REPORT

EXHIBITS

SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
PROJECT No. 7114

1984 GEOTECHNICAL EXPLORATION PROGRAM WATANA DAMSITE

MAIN REPORT

FINAL REPORT

HARZA-EBASCO
SUSITNA JOINT VENTURE

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SUSITNA HYDROELECTRIC PROJECT

1984 GEOTECHNICAL EXPLORATION PROGRAM
WATANA DAMSITE

MAIN REPORT

Report by
Harza-Ebasco Susitna Joint Venture

Prepared for
Alaska Power Authority

Final Report
July 1984

NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING
THIS REPORT SHOULD BE DIRECTED TO
THE ALASKA POWER AUTHORITY
SUSITNA PROJECT OFFICE

1984 GEOTECHNICAL EXPLORATION PROGRAM
WATANA DAMSITE

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1984 GEOTECHNICAL EXPLORATION PROGRAM
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SUMMARY AND CONCLUSIONS

Fins Area

An exploration program comprised of five deep angle holes, totalling 2676 lineal feet of core drilling and borehole testing, was conducted across the upstream entrance face of the area known as the Fins. The program encountered no evidence of major shearing or faulting which would lead to significant underground seepage or erosion under filled reservoir conditions. The rock mass behind the face of the Fins feature is dominantly hard, competent diorite, with locally developed zones of closely spaced fractures, and alteration zones. Individual fracture and alteration zones have maximum widths of about 15 feet.

A residual zone of highly weathered to decomposed diorite exists locally at the bedrock surface, beneath the cover of glacial overburden. The zone has a maximum thickness of about 70-80 feet. The decomposed diorite appears to be the same material as was encountered in borehole DR-20 which prompted concern by the FERC review team in August 1983. The decomposed rock shows a progressively less weathered profile with increasing depth. The in-situ weathered rock does not represent a zone of structural weakness deep within the projected trend of the Fins feature.

Groundwater levels in bedrock at the Fins are consistently high, ranging in elevation from 2070 to 2142 feet. The high groundwater levels support the test data that indicate low transmissibility throughout the bedrock mass, from El. $\pm$ 2160 to river level at El. 1450. With future full pool reservoir level at 2185 ft., the underground hydraulic gradient for seepage over a length of 7000 feet to a possible outlet at Tsusena Creek (El. $\pm$ 1670) is very low, being on the order of only seven percent.

The origin of the Fins topography is interpreted to be the result of headward erosion and ice wedging in normally jointed, fractured and altered rock, rather than being the result of deep erosion of a major shear or fault-zone. The question as to why fin-like topography developed at this particular point along the valley wall appears to be related to the local drainage basin lying immediately above the Fins (See Exhibit 6). The basin directs concentrated surface runoff and seepage to the Fins outcrop area where it can erode the weaker or closely fractured rock and develop enlarged ravines and fin-like ribs by ice wedging and gravity toppling.

Downstream Portals Area

Moderately- to closely-fractured rock exists throughout most of the Downstream Portals Area, however, no major zones of shearing, faulting, or alteration were encountered.

The Downstream Portals Area corresponds to the geologic area previously referred to as the "Fingerbuster". The area is characterized by steep, rugged topography, partially wooded slopes, talus chutes, and limited outcrops along bedrock cliffs and benches. Geologic mapping has identified a dominant northwesterly structural trend and scattered outcrops demonstrate the presence of closely fractured rock and local shear/alteration zones.

Drilling in this area was undertaken to explore the extent of the fracturing, shearing and alteration which had previously been identified by surface mapping. The thickest alteration zone with weak rock material is approximately 10 feet thick. The degree of rock fracturing varies widely in this area, and is influenced by structural control and near-surface, stress relief fracturing.

Groundwater levels in the Downstream Portals Area generally vary from 40 to 80 feet below ground surface.

Local permafrost conditions were encountered in part of the lower right abutment. Ice was found filling fractures in core from boreholes DH84-3 (in the interval from 8.0 to 27.3 feet) and DH84-8 (from approximately 18 to 54 feet). After completion of borehole DH84-6, ice was found blocking the standpipe piezometer at a depth of 50-56 feet. These were the only instances of ice being encountered in rock or soil in the 1984 program.

Powerhouse (Design Refinement Location)

A 765-ft deep borehole was drilled to explore geologic conditions in the area of the proposed underground powerhouse. The rock mass in general is very hard, strong diorite and quartz diorite. Minor fracture zones and weak alteration zones were encountered, but primarily in the upper half of the borehole. Bedrock in the area of the proposed cavern was of excellent quality, characterized by high strength, high RQD's and low permeability.

1.0 INTRODUCTION

1.1 Background

In August of 1983, Engineers of the Federal Energy Regulatory Commission (FERC) conducted a site review of the Susitna Hydroelectric Project. The review included both the Watana and Devil Canyon Developments (See Exhibit 1) as both are included in the license application submitted to FERC by the Alaska Power Authority in March, 1983. The 1984 Geotechnical Exploration Program was developed primarily to answer questions raised by the FERC review panel relative to the Watana development (Exhibit 2).

The conceptual project plan for Watana, as depicted in the license application, consists of an 885 foot high embankment dam impounding a reservoir approximately 40 miles long. Crest length of the dam would be roughly 4000 feet, and the base of the dam would measure approximately 3900 feet in the upstream/downstream direction. Adjacent spillway and power intake structures would be located immediately upstream of the dam alignment on the right abutment. A 1020 MW underground powerstation is proposed in the downstream right abutment (Exhibit 3). Two diversion tunnels would be used to pass river flow during construction.

1 1.1 Principal Issue

During the site visit, FERC Engineers expressed concern over the potential erodibility and seepage potential of the bedrock mass northwest of the Fins, an area of high rock cliffs containing several nearly vertical zones of closely fractured and altered bedrock. The Fins lie immediately upstream of the proposed diversion tunnel intakes. The FERC Engineers also examined core from Corps of Engineers drill holes DR-18, DR-19, and DR-20. The decomposed, friable diorite from hole DR-20 prompted further concern relative to potential seepage and erodibility within the Fins feature.

In a letter dated September 23, 1983, the FERC Engineers formally expressed concern to APA regarding the Fins area. The FERC letter also discussed potential impacts on licensing, and recommended further geotechnical exploration in the Winter/Spring of 1984.

1.1.2 Program Response

In response to the FERC concerns, the Alaska Power Authority initiated correspondence with the FERC to discuss possible exploration programs at the Fins (correspondence dated October 12, 1983; November 1, 1983; November 9, 1983; and December 30, 1983).

The final program recommendation, APA letter to FERC dated December 30, 1983 provided for subsurface investigation of the Fins feature and additional work at the site of the Underground Powerhouse, and in the Downstream Portals Area (Fingerbuster Area). The decision to extend the scope of the investigation beyond the immediate area of the Fins was made primarily to support the license application by obtaining geologic information in the area of the powerhouse and the tailrace area of the proposed hydraulic structures.

1.2 Program Objectives

The principal objective of the 1984 Geotechnical Exploration Program was to further determine the character of the Fins feature and to evaluate the potential for seepage and erosion within the feature. These objectives were to be achieved through a program of surface mapping and subsurface investigations including core drilling, hydraulic pressure testing, borehole geophysical logging and groundwater observations and measurements.

Additional objectives of the program were to obtain basic geologic information in two downstream areas of proposed major structures. The first of these was the Downstream Portals Area which includes the proposed locations for the spillway flip bucket and the outlet structures for the diversion and power tunnels. The second area was at the site of the proposed underground powerhouse (Design Refinement location) in the right abutment. These objectives were also to be achieved by a program of surface mapping and subsurface drilling and testing.

1.3 Purpose and Scope of Report

The purpose of this report is to document and present the results of the 1984 Geotechnical Exploration Program, and to evaluate the data.

The scope of the report also includes discussions of the investigation techniques, the environmental and permitting conditions of the investigation, and background summaries of previous investigations in the areas addressed.

1.4 Acknowledgements

The Joint Venture wishes to acknowledge the participation and support of the Alaska Power Authority throughout both the planning and performance phases of the field program.

Technical advice and field review was provided by Harza-Ebasco Internal Review Board Members, Joe L. Ehasz, David E. Kleiner and Earl E. Komie.

High standards of drilling and borehole testing were carried out by Interstate Exploration, Inc. of Anchorage, Alaska, under direction of the Joint Venture field staff.

Field logistics support for the safe and economic conduct of the program were provided by Frank Mooli. and Associates, Air Logistics, and KNIK ADC.

Survey control and instrumentation monitoring was performed by R&M Consultants.

2.0 EXPLORATION AND TESTING

The scope of the various exploration and testing aspects of the 1984 Geotechnical Program is presented in the following section, 2.1 through 2.11.

2.1 Geologic Mapping

A program of geologic mapping and review of previous work was conducted in August and September, 1983, for the Fins outcrop area and the Downstream Portals area (Fingerbuster Area of previous reports). The limited outcrop on the upper right abutment, in the general area of the proposed spillway approach and power intake, was also mapped at this time. The maps (Exhibits 5, 11 and 14) are presented at scales of one inch = 50 feet for the Fins and the Downstream Portals Area; and one inch = 100 feet for the Upper Right Abutment. The scale change from previous work (one inch = 480 feet) was made to be consistent with future engineering layout work.

Tape and compass field mapping was performed using a close network of established survey points for control. Map preparation involved checking and integrating current work and that from previous mapping programs (Corps of Engineers, 1978; and Acres American, Inc., 1980-1983). The philosophy of the current map presentations is to restrict projection or extension of features beyond their actual limits in the field. This was done in order to more clearly identify known geologic control on the maps. Office work also included preparation of joint set contour summaries for each of the mapped areas.

The geologic mapping has been used in evaluating project refinements to the license application, and in establishing the orientation and location of boreholes for the current Geotechnical Exploration Program.

2.2 Overburden - Drilling and Sampling

All drilling in overburden was accomplished with helicopter-transportable, Longyear-38 drilling rigs equipped with HQ size, triple tube, wireline coring equipment. Samples were recovered using a 5-ft barrel with a split inner liner. Soils from glacial deposits, including alluvium, till and lacustrine materials, were successfully recovered from several boreholes in the Fins area when a polyacrylamide, non-particulate drilling additive was used to increase viscosity of the circulation fluid. Use of the polymer system allowed nearly 100% recovery in the overburden deposits, whereas little to no recovery was possible when using only water as the drilling fluid.

Samples were wrapped in plastic to maintain moisture prior to being photographed, and representative samples were selected for laboratory classification testing (Appendix E).

2.3 Overburden-Borehole Permeability Testing

Several constant head tests and one falling head test were conducted in overburden. Data are presented in Appendix B.

The majority of the overburden drilling in the Fins area was performed, as discussed above, with a polymer drilling additive which allowed virtually 100 percent core recovery in the soil section. Review of the soil samples revealed no materials of potentially high permeability and therefore permeability testing was minimized.

2.4 Bedrock Drilling and Coring

Coring equipment at all rigs was HQ-size, triple tube wireline core barrels, five feet long, with split inner liners. NQ wireline equipment was also

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available but was used in only one borehole to advance approximately 60 feet below the HQ size hole (DH84-4, 318 feet to 378 feet). All holes were drilled at angles of 30°-35° from the vertical.

In most instances it was possible to drill sucessfully with clear water as the drilling medium. In the deeply weathered section of the Fins area, however, it was necessary to use a drilling additive (the non-particulate, polymer discussed in 2.2) to increase core recovery and remove cuttings from the boreholes. Very high core recovery was possible even in zones of friable material when the polymer was used. The polymer also permitted more complete flushing of drill cuttings which otherwise tended to settle and bind the drill string and casing in the borehole.

A total of 4370 lineal feet of bedrock coring was completed during the 1984 program. A summary table of drilling statistics (Table 1.0) is presented at the end of Section 2.0, page 2-8.

All core was logged and checked in the field (See logs in Appendix A). Record photographs of all core were taken and are on file in the Harza-Ebasco office in Anchorage (one record set also submitted with original report to FERC). The core is now housed in storage facilities in Anchorage along with all other core and soil samples from the Watana site.

2.5 Borehole Alignment Surveys

Two deep boreholes in the Fins area, DH84-1, DH84-4A, and the Underground Powerhouse Hole, DH84-2, were surveyed using a Sperry-Sun, single-shot, borehole camera, to determine hole alignment. The unit, which consists of a floating compass, timer, camera and film, and 15 feet of non-magnetic rods, was lowered down the hole through the wireline rods on the wire line cable. The 15-foot length of non-magnetic rods carried the instrument through the wireline bit, beyond the magnetic influence of the drill string. The instrument was retrieved after each reading to process the film disk and reload.

Surveys were generally taken at 100 to 200 foot intervals when the drill rods were pulled, either during a bit change or upon completion of the hole.

Inclinations and bearings in the three boreholes surveyed, remained consistent to within one to two degrees throughout the length of the borehole.

2.6 Groundwater Sampling

A program of groundwater sampling and analysis was initiated in order to characterize the geochemistry of groundwater in the Fins area. Samples for analysis were also obtained from the lake water that was used as drillwater supply.

Following initial sampling at a borehole, the borehole was bailed using a modified air lift, which employed compressed nitrogen introduced at the bottom of each hole through 3/4 inch - diameter steel rods. Samples were again taken after the water level within the borehole had recovered.

The pH of water samples was read directly in the field. The samples were then sealed and shipped to Anchorage for laboratory analysis. The analyses reported the following parameters: conductivity; total dissolved solids; and concentrations of Na, Mg, K, CO_3, HCO_3, HSO_4, CI, NO_3, and B.

The data are maintained on file for incorporation with future monitoring and sampling work.

2.7 Bedrock-Hydraulic Pressure Testing

Hydraulic pressure tests were conducted in boreholes to estimate relative permeabilities of the rock mass. All tests were conducted with an open-bottomed, wireline packer system lowered through the drill rods to test the interval of hole below the drill bit. In general, boreholes were tested in 50-foot intervals as the drilling progressed, however in some cases, longer intervals of boreholes were tested by moving progressively uphole in 50 foot increments. In these cases the water take values of lower intervals were subtracted from higher interval tests to estimate the water takes of higher zones (further discussion is presented in Appendix C).

Boreholes in which drilling additives were used to maintain hole conditions were thoroughly treated and flushed prior to conducting final water tests.

All pressure tests were conducted by measuring water losses at three increasing pressures, and then reversing the sequence of pressures to return to the initial test pressure. The test data were converted to Lugeon values for comparison between test intervals. The summary table of Lugeon values is presented in Appendix C, and representative Lugeon values are shown on Exhibits 10, 13, and 16.

2.8 Geophysical Logging

Geophysical logging was conducted to aid in the interpretation of subsurface data, especially in zones of poor core recovery; and to provide a standard to evaluate use of such techniques in future programs.

The geophysical program consisted of density (gamma gamma), porosity (neutron), and a natural gamma logging. The density tool was selected to develop criteria for recognizing low density zones such as fractured, sheared, altered or deeply weathered rock. The neutron or porosity tool was used to help identify water bearing zones and static water levels. The natural gamma tool was used to indicate correlations between boreholes and to assure that boreholes were free of obstructions (it was necessary to assure the open conditions and safety of each borehole prior to using either the neutron or density tools, since both employ nuclear sources closely regulated by the NRC).

Geophysical surveys were run in all boreholes of the 1984 current program, and they are presented in Appendix D along with equipment descriptions, notes on operational procedures, and general notes on interpretation of the logs.

2.9 Observation Devices

Each of the boreholes drilled in the current program is equipped so that water level(s) within the borehole can be monitored. The specific installations vary from single, open-standpipe piezometers using 3/4 inch to 2-inch ID slotted PVC, to installations covering two intervals within one borehole. Remote sensing pneumatic pressure cells were also added to some installations to ensure continuity of readings during the winter months when near surface water in the piezometers would be subject to freezing. Summary sketches of piezometer installations and recovery curves for the bailed piezometers are presented in Appendix F.

2.10 Laboratory Testing/Soils

Representative samples from the overburden encountered in the Fins, and soil-like materials from the buried weathered zone were tested for classification at the on-site soils laboratory. The materials were classified according to the Unified Soils Classification System. Atterberg limits were determined for the fine grained materials, while grainsize analyses were conducted on the coarser fractions. A total of 15 samples was tested. Results are presented in Appendix E.

2.11 Point Load Testing

Diametral point load tests were performed on representative bedrock samples to establish a range of values for specific rock types. The tests were performed at the on-site laboratory as the core was being reviewed during final logging. Test data and notes are presented in Appendix G.

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Table 1.0 1984 Exploration Program Data Summary

Borehole Number	Azimuth	Inclination From Vertical	Ground Surface Elevation (ft)	Overburden Thickness (ft)[1]	Bedrock Elevation (ft)	Total Depth (ft)
DH84-1	244°	34°	2143.1	18.5	2124.6	848.5
DH84-2	019°	30°	2024.2	14.7	2011.5	765.0
DH84-3	025°	30°	1503.3	8.5	1495.9	132.2
DH84-4	050°	35°	2161.4	116.9	2065.6	378.0
DH84-4A	040°	35°	2167.8	72.4	2108.5	698.5
DH84-5	010°	30°	1725.6	15.1	1712.5	265.0
DH84-6	025°	30°	1521.4	9.0	1513.6	167.8
DH84-7	025°	30°	1625.3	4.2	1621.7	263.5
DH84-8	012°	30°	1677.1	8.5	1669.7	100.0
DH84-9	225°	35°	2161.5	148.2	2040.1	497.5
DH84-10	230°	35°	2161.5	61.6	2111.0	254.0

[1] Overburden thickness as measured along the hole axis.

3.0 PERMITS AND ENVIRONMENTAL PROTECTION

The 1984 Geotechnical Exploration Program was conducted with land use authorizations and permits obtained before and during the program. Permit stipulations and control of exploration activities resulted in the program being executed with minimal damage to the environment.

A nationwide permit (Section 404) from the U.S. Army Corps of Engineers authorized field explorations on Federal lands. The Alaska Power Authority coordinated land use with CIRI Native Corporations.

Other permits obtained include a temporary water use permit (No. SC/MS 84-1) from the Alaska Department of National Resources (ADNR). Archaeological clearance of all boreholes was obtained from the University of Alaska Museum/ADNR. Rail Transport was coordinated with the Alaska Railroad.

