANDESITE, SOUND BUT SOFT |
| 94.2 | 1127.2 | | |

BOTTOM OF HOLE

## D-37

DRILLED 25 JANUARY - 14 FEBRUARY 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1198.7 | GM | SANDY W/SOME ROCK |
| 8.0 | 1190.7 | SM | GRAVELLY W/BROKEN ROCK |
| 14.0 | 1184.7 | | TOP OF ROCK |
| 21.0 | 1177.7 | | BLUISH ALTERED ROCK |
| 24.0 | 1174.7 | | ALTERED ROCK |
| 28.0 | 1170.7 | | SOUND ANDESITE |
| | | | ALTERED ROCK |
| 38.5 | 1160.2 | 90% | ANDESITE W/BADLY BROKEN ROCK. WATER STARTED FROM THIS ZONE. |
| 44.0 | 1150.7 | 65% | |
| | | 100% | ANDESITE W/SOME ANGULAR & ROUNDED ROCK |
| 62.0 | 1136.7 | 70% | |
| 68.0 | 1130.7 | 100% | ANDESITE BRECCIA |
| | | 80% | ANDESITE BRECCIA W/ BADLY BROKEN ROCK |
| 81.5 | 1117.2 | 70% | |
| | | 65% | ANDESITE BRECCIA & TUFF |
| 89.3 | 1109.4 | 100% | SOUND ANDESITE ARTESIAN FLOWING CONSTANTLY |
| 96.6 | 1102.1 | 100% | GRAY ANDESITIC TUFF |
| 108.0 | 1090.7 | 100% | BROKEN ZONE |
| 116.0 | 1082.7 | 100% | ANDESITIC BRECCIA |
| 146.6 | 1052.1 | | ARTESIAN DOUBLED FLOW |
| | | 100% | DARK ANDESITIC TUFF & ANDESITE BRECCIA |
| 187.0 | 1011.7 | 90% | BLACK BASIC ANDESITE |
| 195.0 | 1003.7 | | |
| 201.0 | 997.7 | 100% | ANDESITIC TUFF |

BOTTOM OF HOLE

THE ARTESIAN WATER IN D-37 HAD A STEADY FLOW OF 10 GAL. PER MIN. AND ROSE IN A STANDPIPE 18 FT. ABOVE THE CASING DURING DRILLING. WATER IS ASSUMED TO BE COMING FROM THE 2 ZONES SHOWN IN LOG.

## D-49

DRILLED 20 FEBRUARY - 5 MARCH 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1201.0 | | FILL MATERIAL |
| 4.5 | 1196.5 | SM | NATURAL GROUND SURFACE GRAVELLY |
| 14.0 | 1187.0 | | GM - SANDY |
| 14.9 | 1186.1 | GM | SANDY W/SOME BROKEN ROCK |
| 20.0 | 1181.0 | | ROCK |
| 27.0 | 1174.0 | | BROKEN ROCK |
| 36.0 | 1165.0 | GC | W/BROKEN ROCK |
| 42.0 | 1159.0 | | BROKEN ROCK |
| 46.0 | 1155.0 | | HIT WOOD |
| 46.7 | 1154.3 | | ALTERED BROKEN ROCK |
| 52.0 | 1149.0 | | BOULDERS & PIECES OF WOOD |
| 56.0 | 1145.0 | GP | SANDY W/COBBLES & SOME CLAY |
| 61.5 | 1139.5 | | TOP OF ROCK |
| | | 95% | ANDESITE TUFF W/SOME CLAY & CHLORITE |
| 72.9 | 1128.1 | | |

BOTTOM OF HOLE

## CD-53

DRILLED 23 FEBRUARY - 23 MARCH 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1086.7 | ML | SANDY W/COBBLES & ROCK FRAGMENTS |
| 17.0 | 1069.7 | CL | SANDY, SILTY W/SOME ROCK FRAGMENTS |
| 34.0 | 1052.7 | | SANDY W/ROCK FRAGMENTS |
| 36.0 | 1050.7 | GP | SANDY W/CLAYEY SILT |
| 51.0 | 1035.7 | SP | GRAVELLY W/SILT & SOME ROCK FRAGMENTS |
| 71.0 | 1015.7 | SP | GRAVELLY W/ROCK FRAGMENTS |
| 76.5 | 1010.2 | | WATER TABLE |
| 80.0 | 1006.7 | SP | GRAVELLY W/COBBLES |
| 97.0 | 989.7 | CL | SILTY W/ROCK FRAGMENTS & SOME COBBLES & BOULDERS |
| 111.0 | 975.7 | SP | MED. TO COARSE & SOME ROCK FRAGMENTS |
| 123.0 | 963.7 | GM | SANDY |
| 131.0 | 955.7 | SP | MED. TO COARSE |
| 138.5 | 948.2 | SP, GP, ML & CL | BLUE, FINE, SILTY - INTERBEDDED |
| 161.0 | 925.7 | SP, ML, CL, & CL | FINE, SILTY - BLUE, INTERBEDDED |
| 192.0 | 894.7 | | TOP OF ROCK |
| 200.0 | 886.7 | | ANDESITE |

BOTTOM OF HOLE

## CD-54

DRILLED 28 MARCH - 17 APRIL 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1098.1 | | BOULDERS, COBBLES & SMALLER ROCK FRAGMENTS W/ML, SANDY |
| 29.0 | 1069.1 | | ANDESITE BOULDER |
| 44.5 | 1053.6 | | CH - GRAY |
| 46.5 | 1051.6 | | ANDESITE BOULDER |
| 48.0 | 1050.1 | GM | SANDY, COMPACT |
| 55.0 | 1043.1 | SP | GRAY, MEDIUM TO FINE COMPACT |
| 60.5 | 1037.6 | GM | SANDY, COMPACT |
| 66.5 | 1031.6 | GM | SANDY W/COBBLES & ROCK FRAGMENTS |
| 101.0 | 997.1 | GW | W/COBBLES, SOME SAND & SILT, LOOSE |
| 107.0 | 991.1 | GW | SANDY, LOOSE |
| 111.5 | 986.6 | | SP-MEDIUM, GRAY |
| 114.0 | 984.1 | GM | SANDY, COMPACT |
| 119.0 | 979.1 | | INTERBEDDED SANDS, GRAVELS, SILTY GRAVELS & GRAVELLY SANDS W/OCCASIONAL ROCK FRAGMENTS |
| 190.0 | 908.1 | | TOP OF ROCK |
| 193.0 | 905.1 | | WEATHERED ANDESITE BRECCIA |
| 200.0 | 898.1 | | HARD ANDESITE BRECCIA |

BOTTOM OF HOLE

## D-56

DRILLED 1 - 6 SEPTEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1000.9 | | SAND AND GRAVEL |
| 7.0 | 993.9 | | TOP OF ROCK |
| | | 75%-95% | CLOSELY JOINTED ANDESITE |
| 14.5 | 986.4 | 20% | BADLY BROKEN ANDESITE |
| 15.5 | 985.4 | 100% | SOUND ANDESITE |
| 22.1 | 978.8 | 25% | |

BOTTOM OF HOLE

## D-57

DRILLED 8 - 12 SEPTEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1002.4 | | LARGE BOULDERS |
| 7.0 | 995.4 | GP | SANDY |
| 10.0 | 992.4 | | TOP OF ROCK |
| | | 55%-100% | |
| | | 30%-65% | CLOSELY JOINTED, |
| | | 80%-95% | BADLY BROKEN |
| 25.2 | 977.2 | 70%-75% | ANDESITE |

BOTTOM OF HOLE

## D-58

DRILLED 13 - 16 SEPTEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1004.5 | SP | W/BOULDERS |
| 3.0 | 1001.5 | | TOP OF ROCK |
| 6.3 | 998.0 | 50%-55% | SOFT ALTERED & BROKEN ROCK |
| 9.1 | 995.4 | 70%-100% | SOUND ANDESITE |
| 11.5 | 993.0 | | SOFT ALTERED ANDESITE |
| 14.0 | 990.5 | 100% | SOUND ANDESITE |
| 19.6 | 984.9 | 80%-90% | CLOSELY JOINTED ANDESITE |

BOTTOM OF HOLE

## D-59

DRILLED 21 SEPTEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1004.6 | SP | W/LARGE BOULDERS |
| 5.0 | 999.6 | | TOP OF ROCK |
| 7.3 | 997.3 | 90% | SOFT BROKEN ANDESITE |
| | | 70% | |
| | | 85% | SOUND ANDESITE |
| 21.1 | 983.5 | 100% | |

BOTTOM OF HOLE

## D-60

DRILLED 28 SEPTEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1010.1 | | SW - GRAVELLY |
| 1.0 | 1009.1 | | TOP OF ROCK |
| | | 40%-100% | WELL-JOINTED |
| | | 35%-70% | BROKEN ANDESITE |
| 20.5 | 989.5 | 20%-40% | |

BOTTOM OF HOLE

## D-61

DRILLED 26 - 27 OCTOBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1211.5 | GP | SANDY W/BOULDERS |
| 7.0 | 1204.5 | SW | GRAVELLY |
| 17.5 | 1194.0 | SM | COMPACT & GRAVELLY M=48.0% |
| 25.4 | 1186.1 | | MH - GRAVELLY |
| 26.1 | 1185.4 | SM | COMPACT & GRAVELLY |
| 35.8 | 1175.7 | | TOP OF ROCK |
| | | | WEATHERED ANDESITE |
| 42.6 | 1168.9 | 80%-90% | SOUND ANDESITE |
| 44.2 | 1167.3 | | BROKEN, HEAVILY-JOINTED ANDESITE |
| 50.1 | 1161.4 | 40% | |
| | | 100% | SOUND, HARD ANDESITE |
| 61.7 | 1150.3 | | |

BOTTOM OF HOLE

NOTES: 1. PERCENT OF CORE RECOVERY BELOW TOP OF ROCK IS SHOWN IN THE LOG COLUMN.
2. THE OVERBURDEN WAS DRILLED BY CONTINUOUS DRIVE SAMPLING WHERE POSSIBLE.
3. THE ROCK WAS CORED WITH A DIAMOND DRILL. UNDISTURBED SAMPLES WERE OBTAINED WHERE MOISTURE CONTENTS ARE SHOWN IN THE DRILL LOGS.
4. FIELD LOGS & SAMPLES ARE AVAILABLE FOR INSPECTION IN THE SEATTLE DISTRICT OFFICE, CORPS OF ENGINEERS, 4735 E. MARGINAL WAY, SEATTLE, WASHINGTON.
5. ABSENCE OF GROUND WATER DATA ON DRILL LOGS SHALL NOT BE CONSTRUED AS INDICATING THAT NO WATER WILL BE ENCOUNTERED IN CONSTRUCTION OPERATIONS.

EXHIBIT A2

GREEN RIVER, WASHINGTON
HOWARD A. HANSON DAM
# DRILL LOGS

Sheet of | Scale as shown
U.S. Army Engr. District, Seattle, Wash.
Des: RMW | Date:
Dwn: RMW | File No. E-56-6-61
Chk'd:

## D-62

DRILLED 1 - 5 NOVEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1226.3 | GM | W/ BROKEN ROCK |
| 5.0 | 1221.3 | SC | COMPACT & GRAVELLY w=11.5% |
| 13.0 / 15.0 | 1213.3 / 1211.3 | | CI (10'-15' SATURATED) |
| | | SM | GRAVELLY |
| 24.0 | 1202.3 | GP | W/ BROKEN ROCK |
| 36.0 | 1190.3 | | |
| 38.0 | 1188.3 | | SP-MEDIUM |
| 41.0 | 1185.3 | | SP-COARSE |
| 42.0 | 1184.3 | | TOP OF ROCK |
| 46.2 | 1180.1 | | BROKEN ANDESITE |
| | | 95% | SOUND ANDESITE |
| | | 95% | |
| 70.2 | 1156.1 | | |

BOTTOM OF HOLE

## D-64

DRILLED 11 - 13 JANUARY 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1227.5 | GM | SANDY W/ BROKEN ROCK |
| 5.0 | 1222.5 | | TOP OF ROCK |
| | | 100% | BROKEN, WEATHERED ROCK, ANDESITE BRECCIA |
| 23.6 | 1204.6 | | |
| | | 100% | LIGHT GRAYISH-BLUE ROCK |
| 38.9 | 1188.9 | | |

BOTTOM OF HOLE

## D-65

DRILLED 19 - 23 JANUARY 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1188.6 | GM | W/ BROKEN ROCK |
| 4.0 | 1180.6 | | WEATHERED ROCK W/ SM |
| 11.0 | 1177.6 | | TOP OF ROCK |
| | | 35% | ANDESITE BRECCIA W/ BROKEN ROCK |
| | | 45% | |
| 22.6 | 1166.0 | | |
| | | 100% | HARD ANDESITE |
| 32.0 | 1156.6 | | |
| | | 45% | GREENISH BRITTLE ROCK BADLY FRACTURED |
| 37.0 | 1151.6 | | |
| | | 75% | HARD ANDESITE |
| 46.0 | 1140.6 | | |

BOTTOM OF HOLE

## D-63

DRILLED 9 - 23 NOVEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1222.3 | SM-SC | GRAVELLY w=16.0% w=11.0% |
| 11.0 | 1211.3 | | |
| 17.0 | 1205.3 | SM | COMPACT & GRAVELLY |
| | | SM | BLUE, COMPACT, & GRAVELLY |
| 43.0 | 1179.3 | | |
| | | SM | YELLOW & GRAVELLY |
| 56.5 | 1165.8 | | TOP OF ROCK |
| | | | RED, SOFT, WEATHERED ANDESITE |
| 67.0 | 1155.3 | 40% | |
| 73.0 | 1149.3 | 40% | BROWN-GREEN ANDESITE SOFT BUT SOUND |

BOTTOM OF HOLE

## D-66

DRILLED 17 - 18 JANUARY 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1193.1 | GM | SANDY W/ BROKEN ROCK |
| 2.0 | 1191.1 | | TOP OF ROCK |
| 6.0 | 1187.1 | 60% | ANDESITE BRECCIA |
| 11.3 | 1181.8 | 100% | BROKEN ROCK, BRITTLE |
| | | 100% | GREENISH-BLUE, BRITTLE, HARD, ANDESITE |
| 43.5 | 1149.6 | | |

BOTTOM OF HOLE

## D-67

DRILLED 16 NOV. 57 - 4 DEC. 57

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.00 | 1182.4 | GM | OVERBURDEN (MANY BOULDERS) |
| | | | SANDY W/ BROKEN ROCK |
| 23.6 | 1158.8 | | TOP OF ROCK |
| 32.2 | 1150.2 | 15% | BASIC, PORPHYRITIC ANDESITE, BADLY BROKEN |
| 37.5 | 1144.9 | 70% | BASIC, ANDESITE HEAVILY JOINTED |
| | | 50% | BASIC ANDESITE MODERATELY JOINTED |
| 49.0 | 1133.4 | | |
| 52.5 | 1129.9 | 34% | BASIC ANDESITE |
| 57.1 | 1125.3 | 13% | ANDESITE, |
| | | 52% | HYPOTHERMALLY ALTERED TO CLAYEY SILT |
| 65.8 | 1116.6 | | ANDESITE, DENSE |
| | | 50% | FELSITE, DENSE, BLUE-GREEN |
| 84.2 | 1098.4 | | |

BOTTOM OF HOLE

## D-68

DRILLED 6 - 19 DEC. 1957

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1205.4 | GM | OVERBURDEN (GRAVEL, BOULDERS TO 10" DIA) |
| 24.9 | 1180.5 | | TOP OF ROCK |
| | | 70% | ANDESITE, BLUE-GREENISH GRAY, SOUND |
| 34.5 | 1170.9 | 26% | BRECCIA, BADLY BROKEN |
| 39.5 | 1165.9 | | |
| | | 90% | ANDESITE PORPHYRY SOUND |
| 51.2 | 1154.2 | 95% | ANDESITE BRECCIA PARTLY ALTERED TO CLAY |
| 59.0 | 1146.4 | 70% | BASALT, PORPHYRITIC PARTLY ALTERED TO CLAY |
| 62.6 | 1142.8 | | |
| | | 95% | BASALT, GRAY, PORPHYRITIC, SOUND, MEDIUM HARD, OCC. RECEMENTED BRECCIA MODERATELY JOINTED |
| 90.0 | 1115.4 | 100% | BASALT, GRAY, PORPHYRITIC, SOUND |
| 104.5 | 1100.9 | | |

BOTTOM OF HOLE

## D-69

DRILLED 23 DEC. 1957 - 8 JAN. 1958

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.00 | 1206.1 | GM | OVERBURDEN (GRAVEL, SILT & BOULDERS) |
| 10.5 | 1195.6 | | TOP OF ROCK |
| | | 85% | BASIC ANDESITE BADLY BROKEN |
| 20.0 | 1186.1 | | |
| 24.7 | | | ANDESITE, PORPHYRITIC MED. HARD |
| 25.1 | | 98% | ZONES ALTERED TO SOFT BROKEN ROCK AS INDICATED BY DIAG. LINES |
| 35.4 | | | |
| 37.4 | | | |
| 39.3 | | | |
| 41.3 | | | |
| 47.3 | 1158.8 | | |
| 52.0 | 1154.1 | 100% | ANDESITE BRECCIA |
| 56.0 | 1150.1 | 100% | BASALT PORPHYRY, HARD, MASSIVE |
| | | 100% | ANDESITE BRECCIA & PORPHYRITIC ANDESITE, MED. HARD, SOUND |
| 75.8 | 1130.3 | | |
| | | 100% | ANDESITE BRECCIA, PORPHYRITIC MED. HARD, SOUND |
| 98.5 | 1107.6 | | |

BOTTOM OF HOLE

## D-70

DRILLED 4 - 12 NOV. 1957

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1152.4 | GM | OVERBURDEN (TALUS & SILTY SAND) |
| 29.4 | 1123.0 | | TOP OF ROCK |
| | | 40% | ANDESITE, BLUE, MED. HARD |
| 35.0 | 1117.4 | | ANDESITE, MED. SOFT |
| 40.7 | 1111.7 | 50% | BADLY BROKEN |

BOTTOM OF HOLE

## D-71

DRILLED 4 - 5 NOV. 1957

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.00 | 1174.3 | GM | OVERBURDEN TALUS |
| 7.5 | 1166.8 | | TOP OF ROCK |
| 10.5 | 1163.8 | | ANDESITE, SOUND W/ ALTERED ZONE |
| 10.7 | 1163.6 | | |
| 17.6 | 1156.5 | 34% | ANDESITE, DENSE |
| | | 98% | ANDESITE BRECCIA |
| 37.6 | 1136.7 | | ANDESITE PORPHYRY, MEDIUM HARD |
| 39.3 | 1135.0 | 100% | |

BOTTOM OF HOLE

## D-72

DRILLED 25 - 30 OCT. 1957

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1192.7 | GP | W/ SAND & BROKEN ROCK |
| 9.9 | 1182.8 | | SAND & BROKEN ROCK |
| 15.1 | 1177.6 | | TOP OF ROCK BROKEN ANDESITE |
| 19.2 | 1173.5 | | |
| | | 95% | ANDESITE BRECCIA & PORPHYRY, MED. HARD, BLUE TO GREENISH GRAY, SOUND |
| 55.7 | 1137.0 | | |

BOTTOM OF HOLE

## D-73

DRILLED 10-20 JAN. 1958

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1128.1 | GM | OVERBURDEN, TALUS & SILTY SAND |
| 40.5 | 1087.5 | | TOP OF ROCK |
| | | 47% | ANDESITE MED. HARD |
| 48.5 | 1079.6 | 50% | ANDESITE PARTLY ALTERED TO CLAY |
| 50.0 | | 96% | ANDESITE MED. HARD |
| 54.9 | 1073.2 | 20% | ANDESITE BADLY BROKEN |
| 64.1 | 1164.0 | | |
| | | 90% | ANDESITE & ANDESITE PORPHYRY W/ VOLCANIC BRECCIA, MED. HARD, SOUND W/ BADLY BROKEN ZONES |
| 83.5 | 1044.6 | | |

BOTTOM OF HOLE

## D-74

DRILLED 21 - 29 JAN. 1958

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1123.6 | GM | OVERBURDEN, TALUS & SILTY SAND |
| 30.5 | 1093.1 | | TOP OF ROCK |
| | | 98% | ANDESITE PORPHYRY & ANDESITE BRECCIA, MEDIUM TO HARD |
| 83.0 | 1040.6 | | |
| | | 100% | PORPHYRITIC ANDESITE |
| 90.0 | | | |
| 95.5 | 1028.1 | 100% | RECEMENTED BRECCIA (IN PART) |
| | | 100% | |
| 107.2 | 1016.4 | | |
| 114.3 | 1009.3 | 100% | |

BOTTOM OF HOLE

## D-75

DRILLED 4 - 7 FEB. 1958

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1198.5 | GM | BOULDERS, GRAVEL & SILT |
| 28.5 | 1170.1 | | TOP OF ROCK WEATHERED ZONE |
| | | 95% | ANDESITE BRECCIA, BLUE-GRAY, MEDIUM TO HARD |
| 54.2 | 1144.4 | | |

BOTTOM OF HOLE

## GDD-26

DRILLED 4 - 10 JUNE 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1230.[illegible] | | ORGANIC |
| 2.6 | 1228.[illegible] | | ML - SANDY W/ ROCK FRAG. |
| 3.6 | 1227.[illegible] | | TOP OF ALTERED ROCK |
| 7.8 | 1222.8 | | w=25.5% ALTERED ANDESITE, PLASTIC, |
| 14.7 | 1215.9 | | w=16.5% SUITABLE FOR |
| 17.7 | 1212.9 | | w=27.5% FILL MATERIAL |
| 22.0 | 1208.[illegible] | | BRECCIA TOP OF ROCK |
| [illegible] | [illegible] | 95% | GOOD ANDESITE |

BOTTOM OF HOLE

## GDD-27

DRILLED 16 - 21 JUNE 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1298.0 | | BOULDERS & GP, COARSE |
| 2.0 | 1296.0 | GP | BROKEN ROCK & GRAVEL |
| 10.0 | 1288.0 | GM | BROKEN ROCK & SILT |
| 15.9 | 1282.1 | | |
| 19.0 | 1279.0 | | LOST DRILL, WATER |
| 25.5 | 1272.5 | GP | BROKEN ROCK, FINE GRAVEL & SP, COARSE |
| | | 70% | TOP OF ROCK |
| 30.5 | 1267.5 | 65% TO 90% | ANDESITE TO AGGLOMERATE, HARD ROCK BUT FRACTURED |
| 43.3 | 1254.7 | | |
| | | 100% | |
| | | 80% | |
| 67.4 | 1230.6 | TO 90% | |
| 73.1 | 1224.9 | | HARD ANDESITE |
| | | 100% | |
| 100.0 | 1198.0 | | |

