ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

TASK 5 - GEOTECHNICAL EXPLORATION
1980 GEOTECHNICAL REPORT

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TASK 5 - GEOTECHNICAL EXPLORATION

SUBTASKS 5.01 - 5.04

REPORT ON 1980 STUDIES

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SECTION I

INTRODUCTION

1 - INTRODUCTION

1.1 - Background

The Susitna Hydroelectric Project is located within the upper reaches of the Susitna River basin in south-central Alaska. The current feasibility studies for hydroelectric development are being performed by Acres American Incorporated (Acres) under contract to the Alaska Power Authority (APA).

The overall objectives of the study are:

- To establish technical, economic and financial feasibility of the Susitna Project to meet the future power needs of the Railbelt Region of the State of Alaska;

- To evaluate the environmental consequences of designing and constructing the Susitna Project;

- To file a license application with the Federal Energy Regulatory Commission (FERC) should the project be deemed feasible.

As part of the Plan of Study (POS) a comprehensive program of geotechnical exploration is being undertaken at the proposed project location. The purpose of this report is to present the results of geotechnical work undertaken in 1980.

1.2 - Project Description and Location

The Geotechnical Investigations, Task 5, is an important element of this study. Although the POS includes evaluation of the entire basin for potential hydroelectric development by evaluating the relative merits of several sites, the geotechnical investigations were directed for a two dam scheme. This scheme was determined to be the optimum as the result of previous investigations by the U.S. Army Corps of Engineers (COE) and the U.S. Bureau of Reclamation (USBR) over a period of years from 1955 to 1979. The scheme calls for a large rockfill dam with powerhouse at Watana, and a relatively high concrete dam with underground powerhouse at the Devil Canyon site. The area of study is located within the Coastal Trough Province of south-central Alaska, with a drainage of approximately 6,000 square miles. The Susitna River is glacier-fed, with headwaters on the southern slope of the Alaska Range, an arm of the Gulf of Alaska. From its proglacial channel in the Alaska Range, the Susitna River passes first through a broad glaciated, intermontane valley of knob and kettle and braided channel topography. Swinging westward along the edge of the Copper River lowlands, it enters the deep V-shaped valleys of the proposed dam sites, winding through the Talkeetna Mountains until it emerges into a broad glacial valley leading to Cook Inlet (Figure 1.1).

The Watana site is located at approximately river mile 165. A transmission line approximately 365 miles long is planned to connect the proposed development with the existing power grids at Fairbanks and Anchorage. The Watana dam site is located in a relatively broad U-shaped valley rising in steps, with the steep lower portion breaking into somewhat flatter slopes and becoming much gentler near the top. Access to the lower sections is very limited due to vertical rock outcrops. However, there are some small gravel bars which can be quite wide at low water level. The proposed dam is located between Tsusena Creek and Deadman Creek. The river at this site is wider than at Devil Canyon, but the water is relatively turbulent and swift flowing.

The Devil Canyon site is located on the Susitna River 14 miles upstream from the Alaskan Railroad, 140 miles north of Anchorage, and 160 miles south of Fairbanks. The site is located at approximately river mile 133 (32 river miles downstream of the Watana site). At the Devil Canyon site, the river enters a very narrow gorge about two miles in length with steep walls up to 600 feet high. The dam site is located several hundred feet downstream of the entrance of Devil Canyon. The valley is generally asymmetrical in shape, with the north abutment sloping at about 45° and the south abutment steeper at about 60°. The south abutment displays overhanging cliffs and detached blocks of rock, and while the north abutment is somewhat less rugged in the upper half, the lower portion is very steep. Access at river level is very limited, but narrow benches are accessible at low water levels. The Susitna River in Devil Canyon is approximately 150 feet wide and very turbulent. The canyon itself is approximately 1,000 feet wide at the proposed dam crest elevation.