4.0 INVESTIGATIONS IN FINS AREA

4.1 Introduction

4.1.1 Previous Work

Previous work relating to the Fins feature has involved geological mapping of the outcrop area along the inner gorge of the Susitna River Valley, and subsurface projection to the northwest from the outcrop toward Tsusena Creek. The projections were based on seismic interpretations, and an outcrop of altered and sheared diorite located on the northwest bank of Tsusena Creek (Acres American, 1982 pp. 5-23 to 5-27). In 1978, the U.S. Army Corps of Engineers drilled five boreholes along the strike projection of the feature (DR-16, -17, -18, -19, and -20) but maximum penetration of bedrock was limited to only 42 feet. The 1983 Winter exploration program also involved borings in this area (see Exhibits 6 and 7), but the investigation was aimed primarily at soils exploration and penetration into bedrock was quite limited.

The basic information available from previous mapping is that the outcrop area of the Fins is comprised predominantly of sound, jointed bedrock, but the rock mass also contains steeply inclined, northwesterly trending zones of closely fractured rock, 5-10 foot wide zones of weak, friable altered rock and zones of plastic, sandy clay which measure one inch to approximately one foot in thickness. The zones are difficult to trace in outcrop due to the steepness of the terrain, talus cover, and thick overburden deposits above approximate elevation 2000 feet.

4.1.2 Scope of Current Investigation

The current program to investigate the erodibility and seepage potential of the rock mass in the Fins area involved 2,676 linear feet of coring in a series of five deep, inclined boreholes. The boreholes were spaced across the projected strike of the Fins to achieve coverage of approximately 900 feet perpendicular to strike, and 400 feet parallel to the strike trend (Exhibits 6 and 9).

Hole depths ranged from 254 feet to 848.5 feet. The total vertical span covered approximately 700 feet from an average elevation of about 2150 on the upland surface to elevation 1450 approximately at river level.

Each of the holes was drilled, tested and completed with observation devices under direct supervision of a rig geologist/inspector. Core was logged directly at the hole as it was recovered (logs presented in Appendix A); and all core and logs were reviewed again at the site storage facility for completeness and uniformity.

Boreholes DH84-1 and DH84-4, and -4A follow the original plan of spanning the projection of the Fins feature. Borehole DH84-9 was added to obtain geologic information along strike to the northwest; and DH84-10 was added to extend geologic coverage beyond the projected feature to the southwest.

4.2 Overburden

4.2.1 General Description

Overburden thickness in the area drilled ranged from about 15 feet at DH84-1 to a maximum of about 95 feet at DH84-4. The materials generally consist of moderately weathered to unweathered dense glacial deposits ranging from slightly clayey, silty sand to pebbly, bouldery silty sand. The compact nature of the glacial deposits was confirmed by the geophysical logging which showed the apparent density of the overburden section to be locally comparable to competent bedrock. Drilling in the overburden encountered no zones of high permeability. Testing is primarily limited to several constant head tests performed in DH84-4, and these indicate permeability values on the order of 10^{-4} cm/sec. Data are presented in Appendix B.

Inspection of continuous core across the contact between overburden and the underlying zone of decomposed diorite indicates that the contact is also impermeable.

4.2.2 Classification of Materials

Index property tests were performed on selected samples of overburden and the decomposed diorite from the Fins area. All samples were prepared and tested using ASTM methods. Materials were classified using the Unified Soil Classification System. Soil descriptions are based on field and laboratory visual examination and laboratory test results. The test results for grain size distribution, Atterberg Limits and moisture content tests are presented in Appendix E, and are discussed below in section 4.2.3.

4.2.3 Material Properties

Ten soil samples from the overburden in boreholes DH84-4, -4A, -9 and -10 were selected for grain size distribution and plasticity testing. The samples were found to consist of well graded, medium to fine grained sand, silty sand, and clayey sand (SW, SW-SM, SC); and silt and clay (ML, CL).

The data (see Figures E-1, E-3 and Table E-1 in Appendix E) indicate that the stratigraphically higher soil samples generally consist of clay and very clayey sand, with an average of 51 percent of the material passing through the #200 sieve. The materials have low plasticity with an average Liquid Limit of 19, and an average Plastic Index of 6. Atterberg Limit test results are shown in Figure E-3. The data fall just above the A Line in the clay and silt-clay region of the chart. The stratigraphically lower soil samples generally consist of clean to silty, well graded sands. The average fines content in these samples was determined to be 5 percent passing through the #200 sieve.

In addition to the classification of overburden soils, five samples of decomposed diorite were also tested. The samples were taken from boreholes

DH84-4A, -9, and -10. Inspection of Figure E-2 and Table E-1 (Appendix E) indicates that the deeply weathered diorite, when mechanically broken down to a soil, results in medium to fine grained, poorly to well graded sands and silty sands (SW, SP-SM, SW-SM). The average fines content passing the #200 sieve was 6 percent.

4.3 Bedrock

4.3.1 Bedrock Topography

Buried bedrock topography in the Fins area indicates a northwesterly trending topographic low extending from elevation ± 2100 feet at the current drill area to elevation ± 1700 feet at Tsusena Creek (Exhibit 7). Top of bedrock in the Fins boreholes lies between elevations 2066 and 2125. The close spacing of holes in the area of DH84-4, -4A and -10 indicates that locally the bedrock surface (top of decomposed diorite) varies in relief to a greater extent than the surface topography. Relief on the bedrock surface in this immediate area is shown to be as much as 45 feet vertically in a horizontal distance of only 60 feet (Exhibit 9). The relatively steep relief is believed to be the result of differential erosion prior to deposition of the glacial overburden.

4.3.2 Lithology and Rock Quality

The bedrock encountered in the Fins area consists primarily of hard, strong diorite and quartz diorite. Intervals of andesite porphyry and minor felsic dikes were also encountered.

With the exception of local, highly altered zones and the decomposed diroite weathering zone to be discussed below (sections 4.3.4 and 4.3.5), rock quality across the Fins area appears to be quite good: RQD values vary considerably (Exhibit 10), but with regard to seepage potential erodibility, no uncommon or extensive rock defects were encountered.

4.3.3 Structure

Drill core from the current program presents a virtually complete picture of the structural features of the Fins area. The high percentage of recovered core adds continuity and detail to the structural features observed from mapping, and the new data generally confirm the validity of the early surface observations.

Zones of closely fractured rock as much as 15-20 feet wide are present (see Exhibit 9), in the Fins area, and all boreholes encountered areas of fractured rock. There is however no evidence indicating continuity of fracture zones, either by correlation between boreholes or by high takes during the pressure tests.

Detailed examination of fracture surfaces in the core reveals occasional instances of slickensides, and clay infilling which may be related to local shearing. Healed breccia and healed microfractures are also common in the overall rock mass.

The most significant observation regarding structural features in the core is that no major, through-going structural elements persist through the area of the Fins feature. No major faults, shears, breccia zones or other indications of structural weakness were encountered that might permit excessive seepage or internal erosion of the rock mass comprising the Fins area.

Another indication of the lack of major structural features or extensive poor rock conditions was the ability to drill inclined boreholes to depths of 700 to 850 feet with deviations of bearing and inclination amounting to only 1-2 degrees.

4.3.4 Alteration Zones

Hydrothermal alteration in the Fins, as elsewhere on the site, has affected the bedrock to widely varying degrees. In most cases a yellow to red alteration of feldspars is apparent with little to no effect on the structural integrity of the rock. At the opposite extreme, and to a much lesser extent, the bedrock may be locally altered to a bleached, grey/white, drummy or clayey, low density, friable material with very low strength. This rock can be broken easily with finger pressure. Kaolin and chlorite are the dominant secondary minerals.

The alteration processes appear to have gained access to the rock mass through discrete fractures or fracture systems. In some instances an alteration zone 2 to 3 inches wide may be developed on either side of a distinct fracture, but in most cases there is no readily apparent control structure.

The local zones of deeply altered and weakened rock occur with much the same distribution and lack of continuity as the zones of closely fractured rock. Maximum thickness, assuming verticality, of any single severely altered zone is on the order of 5-10 feet.

4.3.5 Weathering

Two distinct styles of weathering have developed in the Fins area. At borehole HD84-1 on the northeast side of the area, bedrock weathering is shown primarily by iron oxide stains on joints and fractures. On the southwest side of the Fins area, however, a thick weathered zone of decomposed diorite has developed as a "cap" on the bedrock surface. The decomposed diorite was first encountered in hole DH84-4 but core recovery was very low. Subsequent drilling with a polymer additive system increased core recovery to essentially 100% and the nature and origin of the material became readily apparent.

As shown on Exhibit 9, the highly weathered zone is developed to a maximum depth of approximately 70 to 80 feet. The rock within the weathered zone is decomposed diorite, with crystal fabric still quite evident, but the rock is friable and breaks down readily to coarse, sand-size particles. The upper portion of the zone is iron-stained. The transition to sound rock occurs gradually over several tens of feet.

No pressure tests have been obtained in the highly weathered zone due to the inability to seat packers, but there have been no indications of high permeability in the zone, either by loss of drillwater or by visual inspection of the recovered core from DH84-4A, -9 or -10.

The presence of a weathered zone of decomposed bedrock had not been recognized previously at the site, presumably because preservation of the zone is dependent on a mantle of overburden and it has therefore not been observed in outcrop. Material recovered in Corps of Engineers borehole DR-20, however, is also highly weathered-to decomposed diorite from beneath a cover of overburden deposits, and it is now evident that the core from borehole DR-20 represents partial penetration of the same highly weathered bedrock zone defined by the current drilling program.

The areal extent of the buried, decomposed diorite zone is not known with certainty beyond the occurences in boreholes DH84-4, -4A, -9 and -10; and DR-20, 1700 feet to the northwest. Preliminary review of refraction seismic data, however, does indicate a small area in the southeastern part of the Fins feature which has lower seismic velocity response than the surrounding areas (Exhibit 7). The velocity contrast is from 11,000-12,000 ft/sec to 13,000-18,000 ft/sec.

A direct correlation of the lower seismic velocity area with the decomposed diorite zone is not fully tested, however the higher velocity response in the surrounding areas, as well as previous borehole information in the surrounding areas, indicates that the "cap" of decomposed diorite is of limited extent.

4.3.6 Hydraulic Pressure Test Results

The results of hydraulic pressure testing in the Fins boreholes are presented in tabular form in Appendix C, and graphically on Exhibit 10.

The most complete testing was performed in DH84-1, the initial hole in the Fins area, a hole drilled with water as the circulation fluid. The test data indicate very low permeability, with Lugeon values ranging from 0.0 to a maximum of 3.5.

Testing in DH84-4, a second borehole drilled with water, also indicated low water takes. Lugeons values of 0.6 to 1.6 were calculated for the lower part of the borehole but complete testing was not possible due to the lack of packer seats in the decomposed to highly weathered zone at the top of the borehole. Indeed, removal of drill cuttings from the borehole became an increasingly difficult problem as the cuttings continually built up around the rods and caused seizure of the drill string. Repeated cement plugs were not able to control the problem. Even after casing had been advanced through the decomposed diorite zone, cuttings bound the rods at a depth of 378 feet and a decision was made to abandon the hole and redrill using a polymer additive system.

The polymer additive greatly improved recovery in the remaining boreholes and helped eliminate the binding of rods. As a consequence of using the additive, the remaining boreholes were not pressure tested until final depth was reached, at which point the polymer was flushed out; the borehole was treated with a chlorox solution; and then reflushed with fresh water. Short duration hydraulic tests were then conducted over large intervals of the borehole as there was still considerable risk of locking the rods during the testing operation when circulation in the water-filled borings had to be stopped. No tests were conducted in DH84-10 because of indications of binding even with the use of the polymer drilling additive.

Tests from boreholes in which the polymer had been removed also showed low permeability. The range of results for all such tests was 1.0 Lugeon or less.

4.3.7 Geophysical Logging Results

Results of borehole geophysical surveying in the Fins area (see Appendix D)indicate that hard, strong diorite is present at approximately 100 feet (vertically below ground surface) in DH84-4; 110 feet in DH84-10; between 98 and 115 feet in DH 84-1; 115 feet in DH 84-4A; and 220 feet in DH 84-9. In each borehole below these depths, the diorite is less fractured and jointed, is mostly fresh and unweathered, and becomes more dense and more competent with increasing depth.

The overburden is generally characterized by a lower neutron count (higher water content) than the underlying rock. Glacial till is generally characterized by a lower gamma-gamma count (higher density) than the overlying clayey silt and sand and the underlying deeply weathered diorite. For example, in DH 84-4A and DH 84-10 where geologic samples and core indicate stiff, dense basal till overlying weathered diorite, the logs show a slight increase in porosity and a large decrease in density with depth.

The large density shift at 18 feet on DH 84-4A marking the top of brown, clayey sand correlates with the ± 42 foot point on DH 84-4. Dense till is indicated by the density log in the 40-80 foot interval of DH 84-4.

4.4 Groundwater

Bedrock groundwater levels determined in the current investigation of the Fins area are uniformly high, ranging from El. 2070 to El. 2142 (recovery curves and stabilized waterlevels are presented in Appendix F). By plotting piezometer data vertically above the instrument position in the inclined boreholes (see Exhibits 9 and 10), groundwater across the Fins is indicated at a general depth of 10-20 feet below ground surface.

The high groundwater levels associated with all of the current boreholes, as well as previous borings in the area (see also Exhibit 8) are a primary indication of the overall low permeability of the bedrock mass in the Fins area.

Further, it should be noted that the current groundwater levels are only 40 to 115 feet lower than normal pool elevation of 2185 feet, so that full reservoir conditions will mean only slight changes in the elevation head difference of the groundwater between the Fins area and Tsusena Creek, where seepage is now essentially non-existent.

4.5 Permafrost

No ice was present in any of the core recovered from the Fins area drilling and no other indications of permafrost were encountered during subsequent testing and monitoring. This condition is consistent with the results of other borings and thermister data in the immediate area.

4.6 Evaluations

The data obtained in the current investigation indicate that the potential to develop significant seepage losses or internal erosion within the rock mass extending from the Fins outcrop to Tsusena Creek is extremely low.

4.6.1 Erosion Potential

The occurence of soil-like material in the decomposed diorite zone and in severely altered sections in the subsurface of the Fins area has been established by the current investigation. The question of whether the material is erodible, however, is primarily dependent upon the physical nature of the materials (fabric and compactness), the degree of confinement, and/or access to water having sufficient velocity to move particles. Visual inspection of core and soil classification results both indicate that the material is not subject to piping or internal erosion.

On the entrance face of the Fins outcrop it is clear that surface weathering and erosion can preferentially erode weaker rock materials and undermine adjacent areas of strong rock. In the subsurface however, the weak materials are discontinuous in extent and are confined either by massive rock or by an overlying layer of very dense glacial till. Further, there has been no indication of open fractures or breccia zones which could maintain an erosive flow of water. The confinement of weak rock materials in the subsurface, the low gradient (approximately seven percent), and the low bedrock permeability combine to indicate an extremely low probability of developing internal erosion conditions in the Fins feature.

4.6.2 Seepage Potential

The potential for development of excessive seepage through the rock mass of the Fins, from the outcrop in the reservoir area to Tsusena Creek, is also extremely low. For such conditions to develop, the rock mass would have to be characterized by open, permeable conditions which might accompany major regional faults, or shear and breccia zones. The subsurface drilling and testing data demonstrate that the rock mass is not cut by such major structural zones.

The high groundwater levels in the Fins area also indicate low permeability throughout the rock mass. If the rock mass contained areas of high permeability, the regional water table would be drained to a much lower level than is currently maintained. Over 600 feet of head differential now exists between the current boreholes (DH84-1, -4, -4A, -9 and -10) and the Susitna River, a distance of 1200 feet; and this potential gradient of 50 percent has produced no indications of unusual seepage at the Fins.

In conclusion, the addition of about 100 feet of reservoir head to the high static water levels in the Fins would result in an overall gradient of seven percent acting over a 7000-foot flowpath towards Tsusena Creek. This low gradient and the low bedrock permeability would result in insignificant seepage to Tsusena Creek.

5.0 INVESTIGATIONS IN DOWNSTREAM PORTALS AREA

5.0 Introduction

5.1.1 Previous Work

Previous surface work in the Downstream Portals Area, also known as the "Fingerbuster" (Corps of Engineers, 1978), has included general reconnaissance, tape and compass geologic mapping (COE, 1978; Acres 1980-82, and Harza/Ebasco, 1983) and seismic refraction profiling (1978, 1980 and 1982). One deep (401 ft) exploratory borehole (BH-2, Acres 1980) was also drilled in the westernmost portion of the area to investigate the Fingerbuster area (Exhibit 4).

Geologic mapping has indicated dominant northwesterly and northerly structural orientation for jointing and fracturing. Closely fractured, sheared, and weak, hydrothermally altered rocks crop out in limited areas, but their extent is largely concealed by vegetation, talus, and the limited access on steep terrain. As in the Fins area, most of the rock outcrop is hard massive diorite with open jointing very evident on the steep slopes of the inner gorge.

Seismic refraction work has indicated a near surface zone of low velocity rock (7000 ft/sec) extending to depths of roughly 50 to 100 feet below ground surface in the area of the spillway bucket. The seismic lines where this occurs are shown on Exhibit 4 (see SL82-7, SL82-8, and the westernmost 200 feet of SL82-6). Additional low velocity zones, 7500 ft/sec to 9000 ft/sec, were also noted on line SL82-5 further upslope along the spillway alignment (see Acres, 1982 Supplement to the 1980-81 Geotechnical Report, Volume 2, Figs 6, 7 and 8 for profiles of all lines referenced above).

5.1.2 Scope of Current Investigations

The current program to obtain basic geologic information in the Downstream Portals Area consisted of the drilling and evaluation of five inclined boreholes, ranging in depth from 100 to 265 feet. The boreholes were oriented to cross the general northwest strike of the geologic structural trends, with locations in the area of the spillway cut, spillway bucket, and the area of the diversion and tailrace tunnel portals (Exhibit 3).

5.2 Overburden

5.2.1 General Description

Overburden in the Downstream Portals area was found to consist of a shallow pervious cover of talus, slope debris and remnants of river alluvium. Talus blocks generally measure two or three feet in maximum dimension, and overall thickness of the overburden in the boreholes was found to vary from approximately 5 to 15 feet.