BOTTOM OF HOLE

## W-1
## WELL

DRILLED 4 NOVEMBER-13 DECEMBER 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1093.1 | GM | ANGULAR COBBLES & BOULDERS OF GREEN BRECCIA IN A SANDY SILT MATRIX |
| 35.0 | 1058.1 | | |
| 40.0 | 1053.1 | CL | BROWN-BLUE, SANDY |
| | | CL | COMPACT, SANDY W/ ROCK FRAGS. TO ½" & PEBBLES |
| 50.5 | 1042.6 | GC | SUBROUNDED GRAVEL IN SILTY CLAY MATRIX |
| 53.0 | 1040.1 | | |
| | | SP-SM | COMPACT, GRAVELLY w=16.5% |
| | | | GROUND WATER @ 71.5' |
| 82.0 | 1011.1 | GW-SM | GRAVELLY w=11.4% |
| 84.0 | 1009.1 | | GW-SANDY |
| 86.0 | 1007.1 | SW | GRAVELLY |
| 91.0 | 1002.1 | | GP-GM |
| 91.5 | 1001.6 | | ML SANDY w=73% |
| 92.0 | 1000.1 | GC | SANDY & SILTY W/ INTERBEDDED CL |
| 103.7 | 989.4 | | w=21.4% |
| | | ML | SANDY |
| 111.0 | 982.1 | | w=13.6% |
| | | SC | GRAVELLY W/ BLUE-BROWN SILTY CLAY w=14.0% |
| 122.6 | 970.5 | | WEATHERED ROCK |
| 131.6 | 961.5 | | CH SANDY w=13.4 |
| 132.2 | 960.9 | | CL SANDY w=12.4 |
| 132.6 | 960.5 | | ALTERED ANDESITE TOP OF ROCK |
| 136.0 | 957.1 | | FRESH ANDESITE |
| 142.0 | 951.1 | | |

BOTTOM OF HOLE

## O-2
## OBSERVATION WELL

DRILLED 8 - 17 FEBRUARY 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1093.9 | GC | BOULDERS, COBBLES W/ SOME ROCK FRAGS. & SOME SAND, SILT & SILTY CLAY |
| 14.0 | 1079.9 | GC | COBBLES IN SILTY, CLAYEY MATRIX |
| 42.0 | 1051.9 | | |
| 48.0 | 1045.9 | CL | SILTY W/ SOME COBBLES |
| 53.0 | 1040.9 | GM | CLAYEY |
| | | GP | W/ SOME SAND & SILT |
| 60.0 | 1033.9 | | |
| | | GP | SANDY W/ SOME SILT |
| 95.0 | 998.9 | | |
| 100.0 | 993.9 | GM | SANDY |

BOTTOM OF HOLE

## O-5
## OBSERVATION WELL

DRILLED 14 - 26 JANUARY 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 / 2.0 / 6.0 | 1090.6 / 1088.6 / 1084.6 | GC | BLDRS & COBBLES W/ SC SILTY, CLAYEY SAND |
| | | | BLDRS & COBBLES W/ SOME SILTY SAND |
| | | GC | BLDRS, COBBLES & SMALL FRAGS. W/ SOME SANDY, SILTY CLAY |
| 20.0 | 1070.6 | GC | BLDRS & COBBLES W/ SOME SAND, SILT & CLAY |
| 33.0 | 1057.6 | CH | CH - W/ ROCK FRAGS, BLUE-GREEN W/ SAND, SILT & SOME PEBBLES |
| 35.0 | 1055.6 | | |
| 40.0 | 1050.6 | CH | |
| 43.0 | 1047.6 | CH | BLUE-GREEN |
| 46.0 | 1044.6 | SC | GRAVELLY W/ FEW COBBLES |
| | | GW & SW | W/ COBBLES & SOME SANDY SILT |
| 76.0 | 1014.6 | | |
| | | GP & SP | W/ SOME SILT |
| 100.5 | 989.9 | | |

BOTTOM OF HOLE

## O-6
## OBSERVATION WELL

DRILLED 15 DEC. 1955-13 JAN. 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1087.6 | GM | ANGULAR COBBLES, BOULDERS & FRAGS. W/ SOME SANDY SILT |
| 20.0 | 1067.6 | | |
| 27.0 | 1060.6 | GC | SAME AS ABOVE W/ CLAY INCREASING W/ DEPTH w=26.8 |
| | | CL | BLUE w=27.9 |
| 40.0 | 1047.6 | ML | w=26.3 |
| 43.0 | 1044.6 | CH | BLUE & SILTY W/ OCCASIONAL COBBLE TO 5" DIA. |
| 45.0 | 1042.6 | GM | GC-SANDY COMPACT & COARSE |
| 56.0 | 1031.6 | SW | COARSE & GRAVELLY |
| 64.0 | 1023.6 | | |
| | | GW | SANDY W/ MINOR INTERBEDDED SILTS AND CLAYS |
| 100.0 | 987.6 | | |

BOTTOM OF HOLE

## Q-1
## QUARRY HOLE

DRILLED 20 MARCH-2 APRIL 1956

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1192.0 | SM | |
| 6.0 | 1186.0 | GP | COARSE |
| 26.0 | 1166.0 | | TOP OF ROCK |
| | | 85% | |
| | | | HARD ANDESITE BRECCIA WITH FEW SOFT ZONES |
| | | 100% | |
| 99.0 | 1093.0 | | |

BOTTOM OF HOLE

## TP-1

DUG 1 MAY - 4 NOVEMBER 1953

| DEPTH | ELEV. | LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1175.0 | | BROKEN AGGLOMERATIC ANDESITE WITH INTERSTITIAL SILTY SAND |
| 19.0 | 1156.0 | | CLAYEY BROKEN AGGLOMERATIC ANDESITE |
| 46.0 | 1129.0 | | |
| 52.0 | 1123.0 | SM | VERY COMPACT |
| 56.0 | 1119.0 | SP | |
| 72.4 | 1102.6 | | TOP OF ROCK |
| 79.0 | 1096.0 | | ANDESITE |
| 86.0 | 1089.0 | | |

BOTTOM OF PIT

EAST SIDE OF PIT — WEST SIDE OF PIT

## TP-3

DUG 29 APRIL-12 MAY 1954

| DEPTH | ELEV. | LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1169.6 | | BROKEN AGGLOMERATIC ANDESITE FRAGMENTS W/ SILT & SILTY SAND. POCKETS OF CLEAN SAND AT ABOUT 8' DEPTH. |
| 30.0 | 1139.6 | | |

BOTTOM OF PIT

## TP-4

DUG 4 OCTOBER - 1 NOVEMBER 1955

| DEPTH | ELEV. | LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1212.4 | SM | |
| 6.0 | 1206.4 | SP | WATER TABLE FINE |
| 14.0 | 1198.4 | CH&ML | COARSE, SANDY, BLUE SANDY |
| 18.0 | 1194.4 | GM | BOULDER |
| 22.0 | 1190.4 | | SM - GRAVELLY |
| 25.0 | 1187.4 | | |
| 26.0 | 1186.4 | | |

BOTTOM OF PIT

## TP-2

DUG 25 MARCH - 16 APRIL 1954

| DEPTH | ELEV. | LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1135.9 | | BROKEN AGGLOMERATIC ANDESITE, FRAGMENTS TO BOULDERS, W/ SILT & SILTY SAND. SOME THIN LENSES OF CLEAN SAND AT ABOUT 30' DEPTH |
| 42.0 | 1093.9 | | |

BOTTOM OF PIT

## GDD-28

DRILLED 23 - 30 JUNE 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1248.2 | SM | W/ ROCK FRAGMENTS |
| 3.0 | 1245.2 | | |
| | | GM | BROKEN ROCK W/ SM & OL |
| 19.0 | | | w=15.3% |
| 26.8 | | | w=6.1% |
| 29.0 | 1219.2 | | TOP OF ROCK |
| 33.6 | 1214.6 | | |
| | | 90% TO 95% | HARD ANDESITE |
| 56.9 | 1191.1 | | |
| 61.3 | 1186.9 | 100% | |

BOTTOM OF HOLE

## GDD-32

DRILLED 19 - 22 AUGUST 1955

| DEPTH | ELEV. | DRILL LOG | CLASSIFICATION |
|---|---|---|---|
| 0.0 | 1296.3 | ML | SANDY, GRAVELLY |
| 3.6 | 1290.7 | | ML-GRAVELLY |
| 5.0 | 1289.3 | | GM |
| 6.0 | 1288.3 | GM | GP-COARSE W/ SOME BOULDERS |
| 8.0 | 1286.3 | | |
| 15.0 | 1279.3 | | SM FINE GRAVELLY |
| 16.0 | 1278.3 | SM | GRAVELLY |
| 30.0 | 1264.3 | | |

BOTTOM OF HOLE

## LEGEND

- GW - WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
- GP - POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
- GM - SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
- GC - CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
- SW - WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
- SP - POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
- SM - SILTY SANDS, SAND-SILT MIXTURES
- SC - CLAYEY SANDS, SAND-CLAY MIXTURES
- ML - INORGANIC SILTS & VERY FINE SANDS
- CL - INORGANIC CLAYS OF LOW TO MED. PLASTICITY, LEAN CLAYS
- OL - ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
- CH - INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
- w - MOISTURE CONTENT

## A-1
## ADIT

DUG 29 JULY - 21 SEPT. 1955

EL. 1200.8

## A-2
## ADIT

DUG 4 NOV. 1955 - 5 JAN. 1956

EL. 1157.7

MATERIAL IN ADITS CONSISTS OF FRAGMENTS TO 6 FT. BLOCKS OF HARD, GRAY-BLUE TO GREEN ANDESITE & BRECCIA. MOST PIECES FIT TOGETHER SO THAT THE MATERIAL RESEMBLES A FRACTURED, HEAVILY-JOINTED ROCK. "JOINTS" VARY IN WIDTH FROM 1/32" TO 2" WITH SOME VOIDS TO 6" WHERE BLOCKS DO NOT FIT TOGETHER WELL. OTHER "JOINTS" ARE FILLED WITH MIXTURES OF SAND, SILT & CLAY. THERE ARE ALSO ZONES TO 2 FT. WIDE WHICH ARE COMPOSED OF A HETROGENEOUS MIXTURE OF FRAGMENTS, WELL-GRADED FROM SAND SIZE UPWARD.

LEGEND

- ANDESITE BLOCKS
- ROCK FRAGMENTS

NOTES.

1. PERCENT OF CORE RECOVERY BELOW TOP OF ROCK IS SHOWN IN THE 3RD COLUMN.
2. THE OVERBURDEN WAS DRILLED BY CONTINUOUS DRIVE SAMPLING WHERE POSSIBLE.
3. THE ROCK WAS CORED WITH A DIAMOND DRILL. UNDISTURBED SAMPLES WERE OBTAINED WHERE MOISTURE CONTENTS ARE SHOWN IN THE DRILL LOGS.
4. FIELD LOGS & SAMPLES ARE AVAILABLE FOR INSPECTION IN THE SEATTLE DISTRICT OFFICE, CORPS OF ENGINEERS, 1519 S. ALASKAN WAY, SEATTLE, WASHINGTON.
5. ABSENCE OF GROUND WATER DATA ON DRILL LOGS SHALL NOT BE CONSTRUED AS INDICATING THAT NO WATER WILL BE ENCOUNTERED IN CONSTRUCTION EXCAVATIONS.

EXHIBIT A3

GREEN. RIVER, WASHINGTON
HOWARD A. HANSON DAM
# DRILL LOGS

| Sheet of | Scale as shown |
|---|---|
| U.S. Army Engr. District, Seattle, Wash. | |
| Des: RMW Dwn: RMW Chk'd: | Date: File No. E-56-6-61 |

# EXHIBIT B

## WATER PRESSURE TESTING DATA

# REPORT OF WATER PRESSURE TESTING

Project HHD FISH PASSAGE STUDY

Hole No. 94-DD-80
Location
Coordinates N 102,291.016
E 4,763,737.800

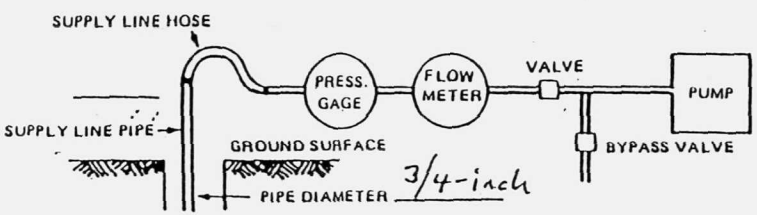
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size 4-inch
Static Water Level (1) 11 ft (bgs) 1153.8'

Surface Elevation 1164.767
Bedrock Elevation 1156.4
Meter Type

Date 4/ /94
Inspector Anna Campbell
Sheet 1 of 2

| Test No. | Test Interval ft m(2) Top | Btm | Lng | Packer P.S.I. | Water Meter cfm gal liters Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 5 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) Ft | Casing Depth Ft | Supply Line Press. (4) | Rate of Flow G.P.M. (5) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 12.5 | 25.1 | 12.6 | 375 | 208992 | 209093 | 101 | 1140 | 1155 | 15 | 40 | 21 | 19 | 18 | 14 | 10 | 7 | 13 | 8.4 | | 6.7 | | | Pump 15 gpm |
| 1b | 12.5 | 25.1 | 12.6 | 375 | 209111 | 209155 | 44 | 1205 | 1220 | 15 | 20 | 13 | 12 | 10 | 9 | 6 | 4 | 13 | 8.4 | | 3 | | | " 15 " |
| 2a | 24 | 38.2 | 14.2 | 375 | 209168 | 209400 | 232 | 1400 | 1415 | 15 | 40 | 17 | 17 | 13 | 11 | 9 | 4 | 24.5 | 8.4 | | 15.5 | | | " 24.5 " |
| 2b | 24 | 38.2 | 14.2 | 375 | 209732 | 209896 | 164 | 1434 | 1441.5 | 7 1/2 | 80 | 20 | 19 | 17 | 10 | 9 | 7 | 24.5 | 8.4 | | 21.9 | | | " 24.5 " |
| 3a | 36.5 | 51.6 | 15.1 | 375 | 209913 | 210034 | 121 | 1630 | 1645 | 15 | 40 | 22 | 19 | 19 | 18 | 12 | 8 | 37 | 8.4 | | 8.1 | | | " 25.2 " |
| 3b | 36.5 | 51.6 | 15.1 | 375 | 210056 | 210126 | 70 | 1650 | 1705 | 15 | 80 | 39 | 30 | 22 | 19 | 9 | 4 | 37 | 8.4 | | 4.7 | | | " 24.3 " |
| 4a | 50 | 64.4 | 14.4 | 325 | 210100 | 210195 | 95 | 0835 | 0850 | 15 | 40 | 21 | 19 | 17 | 14 | 9 | 4 | 50.5 | 8.4 | | 6.3 | | | " 13.2 " |
| 4b | 50 | 64.4 | 14.4 | 325 | 210270 | 210390 | 120 | 0857 | 0912 | 15 | 80 | 58 | 50 | 48 | 44 | 39 | 33 | 50.5 | 8.4 | | 8 | | | " 13.1 " |
| 5a | 63.5 | 76.6 | 13.1 | 325 | 210425 | 210482 | 57 | 1140 | 1155 | 15 | 40 | 20 | 18 | 13 | 9 | 7 | 4 | 64 | 8.4 | | 3.2 | | | " 14.4 " |
| 5b | 63.5 | 76.6 | 13.1 | 320 | 210560 | 210700 | 140 | 1200 | 1215 | 15 | 80 | 47 | 36 | 28 | 19 | 16 | 13 | 64 | 8.4 | | 9.7 | | | " 14.4 " |
| 6a | 75 | 89.5 | 14.5 | 325 | 210711 | 210718 | 7 | 1355 | 1410 | 15 | 40 | 29 | 24 | 21 | 17 | 11 | 8 | 90 | 8.4 | | 0.5 | | | " 15.2 " |
| 6b | 75 | 89.5 | 14.5 | 325 | 210719 | 210741 | 22 | 1420 | 1435 | 15 | 80 | 25 | 19 | 15 | 9 | 3 | 0 | 90 | 8.4 | | 1.5 | | | " 15.5 " |
| 7a | 87.5 | 103.1 | 15.6 | 350 | 210746 | 210746 | 0 | 1610 | 1625 | 15 | 40 | 40 | 39 | 37 | 30 | 24 | 20 | 88 | 8.4 | | 0 | | | " 15.6 " |
| 7b | 87.5 | 103.1 | 15.6 | 350 | 210747 | 210747 | 0 | 1635 | 1650 | 15 | 80 | 49 | 43 | 41 | 38 | 29 | 21 | 88 | 8.4 | | 0 | | | " 15.6 " |
| 8a | 102.5 | 117 | 14.5 | 300 | 210751 | 210751 | 0 | 0845 | 0900 | 15 | 40 | 31 | 27 | 24 | 21 | 18 | 15 | 103 | 8.4 | | 0 | | | |
| 8b | 102.5 | 117 | 14.5 | 300 | 210751 | 210751 | 0 | 0915 | 0930 | 15 | 80 | 40 | 37 | 34 | 29 | 22 | 19 | 103 | 8.4 | | 0 | | | |
| 9a | 116.5 | 130.8 | 14.3 | 300 | 210754 | 210754 | 0 | 1030 | 1045 | 15 | 40 | 27 | 24 | 22 | 21 | 21 | 21 | 103 | 8.4 | | 0 | | | |

TYPICAL EQUIPMENT SKETCH




NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m. increments to 30 g.p.m. on back of this form. Repeat each time the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = $ft^3$ × 7.48 = liter × 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level × (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. − Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

B-1

# REPORT OF WATER PRESSURE TESTING

Project HHD Fish Passage Study

Hole No. 94-DD-80
Location
Coordinates N 102,291.016
E 4,763,737.800

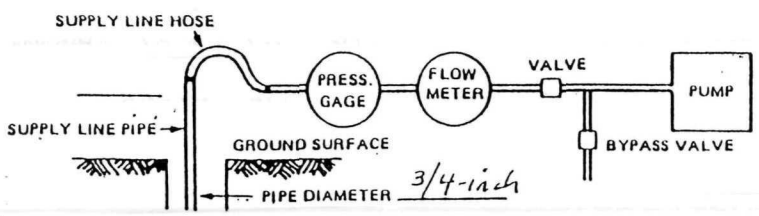
Angle (from Horiz.) 90° (Vertical)
Bearing
Casing Size 4-inch
Static Water Level (1) 11-feet bgs

Surface Elevation 1164.767
Bedrock Elevation 1156.4
Meter Type

Date 4/ /94
Inspector Anna Campbell
Sheet 2 of 2

| Test No. | Test Interval ft m(2) Top | Btm | Lng | Packer P.S.I. | Water Meter cfm gal liters Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 5 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) | Casing Depth | Supply Line Press. (4) | Rate of Flow G.P.M. (6) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9b | 116.5 | 130.8 | 14.3 | 300 | 210754 | 210754 | 0 | 1100 | 1115 | 15 | 80 | 43 | 38 | 35 | 21 | 21 | 21 | 117 | 8.4 | | 0 | | | |
| 10a | 127.5 | 144.4 | 16.9 | 300 | 210757 | 210757 | 0 | 1217 | 1222 | 15 | 40 | 35 | 31 | 31 | 31 | 30 | 30 | 128 | 8.4 | | 0 | | | |
| 10b | 127.5 | 144.4 | 16.9 | 300 | 210760 | 210760 | 0 | 1228 | 1233 | 15 | 80 | 70 | 67 | 63 | 60 | 57 | 50 | 128 | 8.4 | | 0 | | | |
| 11a | 143.5 | 157.9 | 14.4 | 300 | 210790 | 210811 | 21 | 1430 | 1445 | 15 | 40 | 31 | 30 | 30 | 29 | 28 | 26 | 144 | 8.4 | | 1.4 | | | |
| 11b | 143.5 | 157.9 | 14.4 | 300 | 210857 | 210936 | 79 | 1457 | 1512 | 15 | 80 | 75 | 75 | 75 | 70 | 67 | 60 | 144 | 8.4 | | 5.3 | | | |
| 12a | 156 | 165 | 9 | 300 | 210967 | 210991 | 24 | 0710 | 0725 | 15 | 40 | 26 | 22 | 21 | 21 | 20 | 18 | 156.5 | 8.4 | | 1.6 | | | Fluctuating gage 20-60psi range |
| 12b | 156 | 165 | 9 | 300 | 211051 | 211136 | 85 | 0735 | 0750 | 15 | 80 | 70 | 68 | 68 | 63 | 59 | 51 | 156.5 | 8.4 | | 5.7 | | | |

TYPICAL EQUIPMENT SKETCH




NOTES

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NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

BYP

# REPORT OF WATER PRESSURE TESTING

Project HHD Fish Passage Study

Hole No. 94-DD-81
Location LEFT ABUTMENT
Coordinates N 102 503.562
E 1,763,228.777

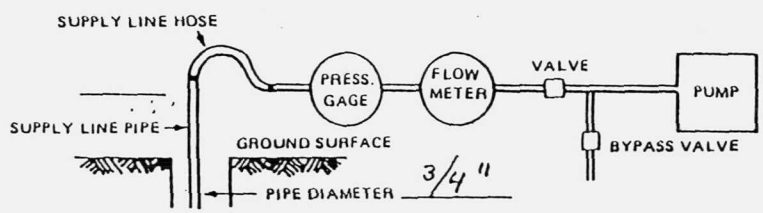
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size 4-inch ID
Static Water Level (1) 30.6 1189.7

Surface Elevation 1220.3 FT
Bedrock Elevation 1197.3 FT
Meter Type

Date 22 Apr 94
Inspector Anna Campbell
Sheet 1 of 1

| Test No. | Test Interval ft m(2) Top | Btm | Lng | Packer P.S.I. | Water Meter cfm gal liters Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 6 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) * | Casing Depth FT | Supply Line Press. (4) | Rate of Flow G.P.M. (5) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 129.5 | 143.6 | 14.1 | 325 | 211174 | 211174 | 0 | 1220 | 1235 | 15 | 40 | 39 | 32 | 30 | 29 | 29 | 29 | 130 | 23 | | 0 | 56 | | 16.6 Pump GPM |
| 1b | 129.5 | 143.6 | 14.1 | 325 | 211175 | 211175 | 0 | 1245 | 1300 | 15 | 80 | 77 | 77 | 74 | 70 | 66 | 61 | 130 | 23 | | 0 | 56 | | 16.3 Pump GPM |
| 2a | 143.0 | 156.2 | 13.2 | 325 | 211400 | 211695 | 295 | 1430 | 1445 | 15 | 40 | 0 | | | | | | 143.5 | 23 | | 19.7 | 62 | | Test terminated at 13.5 min because |
| 2b | 143.0 | 156.2 | 13.2 | 325 | 211875 | 212250 | 375 | 1455 | 1508.5 | 13.5 | 80 | 0 | | | | | | 143.5 | 23 | | 27.8 | 62 | | pump can't meet demand |
| 3a | 155.5 | 170.1 | 14.6 | 325 | 212420 | 212683 | 263 | 1655 | 1710 | 15 | 40 | 0 | | | | | | 156 | 23 | | 17.5 | 67 | | |
| 3b | 155.5 | 170.1 | 14.6 | 325 | 213300 | 213760 | 460 | 0715 | 0730 | 15 | 80 | 0 | | | | | | 156 | 23 | | 30.7 | 67 | | |
| 4a | 169.5 | 178.8 | 9.3 | 325 | 213925 | 214200 | 275 | 0855 | 0910 | 15 | 40 | 0 | | | | | | 170 | 23 | | 18.3 | 73 | | |
| 4b | 169.5 | 178.8 | 9.3 | 325 | 214365 | 214750 | 385 | 0920 | 0935 | 15 | 80 | 17 | 10 | 8 | 6 | 0 | | 170 | 23 | | 25.7 | 73 | | |
| 5a | 177.5 | 190 | 12.5 | 325 | 214781 | 214800 | 19 | 1040 | 1055 | 15 | 40 | 36 | 31 | 30 | 26 | 21 | 19 | 178 | 23 | | 1.3 | 77 | | |
| 5b | 177.5 | 190 | 12.5 | 325 | 214855 | 215048 | 193 | 1110 | 1125 | 15 | 80 | 40 | 39 | 36 | 31 | 21 | 13 | 178 | 23 | | 12.9 | 77 | | |
| | | | | | | | | | | | | | | | | | | | | | | | | * Estimated 4/28/94 |

TYPICAL EQUIPMENT SKETCH




NOTES

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(2) Test each interval at two different gage pressures.

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(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = $ft^3$ ÷ 7.48 = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110 1-1801)
JUNE 1981

A-3

# REPORT OF WATER PRESSURE TESTING

Project HHD FISH PASSAGE STUDY

Hole No. 94-DD-82
Location
Coordinates N 103055.429
E 1,763,015.934

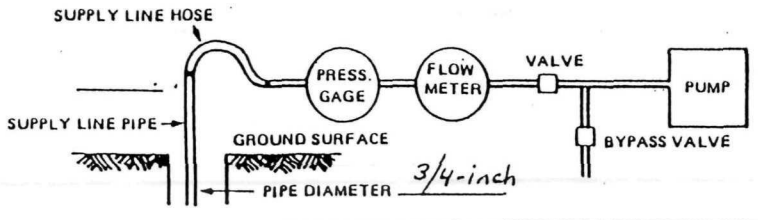
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size 4"
Static Water Level (1) 35.6 1170.8'

Surface Elevation 1206.396
Bedrock Elevation 1202.2
Meter Type

Date 4/19/94
Inspector Anna Campbell
Sheet 1 of 1

| Test No. | Test Interval X ft ___m(2) Top | Btm | Lng | Packer P.S.I. | Water Meter ___cfm X gal ___liters Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 6 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) | Casing Depth | Supply Line Press. (4) | Rate of Flow G.P.M. (5) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 140 | 153.5 | 13.5 | 270 | 211135 | 211135 | 0 | 1600 | 1615 | 15 | 40 | 38 | 34 | 34 | 32 | 29 | 26 | 154 | 4 | | 0 | | | Pump 15 gpm |
| 1b | 140 | 153.5 | 13.5 | 270 | 211135 | 211135 | 0 | 1625 | 1640 | 15 | 80 | 63 | 61 | 60 | 58 | 53 | 46 | 154 | 4 | | 0 | | | " 15 " |
| 2a | 152 | 166.1 | 14.1 | 300 | 211144 | 211144 | 0 | 0735 | 0810 | 15 | 40 | 32 | 32 | 30 | 27 | 22 | 18 | 162.5 | 4 | | 0 | | | " 14.3 " |
| 2b | 152 | 166.1 | 14.1 | 300 | 211144 | 211144 | 0 | 0820 | 0835 | 15 | 80 | 48 | 42 | 38 | 34 | 27 | 18 | 152.5 | 4 | | 0 | | | " 14.3 " |
| 3a | 165.5 | 179.4 | 13.9 | 300 | 211149 | 211149 | 0 | 1010 | 1025 | 15 | 40 | 38 | 38 | 37 | 34 | 31 | 23 | 166 | 4 | | 0 | | | " 14.3 " |
| 3b | 165.5 | 179.4 | 13.9 | 300 | 211149 | 211149 | 0 | 1035 | 1050 | 15 | 80 | 40 | 38 | 34 | 31 | 30 | 26 | 166 | 4 | | 0 | | | " 11.0 " |
| 4a | 177.5 | 192.5 | 15.0 | 300 | 211155 | 211155 | 0 | 1220 | 1235 | 15 | 40 | 34 | 32 | 32 | 30 | 30 | 30 | 178 | 4 | | 0 | | | " 13.7 " |
| 4b | 177.5 | 192.5 | 15.0 | 300 | 211155 | 211155 | 0 | 1245 | 1300 | 15 | 80 | 64 | 62 | 62 | 61 | 61 | 59 | 178 | 4 | | 0 | | | " 13.5 " |
| 5a | 188.5 | 202.4 | 13.9 | 300 | 211160 | 211160 | 0 | 1415 | 1430 | 15 | 40 | 30 | 28 | 25 | 23 | 22 | 22 | 189 | 4 | | 0 | | | " 13.5 " |
| 5b | 188.5 | 202.4 | 13.9 | 300 | 211160 | 211160 | 0 | 1440 | 1455 | 15 | 80 | 59 | 59 | 59 | 55 | 52 | 49 | 189 | 4 | | 0 | | | " 17.3 " |
| 6a | 197.5 | 210 | 12.5 | 275 | 211166 | 211166 | 0 | 1610 | 1625 | 15 | 40 | 24 | 22 | 21 | 20 | 19 | 18 | 198 | 4 | | 0 | | | " 14.0 " |
| 6b | 197.5 | 210 | 12.5 | 275 | 211167 | 211167 | 0 | 1640 | 1655 | 15 | 80 | 40 | 39 | 38 | 37 | 37 | 30 | 198 | 4 | | 0 | | | " 13.8 " |

TYPICAL EQUIPMENT SKETCH




NOTES

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(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m. increments to 30 g.p.m. on back of this form. Repeat each time

(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = $ft^3$ ÷ 7.48 = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

Bx-L

# REPORT OF WATER PRESSURE TESTING

Project HHD FISH PASSAGE STUDY

Hole No. 94-DD-83
Location SPILLWAY
Coordinates N 109,494.837
E 1,763,093.729

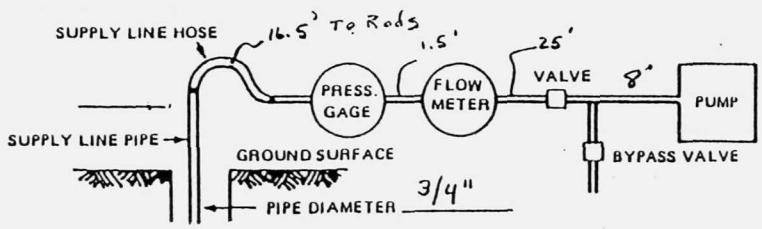
Angle (from Horiz.) 70°
Bearing Due West
Casing Size 4-inch
Static Water Level (1) 56.8' downhole = 53' vertical EL 1051.8'

Surface Elevation 1104.810
Bedrock Elevation 1104.810
Meter Type

Date 3/31/94
Inspector Anna Campbell
Sheet 1 of 1

| Test No. | Test Interval X ft m(2) Angle Depth Top | Btm | Lng | Packer P.S.I. | Water Meter X cfm gal liters Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 5 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) Ft | Casing Depth Ft | Supply Line Press. (4) | Rate of Flow G.P.M. (5) | Column P.S.I. (6) | Net Pres. P.S.I. (7) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 120 | 133.7 | 13.7 | 225 | 19 | 64 | 45 | 1403 | 1418 | 15 | 40 | 40 | 40 | 40 | 39 | 38 | 25 | 51 | 3.5 | | 3 | 23 | | Pump 16 gpm |
| 1b | 120 | 133.7 | 13.7 | 225 | 46 | 231 | 185 | 1422 | 1437 | 15 | 80 | 60 | 50 | 45 | 40 | 30 | 30 | 51 | 3.5 | | 12.5 | 23 | | " 15 " |
| 2a | 133 | 147.5 | 14.5 | 275 | 60 | 64 | 4 | 1640 | 1649 | 9 | 40 | 30 | 20 | 18 | 5 | 0 | 0 | 51 | 3.5 | | 0.4 | 23 | | " 16 " |
| 2b | 133 | 147.5 | 14.5 | 275 | 89 | 102.5 | 13.5 | 0720 | 0735 | 15 | 80 | 50 | 40 | 38 | 20 | 0 | 0 | 51 | 3.5 | | 0.9 | 23 | | " 13 " |
| 3a | 146 | 160.5 | 14.5 | 275 | 41 | 96 | 55 | 0935 | 0950 | 15 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 51 | 3.5 | | 3.7 | 23 | | " 13 " |
| 3b | 146 | 160.5 | 14.5 | 275 | 49 | 181 | 132 | 0955 | 1010 | 15 | 80 | 60 | 30 | 20 | 15 | 0 | 0 | 51 | 3.5 | | 8.8 | 23 | | " 13 " |
| 4a | 160 | 173.3 | 13.3 | 300 | 55 | 184 | 129 | 1230 | 1245 | 15 | 40 | 25 | 18 | 18 | 15 | 10 | 10 | 51 | 3.5 | | 8.6 | 23 | | " 16 " |
| 4b | 160 | 173.3 | 13.3 | 300 | 43.5 | 183 | 139.5 | 1250 | 1305 | 15 | 80 | 75 | 60 | 40 | 37 | 37 | 32 | 51 | 3.5 | | 9.3 | 23 | | " 16 " |
| 5a | 173 | 187.6 | 14.6 | 325 | 21 | 50 | 29 | 1530 | 1545 | 15 | 40 | 20 | 18 | 15 | 10 | 5 | 0 | 51 | 3.5 | | 2 | 23 | | " 13 " |
| 5b | 173 | 187.6 | 14.6 | 325 | 69 | 111 | 42 | 1550 | 1605 | 15 | 80 | 65 | 60 | 56 | 42 | 20 | 12 | 51 | 3.5 | | 3 | 23 | | " 13 " |
| 6a | 187 | 200.9 | 13.9 | 275 | 79 | 152.5 | 73.5 | 0850 | 0905 | 15 | 40 | 30 | 25 | 22 | 22 | 19 | 14 | 51 | 3.5 | | 5 | 23 | | " 13 " |
| 6b | 187 | 200.9 | 13.9 | 275 | 97 | 270 | 173 | 0915 | 0930 | 15 | 80 | 58 | 52 | 52 | 48 | 42 | 34 | 51 | 3.5 | | 11.5 | 23 | | " 11 " |
| 7a | 200 | 210.5 | 10.5 | 275 | 77 | 142.5 | 65.5 | 1114 | 1124 | 10 | 40 | 22 | 21 | 19 | 17 | 10 | 0 | 51 | 3.5 | | 6.5 | 23 | | " 16 " |
| 7b | 200 | 210.5 | 10.5 | 275 | 4 | 80.5 | 76.5 | 1129 | 1139 | 10 | 80 | 60 | 42 | 30 | 27 | 22 | 18 | 51 | 3.5 | | 5 | 23 | | " 16 " |
| 8a | 207 | 220 | 13 | 325 | 89.5 | 89.5 | 0 | 1347 | 1352 | 5 | 40 | 27 | 21 | 20 | 18 | 12 | 7 | 51 | 3.5 | | 0 | 23 | | " 13 " |
| 8b | 207 | 220 | 13 | 325 | 90 | 90.5 | 0.5 | 1358 | 1403 | 5 | 80 | 63 | 39 | 31 | 21 | 18 | 9 | 51 | 3.5 | | 0.1 | 23 | | " 13 " |

TYPICAL EQUIPMENT SKETCH




NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in Sg. p.m. increments to 30 g.p.m. on back of this form. Repeat each time

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(5) Gallon = $ft^3$ ÷ 7.48 = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110-1-1801)

# REPORT OF WATER PRESSURE TESTING

Project HHD Fish Passage Study

Hole No. 94-DD-84
Location
Coordinates N 103,792.632
E 1,763,150.124

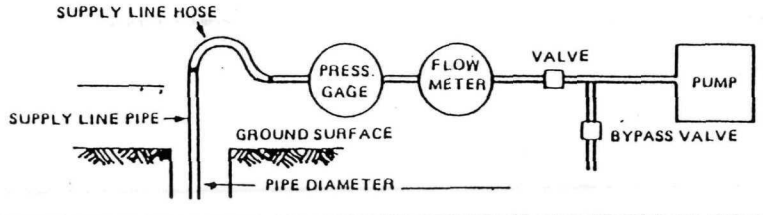
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size
Static Water Level (1) 9' bgs; 12' below gage

Surface Elevation 1035.044
Bedrock Elevation 1035.044
Meter Type
EL 1026

Date 4/3/94
Inspector Anna Campbell
Sheet 1 of 1

| Test No. | Test Interval ft m(2) Top | Btm | Lng | Packer P.S.I. | Water Meter (cfm / X gal / liters) Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 5 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) | Casing Depth | Supply Line Press. (4) | Rate of Flow G.P.M. (5) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 6.5 | 24.8 | 18.3 | 200 | 203885 | 203954 | 69 | 1515 | 1530 | 15 | 40 | 19 | 18 | 13 | 11 | 10 | 8 | 7.0 | | | 4.6 | 1.6 | | Pump 9.5 gpm |
| 1b | 6.5 | 24.8 | 18.3 | 200 | 204066 | 204066 | 0 | 1543 | 1558 | 15 | 20 | 18 | 12 | 9 | 6 | 4 | 0 | 7.0 | | | 0 | 1.6 | | Pump 16.0 gpm |
| 2a | 24 | 39.1 | 15.1 | 200 | 204172 | 204277 | 105 | 0718 | 0733 | 15 | 40 | 8 | 3 | 1 | 0 | | | 24.5 | | | 7 | 5.2 | | Pump 13 " |
| 2b | 24 | 39.1 | 15.1 | 200 | 204305 | 204412 | 91.5 | 0740 | 0755 | 15 | 20 | 9 | 4 | 0 | | | | 24.5 | | | 6.1 | 5.2 | | Pump 8 " |
| 3a | 37.5 | 51.2 | 14.7 | 325 | 204525 | 204668 | 143 | 0950 | 1005 | 15 | 40 | 0 | | | | | | 38 | | | 9.5 | 5.2 | | Pump 12 " |
| 3b | 37.5 | 51.2 | 14.7 | 325 | 204824 | 205179 | 355 | 1012 | 1027 | 15 | 80 | 10 | 9 | 6 | 4 | 0 | | 38 | | | 23.7 | 5.2 | | Pump 28 " |
| 4a | 49.5 | 63.7 | 14.2 | 300 | 205319 | 205501 | 182 | 1215 | 1230 | 15 | 40 | 0 | | | | | | 50 | | | 12 | 5.2 | | Pump 15 " |
| 4b | 49.5 | 63.7 | 14.2 | 300 | 205700 | 205967 | 267 | 1245 | 1300 | 15 | 80 | 0 | | | | | | 50 | | | 17.7 | 5.2 | | Pump 23 " |
| 5a | 63 | 79.1 | 16.1 | 325 | 206193 | 206397 | 204 | 1455 | 1510 | 15 | 40 | 0 | | | | | | 63.5 | | | 13.7 | 5.2 | | Pump 17.5 " |
| 5b | 63 | 79.1 | 16.1 | 325 | 206470 | 206768 | 298 | 1520 | 1535 | 15 | 80 | 0 | | | | | | 63.5 | | | 20 | 5.2 | | Pump 22 " |
| 6a | 78 | 88.1 | 10.1 | 300 | 207100 | 207312 | 212 | 0707 | 0722 | 15 | 40 | 0 | | | | | | 78.5 | | | 14 | 5.2 | | leak - Packer not sealed |
| 6b | 78 | 88.1 | 10.1 | 300 | 207401 | 207805 | 394 | 0730 | 0747 | 15 | 80 | 0 | | | | | | 78.5 | | | 26 | 5.2 | | |
| 7a | 87.5 | 100 | 12.5 | 300 | 207411 | 208299 | 254 | 1020 | 1035 | 15 | 40 | 0 | | | | | | 88 | — | | 16.9 | 5.2 | | Pump 22.6 gpm |
| 7b | 87.5 | 100 | 12.5 | 300 | 208460 | 208830 | 370 | 1045 | 1100 | 15 | 80 | 10 | 7 | 3 | 0 | | | 88 | — | | 24.7 | 5.2 | | Pump 30 gpm |

TYPICAL EQUIPMENT SKETCH




NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in 5g. p.m. increments to 30 g.p.m. on back of this form. Repeat each time

(4) Cont. - the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = $ft^3$ ÷ 7.48 = liter x 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level x (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. - Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

B1-6

# REPORT OF WATER PRESSURE TESTING

Project HHD TOWER STUDY

Hole No. 94-DD-85
Location HHD
Coordinates N 102,508.189
E 1,763,518.223

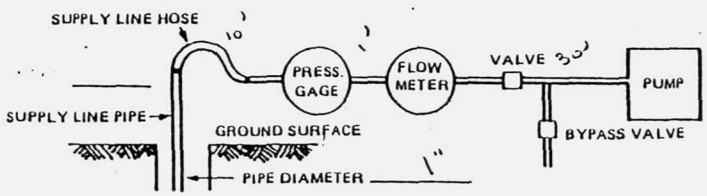
Angle (from Horiz.) 90° (Vertical)
Bearing ---
Casing Size 3½"
Static Water Level (1) 45-7.0' bgs

Surface Elevation 1140.095
Bedrock Elevation 1138.095
Meter Type ROTAMETER

Date 9/19/94 - 9/20/94
Inspector ARMIN SANDERS
Sheet 1 of 1

| Test No. | Test Interval ft (2) Top | Btm | Lng | Packer P.S.I. | Water Meter (cfm / gal / liters) Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 6 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) | Casing Depth | Supply Line Press. (4) | Rate of Flow G.P.M. (5) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 6 | 16 | 10 | 120 | 00193544 | 00193544 | 0 | 1047 | 1057 | 10 | 15 | 0 | — | — | — | — | → | 7 | 4 | | 0 | 2.4 | | |
| 1b | 6 | 16 | 10 | 120 | 00193544 | 00193544 | 0 | 1056 | 1106 | 10 | 30 | 0 | — | — | — | — | → | 7 | 4 | | 0 | 2.4 | | |
| 2a | 15 | 26 | 11 | 150 | 00193544 | 00193544 | 0 | 1408 | 1412 | 10 | 15 | 0 | — | — | — | — | → | 18 | 13 | | 0 | 3.0 | | WATER @ 7' bgs |
| 2b | 15 | 26 | 11 | 150 | 00193544 | 00193544 | 0 | 1423 | 1433 | 10 | 30 | 0 | — | — | — | — | → | 18 | 13 | | 0 | 3.0 | | |
| 3a | 25 | 36 | 11 | 150 | 00193544 | 00193544 | 0 | 1639 | 1649 | 10 | 20 | 0 | — | — | — | — | → | 28 | 23 | | 0 | 3.0 | | |
| 3b | 25 | 36 | 11 | 150 | 00193544 | 00193544 | 0 | 1655 | 1705 | 10 | 40 | 10 | 0 | — | — | — | → | 28 | 23 | | 0 | 3.0 | | |
| 4a | 35 | 46 | 11 | 150 | 00193546 | 00193546 | 0 | 0945 | 0955 | 10 | 20 | 10 | 0 | — | — | — | → | 38 | 33 | | 0 | 1.9 | | WATER @ 34.5' bgs |
| 4b | 35 | 46 | 11 | 150 | 00193546 | 00193546 | 0 | 0956 | 1006 | 10 | 40 | 12 | 0 | — | — | — | → | 38 | 33 | | 0 | 1.9 | | |
| 5a | 45 | 56 | 11 | 150 | 00193546 | 00193546 | 0 | 1212 | 1222 | 10 | 20 | 8 | 0 | — | — | — | → | 49 | 43 | | 0 | 1.9 | | |
| 5b | 45 | 56 | 11 | 150 | 00193550 | 00193550 | 0 | 1226 | 1236 | 10 | 40 | 14 | 0 | — | — | — | → | 49 | 43 | | 0 | 1.9 | | |

TYPICAL EQUIPMENT SKETCH




NOTES

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NPS FORM 140 (EM 1110-1-1801)
JUNE 198[illegible]

RY-7

# REPORT OF WATER PRESSURE TESTING

Project HHD TOWER STUDY

Hole No. 94-DD-86
Location HHD TOWER
Coordinates N 102,525.236
E 1,763,496.572

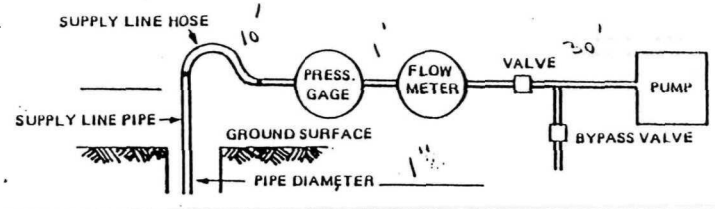
Angle (from Horiz.) 90° (Vertical)
Bearing —
Casing Size 6"
Static Water Level (1) 10-13 bgs

Surface Elevation 1159.7
Bedrock Elevation 1157.1
Meter Type ROCKWELL INTERNATIONAL

Date 9/18/94
Inspector ANNA SAMPLE
Sheet 1 of 1

| Test No. | Test Interval 10 ft m(2) Top | Btm | Lng | Packer P.S.I. | Water Meter ___ cfm X gal ___ liters Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 5 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) | Casing Depth | Supply Line Press. (4) | Rate of Flow G.P.M. (5) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 27 | 37 | 10 | 150 | 0019335 | 0019335 | 0 | 0815 | 0825 | 10 | 15 | 10 | 0 | — | — | — | → | 23 | 21.5 | | 0 | 4.3 | | water at 10' bgs |
| 1b | 27 | 37 | 10 | 150 | 0019336 | 0019336 | 0 | 0830 | 0840 | 10 | 30 | 15 | 0 | — | — | — | → | 23 | 21.5 | | 0 | 4.3 | | " |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| 2a | 18 | 28 | 10 | 150 | 0019336 | 0019336 | 0 | 0930 | 0940 | 10 | 15 | 0 | — | — | — | — | → | 16 | 0 | | 0 | 5.6 | | water level drops to 12' |
| 2b | 18 | 28 | 10 | 150 | 0019336 | 0019336 | 0 | 0945 | 0955 | 10 | 30 | 0 | — | — | — | — | → | 16 | 0 | | 0 | 5.6 | | bgl when casing removed |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| 3. | 9 | 19 | 10 | 150 | | | | | | | 15 | | | | | | | 5 | 0 | | | 1.7 | | TEST TERMINATED; |
| | | | | | | | | | | | | | | | | | | | | | | | | WATER FLOWING OUT |
| | | | | | | | | | | | | | | | | | | | | | | | | OF HOLE |

TYPICAL EQUIPMENT SKETCH

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NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

# REPORT OF WATER PRESSURE TESTING

Project Fish Facility Tower/Tunnel

Hole No. 96-DD-87
Location Howard Hanson Dam
Coordinates N
E

Angle (from Horiz.) N/A
Bearing N/A
Casing Size 4" ID to 3'
Static Water Level (1) 116.8 bgs

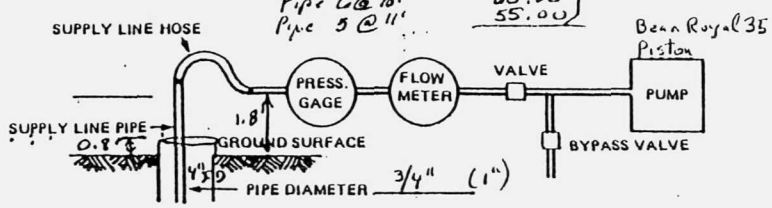
Surface Elevation 1165.7
Bedrock Elevation 1164.7
Meter Type 3/4 x 3/4 Neptune - Trident Tricomal S/N 20889675 (Neptune Meter Co, N.Y.)