5.3 Bedrock

5.3.1 Bedrock Topography

The generally steep valley slopes in the Downstream Portals Area contain little to no overburden as evidenced by mapping and the current drilling program. As a result, surface topography of the steeper slopes is a reliable indicator of bedrock topography.

The only general exception is the area southeast of boreholes DH84-3 and -6. Here, the terrace-like bench below Elevation 1500 suggests deeper overburden cover and this is supported by the approximately 50-foot (vertical) section of alluvial material encountered in borehole HD83-47 which was inclined beneath the terraced area from the north bank of the river.

5.3.2 Lithology/Rock Quality

Bedrock in the Downstream Portals area ranges in composition from diorite to quartz diorite. Much of the rock mass is unaltered, but the effects of hydrothermal alteration are still evident to varying degrees.

As elsewhere on the site, the quality of the rock mass is largely a function of the degree and extent of alteration and fracturing. In general terms, rock quality in this area can best be characterized as highly variable. The extent or degree of alteration is not unusual (see section 5.3.4), however the intensity of fracturing, especially in the boreholes drilled on the steeper rock slopes (DH 84-5 and -7), is such that low RQD values can be found throughout much of any given borehole. In contrast, there are areas of very high quality rock as in borehole DH84-3 which encountered very strong, hard diorite throughout its length (see Exhibit 13).

The rock quality in the Downstream Portals Area is controlled by a combination of structural influence as well as near surface stress relief.

5.3.3 Structure

All five boreholes drilled in the Downstream Portals Area were oriented to intersect the major west-northwest trending joint systems determined from surface mapping (Exhibit 11). Although the boreholes did encounter much variability in fracturing, no major structural features were identified. The area is characterized by a widespread condition of variable jointing, local sheared and altered areas, and local occurrences of healed breccia.

5.3.4 Alteration Zones

Hydrothermal alteration of bedrock in the Downstream Portals Area involves essentially the same range of variations as seen in the Fins area. Slight alteration is suggested by minor color changes in the feldspar groundmass with no apparent loss in rock strength. Severely altered material however has a bleached appearance from the development of kaolin and chlorite, and frequently has a drummy, friable texture, and very low strength.

Severely altered rock occurs in zones 0.1 to 0.2 feet wide adjacent to shear or fracture planes, or in nearly vertical zones up to approximately 8-10 feet in thickness. There appear to be no predictable patterns to its distribution.

5.3.5 Weathering

Surface weathering in the Downstream Portals Area is limited primarily to iron-oxide staining. There is no in-situ zone of decomposition, as noted in portions of the Fins area. The depth of staining is quite variable owing to the control of fracturing and has little effect on the quality of rock from a structural standpoint.

5.3.6 Hydraulic Pressure Test Results

The results of hydraulic pressure testing in the Downstream Portals Area are presented in tabular form in Appendix C and graphically on Exhibit 13.

Hydraulic pressure tests were conducted in this area to explore for open fractures. As seen on Exhibit 13 and in Appendix C, water takes were locally quite high, however such water takes are not unusual considering the steep relief through the area and attendent stress relief fracturing.

5.3.7 Geophysical Logging Results - Downstream Portals Area

Borehole geophysical logging in the downstream portal area was completed in all five shallow boreholes: DH 84-3, -5, -6, -7, and -8. All of the borehole logs show increasing density with depth below 65 feet (vertical) becoming very dense below 156 feet in DH 84-7 and below 192 feet in DH 84-5. The neutron log indicates that fractures are closed (non-water bearing) below 182 feet in DH84-7, and below 187 feet in DH84-5.

5.4 Groundwater

Groundwater in the Downstream Portals Area generally occurs 40 to 80 feet below the ground surface (Exhibit 12). Artesian flow of one gpm occurs at borehole DH84-8, with an elevation head approximately equal to the collar elevation of the borehole, El. ± 1675 (Exhibit 13).

The presence of discontinuous permafrost, discussed below in Section 5.5, may affect groundwater in this area by creating local perched or confined conditions.

5.5 Permafrost

Permafrost conditions have been recognized in the south abutment of the Watana damsite in previous investigations (Corps of Engineers, 1978; Acres American, Inc., 1980-1981). No evidence of permafrost had been noted in the north abutment, however, with the exception of one instrumented borehole, BH-6, which was drilled beneath the north bank of the river from ground El. 1608.8 feet.

In the current investigation, permafrost conditions were encountered in three boreholes drilled from the lower part of the north abutment. Partially ice-filled fractures, 1/8 to 3/4 inch wide were recovered in core from DH84-3 at a depth of 8.0 to 27.3 feet. Traces of ice were also recovered from DH84-8 at a depth of 18.0 to 54.0 feet. Trace ice was logged from a depth of 9.0 to 20.0 feet in DH84-6, and ice formed in the borehole blocking the piezometer pipe at a depth of 50-55 feet.

The permafrost ice encountered in these boreholes appears to be local and discontinuous. Its occurrence in the lower portion of the north abutment is probably related to shade, due to the screening effect of the high, steep valley walls of the south abutment.

6.0 INVESTIGATIONS IN AREA OF UNDERGROUND POWERHOUSE

(Design Refinement Location)

6.1 Introduction

6.1.1 Previous Work

Previous work in the area of the Underground Powerhouse was conducted by Acres American, Inc., in 1981, with the drilling of two 950-foot deep boreholes, BH-3 and BH-4. Both boreholes were directed to proposed chambers approximately 500 feet northwest of the current, FERC license design refinement location for the underground powerhouse.

Two relatively shallow boreholes, 200 to 300 feet deep, were also drilled in the vicinity by the Corps of Engineers (1978). These holes (DH-10 and DH-11) are located approximately 60 feet northeast of the current program borehole, DH84-2.

Previous seismic work, 1980-1982, also crossed the area but is limited to near surface refraction profiling.

Borings BH-3 and BH-4 encountered sound rock with areas of fracturing and alteration but nothing to preclude siting underground chambers within this portion of the abutment. The reorientation and relocation of the power house for the design refinement location was done so that the dominant structural trends of N50W would be intersected perpendicularly by the long walls of the major caverns. The initial orientation bisected the dominant and secondary joint sets.

6.1.2 Scope of Current Investigations

The current program to obtain basic geologic information in the Underground Powerhouse Area consisted of drilling and testing one 765-foot deep, inclined borehole. The borehole was drilled on a bearing of N25E, parallel to the long axes of the proposed chambers, and was inclined 30 degrees from vertical.

6.2 Overburden

6.2.1 General Description

Approximately 12.5 feet of coarse overburden was encountered in borehole DH84-2. Similar shallow overburden, ranging from 10.5 to 25.0 feet in thickness was reported in the four other boreholes in the immediate area (DH-10, and -11; and BH-3, and -4). The materials are generally described as gravelly, pebbly sands with occasional boulders to 2.0 feet diameter.

6.3 Bedrock

6.3.1 Bedrock Topography

Refraction seismic data and the borehole data in the immediate area indicate that the top of bedrock generally lies at a depth of 25 feet or less.

6.3.2 Lithology and Rock Quality

The current borehole, DH84-2, encountered diorite and quartz diorite with minor felsic intrusions. As in other boreholes at the site, the rock mass shows varying degrees of hydrothermal alteration and fracturing, but the majority of the rock mass is hard and strong. RQD values in the lower portion of the borehole, and specifically in the underground chamber area are good to excellent (see Exhibit 16). Similar conditions were also encountered at cavern level in nearby borehole BH-3.

6.3.3 Structure

No indications of major geologic structural features were encountered in DH84-2. Discrete planar shears, slickensided joints, fractured zones, and associated alteration zones and clay filled fractures are present locally, however the rock mass in the area of the underground powerhouse appears to be generally excellent.

6.3.4 Alteration Zones

Slight alteration of the rock mass is quite common in DH84-2, with a characteristic red color in large portions of the groundmass. Deeply altered zones, however, characterized by significant decrease in rock strength are limited in distribution, and generally involve zones of 2 to 3 feet or less in thickness.

6.3.5 Weathering

Surface weathering in borehole DH84-2 was primarily limited to iron-staining in zones of fracturing. No zone of decomposed rock was encountered as in borings on the southwest side of the Fins area. The deepest occurrence of significant weathering in DH84-2 was at a vertical depth of 59.0 feet.

6.3.6 Hydraulic Pressure Test Results

Hydraulic pressure test results for the Underground Powerhouse borehole, DH84-2, are presented in tabular form in Appendix C and in graphic form on Exhibit 16.

The majority of the testing indicated very low permeability. Within the area of the powerhouse cavern, Lugeon values were in the range of 0.0 to 0.4. Lugeons varied to a maximum value of 5.5 in the upper portion of the hole.

Similarly, low permeability values were obtained when borehole BH-3 was tested. This hole was tested at ten foot intervals with the exception of depths 471 to 520 feet, 110-121 feet and 0-34 feet where no tests were completed because of hole conditons. The vast majority of the remaining test values were in the range of 10^{-5} to 10^{-7}cm/sec. No high take zones were identified.

6.3.7 Geophysical Logging Results

Borehole geophysical logs run in DH 84-2 to a depth of 626 feet vertically below ground surface indicate that fractures are very tight and much less frequent below a depth of 295 feet. The density log for depths below 295 feet is relatively uniform and shows the diorite to be quite dense.

6.4 Groundwater

Bedrock groundwater level is monitored at two depths in borehole DH84-2. The data indicate that the groundwater table occurs 25 to 50 feet below ground surface (Exhibit 16).

Artesian flows of approximately 1.0 to 1.5 gpm were noted in DH84-2 during tests in the lower portion of the borehole. The slight flow originates from depth interval 570 to 660 (El.1530 to 1452), in the upper levels of the proposed chamber. Total elevation head indicated by the pneumatic piezometer installed at elevation 1515 feet is approximately El.2070 (Appendix F).

6.5 Permafrost

No ice was noted in any of the core recovered from DH84-2 and no other indications of permafrost conditions were encountered during drilling, testing or monitoring. Neighboring boreholes BH-3, BH-4, DH-10, and DH-11 also encountered no indications of permafrost.

6.6 Foundation Evaluation

Initial indications of the general foundation conditions in the area of the proposed Underground Powerhouse are quite favorable. The rock is generally sound and massive, and no major shears, faults or alteration zones were encountered in DH84-2. The volumes of water to be handled by drainage and pumping during construction are expected to be low, based on the low permeability test values in the cavern area.

REFERENCES

Harza-Ebasco Susitna Joint Venture, Watana Development, Winter 1983 Geotechnical Exploration Program, 1983.

Acres American Incorporated, Susitna Hydroelectric Project, 1980-81 Geotechnical Report, 1981.

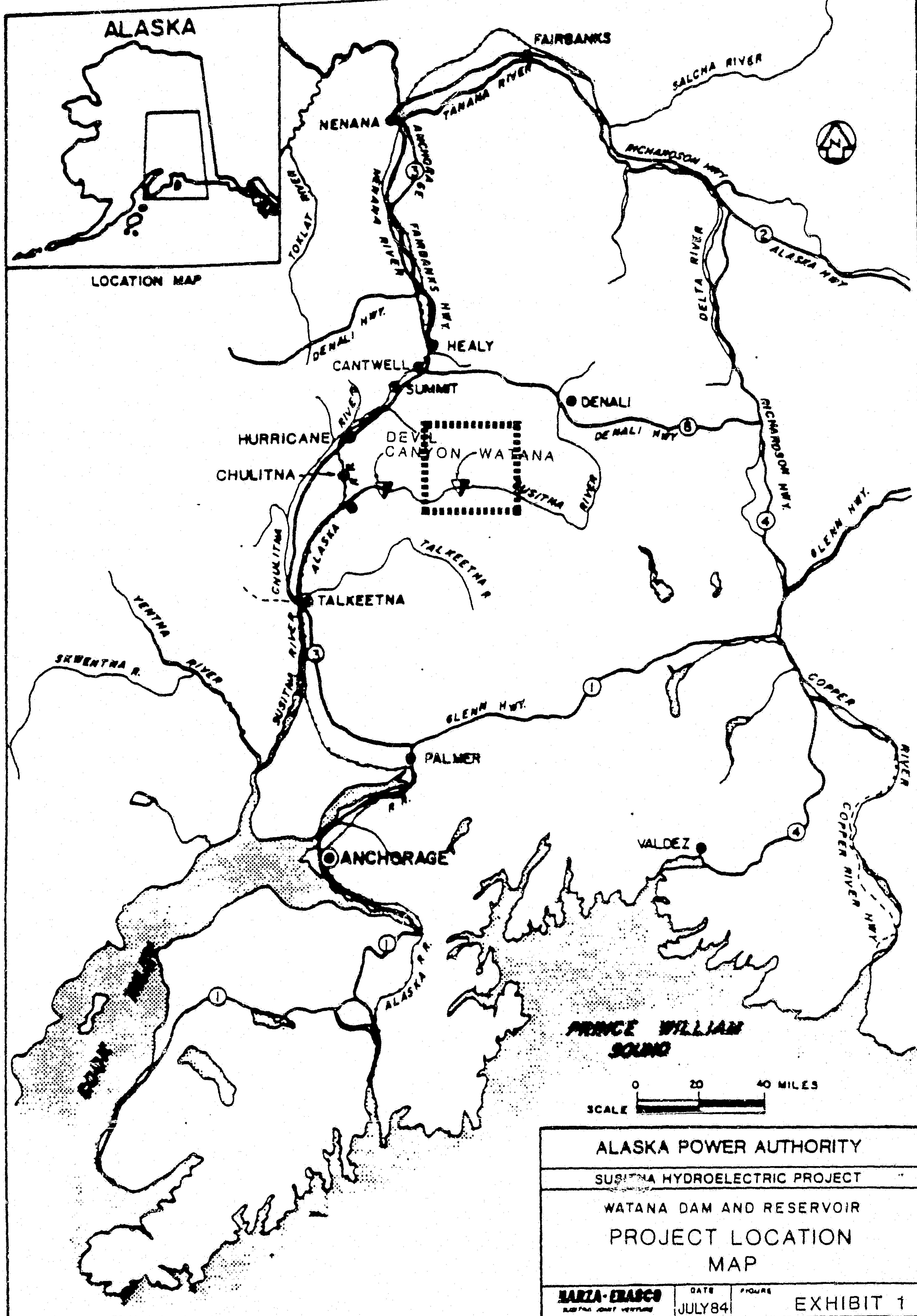
Acres American Incorporated, Susitna Hydroelectric Project, 1982 Supplement to the 1980-81 Geotechnical Report, 1982.

Acres American Incorporated, Susitna Hydroelectric Project, Feasibility Report, 1982.

U.S. Army Corps of Engineers, Hydroelectric Power and Related Purposes, Upper Susitna River Basin, Southcentral Railbelt Area, Alaska, Final Feasibility Report, 1978.

EXHIBITS

EXHIBITS



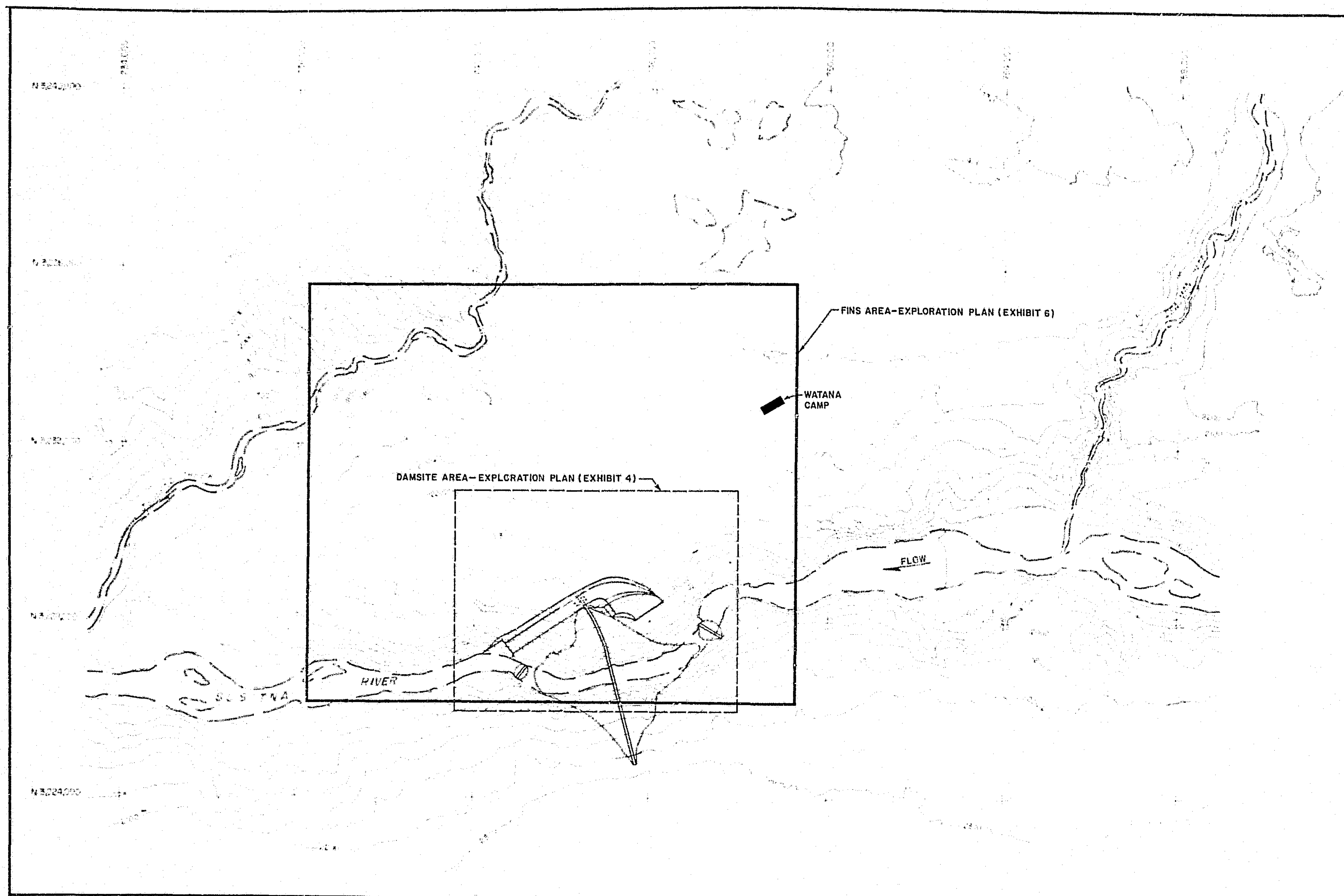
ALASKA POWER AUTHORITY

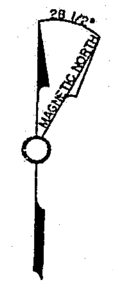
SUSITNA HYDROELECTRIC PROJECT

WATANA DAM AND RESERVOIR

PROJECT LOCATION MAP

HARZA-EBASCO SUSITNA JOINT VENTURE | DATE JULY 84 | FIGURE EXHIBIT 1



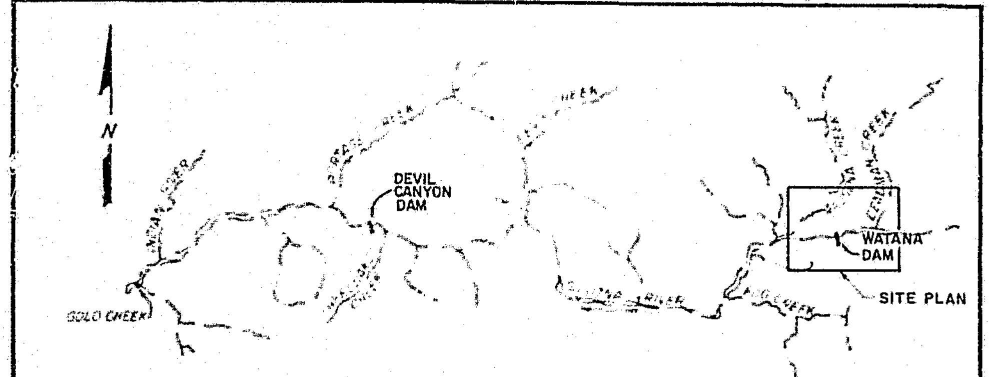


NOTES:

1. BASE MAP FROM 1978 CORPS OF ENGINEERS 1" = 200' DAMSITE TOPOGRAPHY.

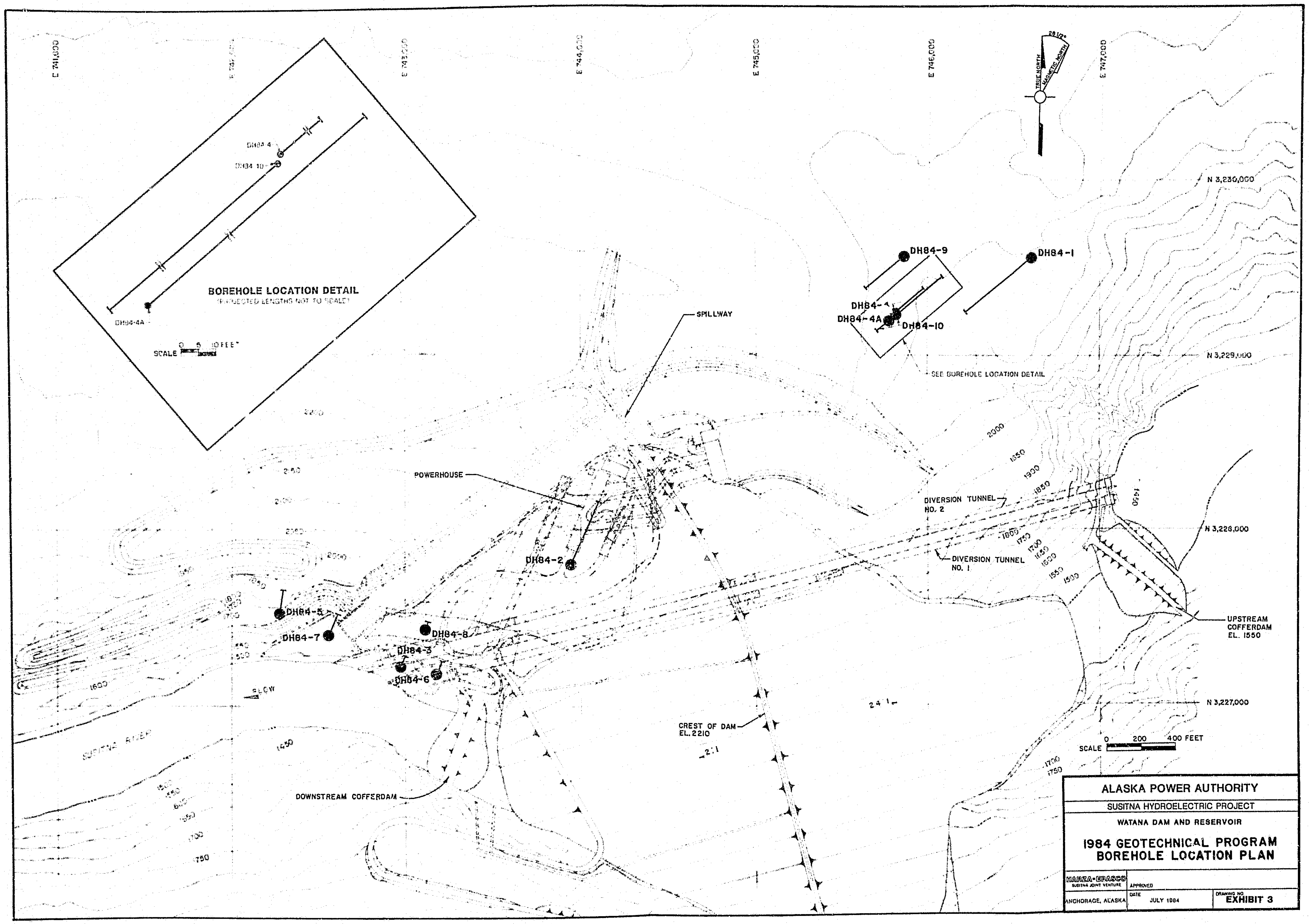
2. DAM LAYOUT FROM "SUSITNA HYDROELECTRIC PROJECT, BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION - APPLICATION FOR LICENSE FOR MAJOR PROJECT", PREPARED BY ACRES AMERICAN, INC., FEBRUARY 1983

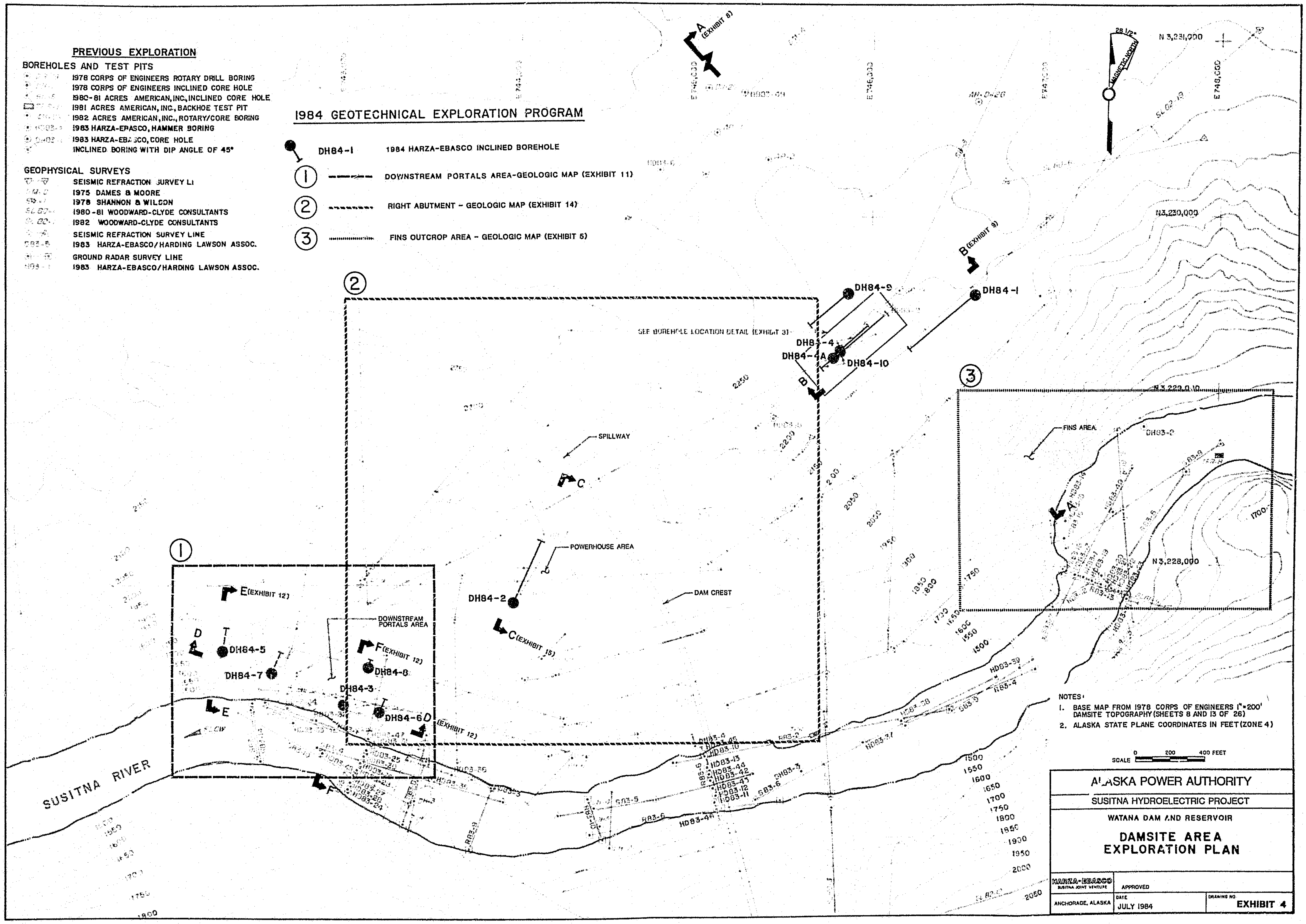
SCALE 0 1000 2000 FEET

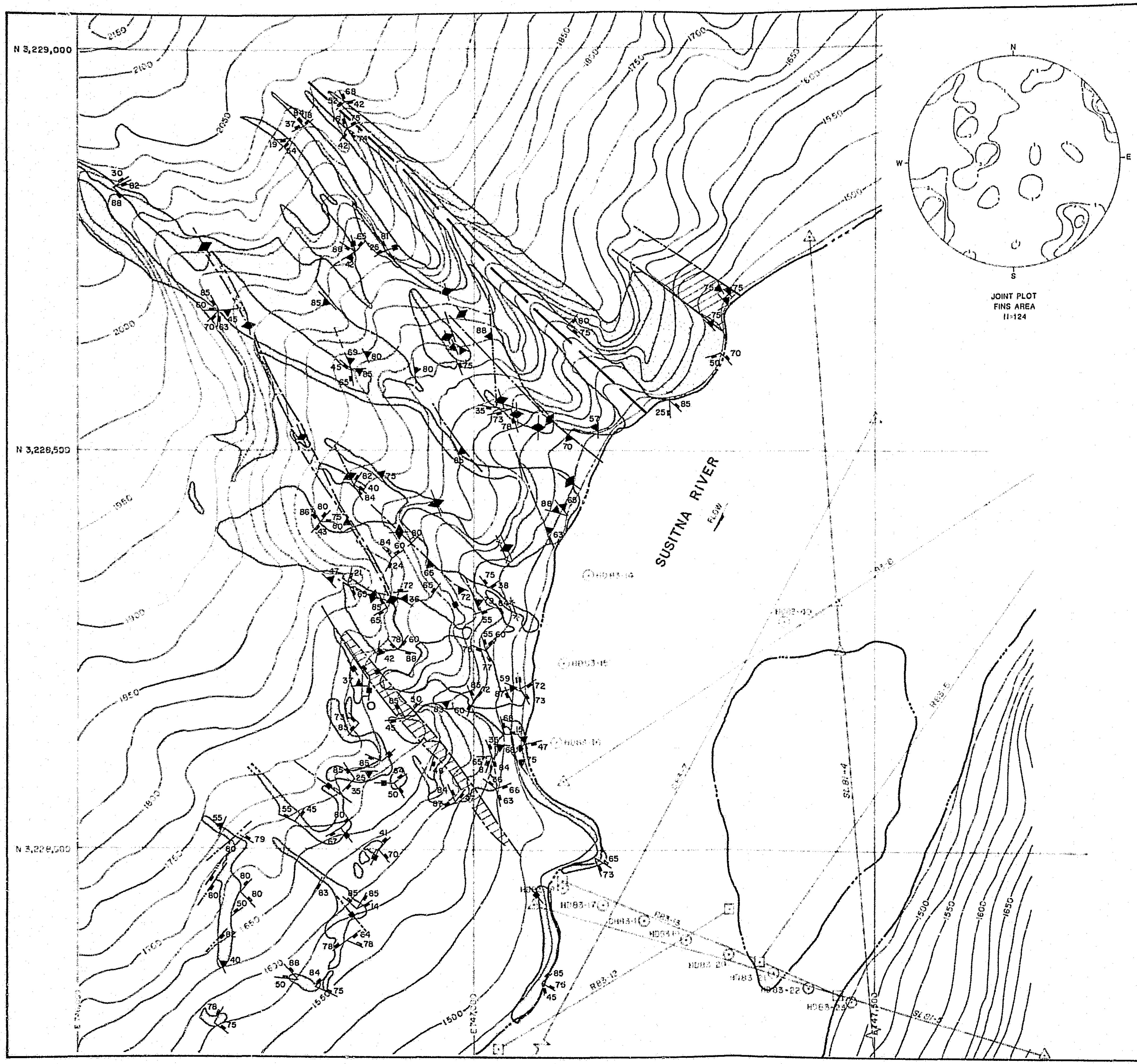


SUSITNA PROJECT DAMSITES VICINITY MAP

ALASKA POWER AUTHORITY		
SUSITNA HYDROELECTRIC PROJECT		
WATANA DAM AND RESERVOIR		
SITE PLAN AND VICINITY MAP		
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY 1984	DRAWING NO EXHIBIT 2


BOREHOLE LOCATION DETAIL
(PROJECTED LENGTHS NOT TO SCALE)
SPILLWAY
POWERHOUSE
SEE BOREHOLE LOCATION DETAIL
DIVERSION TUNNEL NO. 2
DIVERSION TUNNEL NO. 1
UPSTREAM COFFERDAM EL. 1550
CREST OF DAM EL. 2210
DOWNSTREAM COFFERDAM
SUSITNA RIVER
FLOW
DH84-1
DH84-2
DH84-3
DH84-4A
DH84-5
DH84-6
DH84-7
DH84-8
DH84-9
DH84-10
N 3,230,000
N 3,229,000
N 3,228,000
N 3,227,000
E 741,000
E 743,000
E 744,000
E 745,000
E 746,000
E 747,000
TRUE NORTH
MAGNETIC NORTH
SCALE 0 200 400 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM AND RESERVOIR
1984 GEOTECHNICAL PROGRAM
BOREHOLE LOCATION PLAN
HARZA-EBASCO SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA
APPROVED
DATE JULY 1984
DRAWING NO. EXHIBIT 3


PREVIOUS EXPLORATION
BOREHOLES AND TEST PITS
1978 CORPS OF ENGINEERS ROTARY DRILL BORING
1978 CORPS OF ENGINEERS INCLINED CORE HOLE
1980-81 ACRES AMERICAN, INC, INCLINED CORE HOLE
1981 ACRES AMERICAN, INC., BACKHOE TEST PIT
1982 ACRES AMERICAN, INC., ROTARY/CORE BORING
1983 HARZA-EBASCO, HAMMER BORING
1983 HARZA-EBASCO, CORE HOLE
INCLINED BORING WITH DIP ANGLE OF 45°
GEOPHYSICAL SURVEYS
SEISMIC REFRACTION SURVEY LI
1975 DAMES & MOORE
1978 SHANNON & WILSON
1980-81 WOODWARD-CLYDE CONSULTANTS
1982 WOODWARD-CLYDE CONSULTANTS
SEISMIC REFRACTION SURVEY LINE
1983 HARZA-EBASCO/HARDING LAWSON ASSOC.
GROUND RADAR SURVEY LINE
1983 HARZA-EBASCO/HARDING LAWSON ASSOC.
1984 GEOTECHNICAL EXPLORATION PROGRAM
DH84-1 1984 HARZA-EBASCO INCLINED BOREHOLE
1 DOWNSTREAM PORTALS AREA-GEOLOGIC MAP (EXHIBIT 11)
2 RIGHT ABUTMENT - GEOLOGIC MAP (EXHIBIT 14)
3 FINS OUTCROP AREA - GEOLOGIC MAP (EXHIBIT 5)
A (EXHIBIT 6)
B (EXHIBIT 9)
N 3,231,000
N3,230,000
N3,228,000
E748,000
E746,000
MAGNETIC NORTH
28 1/2°
DH84-9
DH84-1
SEE BOREHOLE LOCATION DETAIL (EXHIBIT 3)
DH84-4
DH84-4A
DH84-10
FINS AREA
SPILLWAY
POWERHOUSE AREA
DAM CREST
DH84-2
C (EXHIBIT 15)
E (EXHIBIT 12)
F (EXHIBIT 12)
D (EXHIBIT 12)
DOWNSTREAM PORTALS AREA
DH84-5
DH84-7
DH84-8
DH84-3
DH84-6
SUSITNA RIVER
NOTES:
1. BASE MAP FROM 1978 CORPS OF ENGINEERS 1"=200' DAMSITE TOPOGRAPHY (SHEETS 8 AND 13 OF 26)
2. ALASKA STATE PLANE COORDINATES IN FEET (ZONE 4)
SCALE 0 200 400 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM AND RESERVOIR
DAMSITE AREA EXPLORATION PLAN
HARZA-EBASCO SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA
APPROVED
DATE JULY 1984
DRAWING NO EXHIBIT 4



JOINT PLOT
FINS AREA
N=124

LEGEND

LITHOLOGY:

- SURFICIAL DEPOSITS; INCLUDES ALLUVIUM AND COLLUVIUM
- DIORITE; INCLUDES QUARTZ DIORITE/ GRANODIORITE
- ANDESITE PORPHYRY
- FELSIC DIKE

CONTACTS:

- BEDROCK CONTACT, DASHED WHERE APPROXIMATE
- BEDROCK/SURFICIAL DEPOSITS, DASHED WHERE APPROXIMATE

STRUCTURE:

- SHEAR ZONE; WIDTH GREATER THAN 5 FEET, EXTENSIONS SHOWN BY DASHES
- SHEAR ZONE; WIDTH 1 TO 5 FEET, EXTENSIONS SHOWN BY DASHES
- 65 SHEAR
- FRACTURE ZONE, WIDTH GREATER THAN 5 FEET; EXTENSIONS SHOWN BY DASHES
- FRACTURE ZONE, WIDTH 1 TO 5 FEET; EXTENSIONS SHOWN BY DASHES WHERE KNOWN OR INFERRED
- 70 70 JOINTS; INCLINED, OPEN INCLINED, VERTICAL

OTHER:

- RIVER EDGE

PREVIOUS EXPLORATION

BOREHOLES:

- 1978 CORPS OF ENGINEERS INCLINED CORE HOLE
- 1980-81 ACRES AMERICAN, INC., INCLINED CORE HOLE
- 1983 HARZA-EBASCO, HAMMER BORING
- HARZA-EBASCO CORE HOLE

GEOPHYSICAL SURVEYS:

- SEISMIC REFRACTION SURVEY LINE
- 1978 SHANNON & WILSON
- 1980 WOODWARD-CLYDE CONSULTANTS
- 1981 WOODWARD-CLYDE CONSULTANTS
- 1982 WOODWARD-CLYDE CONSULTANTS
- SL83-4 1983 HARZA-EBASCO/HARDING LAWSON ASSOC.
- GROUND RADAR SURVEY LINE
- RB3-4 1983 HARZA-EBASCO/HARDING LAWSON ASSOC

NOTES:

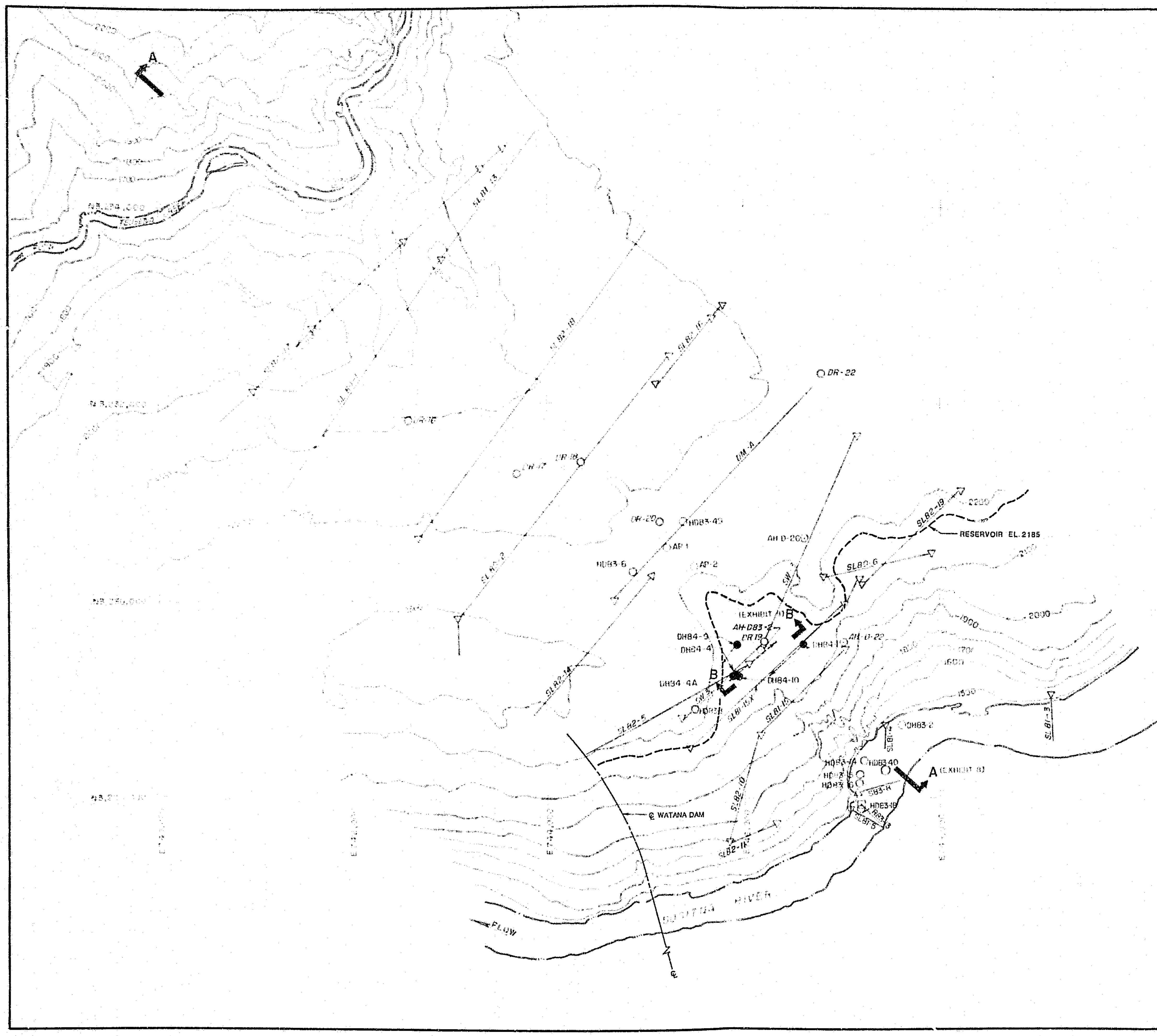
1. COMPOSITE GEOLOGIC MAP BASED ON DATA FROM CORPS OF ENGINEERS, 1978; ACRES AMERICAN, INC., 1980-82; HARZA-EBASCO, 1983
2. BASE MAP FROM 1978 CORPS OF ENGINEERS 1"=200' DAMSITE TOPOGRAPHY
3. JOINT PLOT CONTOURS ARE THE PERCENT OF JOINTS PER 1% OF AREA; CONTOUR INTERVALS ARE 1, 3, AND 5%

SCALE 0 50 100 FEET

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM AND RESERVOIR

FINS OUTCROP AREA GEOLOGIC MAP

HARZA-EBASCO SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA
APPROVED
DATE JULY 1984
DRAWING NO EXHIBIT 5



PREVIOUS EXPLORATION

BOREHOLES AND TEST PITS

DR-19	1978 CORPS OF ENGINEERS ROTARY DRILL BORING
DH-1	1978 CORPS OF ENGINEERS INCLINED CORE HOLE
BH-5	1980-81 ACRES AMERICAN, INC., INCLINED CORE HOLE
TPR-11	1981 ACRES AMERICAN, INC., BACKHOE TEST PIT
AH-D-22	1982 ACRES AMERICAN, INC., ROTARY/CORE BORING
HD83-1	1983 HARZA-EBASCO, HAMMER BORING
DH83-1	1983 HARZA-EBASCO, CORE HOLE
	INCLINED BORING WITH DIP ANGLE OF 45°
DH84-1	1984 HARZA-EBASCO INCLINED BOREHOLE

GEOPHYSICAL SURVEYS

	SEISMIC REFRACTION SURVEY LINE
DM-C	1975 DAMES & MOORE
SW-1	1978 SHANNON & WILSON
SL 80-1	1980 WOODWARD-CLYDE CONSULTANTS
SL 81-2	1981 WOODWARD-CLYDE CONSULTANTS
SL 82-1	1982 WOODWARD-CLYDE CONSULTANTS
	SEISMIC REFRACTION SURVEY LINE
S83-5	1983 HARZA-EBASCO/HARDING LAWSON ASSOC.
	GROUND RADAR SURVEY LINE
R83-1	1983 HARZA-EBASCO/HARDING LAWSON ASSOC.

NOTE:
1984 EXPLORATION IN THE FINS AREA IS SHOWN IN MORE DETAIL IN EXHIBIT 3.

SCALE 0 400 1000 FEET

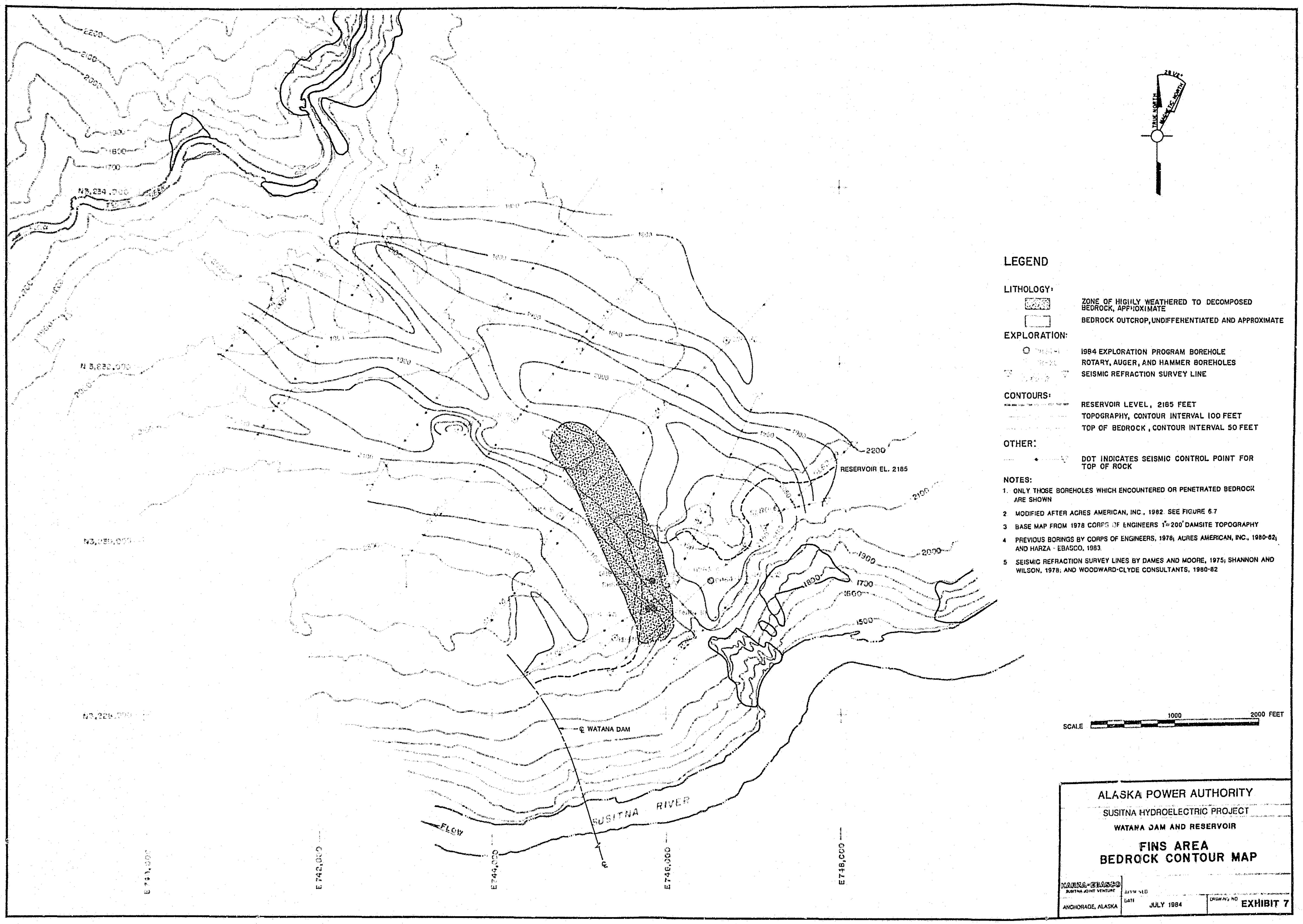
ALASKA POWER AUTHORITY

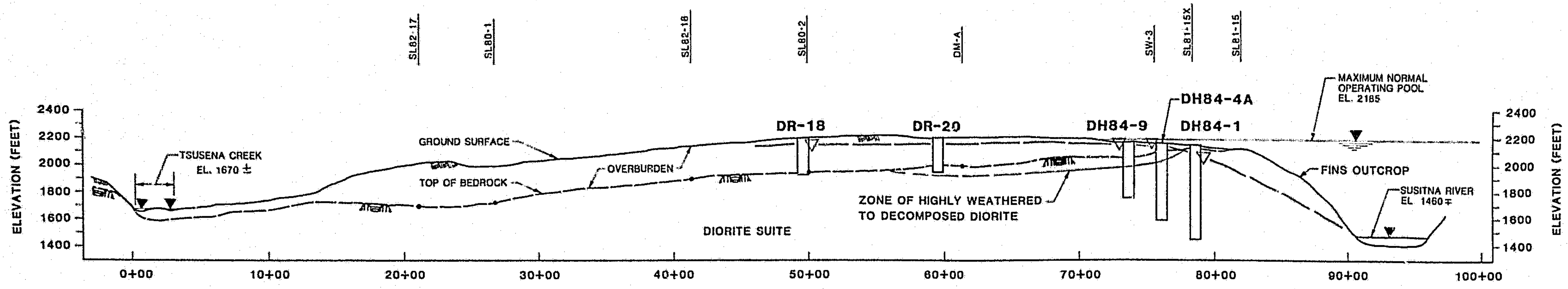
SUSITNA HYDROELECTRIC PROJECT

WATANA DAM AND RESERVOIR

FINS AREA
EXPLORATION PLAN

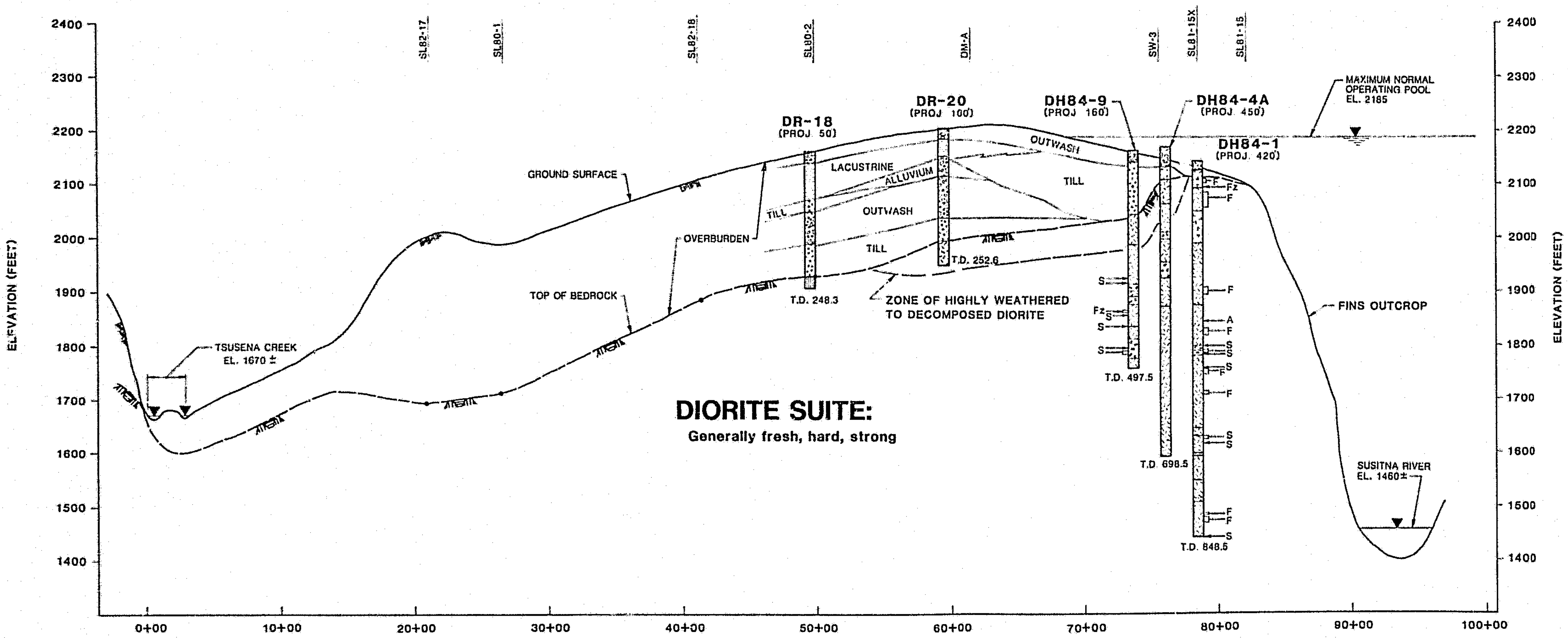
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY 1984	DRAWING NO. EXHIBIT 6


LEGEND
LITHOLOGY:
ZONE OF HIGHLY WEATHERED TO DECOMPOSED BEDROCK, APPROXIMATE
BEDROCK OUTCROP, UNDIFFERENTIATED AND APPROXIMATE
EXPLORATION:
1984 EXPLORATION PROGRAM BOREHOLE
ROTARY, AUGER, AND HAMMER BOREHOLES
SEISMIC REFRACTION SURVEY LINE
CONTOURS:
RESERVOIR LEVEL, 2185 FEET
TOPOGRAPHY, CONTOUR INTERVAL 100 FEET
TOP OF BEDROCK, CONTOUR INTERVAL 50 FEET
OTHER:
DOT INDICATES SEISMIC CONTROL POINT FOR TOP OF ROCK
NOTES:
1. ONLY THOSE BOREHOLES WHICH ENCOUNTERED OR PENETRATED BEDROCK ARE SHOWN
2. MODIFIED AFTER ACRES AMERICAN, INC., 1982. SEE FIGURE 6.7
3. BASE MAP FROM 1978 CORPS OF ENGINEERS 1"=200' DAMSITE TOPOGRAPHY
4. PREVIOUS BORINGS BY CORPS OF ENGINEERS, 1978; ACRES AMERICAN, INC., 1980-82; AND HARZA - EBASCO, 1983
5. SEISMIC REFRACTION SURVEY LINES BY DAMES AND MOORE, 1975; SHANNON AND WILSON, 1978; AND WOODWARD-CLYDE CONSULTANTS, 1980-82
TRUE NORTH
MAGNETIC NORTH
28 1/2°
RESERVOIR EL. 2185
2200
2100
2000
1900
1800
1700
1600
1500
℄ WATANA DAM
SUSITNA RIVER
FLOW
N3,234,000
N3,232,000
N3,230,000
N3,228,000
E741,000
E742,000
E744,000
E746,000
E748,000
SCALE
1000
2000 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM AND RESERVOIR
FINS AREA
BEDROCK CONTOUR MAP
HARZA-EBASCO
SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA
APPROVED
DATE JULY 1984
DRAWING NO. EXHIBIT 7



GEOLOGIC PROFILE A-A

TRUE SCALE



GEOLOGIC PROFILE A-A

SCALE EXAGGERATED 4V TO 1H

LEGEND

SOIL

- OUTWASH
- TILL
- LACUSTRINE
- ALLUVIUM

ROCK

- DIORITE SUITE; DIORITE, QUARTZ DIORITE, GRANODIORITE
- DIORITE SUITE; SEVERELY WEATHERED
- ALTERED DIORITE, MODERATELY TO SEVERELY ALTERED
- MONZONITE TO GRANITE
- ANDESITE PORPHYRY
- FELSIC

CONTACTS

- SURFICIAL DEPOSIT
- TOP OF BEDROCK
- BEDROCK, DOTTED WHERE APPROXIMATE

OTHER:

- GROUNDWATER TABLE WITH DATA POINT JULY 3, 1984
- S — FEATURE LESS THAN 3 FEET WIDE
- S — FEATURE GREATER THAN 3 FEET WIDE
- S — SHEAR
- F — CLOSELY TO VERY CLOSELY FRACTURED
- Fz — FRACTURE ZONE (VERY CLOSELY FRACTURED)
- A — ALTERED, WEAK

NOTES:

1. SECTION LOCATION SHOWN ON EXHIBIT 6.
2. SURFACE PROFILE FROM 1" = 200' TOPOGRAPHIC MAP; CORPS OF ENGINEERS, 1978.
3. FOR DETAILED BOREHOLE DESCRIPTIONS, SEE EXPLORATION LOGS IN APPENDIX A.
4. FOR GROUNDWATER DATA SEE APPENDIX F.
5. CHANGES IN LITHOLOGY ARE SHOWN FOR THICKNESSES GREATER THAN 4 FEET.
6. TOP OF ROCK PROFILE ADJUSTED TO FIT THE BEDROCK ELEVATION IN EACH PROJECTED BOREHOLE
7. FOR GEOLOGIC NOTES ON DH84-4A, SEE FINS AREA GEOLOGIC PROFILE B-B
8. ELEVATION OF GROUNDWATER TABLE IN DR-18 IS FROM AUG. 1978. INSTRUMENTATION MONITORING INDICATES LITTLE CHANGE IN GROUNDWATER TABLE AFTER WATER LEVELS HAVE STABILIZED, THEREFORE DATA FROM DR-18 IS CONSIDERED VALID.
9. ALL BOREHOLES ARE PROJECTED. THE DISTANCE PROJECTED IS FROM THE BOREHOLE COLLAR.