Date 5/9/96
Inspector Eckerlin
Sheet 1 of 2

| Test No. | Test Interval X ft m(2) Top | Btm | Lng | Packer P.S.I. | Water Meter X cfm gal liters Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 6 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) | Casing Depth | Supply Line Press. (4) | Rate of Flow G.P.M (5) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS Above G.S. | SWL Begin Test | Pressure Packers (5 min) | End Test Packers Pr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 114.1 | 129.7 | 15.6 | 110 | 1814.0 | 1820.4 | 6.4 | 1541:25 | 1546:25 | 5 | 45 | 32 | 28 | 26 | 22 | 18 | 12 | 118.8 | | | 1.3 | | | S/4 = 4.7 | 11.0 | — | — |
| 2 | 104.4 | 120.0 | 15.6 | 110 | 1825.0 | 1830.6 | 5.6 | 1607:38 | 1612:38 | 5 | 45 | 32 | 29 | 26 | 21 | 15 | 10 | 108.7 | | | 1.1 | | | S/4 = 4.3 | 11.7 | — | — |
| 3A | 94.3 | 109.6 | 15.6 | 110 | 1842.0 | 1855.2 | 13.2 | 1627:27 | 1632:27 | 5 | 50 | 37 | 34 | 30 | 25 | 17 | 10 | 98.7 | | | 2.6 | | | S/4 = 4.4 | — | — | 12.4 |
| 3B | 94.3 | 109.6 | 15.6 | 110 | 1856.0 | 1862.4 | 6.4 | 1635:06 | 1640:06 | 5 | 25 | 20 | 18 | 16 | 13 | 10 | 6 | 98.7 | | | 1.3 | | | S/4 4.4 | | | |
| 4A | 84.1 | 99.7 | 15.6 | 110 | 1870.0 | 1900.7 | 30.7 | 1652:35 | 1702:35 | 10 | 64 | 62 | 59 | 57 | 52 | 46 | 36 | 88.6 | | | 3.1 | | | S/4 4.5 | — | — | 8.7 |
| 4B | 84.1 | 99.7 | 15.6 | 110 | 1910.0 | 1923.7 | 13.7 | 1705:47 | 1715:47 | 10 | 32 | 30 | 29 | 28 | 26 | 25 | 21 | 88.6 | | | 1.4 | | | S/4 4.5 | — | — | — |
| 5A | 74.1 | 89.7 | 15.6 | 110 | 1930.0 | 1953.7 | 23.7 | 1731:23 | 1741:23 | 10 | 65 | 64 | 60 | 58 | 55 | 49 | 40 | 78.6 | | | 2.4 | | | S/4 4.5 | 8.7 | 13.6 | — |
| 5B | 74.1 | 89.7 | 15.6 | 110 | 1953.7 | 1958.0 | 4.3 | 1747:10 | 1752:10 | 5 | 30 | 30 | 30 | 29 | 27 | 25 | 21 | 78.6 | | | 0.8 | | | S/4 4.5 | — | 14.1 | — |

TYPICAL EQUIPMENT SKETCH

Top Packer length = 2.8
Hipply 0.4
Couplings (ea) 0.05
Pipe 6 @ 10' 60.00
Pipe 5 @ 11' 55.00
} Supply Line

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NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

# REPORT OF WATER PRESSURE TESTING

Project Fish Facility Tower/Tunnel

Hole No. 96-DD-87
Location Howard Hanson Dam
Coordinates N
E

Angle (from Horiz.) N/A
Bearing N/A
Casing Size 4" ID to 8'
Static Water Level (1) 11.0 bgs

Surface Elevation 1165.7
Bedrock Elevation 1164.7
Meter Type 3/4x3/4 Neptune Trident Triseal

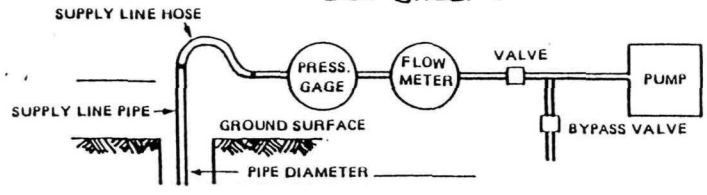
Date 5/10/96 (F)
Inspector Eckerlin
Sheet 2 of 2

Begin Shift 0730

| Test No. | Test Interval ☒ ft ___ m (2) Top | Bun | Lng | Packer P.S.I. | Water Meter ___ cfm ☒ gal ___ liters Start | End | Total | Time Start | End | Total Min | Gage P.S.I. | Pressure Dropoff Test (P.S.I. Gage) seconds 5 | 10 | 15 | 30 | 60 | 120 | Total pipe (3) | Casing Depth | Supply Line Press. (4) | Rate of Flow G.P.M. (5) | Column P.S.I. (6) | Net Press. P.S.I. (7) | COMMENTS Above G.S. | Begin Test | SWL 5min into Packer Inflate | Following Dropoff |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6A | 64.3 | 79.9 | 15.6 | 110 | 1960.0 | 1966.5 | 6.5 | 0813:00 | 0823:00 | 10 | 55 | 48 | 44 | 40 | 33 | 24 | 16 | 68.5 | | | 0.65 | | | S/u = 4.2 | 11.0 | 13.3 | 14.6 |
| 6B | 64.3 | 79.9 | 15.6 | 110 | 1967.0 | 1970.8 | 3.8 | 0824:46 | 0834:46 | 10 | 35 | 30 | 28 | 26 | 21 | 16 | 12 | 68.5 | | | 0.38 | | | S/u = 4.2 | — | 15.3 | 15.8 |
| 7A | 55.0 | 70.6 | 15.6 | 100 | 1972.3 | 1978.1 | 5.8 | 0849:17 | 0859:17 | 10 | 52 | 41 | 37 | 35 | 28 | 20 | 14 | 58.4 | | | 0.58 | | | S/u = 3.4 | 10.0 | 14.2 | 15.2 |
| 7B | 55.0 | 70.6 | 15.6 | 100 | 1978.9 | 1981.0 | 1.1 | 0903:21 | 0904:21 | 6 | 36 | 29 | 26 | 25 | 20 | 16 | 10 | 58.4 | | | 0.18 | | | S/u = 3.4 | — | 15.7 | 16.1 |
| 8A | 44.0 | 59.6 | 15.6 | 100 | 1981.9 | 1983.8 | 1.9 | 0920:30 | 0930:30 | 10 | 50 | 45 | 42 | 39 | 34 | 26 | 20 | 47.4 | | | 0.19 | | | S/u = 3.4 | 11.0 | 13.9 | 14.6 |
| 8B | 44.0 | 59.6 | 15.6 | 100 | 1984.0 | 1984.5 | 0.5 | 0934:45 | 0944:45 | 6 | 25 | 25 | 24 | 23 | 22 | 19 | 16 | 47.4 | | | 0.10 | | | S/u = 3.4 | — | 15.2 | 15.5 |
| 9A | 32.8 | 48.4 | 15.6 | 100 | 1985.3 | 1987.6 | 2.3 | 0953:00 | 1003:00 | 10 | 52 | 48 | 45 | 42 | 36 | 28 | 20 | 36.3 | | | 0.23 | | | S/u = 3.5 | 10.9 | 13.7 | 14.4 |
| 9B | 32.8 | 48.4 | 15.6 | 100 | 1987.7 | 1988.3 | 0.6 | 1007:00 | 1013:00 | 6 | 26 | 23 | 22 | 22 | 20 | 19 | 16 | 36.3 | | | 0.10 | | | S/u = 3.5 | — | 14.8 | 15.2 |
| 10A | 21.9 | 37.5 | 15.6 | 80 | 2030 | Terminated | | 1025:30 | — | — | 25 | — | | | | | | 25.3 | | | — | | | S/u = 3.4 | 11.0 | Suspected leaking! | |
| 10B | 21.9 | 37.5 | 15.6 | 100 | 2200 | 2461.5 | 261.5 | 1033:45 | 1043:45 | 10 | 20 | 8 | 7 | 5 | 2 | 0 | — | 25.3 | | | 26.1 | | | S/u = 3.4 | 11.0 | 11.7 | — |
| | | | | | | | | | | | | | | | | | | | | | | | | Water Vented on Slope | | | |
| 11 | 10.8 | 26.4 | 15.6 | 80 | 2510.0 | 2780.0 | 270 | 1055:35 | 1105:35 | 10 | 15 | 0 | — | | | | | 14.2 | | | 27.0 | | | S/u = 3.4 | — | 4.8 | — |
| | | | | | | | | 1115:00 | | | | | | | | | | | | | | | | Packers out SWL 12.3 bgs | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | Water Vented on slope ~~[illegible]~~ to 1115 | | | |

TYPICAL EQUIPMENT SKETCH

See Sheet 1




NOTES

(1) Use comments space if changes occur in the static water level during testing.

(2) Test each interval at two different gage pressures.

(3) Give accumulative total length of supply line pipe exclusive of supply line hose and packer assy.

(4) Connect packer to supply line hose on horiz. surface. Record gage pressure for flow in ~~g.p.m.~~ gpm increments to 30. g.p.m. on back of this form. Repeat each time the supply line diameter or length, or packer is changed. This data will be used later in the office to calculate supply line pressure.

(5) Gallon = $ft^3$ × 7.48 = liter × 3.79

(6) Column Pressure (P.S.I.) = Vertical dist. from gage to the smaller of packer or static water level × (0.433 P.S.I./ft)

(7) Net Pressure (P.S.I.) = Gage Press. + Column Press. − Supply Line Press. (This is the actual internal pressure.)

NPS FORM 140 (EM 1110-1-1801)
JUNE 1981

# EXHIBIT C

# LABORATORY RESULTS

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION LABORATORY
CORPS OF ENGINEERS
1491 N.W. GRAHAM ROAD
TROUTDALE, OREGON 97060-9508

REPLY TO
ATTENTION OF:

CENPP-PE-L (1110-1-8100c) 10-Oct-96

MEMORANDUM FOR: Commander, Seattle District ATTN: CENPS-EN-GT-GE (Eckerlin)

SUBJECT: W.O.# 96-245, Report of Tests on Rock Cores

Project: Howard Hanson Dam Fish Facility Feasibility Study
Intended Use: Stabilization of turn under at tunnel portal
Source of Material: Rock slope above tunnel portal, Drill Hole No. 96-DD-87
Submitted by: CENPS-EN-GT-GE
Date Sampled: -- Date Received: 28 May 96
Method of Test or Specification: ASTM, CRD, RTH
Reference: a) DD Form 448, MIPR No. E86-96-3105 dated 30 May 96.
b) Our report, this subject, dated 22 Aug 96.

1. Enclosed is report of Petrographic Examination made on a portion of rock core sample No. 3. The petrographic examination was performed by the Corps of Engineers, Missouri River District Laboratory, Omaha, Nebraska.

2. Results indicate the rock is composed of well fractured altered meta-volcanic porphyritic meta-basalt.

3. This completes all work requested.

Enclosure

JAMES K. HINDS, PE
Deputy Director

RECEIVED
SEP 26 1996

MR LAB NO. 4116

Sheet 1 of 1

23 SEP 1996

DEPARTMENT OF THE ARMY
MISSOURI RIVER LABORATORY
CORPS OF ENGINEERS
OMAHA, NEBRASKA 68102

Subject: Petrographic Analysis of Rock Core - Final
Project: Howard Hanson Dam Fish Facility Feasibility Study
Intended Use: Investigation
Source of Material: 2. 3 inch Diameter Rock Core
Submitted by: Chief, CENPDL
Date Sampled: _____, Date Received: 27 June, 1996
Method of Test or Specification: See "Test Method"
References: North Pacific Division Lab MIPR No. 96-0245 dated 06/19/96

## SUMMARY

1. Sample identification and test methods are provided in Appendix A. Test results and discussion are presented in Appendix B. Documentation photographs and photomicrographs are presented in Figure Nos. 1 through 7.

2. Petrographic analysis to determine bulk rock mineralogy and to determine sulfate and sulfide mineral content was performed on a 2.3 in. dia. rock core from the Howard Hanson Dam Fish Facility Feasibility Study Project submitted by North Pacific Division Lab. Test results indicate the rock is composed of well fractured (brecciated), altered meta-volcanic rock identified as porphyritic meta-basalt with the majority of principal original volcanic rock mineral constituents altered to chlorite, calcite and mica. The fractures associated with brecciation are closely spaced, closed and healed with secondary minerals that include chlorite, carbonate and microcrystalline silica. Iron ore identified in the sample is composed predominately of iron sulfide (pyrite) and comprises approximately 15 % of the rock as determined by modal analysis. Chemical analysis indicates whole rock sulfate content is less than 0.1 % and the iron sulfide appears to be chemically inert based on results from sodium and calcium hydroxide immersion tests.

Submitted by:

Douglas B. Taggart

Douglas B. Taggart
Director, MR Laboratory

CX-2

# APPENDIX A

## SAMPLE IDENTIFICATION

1. One rock core from the Howard Hanson Dam - Fish Facility Feasibility Study Project was submitted by North Pacific Division for petrographic and chemical analysis. The core is identified as CENPDL # 5547 (138.5 - 139.0 ft.) based on sample identification information provided in the sample transmittal document submitted with the core sample.

## TEST METHOD

2. The analysis was conducted in accordance with the following test methodology:

The subject rock core sample was examined with stereo- and polarized light microscope (PLM) instrumentation using powder mounts and thin section techniques in accordance with CRD-C 57 (ASTM -856-83), -C 127 (ASTM C 295-85), -C 139 (ASTM C 294-86) to determine gross composition, general condition, to select zones for further analysis and to document the as-received condition of the sample. Specimen dimensional measurements were taken and unique features recorded. Thin section modal analysis was performed to determine iron sulfide mineral distribution. Whole rock representative subsamples were obtained and comminuted to produce samples for chemical analysis (sulfate test) in accordance with CRD-C 403-71 "Method of Test for Determination of Sulfate Ions in Water and Soil" and to provide powder mounts for x-ray diffraction analysis. Both random and oriented powder mounts were used to determine bulk mineralogy and were scanned with a GE 500 x-ray diffractometer interfaced with a Siemens D-500 automation system using monochromatic CuK alpha x-radiation with an Ni filter at a stepping rate of 2 degrees/two-theta per minute. All external instrumental variables were not altered to increase precision and reduce experimental error. Selected rock polished sections were immersed in 1 N sodium hydroxide and saturated calcium hydroxide solutions for 2 weeks to assess sulfide mineral chemical stability (Method after Dolar-Mantuani).

# APPENDIX B

## TEST RESULTS

1. Petrographic analysis to determine rock type and sample condition reveals the following information;

Sample No. CENPDL # 5547 (138.5 - 139.0 ft.). This core sample measures approximately 7.0 inches in length by 2.3 inches in diameter (Figure No. 1) and is composed of dense, dark greenish black (5G 4/1, Munsell Color Classification-wet) rock containing grayish olive green (5 GY 3/2) brecciated zones. The fractures associated with brecciation are closely spaced, closed and healed with secondary minerals that include chlorite, carbonate and microcrystalline silica (Figure No. 5). Thin section analysis indicates the rock type is classified as a dense, porphyritic meta-volcanic rock (porphyritic meta-basalt) with coarse, well-formed, occasionally oscillatory-zoned feldspar phenocrysts of andesite / labradorite composition in a fine grain matrix of fine plagioclase feldspar microlites (showing flow structure), devitrified volcanic glass and abundant black, opaque iron ore (pyrite - iron sulfide dominant, See Figure No. 7)). The majority of plagioclase phenocrysts are corroded, having been replaced with mica and calcite which complicated the determination of the original composition of plagioclase and the rock classification. The original matrix (especially in the brecciated zones) is partially to extensively altered or replaced by secondary minerals such as chlorite, quartz and calcite. Granulation of the parent rock is visible both on a macro and microscopic scale and voids created by the brecciation (Figure No. 3) are partially to completely in-filled with similar secondary minerals (Figure Nos. 4 and 6). Bulk x-ray diffraction analysis confirms the presence of plagioclase feldspar, quartz, calcite, ferromagnesian minerals, mica and chlorite group minerals and iron ore (magnetite and pyrite) minerals but did not detect significant quantities of expansive clay minerals present in the rock that would have been derived from the weathering of glassy, volcanic matrices. Thin section modal analysis indicate iron sulfide minerals (predominantly pyrite) comprises approximately 15.4 % of the rock. Selected rock polished sections were immersed in a 1 N sodium hydroxide and saturated calcium hydroxide solutions for 2 weeks (Method after Dolar-Mantuani) to visually assess sulfide mineral chemical stability. The sulfide minerals showed only minor tarnishing after the immersion tests, with no conversion to ferrous sulfate (bluish-green gelatinous precipitate). Bulk chemical analysis indicated sulfate content of the rock is 0.07 % (normally reported as less than 0.1 %).

DEPARTMENT OF THE ARMY
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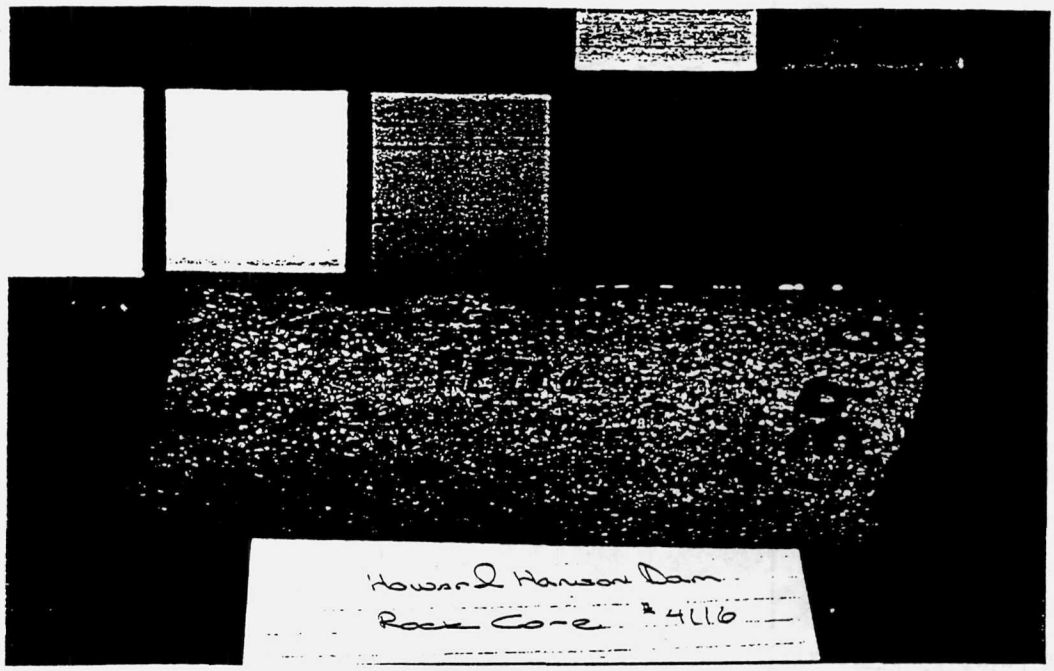
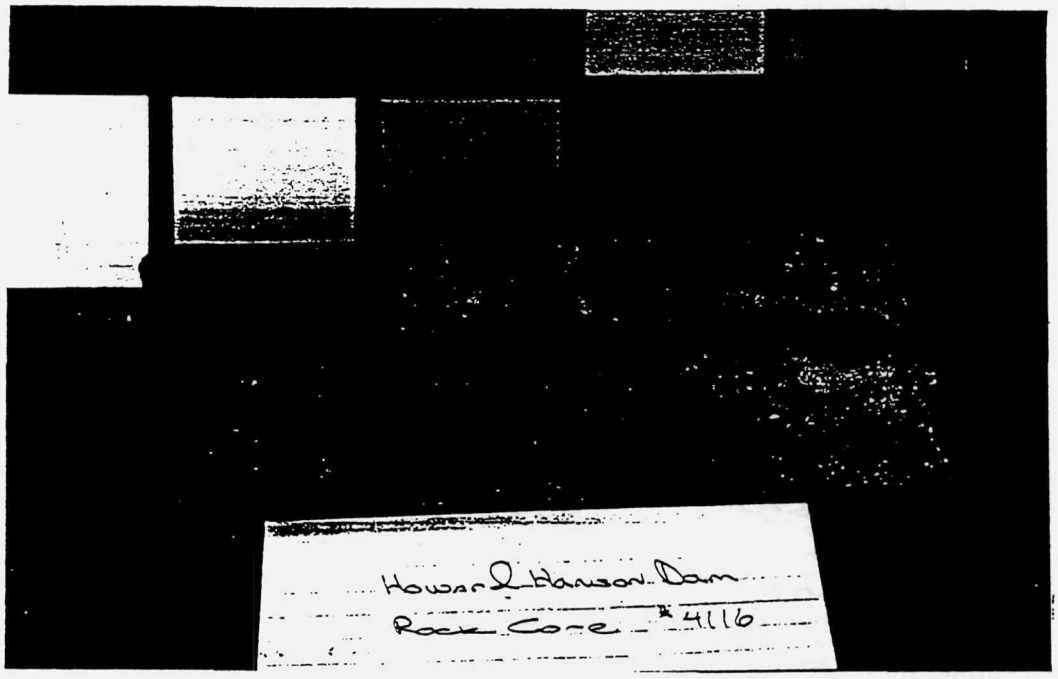
CORPS OF ENGINEERS
OMAHA, NEBRASKA 68102

Figure No. 1




Core Sample No. CENPDL # 5547. Profile view of the subject core showing condition and identification information (core top - left side of photo). Core Dia. 2.3 inches.

Figure No. 2




Core Sample No. CENPDL # 5547. Profile view of surface cut parallel to the core axis detailing variable textural nature of the rock due to brecciation. Core Dia. 2.3 inches.

Plate No. 1

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OMAHA, NEBRASKA 68102

Figure No. 3

Core Sample No. CENPDL # 5547. Thin section photomicrograph detailing texture of rock classified as a porphyritic meta-basalt. Note the elongate greenish structure (arrow) in center of photo representing void in-filled with radially fibrous chlorite crystals. Magnification 63 X.

Figure No. 4

Core Sample No. CENPDL # 5547. Further magnification of previous view showing radially fibrous nature of chlorite (arrow) filling void. Gold-colored zone (same arrow) is secondary carbonate (calcite) precipitate lining same void. Crossed polarized light. 115 X Mag.

Plate No. 2

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OMAHA, NEBRASKA 68102

Figure No. 5

Core Sample No. CENPDL # 5547. Thin section photomicrograph detailing fractures (arrows) healed with chlorite and carbonate (calcite-gold-colored) secondary precipitate. Crossed polarized light. 63 X Magnification.

Figure No. 6

Core Sample No. CENPDL # 5547. Thin section photomicrograph detailing void in-filled with radially fibrous chlorite secondary precipitate. Crossed polarized light. 115 X Mag.