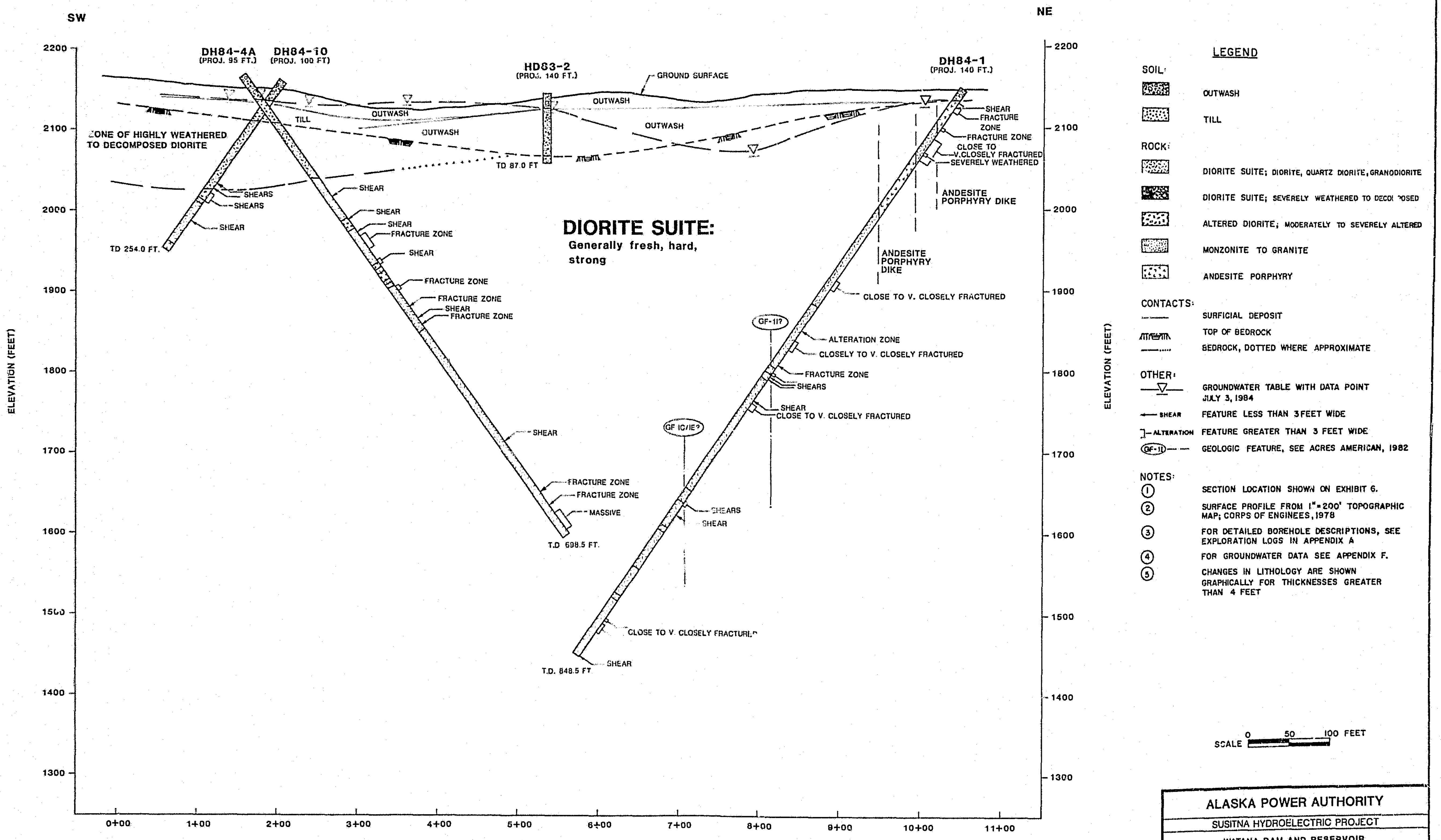
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA DAM AND RESERVOIR

FINS AREA GEOLOGIC PROFILE A-A

HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY 1984	DRAWING NO EXHIBIT 8

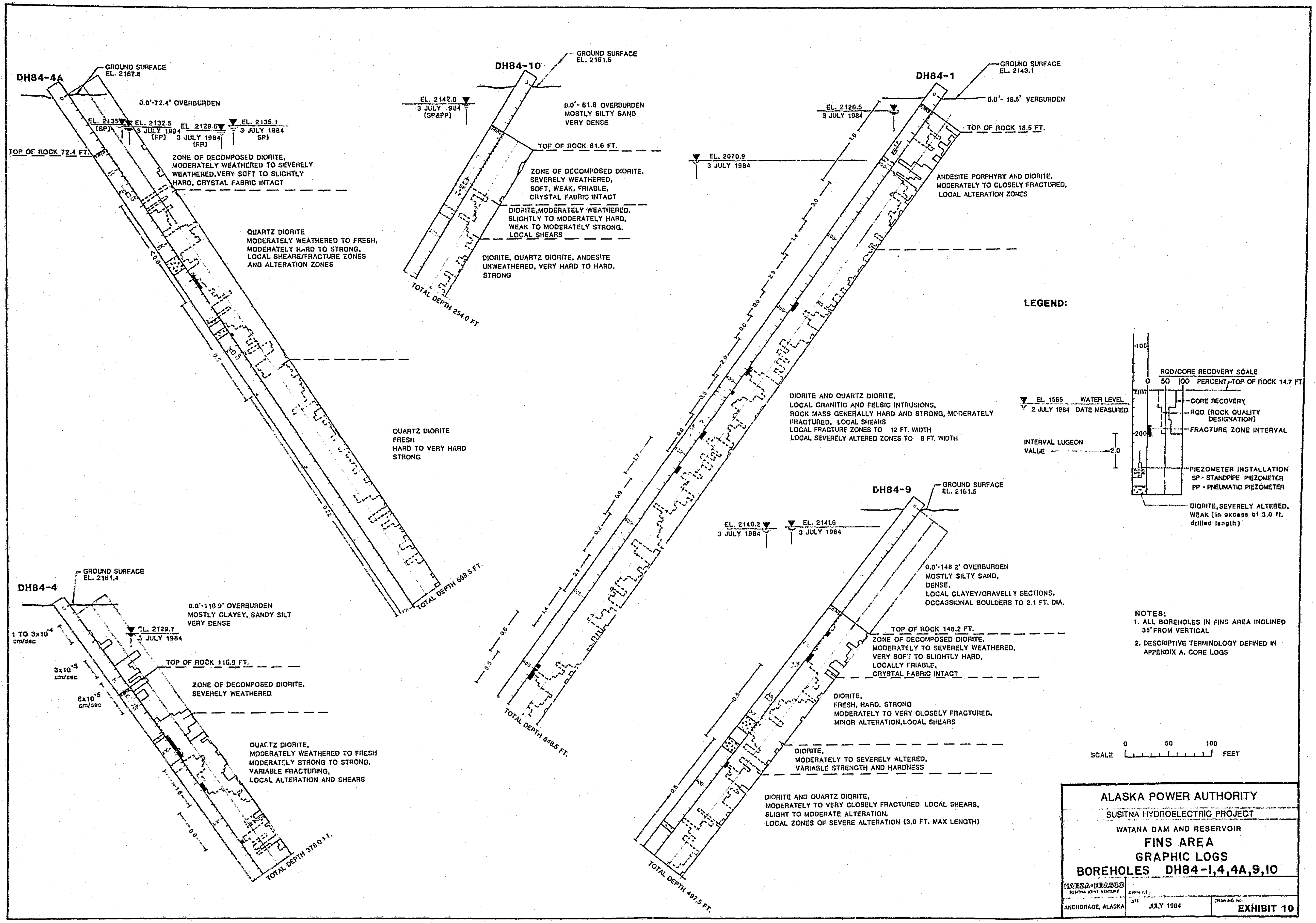


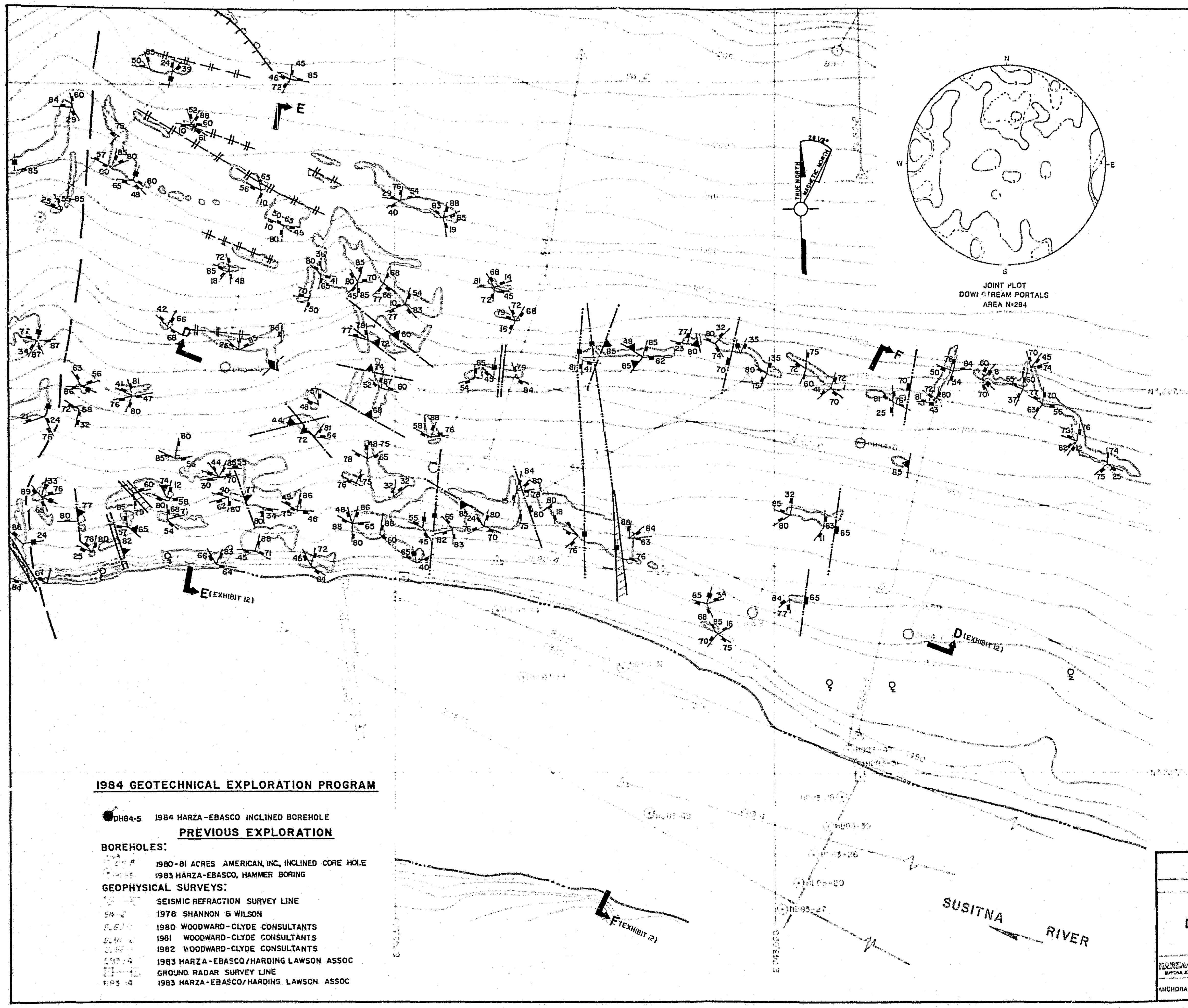
GEOLOGIC SECTION B-B

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM AND RESERVOIR

FINS AREA
GEOLOGIC SECTION B-B

HARZA-EBASCO SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA
DATE JULY 1984
EXHIBIT 9


DH84-4A
GROUND SURFACE EL. 2167.8
0.0'-72.4' OVERBURDEN
EL. 2135 (SP)
EL. 2132.5 3 JULY 1984 (PP)
EL. 2129.6 3 JULY 1984 (PP)
EL. 2135.1 3 JULY 1984 SP)
TOP OF ROCK 72.4 FT.
ZONE OF DECOMPOSED DIORITE, MODERATELY WEATHERED TO SEVERELY WEATHERED, VERY SOFT TO SLIGHTLY HARD, CRYSTAL FABRIC INTACT
QUARTZ DIORITE MODERATELY WEATHERED TO FRESH, MODERATELY HARD TO STRONG, LOCAL SHEARS/FRACTURE ZONES AND ALTERATION ZONES
QUARTZ DIORITE FRESH HARD TO VERY HARD STRONG
TOTAL DEPTH 699.5 FT.
DH84-10
GROUND SURFACE EL. 2161.5
EL. 2142.0 3 JULY 1984 (SP&PP)
0.0'- 61.6 OVERBURDEN MOSTLY SILTY SAND VERY DENSE
TOP OF ROCK 61.6 FT.
ZONE OF DECOMPOSED DIORITE, SEVERELY WEATHERED, SOFT, WEAK, FRIABLE, CRYSTAL FABRIC INTACT
DIORITE, MODERATELY WEATHERED, SLIGHTLY TO MODERATELY HARD, WEAK TO MODERATELY STRONG, LOCAL SHEARS
DIORITE, QUARTZ DIORITE, ANDESITE UNWEATHERED, VERY HARD TO HARD, STRONG
TOTAL DEPTH 254.0 FT.
DH84-1
GROUND SURFACE EL. 2143.1
0.0'- 18.5' VERBURDEN
EL. 2120.5 3 JULY 1984
TOP OF ROCK 18.5 FT.
EL. 2070.9 3 JULY 1984
ANDESITE PORPHYRY AND DIORITE, MODERATELY TO CLOSELY FRACTURED, LOCAL ALTERATION ZONES
DIORITE AND QUARTZ DIORITE, LOCAL GRANITIC AND FELSIC INTRUSIONS, ROCK MASS GENERALLY HARD AND STRONG, MODERATELY FRACTURED, LOCAL SHEARS LOCAL FRACTURE ZONES TO 12 FT. WIDTH LOCAL SEVERELY ALTERED ZONES TO 8 FT. WIDTH
TOTAL DEPTH 848.5 FT.
DH84-4
GROUND SURFACE EL. 2161.4
0.0'-116.9' OVERBURDEN MOSTLY CLAYEY, SANDY SILT VERY DENSE
EL. 2129.7 3 JULY 1984
1 TO 3x10^-4 cm/sec
3x10^-5 cm/sec
6x10^-5 cm/sec
TOP OF ROCK 116.9 FT.
ZONE OF DECOMPOSED DIORITE, SEVERELY WEATHERED
QUARTZ DIORITE, MODERATELY WEATHERED TO FRESH MODERATELY STRONG TO STRONG, VARIABLE FRACTURING, LOCAL ALTERATION AND SHEARS
TOTAL DEPTH 378.0 FT.
DH84-9
GROUND SURFACE EL. 2161.5
EL. 2140.2 3 JULY 1984
EL. 2141.6 3 JULY 1984
0.0'-148.2' OVERBURDEN MOSTLY SILTY SAND, DENSE, LOCAL CLAYEY/GRAVELLY SECTIONS, OCCASSIONAL BOULDERS TO 2.1 FT. DIA.
TOP OF ROCK 148.2 FT.
ZONE OF DECOMPOSED DIORITE, MODERATELY TO SEVERELY WEATHERED, VERY SOFT TO SLIGHTLY HARD, LOCALLY FRIABLE, CRYSTAL FABRIC INTACT
DIORITE, FRESH, HARD, STRONG MODERATELY TO VERY CLOSELY FRACTURED, MINOR ALTERATION, LOCAL SHEARS
DIORITE, MODERATELY TO SEVERELY ALTERED, VARIABLE STRENGTH AND HARDNESS
DIORITE AND QUARTZ DIORITE, MODERATELY TO VERY CLOSELY FRACTURED. LOCAL SHEARS, SLIGHT TO MODERATE ALTERATION, LOCAL ZONES OF SEVERE ALTERATION (3.0 FT. MAX LENGTH)
TOTAL DEPTH 497.5 FT.
LEGEND:
RQD/CORE RECOVERY SCALE
0 50 100 PERCENT
TOP OF ROCK 14.7 FT.
EL. 1555 WATER LEVEL
2 JULY 1984 DATE MEASURED
CORE RECOVERY
RQD (ROCK QUALITY DESIGNATION)
FRACTURE ZONE INTERVAL
INTERVAL LUGEON VALUE 2.0
PIEZOMETER INSTALLATION SP - STANDPIPE PIEZOMETER PP - PNEUMATIC PIEZOMETER
DIORITE, SEVERELY ALTERED, WEAK (In excess of 3.0 ft. drilled length)
NOTES:
1. ALL BOREHOLES IN FINS AREA INCLINED 35° FROM VERTICAL
2. DESCRIPTIVE TERMINOLOGY DEFINED IN APPENDIX A, CORE LOGS
SCALE 0 50 100 FEET
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM AND RESERVOIR
FINS AREA
GRAPHIC LOGS
BOREHOLES DH84-1,4,4A,9,10
HARZA-EBASCO SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA
JULY 1984
EXHIBIT 10