Plate No. 3

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OMAHA, NEBRASKA 68102

Figure No. 7

Core Sample No. CENPDL # 5547. Thin section photomicrograph detailing the distribution of opaque iron ore particles (black particles) in the rock matrix. Light colored, elongated crystals are plagioclase microlites. Magnification 190 X.

Plate No. 4

1 x 8

## APPENDIX B

## DISCUSSION

2. Petrographic analysis performed on the subject core sample from Howard Hanson Dam Fish Facility Feasibility Study Project submitted by North Pacific Division Laboratory indicates the sample represents rock classified as a brecciated, porphyritic meta-basalt, with the original mineral constituents extensively altered to secondary minerals such as chlorite, microcrystalline silica and calcite. The fractures associated with the brecciation appear to be well cemented and the mineral alteration does not appear to have adversely affected rock matrix density. The bulk rock sulfate content is 0.07 % and sulfide minerals common in the matrix appear chemically stabile as these minerals did not produce significant reaction or alteration to ferrous sulfate during immersion in sodium or calcium hydroxide (saturated lime) solutions.

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION LABORATORY
CORPS OF ENGINEERS
1491 N.W. GRAHAM AVENUE
TROUTDALE, OREGON 97060-9503

CENPP-PE-L (1110-1-8100c) 22 Aug 96

MEMORANDUM FOR: Commander, Seattle District ATTN: CENPS-EN-GT-GE (Eckerlin)

SUBJECT: W.O.# 96-245, Report of Tests on Rock Cores

Project: Howard Hanson Dam Fish Facility Feasibility Study
Intended Use: Stabilization of turn under at tunnel portal
Source of Material: Rock slope above tunnel portal, Drill Hole No: 96-DD-87
Submitted by: CENPS-EN-GT-GE
Date Sampled: -- Date Received: 28 May 96
Method of Test or Specification: ASTM, CRD, RTH
Reference: a) DD Form 448, MIPR No. E86-96-3105 dated 30 May 96.
b) NPD Form 300, Transmittal of Materials Samples, dated 28 May 96.
c) Telephone conversations 22 May through 7 Aug 96 with Mr. Rick Eckerlin, wherein test program and costs were discussed.
d) Facsimile report of preliminary data dated 9 Aug 96, wherein results to date were reported.

1. Enclosed is report of tests made on rock cores taken from the vicinity of the tunnel portal of the Howard Hanson Dam. Included are:

a) Enclosure 1, Table I, Report of Unconfined Compressive and Direct Tensile Strength Tests on Andesite Breccia Rock Cores.

b) Enclosure 2, Table II, Report of Specific Gravity, Absorption, Unit Weight, and Dynamic Modulus of Elasticity Tests on Andesite Breccia Rock Cores.

c) Enclosure 3, Table III, Report of Bi-Axial Direct Shear Strength Tests on Sawn Rock-Grouted Joints.

d) Enclosure 4, Figure I, Graphical Report of Bi-Axial Direct Shear Strength Tests on Sawn Rock-Grouted Joints.

2. Approximately 20 linear feet of andesite breccia HQ rock core was received on 28 May 96 for compressive strength, direct tensile strength, unit weight, sonic tests, and bi-axial direct shear tests on sawn rock-grouted joints.

3. A petrographic examination is currently being performed on a portion of Sample No. 3. Results will be forwarded when available.

Enclosures

JAMES K. HINDS, PE
Deputy Director

RX-10

Howard Hanson Dam Fish Facility Feasibility Study

Table I
Report of Unconfined Compressive and Direct Tensile Strength Tests
on Andesite Breccia Rock Cores 1/, Drill Hole No. 96-DD-87

1. Compressive Strength Test Data

| Sample No. | Depth, ft. | Diameter, in. | Height, in. | Moisture Content 2/, % | Compressive Strength, psi | Modulus of Elasticity, 3/ Ec x $10^6$ psi | Poisson's Ratio, $\mu$ 3/ |
|---|---|---|---|---|---|---|---|
| 1 | $61^{9}$ - $62^{2}$ | 2.39 | 5.13 | 2.1 | 4010 | 4.55 | 0.172 |
| 2 | $113^{2}$ - $113^{5}$ | 2.40 | 4.98 | 0.8 | 8670 | 3.73 | 0.152 |
| 2 | $113^{7}$ - $114^{0}$ | 2.39 | 4.97 | 1.3 | 7200 | 1.44 | 0.155 |
| 3 | $136^{5}$ - $136^{8}$ | 2.39 | 4.90 | 0.7 | 11190 | 4.06 | 0.167 |

2. Direct Tensile Strength Data

| Sample No. | Depth, ft. | Diameter, in. | Height, in. | Direct Tensile Strength, psi |
|---|---|---|---|---|
| 1 | $61^{2}$ - $61^{5}$ | 2.39 | 4.82 | 45 4/ |
| 2 | $112^{8}$ - $113^{1}$ | 2.40 | 4.85 | 200 |
| 3 | $137^{1}$ - $137^{4}$ | 2.39 | 4.93 | 740 |

Notes: 1/ Tested in accordance with Rock Testing Handbook, RTH Methods 111 and 112.
2/ Moisture content of sample at time of test.
3/ Modulus of Elasticity and Poisson's Ratio tests made using glue-on electrical resistance strain gauges.
4/ Examination of Sample No. 1 after test indicates failure occurred along an existing slicken-sided seam comprising approximately 50% of the total failure plane.

CENPDL No. 5547; samples received 28 May 96.

Howard Hanson Dam Fish Facility Feasibility Study

Table II
Report of Specific Gravity, Absorption, Unit Weight, and Sonic Tests on Andesite Breccia Cores*,
Drill Hole No. 96-DD-87

| Sample No. | Depth, ft. | Specific Gravity | Absorption, % | Unit Weight, $lb/ft^3$ | Longitudinal Dynamic Modulus of Elasticity, $E \times 10^6$ psi | Sonic Velocity, V, ft/sec. | |
|---|---|---|---|---|---|---|---|
| | | | | | | Longitudinal | Transverse |
| 1 | $59\frac{7}{}$ - $70\frac{3}{}$ | 2.66 | 1.7 | 165.7 | -- | -- | -- |
| 2 | $111\frac{4}{}$ - $117\frac{5}{}$ | 2.50 | 5.3 | 155.8 | -- | -- | -- |
| 3 | $135\frac{1}{}$ - $139\frac{7}{}$ | 2.54 | 3.8 | 158.2 | -- | -- | -- |
| 3 | $137\frac{1}{}$ - $138\frac{1}{}$ | -- | -- | -- | 0.513 | 3960 | 2540 |

* Tested in accordance with Rock Testing Handbook, RTH Methods 107 and 110.

CENPDL No. 5547; samples received 28 May 96.

Howard Hanson Dam Fish Facility Feasibility Study

Table III
Summary of Bi-Axial Direct Shear Strength Tests
on Sawn Rock-Grout Joints, Drill Hole No. 96-DD-87

1. Bi-Axial Direct Shear Strength, Grout-Rock Bond 1/

| Sample No. | Depth, ft | Shear Strength, psi Confining Pressure, psi 5 | 50 | 100 | Angle of Internal Friction, Φ, degrees | Cohesion, psi |
|---|---|---|---|---|---|---|
| 2 | 111 7/ | 75 | -- | -- | -- | -- |
| 2 | 111 9/ | -- | 440 | -- | -- | -- |
| 2 | 115 7/ | -- | -- | 365 | -- | -- |
| 2 | 115 9/ | 230 | -- | -- | -- | -- |
| 2 | 115 9/ | -- | 435 | -- | -- | -- |
| 2 | 117 6/ | -- | 390 | -- | -- | -- |
| 2 | 117 4/ | -- | -- | 505 | -- | -- |
| | Average: | 155 | 420 | 435 | 71.0 | 187 |
| 3 | 135 5/ | 85 | -- | -- | -- | -- |
| 3 | 137 7/ | -- | 240 | -- | -- | -- |
| 3 | 138 3/ | -- | -- | 390 | -- | -- |
| | Average: | 85 | 240 | 390 | 72.7 | 73 |

2. Compressive Strength of Neat Cement Grout Cubes 2/

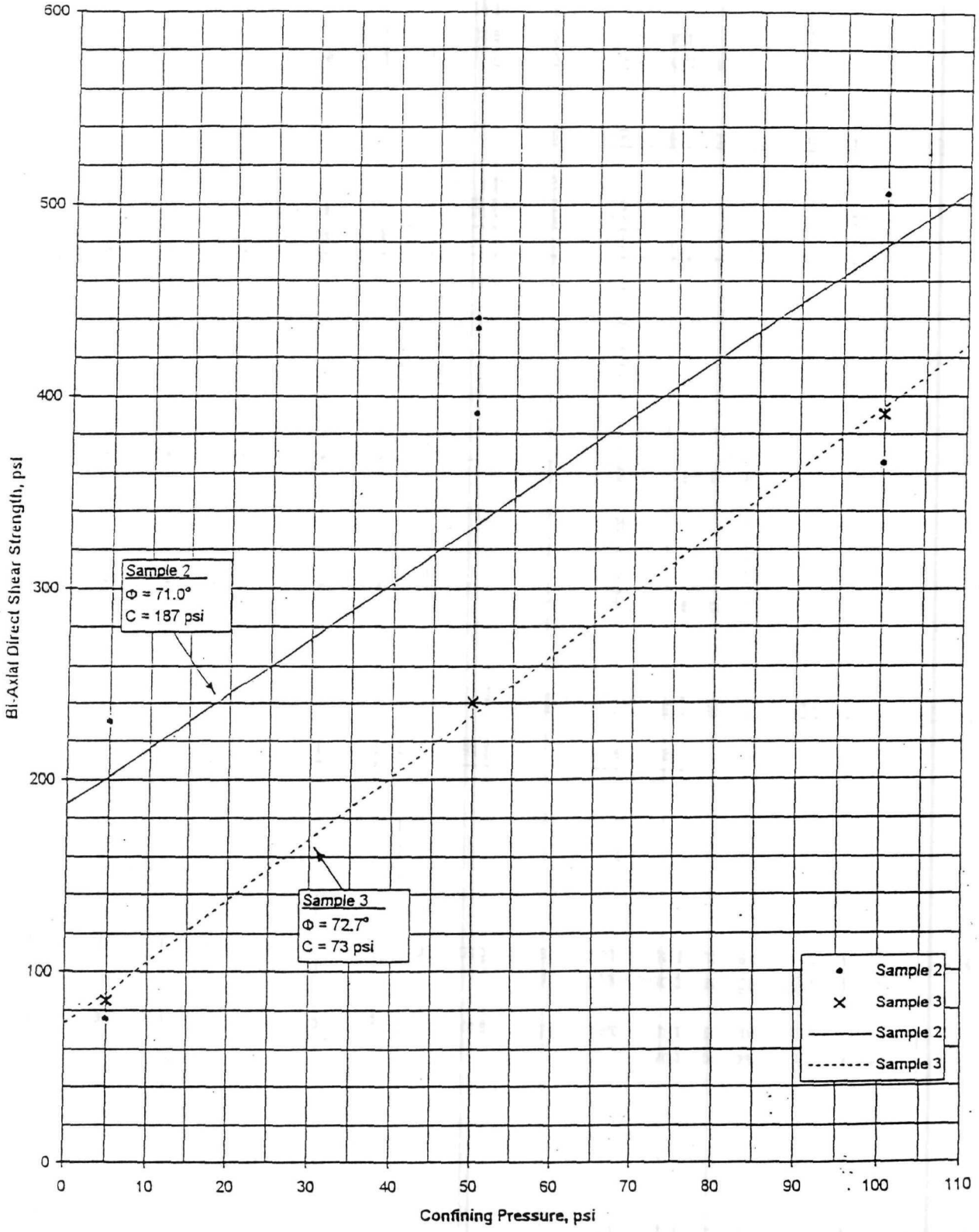
| Test Age, days | Compressive Strength, psi |
|---|---|
| 3 | 3340 |
| 7 | 4710 |
| 10 | 5120 |
| 28 | 6260 |

Notes: 1/ Grout/rock bi-axial direct shear tests made at grout age 10 days. All tests performed in accordance with Rock Testing Handbook Method 203

2/ Grout batched with laboratory blend Type II cement (CENPDL No. 4959) at a water:cement ratio of 0.49 with 20.0 seconds flow.

CENPDL No. 5547; samples received 28 May 96.

Howard Hanson Dam Fish Facility Feasibility Study
Figure I
Bi-Axial Direct Shear Strength versus Confining Pressure,
Sawn Rock-Grout Joints






CX-14

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION LABORATORY
CORPS OF ENGINEERS
1491 N.W. GRAHAM AVENUE
TROUTDALE, OREGON 97060-3503

CENPD-ET-P-L (1110-1-8100c) April 10, 1995

MEMORANDUM FOR Commander, Seattle District, ATTN: CENPS-EN-GT (Hancock)

SUBJECT: W.O. # 95-099, Report of Tests on Foundation Rock Cores

Project: HOWARD HANSEN DAM INTAKE TOWER RETROFIT
Intended Use: Stabilization of intake tower buttress
Source of Material: Intake tower vicinity foundation
Submitted by: CENPS-EN-GT (Hancock)
Date Sampled: 16-20 Sep 94 Date Received: 21 Nov 94
Method of Test or Specification: CRD, ASTM, RTH
Reference: a) DD Form 448, MIPR No. E86-95-3065, dated 14 Nov 94
b) NPD Form 300, Transmittal of Materials Samples, dated 15 Nov 94
c) Telephone conversations 22 Nov 94 - 12 Jan 95 with Mr. Bill Hancock, wherein test program and costs were discussed
d) Facsimile report dated 29 Dec 94, wherein results to date were reported

1. Enclosed is report of tests made on foundation rock cores taken from the vicinity of the intake tower of the Howard Hansen Dam. Included are:

a) Enclosure 1, Table I, Report of Unconfined Compressive and Direct Tensile Strength Tests on Andesite Rock Cores

b) Enclosure 2, Table II, Report of Point Load Strength Tests on Andesite Rock Cores

c) Enclosure 3, Table III, Summary of Bi-Axial Direct Shear Strength Tests on Rock Cores and Sawn Rock-Grouted Joints

d) Enclosure 4 a-d, Figures I through IV, Graphical Report of Compressive Strength versus strain, one for each of four cores tested.

2. Approximately 90 lineal feet of andesite HQ and 4-inch diameter rock core was received 21 Nov 94 for unconfined compressive strength, direct tensile strength, point load, and bi-axial direct shear strength tests. The cores were received in an air-dry, unsealed condition, and were tested in accordance with Rock Testing Handbook Methods 111, 112, 203 and 325.

3. Several tests were requested to be made within the section of core at depth 15' to 20' in Drill Hole No. 95-CC-85. In general, the core within this zone was heavily fractured, and tests were rescheduled to be performed as closely as possible in adjacent areas.

4. This completes all work requested.

James K. Hinds, PE
Deputy Director

Enclosures

Copy Furnished: CENPD-ET-P

# HOWARD HANSEN DAM INTAKE TOWER

## Table I

### Report of Unconfined Compressive and Direct Tensile Strength Tests on Andesite Rock Cores[1]

1. Compressive Strength Test Data

| Drill Hole No. | Depth, feet | Diameter, inches | Height, inches | Moisture[2] Content, % | Unconfined Compressive Strength: Ultimate Load, lbs. | psi | Corrected[3] psi | $\times 10^6$ psi Modulus of Elasticity |
|---|---|---|---|---|---|---|---|---|
| 94-DD-85 | 6.5-6.8 | 2.38 | 4.87 | 1.7 | 16,300 | 3,660 | 3,670[4] | 0.67 |
| | 13.6-13.9 | 2.39 | 5.17 | 2.0 | 20,600 | 4,590 | 4,630[4] | 2.11 |
| | 15.0-15.4 | 2.40 | 5.15 | 2.2 | 39,200 | 8,670 | 8,740 | --- |
| | 19.0-19.4 | 2.40 | 4.87 | 0.9 | 122,500 | 27,080 | 27,130 | --- |
| | 24.7-25.0 | 2.39 | 4.67 | 1.8 | 56,000 | 12,480 | 12,440 | 3.26 |
| | 25.0-25.3 | 2.38 | 4.72 | 1.3 | 53,700 | 12,070 | 12,060 | 3.42 |
| 94-DD-86 | 24.0-24.7 | 3.97 | 8.16 | 1.8 | 84,000 | 6,790 | 6,830 | --- |
| | 39.3-40.0 | 3.98 | 7.59 | 2.3 | 98,500 | 7,920 | 7,870 | --- |

2. Direct Tensile Strength Data

| Drill Hole No. | Depth, feet | Diameter, inches | Height, inches | Direct Tensile Strength: Ultimate Load, lbs. | psi |
|---|---|---|---|---|---|
| 94-DD-85 | 10.1-10.5 | 2.40 | 4.83 | 2,260 | 500[5] |
| | 10.5-10.8 | 2.39 | 4.82 | 1,960 | 440 |
| | 11.7-12.0 | 2.38 | 4.63 | 480 | 110[5] |

Notes: 1/ Tested in accordance with Rock Testing Handbook, RTH Methods 111, 112, and 201.
2/ Moisture content of sample at time of test.
3/ Corrected for length-to-diameter ratio.
4/ Specimen had hairline crack before test
5/ Specimen had hyperbolic open seam before test.

CENPDL No. 5087, Received 21 Nov 94

HOWARD HANSEN DAM INTAKE TOWER

Table II

Report of Point Load Strength Tests
on Andesite Rock Cores[1]

| Drill Hole No. | Depth, feet | Diameter,[2] inches | Length, inches | Ultimate Load, lbs | Point Load Index, psi |
|---|---|---|---|---|---|
| 85 | 15.3 | 2.36 | 3.00 | 2550 | 460 |
| | 18.8 | 2.24 | 3.00 | 5050 | 1005[3] |
| | 20.4 | 2.38 | 3.00 | 530 | 95[4] |
| | 25.7 | 1.97 | 3.00 | 2450 | 630 |
| | 30.3 | 2.22 | 3.00 | 2730 | 555 |
| | 35.1 | 1.87 | 3.00 | 1600 | 460[3] |
| | 39.9 | 2.16 | 3.00 | 1680 | 360 |
| | 45.5 | 2.20 | 3.00 | 1070 | 220[3] |
| | 45.3 | 1.76 | 3.00 | 2440 | 790[3] |
| | 48.7 | 2.15 | 3.00 | 2150 | 465 |
| | 50.3 | 2.10 | 3.00 | 3990 | 905[3] |
| 86 | 10.0 | 3.95 | 5.00 | 1800 | 115 |
| | 15.3 | 3.92 | 4.00 | 2020 | 130[3] |
| | 16.2 | 3.92 | 4.00 | 2090 | 135[3,5] |
| | 16.4 | 3.82 | 4.00 | 2700 | 185[3] |
| | 19.6 | 3.96 | 4.00 | 1430 | 90[3] |
| | 24.7 | 3.97 | 4.00 | 2040 | 130[3] |
| | 25.5 | 3.79 | 4.00 | 1520 | 105[3] |
| | 25.8 | 3.42 | 4.00 | 4320 | 370[3] |
| | 29.5 | 3.97 | 4.00 | 950 | 60[5] |
| | 29.7 | 3.97 | 4.00 | 1350 | 85[4] |
| | 38.0 | 3.60 | 5.00 | 200 | 15 |

Notes: 1/ Specimens tested diametrically, in accordance with RTH-325 requirements
2/ Diameter used for calculation of Point Load Index, based on distance between points of point load apparatus at the time of failure.
3/ Specimen did not break through both points of point load apparatus
4/ Specimen tested with points parallel to weak planes/seams
5/ Specimen tested with points normal to weak planes/seams

CENPDL No. 5087, Received 21 Nov 94

HOWARD HANSEN DAM INTAKE TOWER

Table III

Summary of Bi-Axial Direct Shear Strength Tests
Intact Rock Cores and Sawn Rock-Grout Joints

1. Intact Rock Core

| Drill Hole No. | Depth, Feet | Ultimate Load, lbs. | Area Inches$^2$ | Shear Strength, psi — Confining Load, psi 10 | 50 | 100 | Angle of Internal Friction, degrees | Cohesion, psi |
|---|---|---|---|---|---|---|---|---|
| S6 | 24.3 | 12020 | 12.379 | 970 | -- | -- | -- | -- |
| S6 | 28.4 | 7700 | 12.316 | 625 | -- | -- | -- | -- |
| S6 | 23.3 | 13300 | 12.130 | -- | 1095 | -- | -- | -- |
| S6 | 19.0 | 11560 | 12.316 | -- | -- | 940 | -- | -- |
| S6 | 27.4 | 9700 | 12.316 | -- | -- | 790 | -- | -- |
| | | | Average | 800 | 1095 | 865 | 33.0 | 887 |

2. Grout-Rock Bond*

| Drill Hole No. | Depth, Feet | Ultimate Load, lbs | Area Inches$^2$ | Shear Strength, psi — Confining Load, psi 10 | 25 | 50 | 100 | Angle of Internal Friction, degrees | Cohesion, psi |
|---|---|---|---|---|---|---|---|---|---|
| S5 | 10.8 | 840 | 4.486 | 185 | -- | -- | -- | -- | -- |
| S5 | 19.5 | 1160 | 4.449 | -- | 260 | -- | -- | -- | -- |
| S5 | 26.1 | 900 | 4.486 | -- | -- | 200 | -- | -- | -- |
| S6 | 27.8 | 3250 | 12.629 | -- | -- | -- | -- | -- | -- |
| S6 | 16.1 | 2050 | 12.629 | 255 | 160 | -- | -- | -- | -- |
| 86 | 15.7 | 3220 | 12.629 | -- | -- | 255 | -- | -- | -- |
| 85 | 13.0 | 820 | 4.524 | -- | -- | 180 | -- | -- | -- |
| 85 | 12.0 | 1320 | 4.524 | -- | -- | -- | 285 | -- | -- |
| | | | Average | 220 | 210 | 210 | 285 | 38.2 | 195 |

*Grout/rock biaxial direct shear tests made at grout age 7-days. All tests made in accordance with Rock Testing Handbook Method 203. Compressive Strength of Neat Cement Grout Cubes as follows:

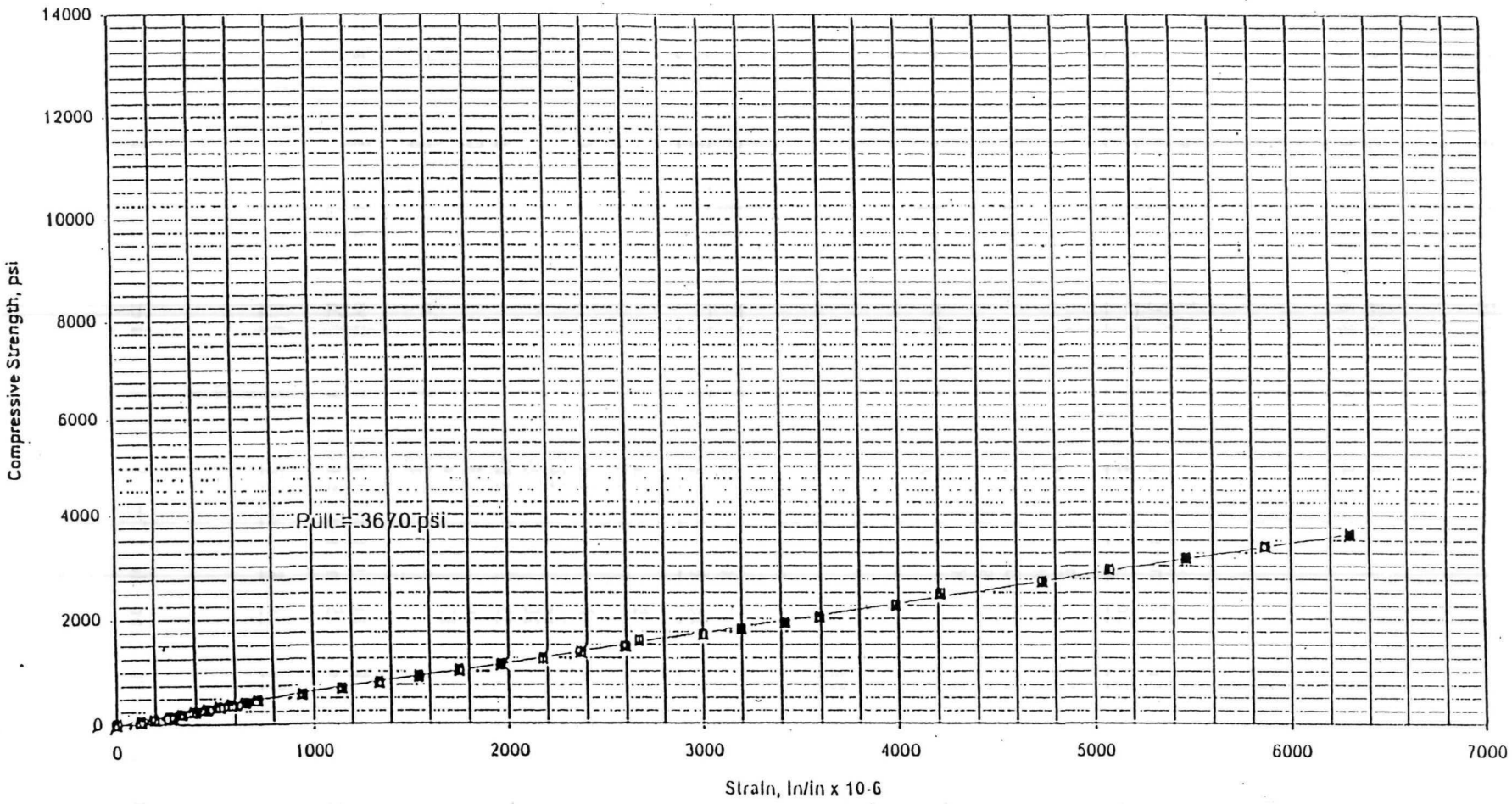
| Test Age, days | Compressive Strength, psi |
|---|---|
| 4 | 4530 |
| 7 | 5490 |
| 28 | 9140 |

Grout batched with laboratory blend Type II cement at a water:cement ratio of 0.42, and 22.4 second flow.

CENPDL No. 5087, Received 21 Nov 94

Figure I

Unconfined Compressive Strength versus Strain
Nominal 2-inch Diameter Rock Core
Drill Hole No. 94-DD-85, Depth 6.5'-6.8'

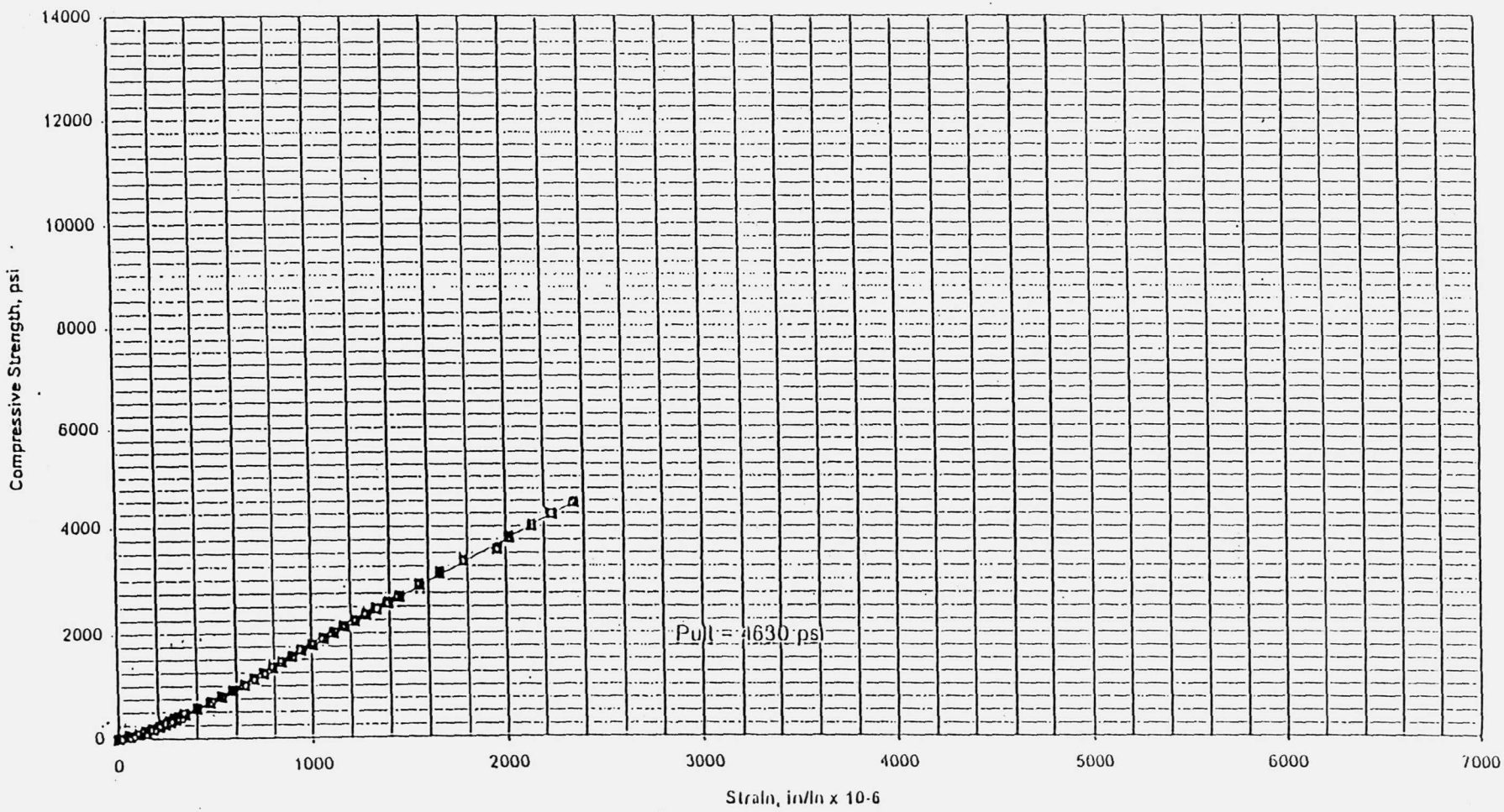





CX-20

Figure II

Unconfined Compressive Strength versus Strain
Nominal 2-inch Diameter Rock Core
Drill Hole No. 95-DD-95, Depth 13.6'-13.9'



HOWARD HANSEN DAM INTAKE TOWER

Figure III

Unconfined Compressive Strength versus Strain
Nominal 2-inch Diameter Rock Core
Drill Hole No. 94-DD-85, Depth 24.7'-25.0'

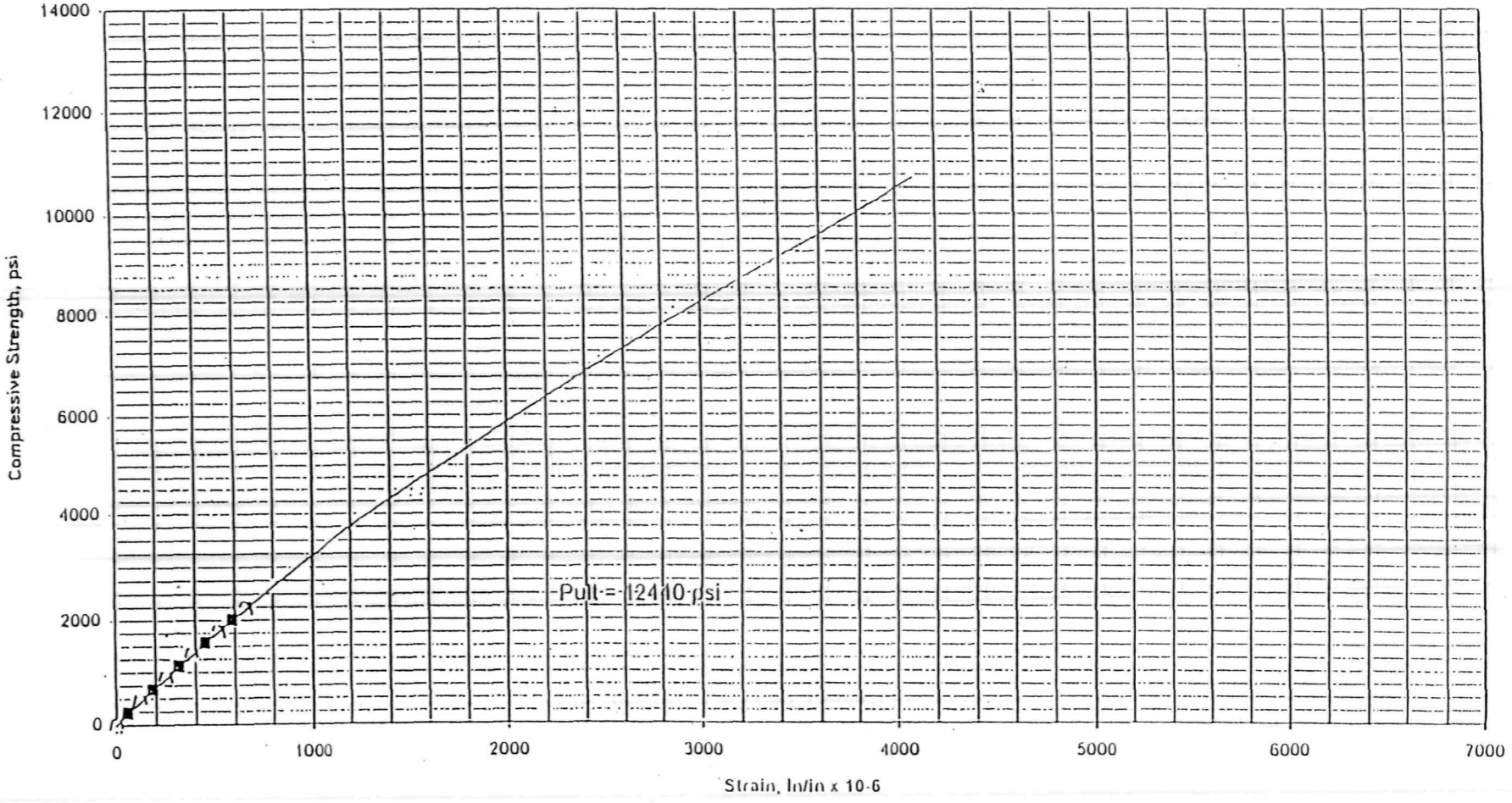
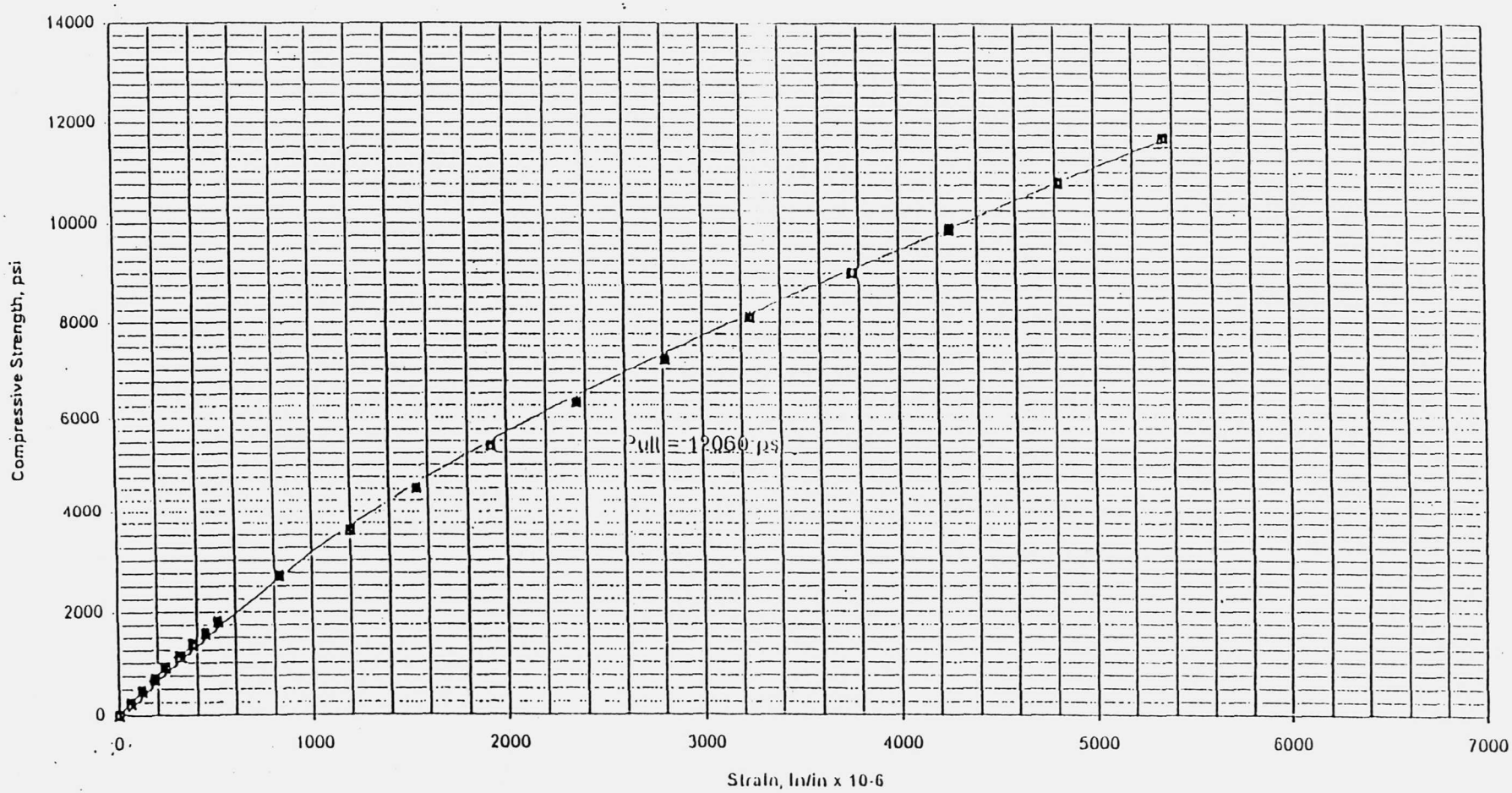



Figure III

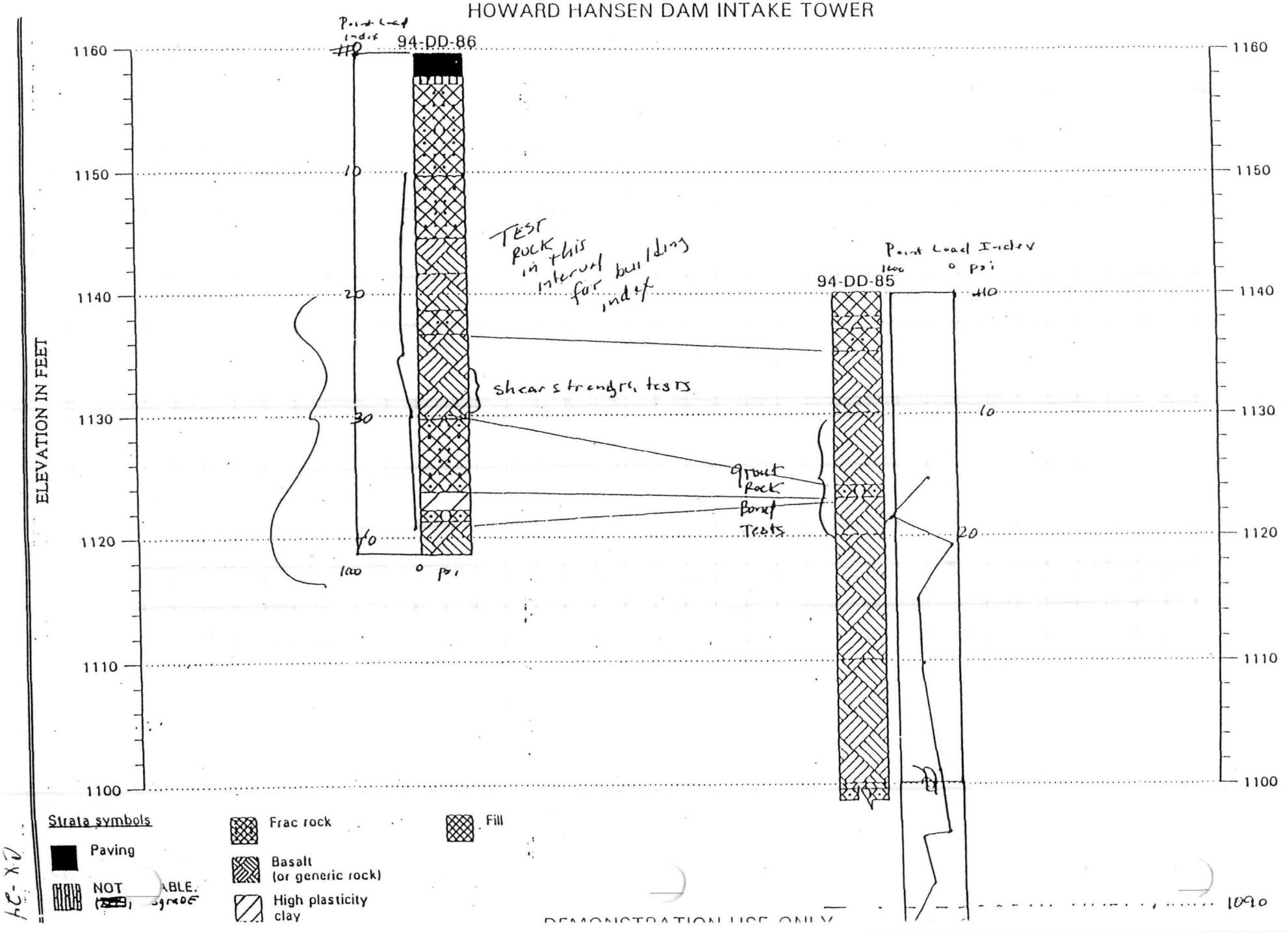
HOWARD HANSEN D. M INTAKE TOWER

Figure IV

Unconfined Compressive Strength versus Strain
Nominal 2-inch Diameter Rock Core
Drill Hole No. 95-DD-85, Depth 25.0'-25.3'



# LOG OF BORINGS
## HOWARD HANSEN DAM INTAKE TOWER




DEMONSTRATION USE ONLY

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION LABORATORY
CORPS OF ENGINEERS
1491 N.W. GRAHAM AVENUE
TROUTDALE, OREGON 97060-9503

CENPD-PE-GE-L (1110 - 1 - 8100c) July 13, 1994

MEMORANDUM FOR Commander, Seattle District, ATTN: CENPS-EN-GT-GE (Eckerlin)

SUBJECT: W.O. # 94-314, Report of Tests on Foundation Rock Cores.

Project: Howard Hanson Dam Fish Passage Study
Intended Use: Foundation Investigation
Source of Material: Left abutment of Howard Hanson Dam

Submitted by: CENPS-EN-GT-GE
Date Sampled: ------ Date Received: 4 May 94
Method of Test or Specification: ASTM, Rock Testing Handbook (WES)
Reference: a) MIPR No. E86-94-3101 dated 4 May 94
b) NPD Form 300, Transmittal of Rock Cores, dated 18 Apr 94
c) Telecon 14 Apr 94 with Mr. Rick Eckerlin wherein test program was discussed.

1. Attached is report of tests on foundation rock cores from the above source.

2. This completes all work requested.

Timothy J. Seeman

TIMOTHY J. SEEMAN
Director

Enclosures

Copy Furnished: CENPD-PE-GE

IX-25

CENPD-PE-GE-L (94-314)

HOWARD HANSON DAM FISH PASSAGE STUDY
Report of Tests on Foundation Rock Cores

| CENPS Sample No. | Rock Type | Depth 1/ ft. | Moisture 2/ Content, % | Specific Gravity | Absorption % | Unit Weight pcf | Unconfined 3/ Compressive Strength, psi |
|---|---|---|---|---|---|---|---|
| 94-DD-80 | Andesite Breccia | 139.3 | 1.1 | 2.42 | 6.6 | 150.8 | 5410 |
| 94-DD-81A | Andesite Breccia | 175.2 | 0.9 | 2.61 | 2.0 | 162.6 | 8790 |
| 94-DD-81B | Andesite | 187.5 | 2.0 | 2.65 | 1.6 | 165.1 | 9170 |
| 94-DD-82A | Andesite Breccia | 179.9 | 0.5 | 2.59 | 2.1 | 161.4 | 21920 |
| 94-DD-83A | Andesite Breccia | 147.5 | 0.5 | 2.42 | 6.1 | 150.8 | 13510 |
| 94-DD-83B | Andesite Breccia | 150.2 | 0.5 | 2.39 | 6.5 | 148.9 | 8900 |
| 94-DD-84A | Andesite Breccia | 35.0 | 0.4 | 2.72 | 0.8 | 169.5 | 18010 |
| 94-DD-84B | Andesite Breccia | 53.1 | 0.8 | 2.76 | 0.9 | 171.9 | 8320 |

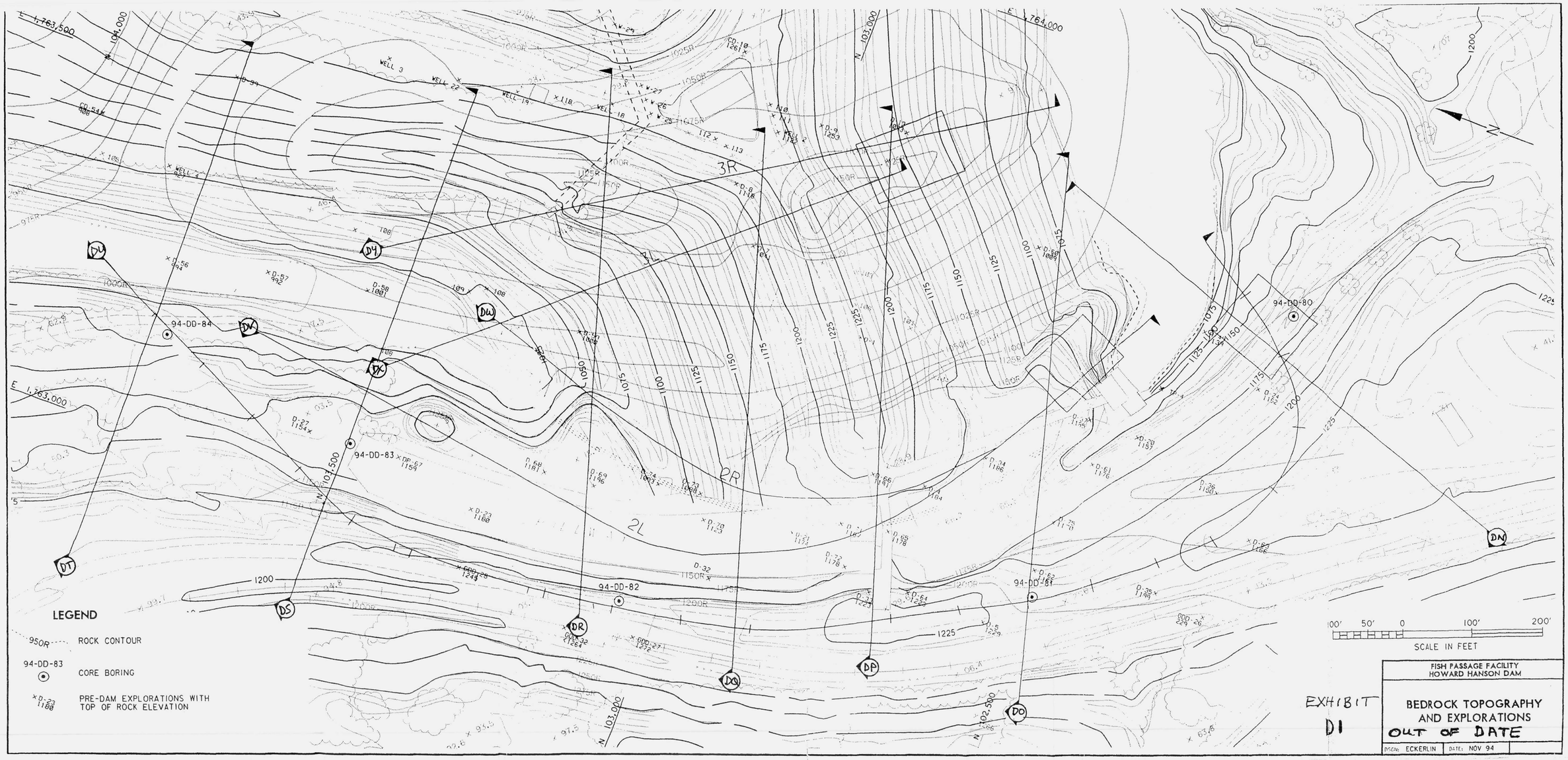
1/ Depth to top of core.
2/ Moisture content at time of unconfined compressive strength test.
3/ Compressive Strength corrected in accordance with ASTM D-2938 for cores with length to diameter ratio of less than 2.