JOINT PLOT
DOWNSTREAM PORTALS
AREA N=294

LEGEND

LITHOLOGY:

- SURFICIAL DEPOSITS; INCLUDES ALLUVIUM AND COLLUVIUM
- DIORITE; INCLUDES QUARTZ DIORITE / GRANODIORITE
- ANDESITE PORPHYRY
- FELSIC DIKE

CONTACTS:

- BEDROCK CONTACT, DASHED WHERE APPROXIMATE
- BEDROCK / SURFICIAL DEPOSITS, DASHED WHERE APPROXIMATE

STRUCTURE:

- SHEAR ZONE; WIDTH GREATER THAN 5 FEET, EXTENSIONS SHOWN BY DASHES
- SHEAR ZONE; WIDTH 1 TO 5 FEET, EXTENSIONS SHOWN BY DASHES
- 65 SHEAR
- FRACTURE ZONE, WIDTH GREATER THAN 5 FEET; EXTENSIONS SHOWN BY DASHES
- FRACTURE ZONE, WIDTH 1 TO 5 FEET; EXTENSIONS SHOWN BY DASHES WHERE KNOWN OR INFERRED
- 70 70 JOINTS; INCLINED, OPEN INCLINED, VERTICAL
- BEDROCK SCARP, TO 20 FEET HIGH, JOINT CONTROLLED
- RIDGE CREST OF SLUMP BLOCK

OTHER:

- A A LINE OF SECTION
- SPRING

NOTES:

1. COMPOSITE GEOLOGIC MAP BASED ON DATA FROM CORPS OF ENGINEERS, 1978; ACRES AMERICAN, INC., 1980-82; HARZA-EBASCO, 1983
2. GEOLOGIC SECTIONS ARE SHOWN ON EXHIBIT 12
3. BASE MAP FROM 1978 CORPS OF ENGINEERS 1" = 200' DAMSITE TOPOGRAPHY
4. JOINT PLOT CONTOURS ARE THE PERCENT OF JOINTS PER 1% OF AREA; CONTOUR INTERVAL OF 1,3,5,7 %

SCALE 0 50 100 FEET

1984 GEOTECHNICAL EXPLORATION PROGRAM

DH84-5 1984 HARZA-EBASCO INCLINED BOREHOLE

PREVIOUS EXPLORATION

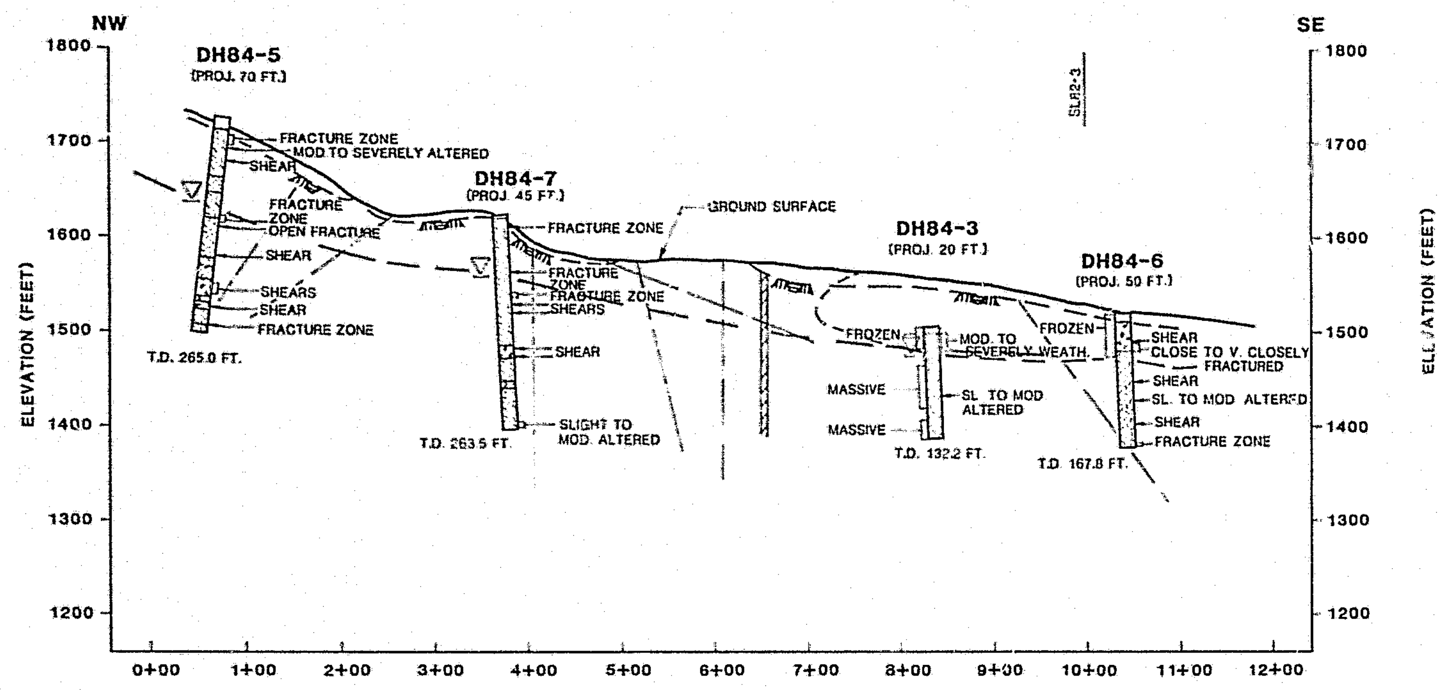
BOREHOLES:

- 1980-81 ACRES AMERICAN, INC., INCLINED CORE HOLE
- 1983 HARZA-EBASCO, HAMMER BORING

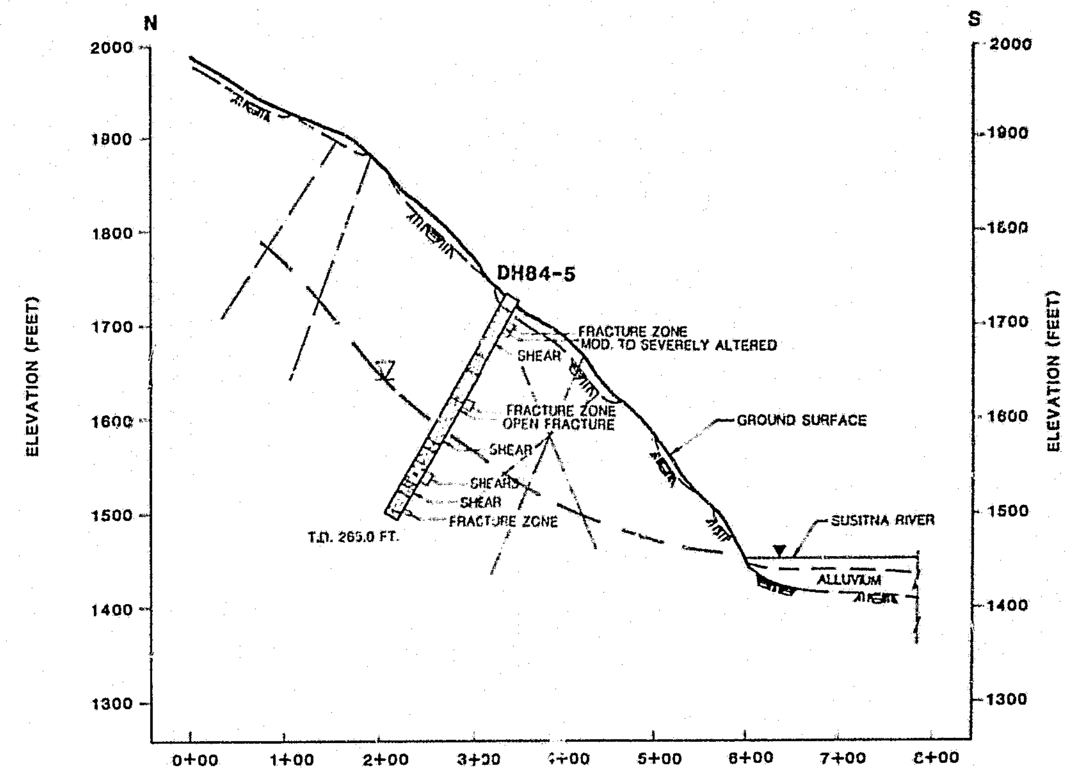
GEOPHYSICAL SURVEYS:

- SEISMIC REFRACTION SURVEY LINE
- SW-2 1978 SHANNON & WILSON
- 1980 WOODWARD-CLYDE CONSULTANTS
- 1981 WOODWARD-CLYDE CONSULTANTS
- 1982 WOODWARD-CLYDE CONSULTANTS
- 1983 HARZA-EBASCO/HARDING LAWSON ASSOC
- GROUND RADAR SURVEY LINE
- 1983 HARZA-EBASCO/HARDING LAWSON ASSOC

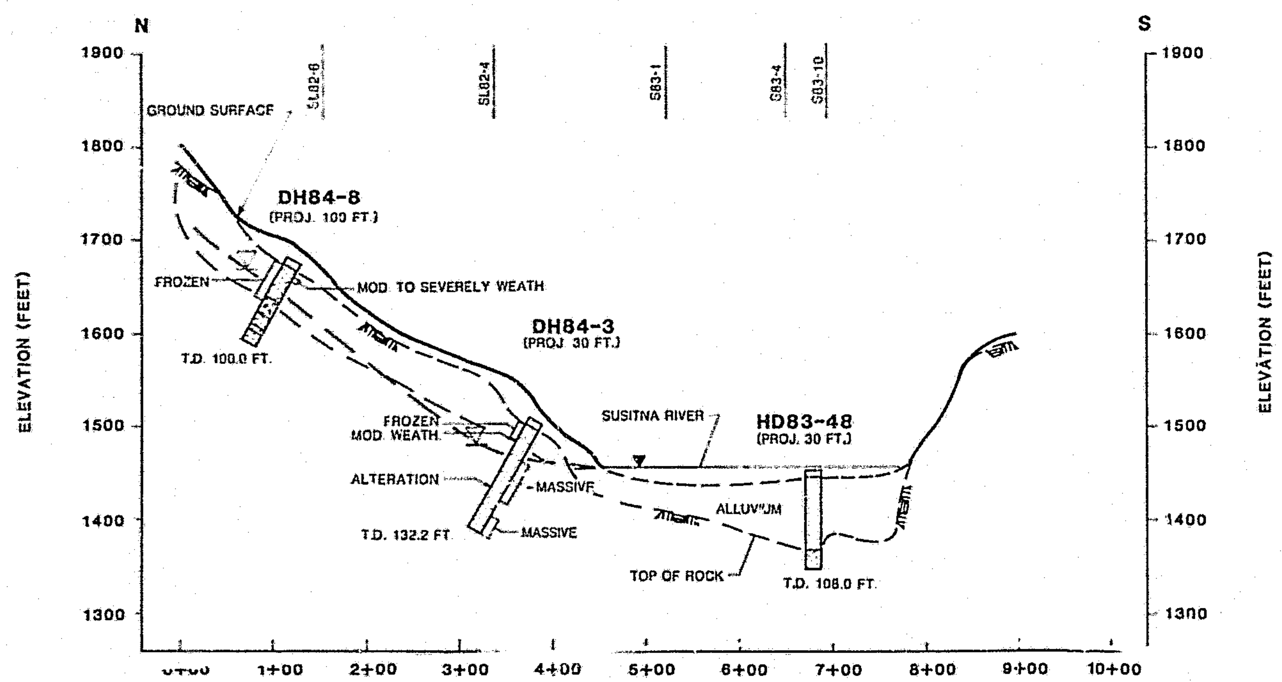
ALASKA POWER AUTHORITY	
SUSITNA HYDROELECTRIC PROJECT	
WATANA DAM AND RESERVOIR	
DOWNSTREAM PORTALS AREA GEOLOGIC MAP	
HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED
ANCHORAGE, ALASKA	DATE JULY 1984
DRAWING NO	EXHIBIT 11



GEOLOGIC SECTION D-D



GEOLOGIC SECTION E-E



GEOLOGIC SECTION F-F

LEGEND

SOIL:

- ALLUVIUM

ROCK:

- DIORITE SUITE; DIORITE, QUARTZ DIORITE, GRANODIORITE
- ALTERED DIORITE; MODERATELY TO SEVERELY ALTERED
- MONZONITE TO GRANITE

STRUCTURE:

- SHEAR ZONE, WIDTH 1 TO 5 FEET
- FRACTURE ZONE, WIDTH GREATER THAN 5 FEET
- FRACTURE ZONE, WIDTH 1 TO 5 FEET

CONTACTS:

- TOP OF BEDROCK

OTHER:

- GROUNDWATER TABLE WITH DATA POINT, JULY 3, 1984
- SHEAR — FEATURE LESS THAN 5 FEET WIDE
- ALTERATION — FEATURE GREATER THAN 5 FEET WIDE
- PERMAFROST INDICATED BY BOREHOLES

NOTES:

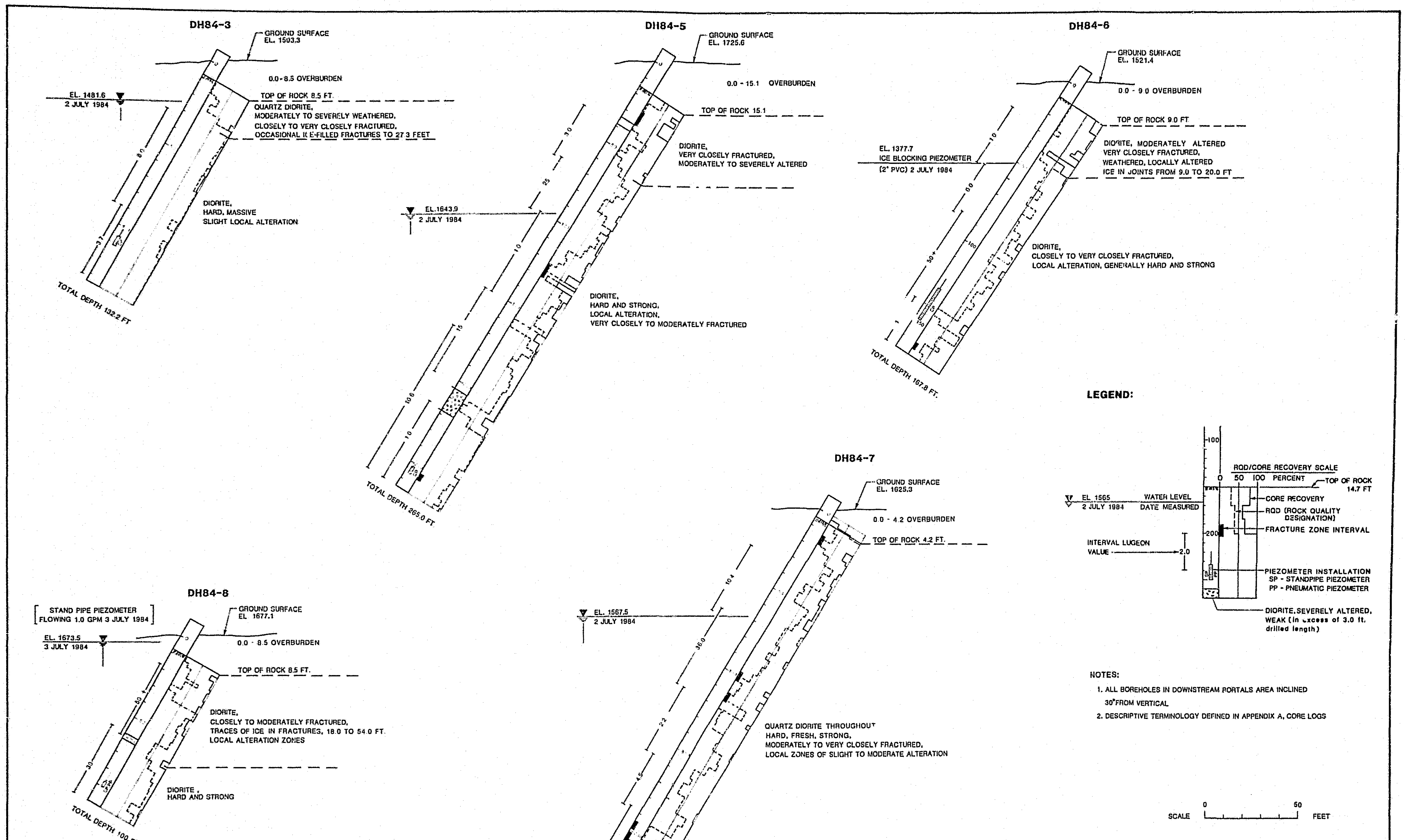
1. SECTION LOCATIONS SHOWN ON EXHIBIT 11
2. SURFACE PROFILE FROM 1" = 200' TOPOGRAPHIC MAP; CORPS OF ENGINEERS, 1978.
3. FOR DETAILED BOREHOLE DESCRIPTIONS, SEE EXPLORATION LOGS IN APPENDIX A.
4. FOR GROUNDWATER DATA SEE APPENDIX F.
5. CHANGES IN LITHOLOGY ARE SHOWN GRAPHICALLY FOR THICKNESSES GREATER THAN 5 FEET.
6. ALL BOREHOLES ARE PROJECTED. THE IDENTIFIED DISTANCE IS TO THE BOREHOLE COLLAR.