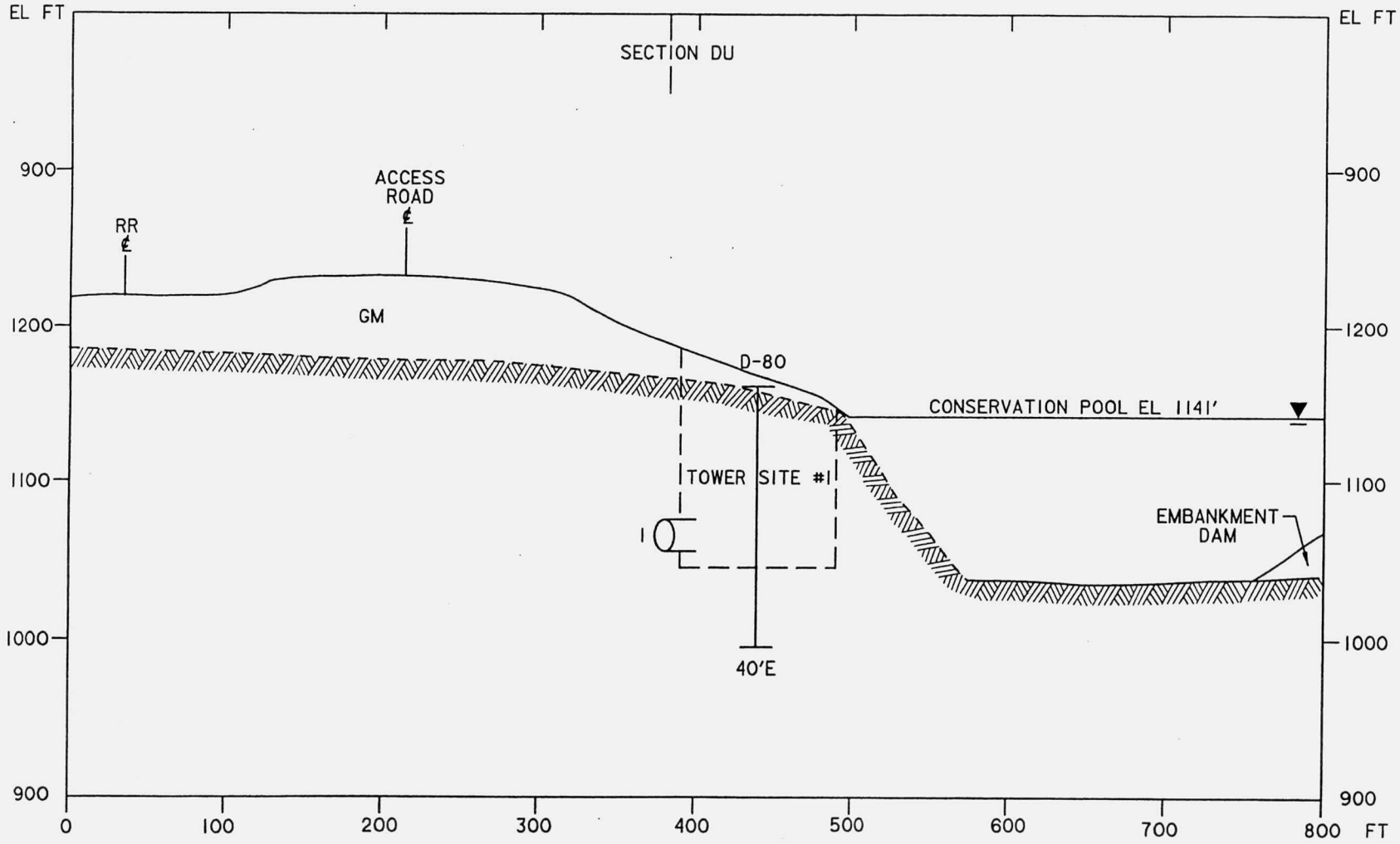
CENPDL No. 4936 Received 4 May 94

CX-2

# EXHIBIT D

# EVALUATED ALTERNATIVE SITES


LEGEND
950R ROCK CONTOUR
94-DD-83 CORE BORING
PRE-DAM EXPLORATIONS WITH TOP OF ROCK ELEVATION
SCALE IN FEET
100' 50' 0 100' 200'
FISH PASSAGE FACILITY
HOWARD HANSON DAM
BEDROCK TOPOGRAPHY AND EXPLORATIONS
OUT OF DATE
DRAWN ECKERLIN
DATE: NOV 94
EXHIBIT D1
94-DD-84
94-DD-83
94-DD-82
94-DD-81
94-DD-80
WELL 3
WELL 22
WELL 19
WELL 18
WELL 2
3R
3L
2R
2L
E 1,763,500
E 1,764,000
E 1,763,000
N 104,000
N 103,000
N 102,500
N 101,500