SCALE 0 100 200 FEET

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA DAM AND RESERVOIR

DOWNSTREAM PORTALS AREA
GEOLOGIC SECTIONS D-D, E-E, F-F

ANCHORAGE, ALASKA	DATE JULY 1984	EXHIBIT 12



NOTES:

1. ALL BOREHOLES IN DOWNSTREAM PORTALS AREA INCLINED 30°FROM VERTICAL
2. DESCRIPTIVE TERMINOLOGY DEFINED IN APPENDIX A, CORE LOGS

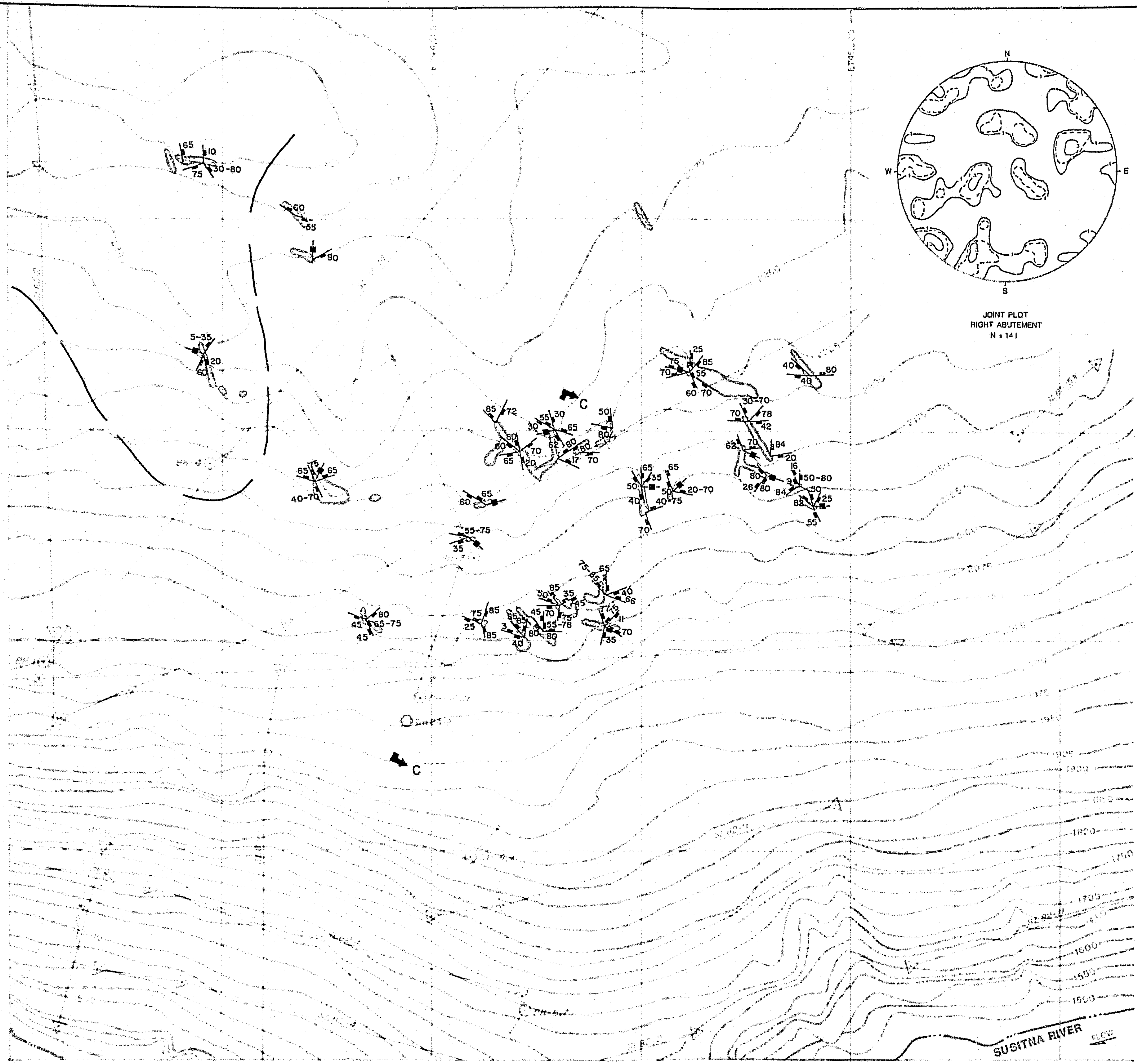
ALASKA POWER AUTHORITY

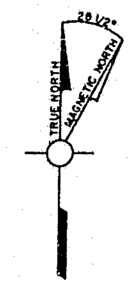
SUSITNA HYDROELECTRIC PROJECT

WATANA DAM AND RESERVOIR

DOWNSTREAM PORTALS AREA GRAPHIC LOGS BOREHOLES DH84-3,5,6,7,8

HARZA-EBASCO SUSITNA JOINT VENTURE	APPROVED	
ANCHORAGE, ALASKA	DATE JULY 1984	DRAWING NO. EXHIBIT 13





LEGEND

LITHOLOGY:

- SURFICIAL DEPOSITS: INCLUDES ALLUVIUM AND COLLUVIUM
- DIORITE: INCLUDES QUARTZ DIORITE/GRANODIORITE
- ANDESITE PORPHYRY

CONTACTS:

- BEDROCK CONTACT, DASHED WHERE APPROXIMATE
- BEDROCK/SURFICIAL DEPOSITS, DASHED WHERE APPROXIMATE

OTHER:

A A LINE OF SECTION

1984 GEOTECHNICAL EXPLORATION PROGRAM

DH84-1 1984 HARZA-EBASCO INCLINED BOREHOLE

PREVIOUS EXPLORATION

BOREHOLES:

- DH-21 1978 CORPS OF ENGINEERS INCLINED CORE HOLE
- BH-5 1980-81 ACRES AMERICAN, INC., INCLINED CORE HOLE

GEOPHYSICAL SURVEY:

- SEISMIC REFRACTION SURVEY LINE
- SW-1 1978 SHANNON & WILSON
- SL 80-1 1980 WOODWARD-CLYDE CONSULTANTS
- SL 81-2 1981 WOODWARD-CLYDE CONSULTANTS
- SL 82-1 1982 WOODWARD-CLYDE CONSULTANTS

NOTES:

1. BASE MAP FROM 1978 CORPS OF ENGINEERS 1" = 200' DAMSITE TOPOGRAPHY.
2. JOINT PLOT CONTOURS ARE THE PERCENT OF JOINTS PER 1% OF AREA; CONTOUR INTERVAL OF 1, 2, AND 3%

SCALE 0 100 200 FEET

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA DAM AND RESERVOIR

RIGHT ABUTMENT GEOLOGIC MAP

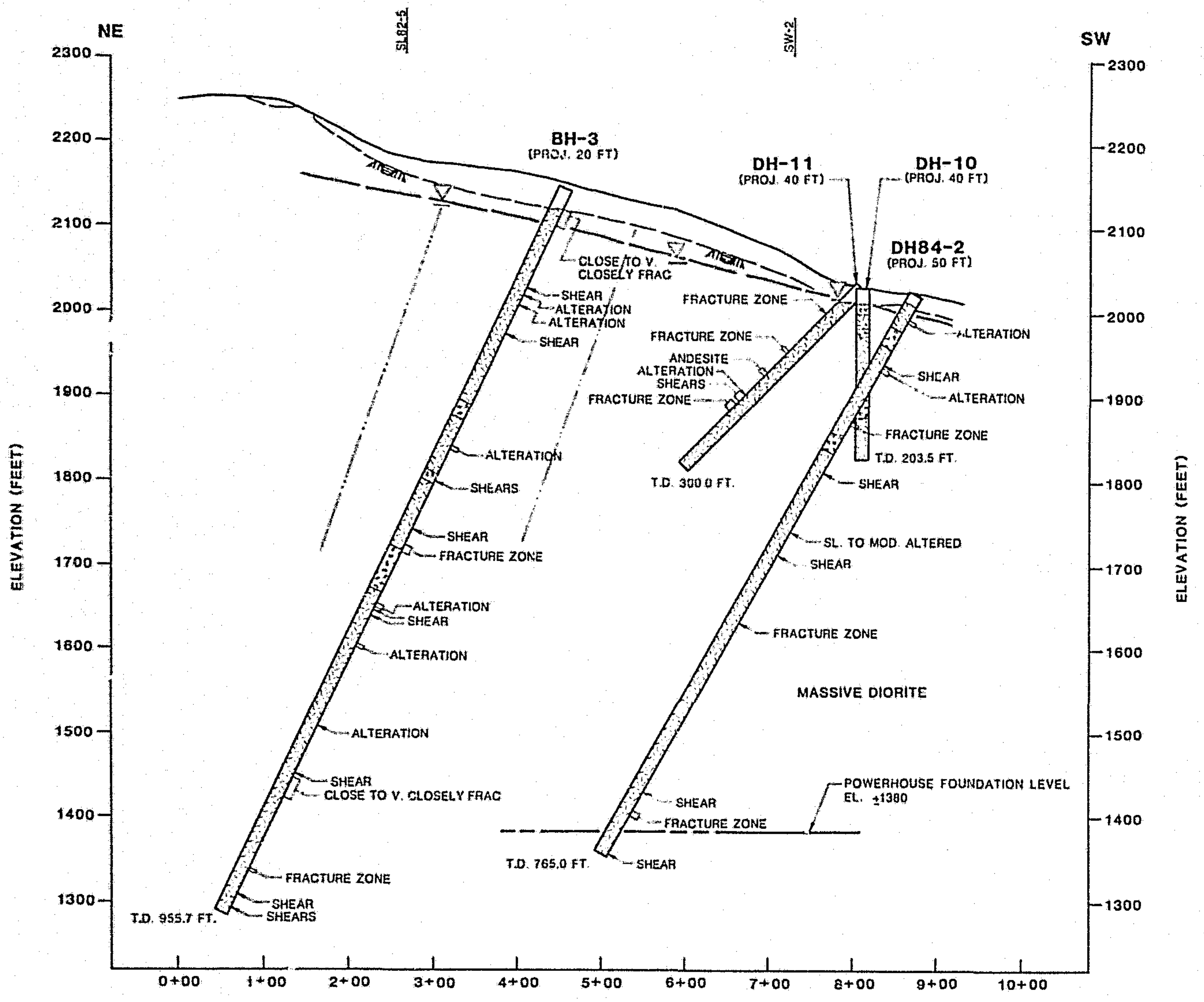
HARZA-EBASCO SUSITNA JOINT VENTURE

ANCHORAGE, ALASKA

APPROVED

DATE JULY 1984

DRAWING NO. EXHIBIT 14



GEOLOGIC SECTION C-C

LEGEND

ROCK:

- DIORITE SUITE; DIORITE, QUARTZ DIORITE, GRANODIORITE
- ALTERED DIORITE; MODERATELY TO SEVERELY ALTERED
- MONZONITE TO GRANITE

STRUCTURE:

- SHEAR ZONE, WIDTH 1 TO 5 FEET

CONTACTS:

- TOP OF BEDROCK

OTHER:

- GROUNDWATER TABLE WITH DATA POINT, JUNE/JULY 1984
- SHEAR — FEATURE LESS THAN 3 FEET WIDE
- ALTERATION — FEATURE GREATER THAN 3 FEET WIDE

NOTES:

1. SECTION LOCATIONS SHOWN ON EXHIBIT 12.
2. SURFACE PROFILE FROM 1"=200' TOPOGRAPHIC MAP; CORPS OF ENGINEERS, 1978.
3. FOR DETAILED BOREHOLE DESCRIPTIONS, SEE EXPLORATION LOGS IN APPENDIX A.
4. FOR GROUNDWATER DATA SEE APPENDIX F.
5. CHANGES IN LITHOLOGY ARE SHOWN GRAPHICALLY FOR THICKNESSES GREATER THAN 5 FEET.
6. ALL BOREHOLES ARE PROJECTED. THE IDENTIFIED DISTANCE IS TO THE BOREHOLE COLLAR.
7. THE NOTES FOR BH-3 AND DH-11 ARE MODIFIED FROM ACRES AMERICAN, 1981.

SCALE 0 50 100 FEET

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

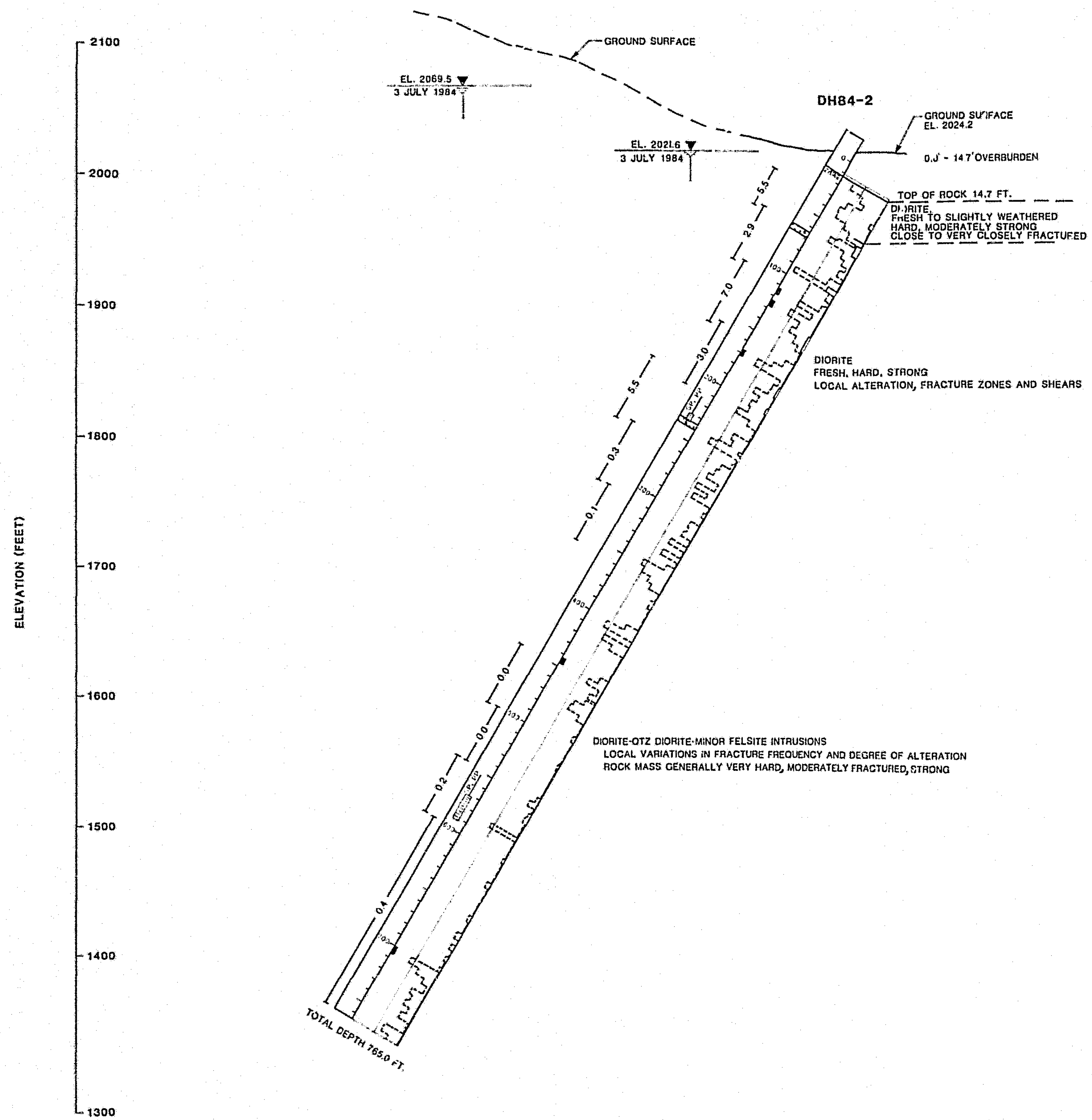
WATANA DAM AND RESERVOIR

POWERHOUSE AREA

GEOLOGIC SECTION C-C

HARZA-EBASCO SUSITNA JOINT VENTURE

ANCHORAGE, ALASKA | JULY 1984 | EXHIBIT 15



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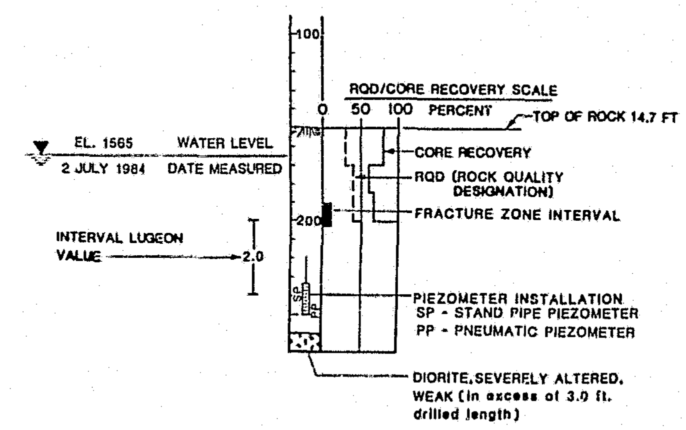

NOTES:

1. BOREHOLE IN POWERHOUSE AREA INCLINED 30° FROM VERTICAL
2. DESCRIPTIVE TERMINOLOGY DEFINED IN APPENDIX A, CORELOGS

SCALE 0 50 100 FEET

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA DAM AND RESERVOIR

POWERHOUSE AREA
GRAPHIC LOG
BOREHOLE DH84-2

HARZA-EBASCO
SUSITNA JOINT VENTURE
ANCHORAGE, ALASKA

APPROVED

DATE JULY 1984

DRAWING NO **EXHIBIT 16**