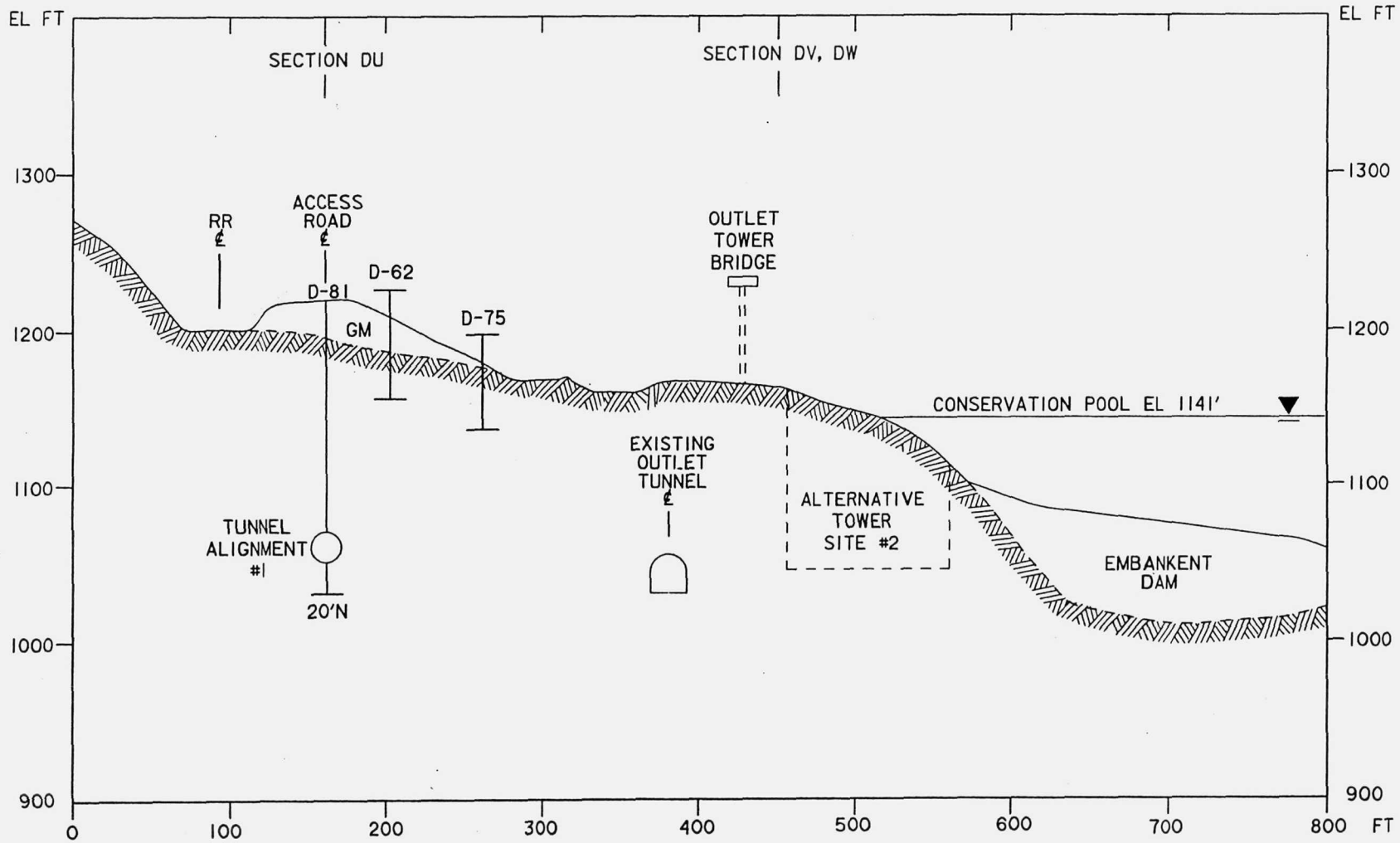



DN

**SECTION DN**
**DOWNSTREAM VIEW**

DN

EXHIBIT D2

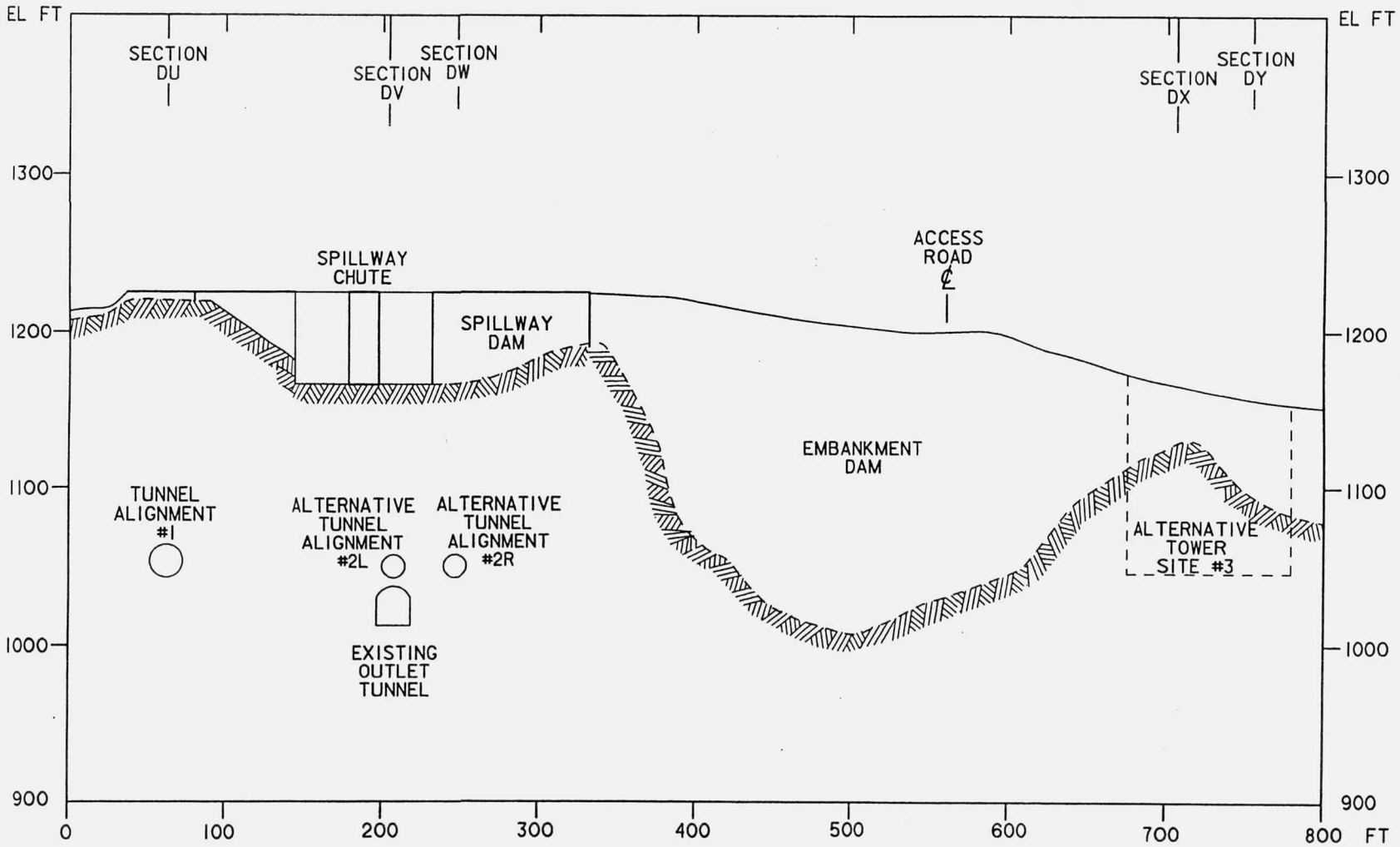



DO

**SECTION DO**
**DOWNSTREAM VIEW**

DO

EXHIBIT D3

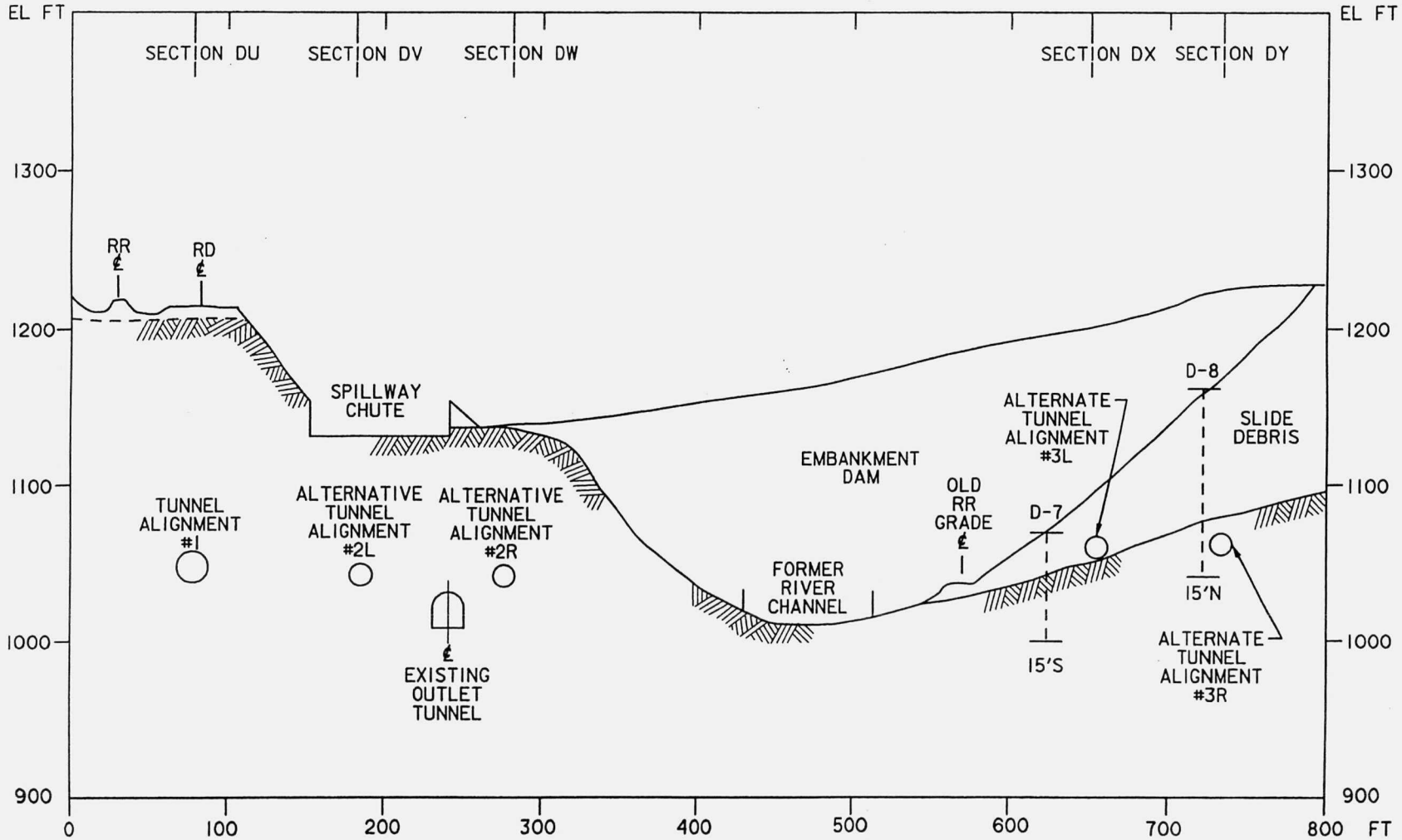



DP

**SECTION DP**
**DOWNSTREAM VIEW**

DP

EXHIBIT D4

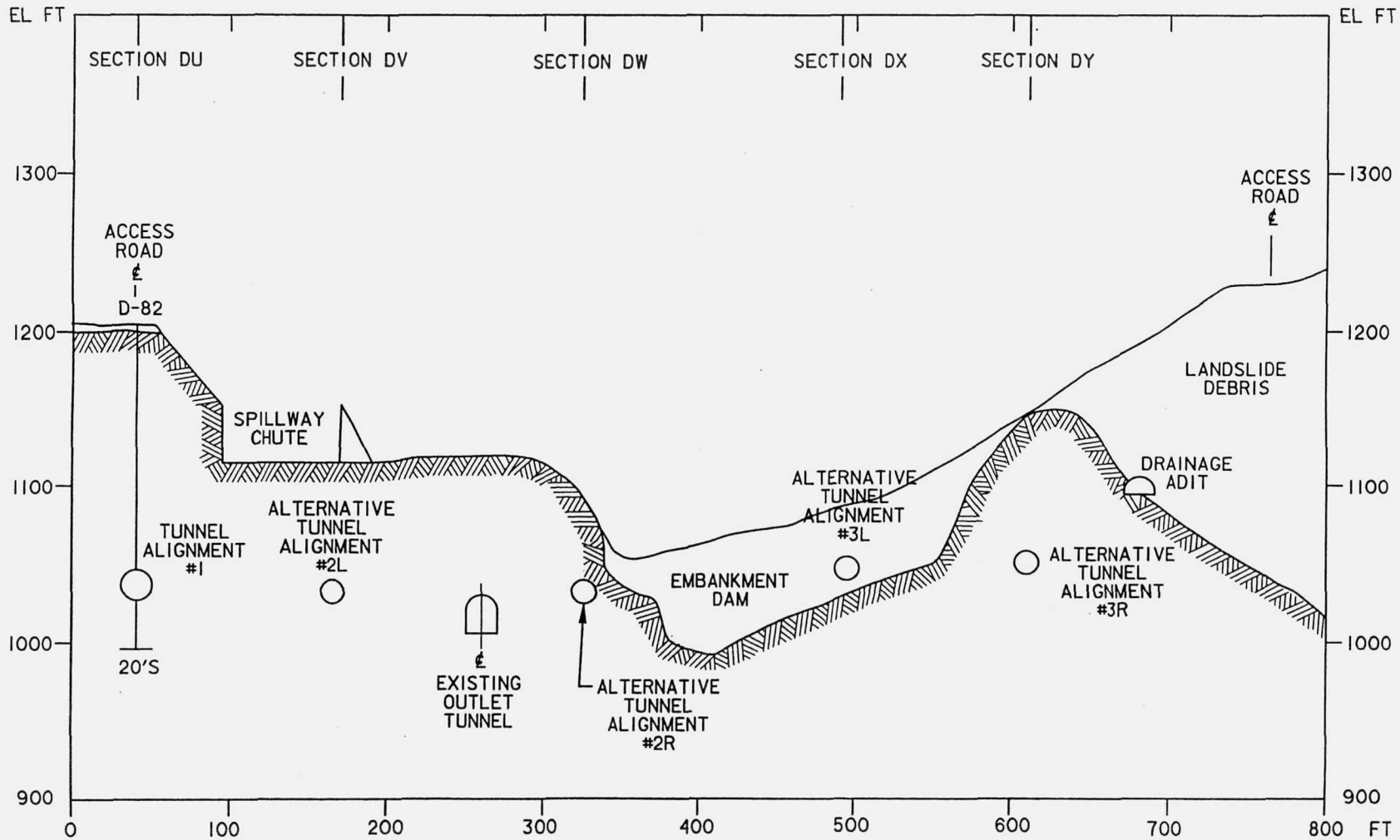



DQ

**SECTION DQ**
**DOWNSTREAM VIEW**

DQ

EXHIBIT D5

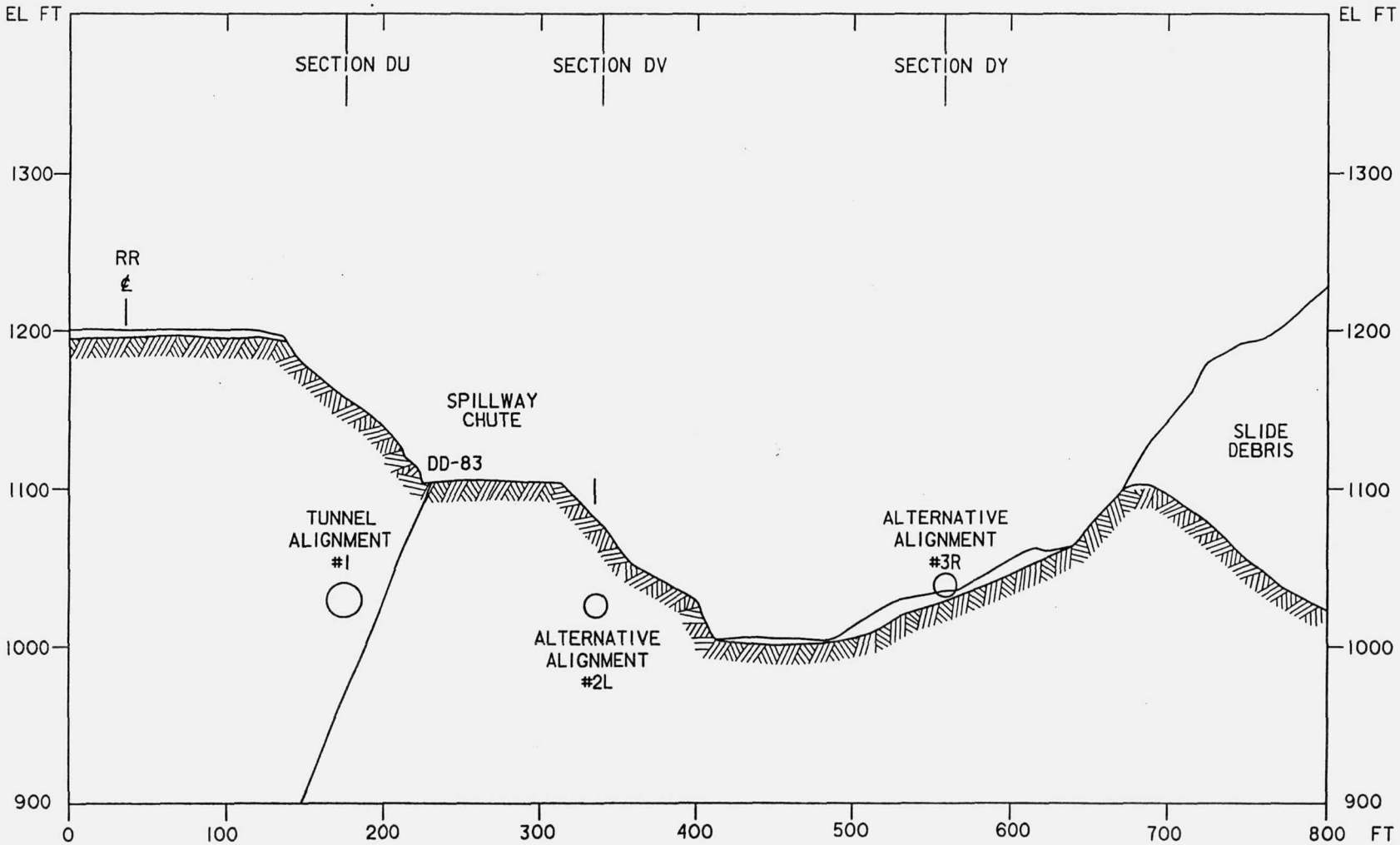



DR

**SECTION DR**
**DOWNSTREAM VIEW**

DR

EXHIBIT D6

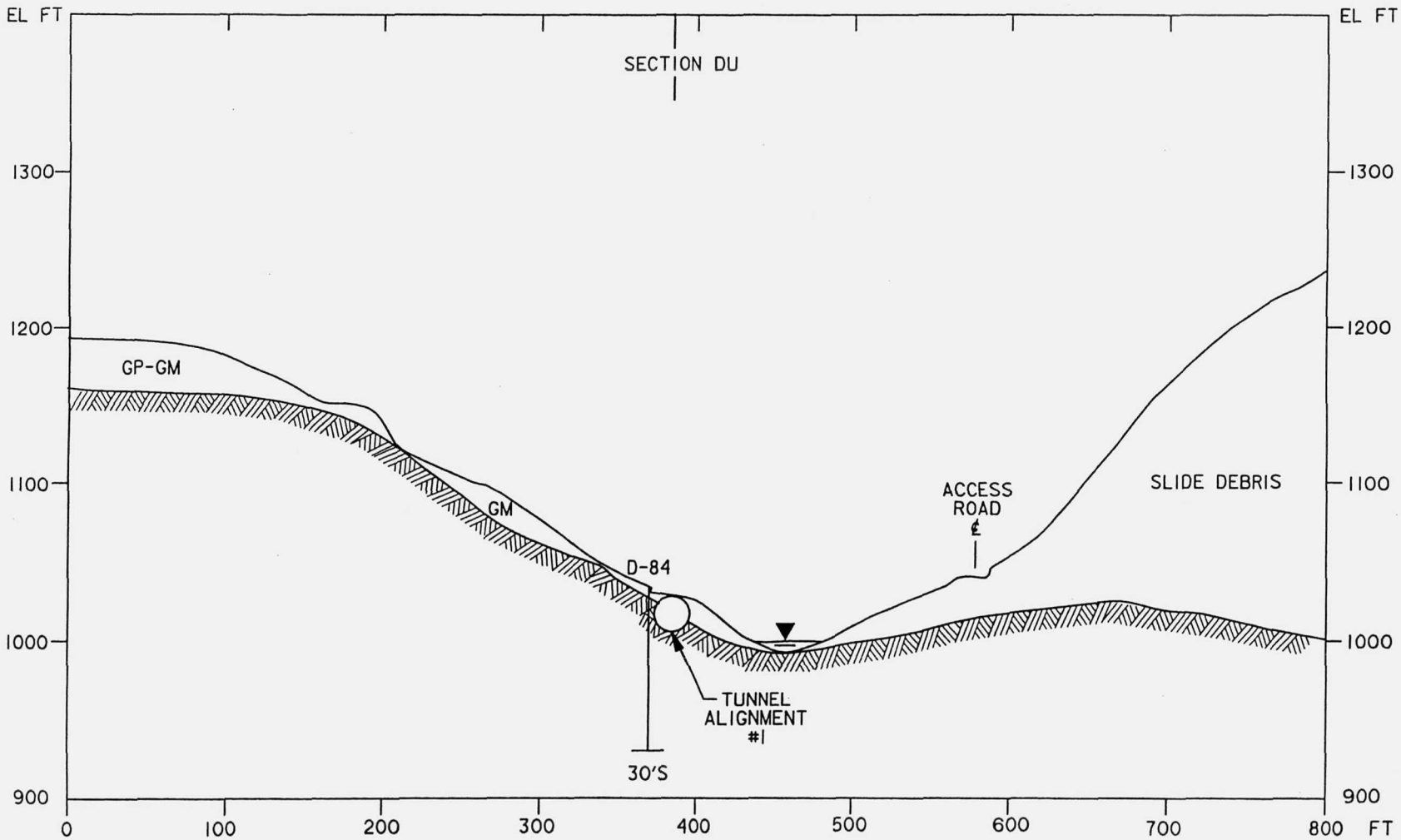



DS

**SECTION DS**
**DOWNSTREAM VIEW**

DS

EXHIBIT D7

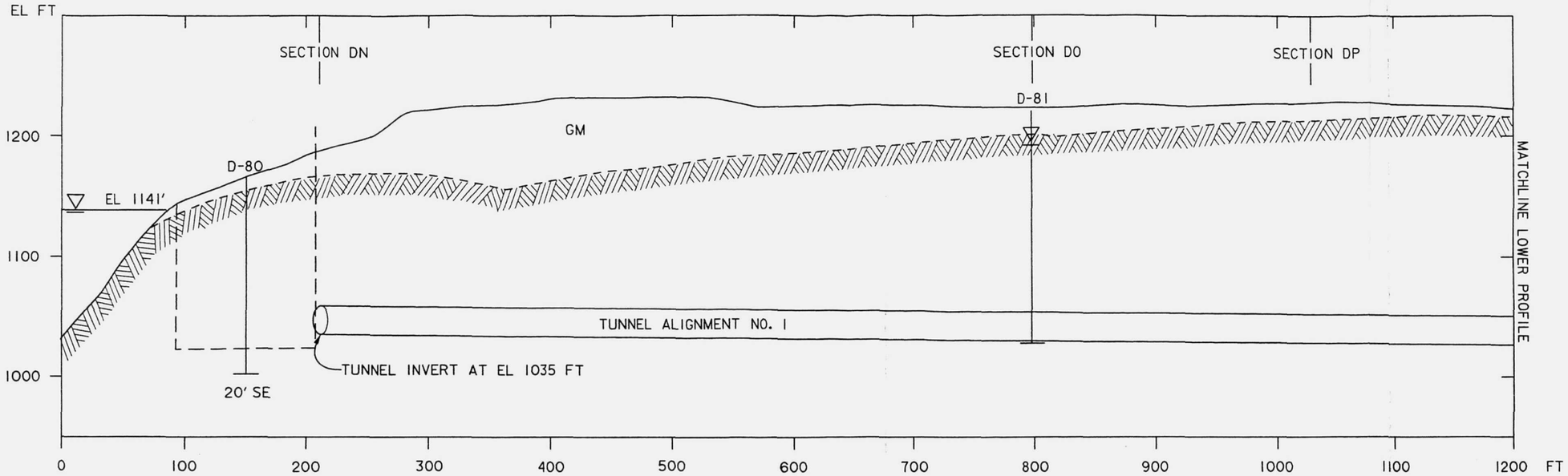



DT

**SECTION DT**
**DOWNSTREAM VIEW**

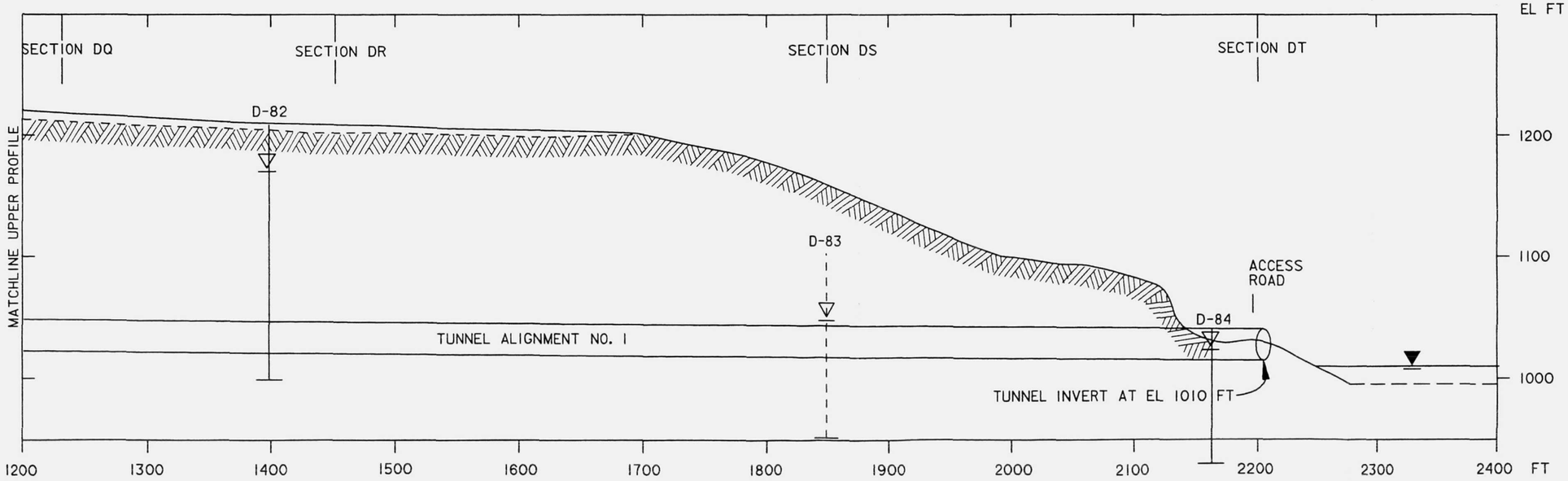
DT

EXHIBIT D8




NOTE: ▽ STATIC WATER LEVEL IN BORINGS APR 94

BORING DD-83 IS LOCATED 60' NORTH OF THIS SECTION AND IS INCLINED 70° FROM HORIZONTAL.

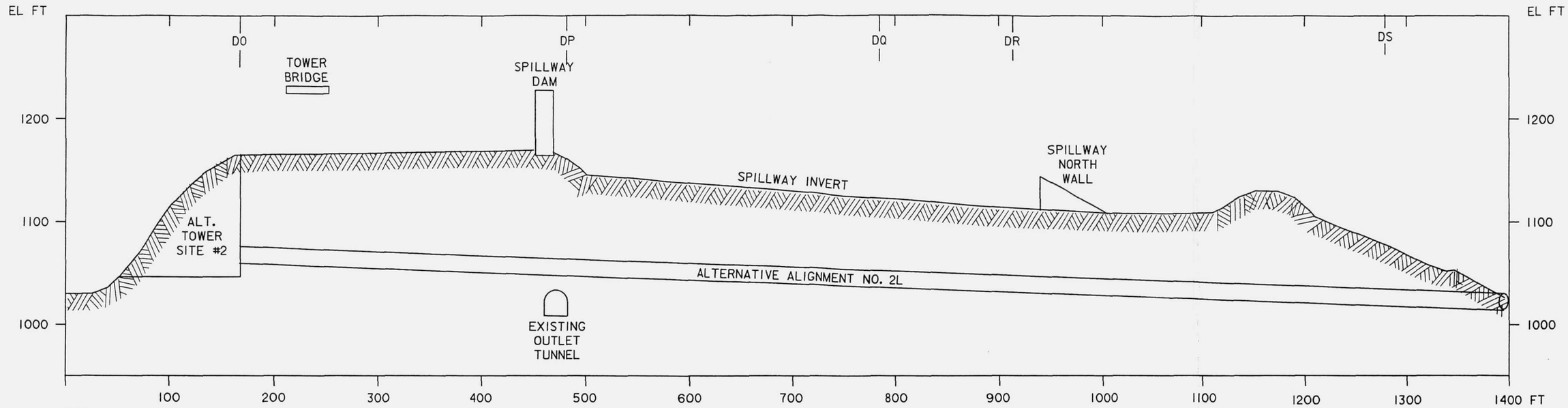



DU

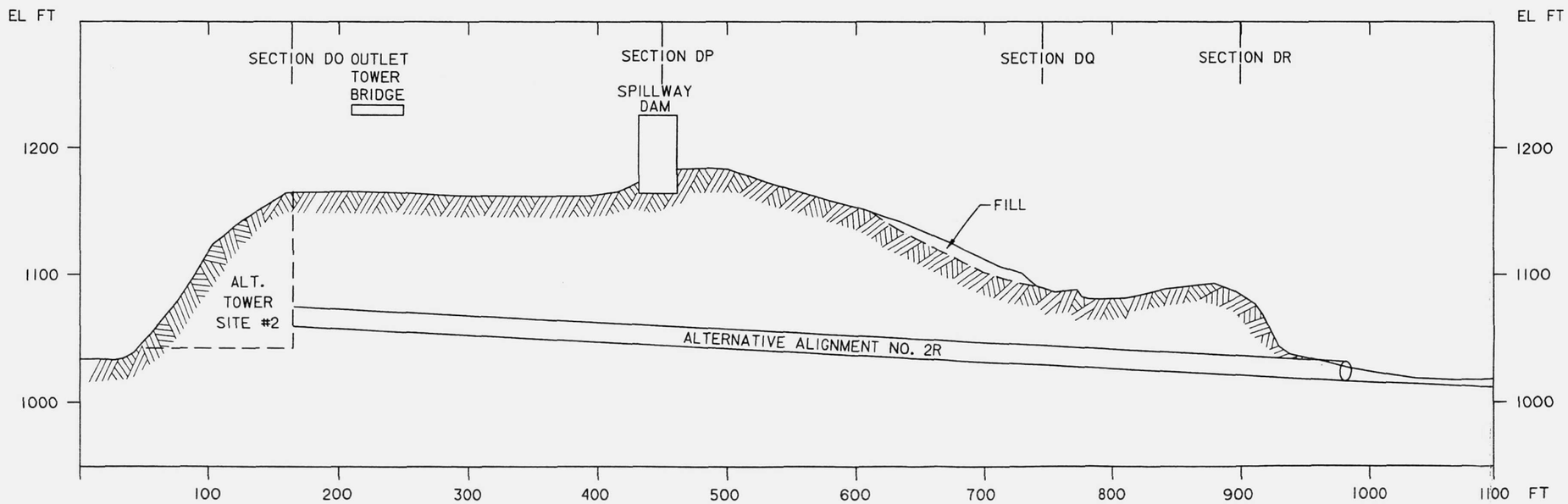
**SECTION DU**
**SOUTH ABUTMENT VIEW**

DU

| | |
|---|---|
| FISH PASSAGE FACILITY<br>HOWARD HANSON DAM | |
| GEOLOGIC SECTION DU<br>TUNNEL ALIGNMENT NO. 1 | |
| DSGN: ECKERLIN | DATE: 94 NOV 4 | EXHIBIT D9 |




**SECTION DV**
**SOUTH ABUTMENT VIEW**

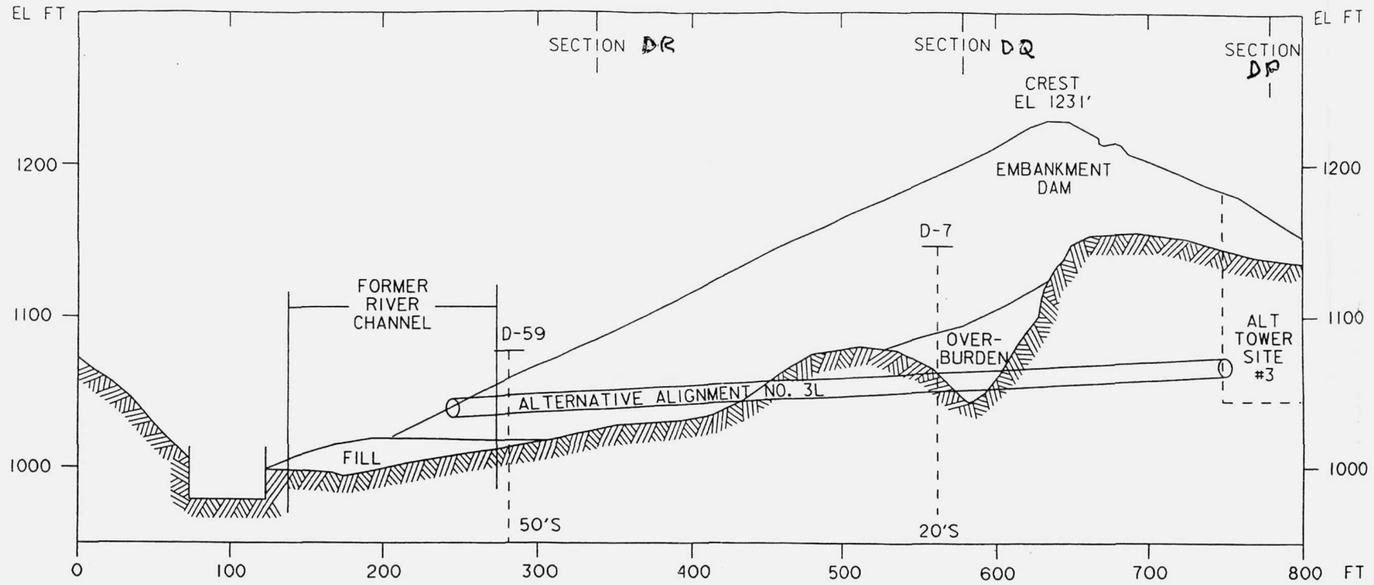



**SECTION DW**
**SOUTH ABUTMENT VIEW**

FISH PASSAGE FACILITY
HOWARD HANSON DAM

**GEOLOGIC SECTIONS DV & DW**
**TUNNEL ALIGNMENT NO. 2**

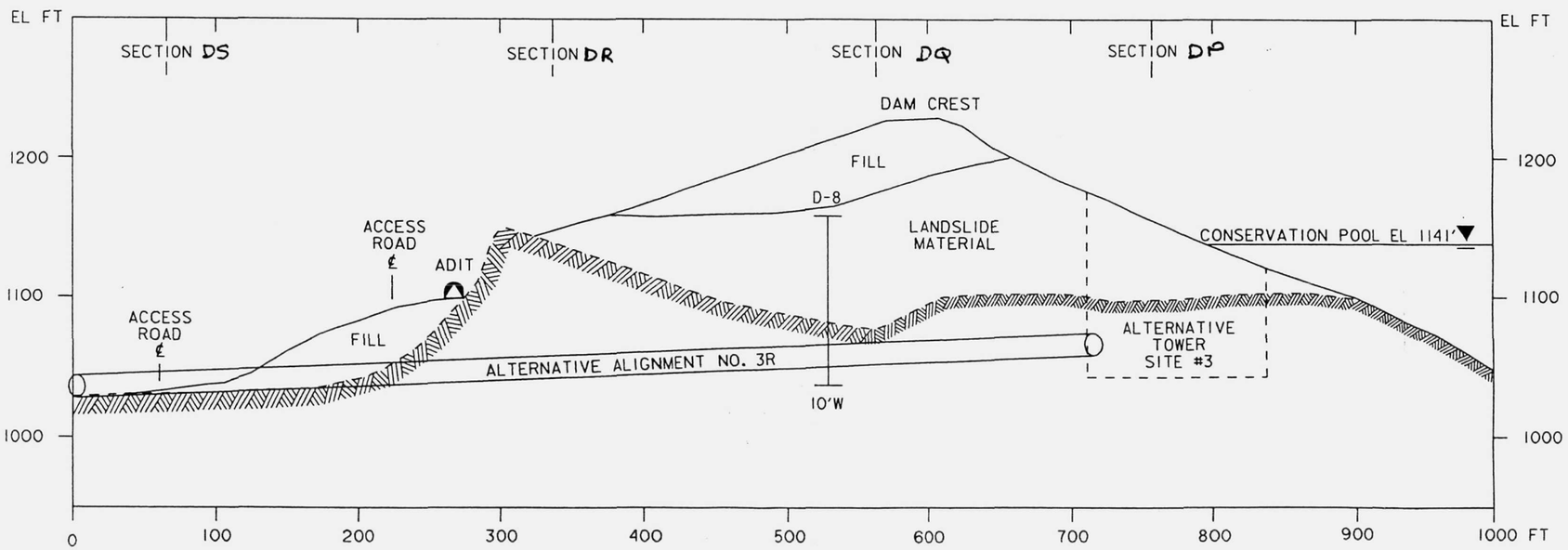
| DSGN: ECKERLIN | DATE: NOV 94 | EXHIBIT D10 |
|---|---|---|




DX

**SECTION DX**
**NORTH ABUTMENT VIEW**

DX




DY

**SECTION DY**
**NORTH ABUTMENT VIEW**

DY

FISH PASSAGE FACILITY
HOWARD HANSON DAM

**GEOLOGIC SECTIONS DX & DY**
**TUNNEL ALIGNMENT NO. 3**

EXHIBIT D1

| DSGN: ECKERLIN | DATE: NOV 94 | |
|---|---|---|