1.3 - Plan of Study

(a) Objectives

The objectives of the Task 5 studies are to determine the surface and subsurface geology and geotechnical conditions for the feasibility of:

- A large rockfill dam, powerhouse (underground or surface) and associated structures at Watana site;
- A concrete dam or alternative structure with underground powerhouse and associated structures at Devil Canyon site;
- Transmission lines to connect the proposed development with the existing power grid system and;
- Access roads to the proposed development.

In addition, the river canyon reaches which would be flooded by the proposed reservoirs will be studied to determine potential areas of instability, and to identify the major geological features that could affect the feasibility of the projects.

(b) Scope

The task was subdivided into a series of subtasks to meet the overall objectives. The subtasks and their corresponding objectives were:

Subtask	Objectives
5.01 - Data Collection and Review	- To collect and review all existing geological and geotechnical data pertaining to the Susitna Project including the access road and transmission line corridors and the upper Susitna River basin
5.02 - Photointerpretation	- Perform air photointerpretation and terrain analysis of the Watana and Devil Canyon dam site areas, reservoir areas, construction material borrow areas and access road and transmission line corridors, and identify adverse geological features and geotechnical conditions that could significantly affect the design and construction of project features
5.03 - Exploratory Program Design (1980)	- Design the geotechnical exploratory investigation programs for 1980 for Watana and Devil Canyon dam sites, dam construction materials, and reservoir areas, and along the access road route
5.04 - Exploratory Program (1980)	- Perform initial surface and subsurface investigations at Watana and Devil Canyon sites and reservoir areas and access road routes to establish general and specific geological and foundation conditions
5.05 - Exploratory Program Design (1981)	- Design the geotechnical exploratory investigation programs for 1981 for Watana and Devil Canyon dam sites, dam construction materials and reservoir areas, and for the selected access road and transmission line routes
5.06 - Exploration Program (1981)	- Complete surface and subsurface investigations at Watana and Devil Canyon dam sites, reservoir areas, access roads and transmission line routes to the extent necessary to provide adequate data to confirm project feasibility and for submission of FERC license application, currently scheduled for June, 1982

5.07 - Exploratory Program Design (1982-1984)	- Design of the geotechnical program exploratory investigations program for 1982 to 1984 to obtain basic design data for Watana dam site, dam construction materials and reservoir area, and for the selected access road and transmission line routes
5.08 - Data Compilation	- Assemble all geotechnical exploratory data into documents suitable for inclusion in relevant project reports and licensing documentation

(c) Approach

To meet the objectives of the task in an orderly and timely manner, the geotechnical exploratory programs are divided into three stages, i.e. the 1980 activities, 1981 activities and the activities during and after 1982 (after the FERC license application is submitted). The 1980 geotechnical activities were planned to identify and investigate in limited detail those geological and geotechnical conditions which have been identified by previous investigators and which could significantly affect the feasibility of the project. The scope of field investigations was, therefore, limited in nature. These activities included Subtasks 5.01 through 5.04. The material investigated in Subtask 5.01 is summarized as Appendix A. Subtask 5.02, undertaken by R&M Consultants, has been submitted for review and will be published as Appendix F.

Subtasks 5.05 through 5.07 are to be undertaken during 1981 and early 1982, respectively. Under these activities, a more detailed study will be made of those geological and geotechnical conditions identified during 1980 studies. Also, the explorations for the access roads and the transmission lines will be undertaken under these subtasks.

It should be noted that the results presented in this report are preliminary and are subject to revision depending on the results of future investigations. In particular, the geologic history of this region is very complex and it is not possible at this time to fully define the site geology on the basis of the relatively limited available data. The conclusions drawn are very general and are intended to be used for work of a preliminary layout and engineering feasibility nature. A more complete evaluation will be developed after the completion of Subtasks 5.05 through 5.08.

1.4 - Report Contents

A summary and preliminary conclusions of the Task 5 studies to date are presented in Section 2 of this report. A review of previous work undertaken by the COE, USBR and others is presented in Section 3, and a preliminary assessment of regional geology is in Section 4. The scope of the 1980 geotechnical exploration program is presented in Section 5, with the review of the results in Section 6. Detailed results of drilling, testing, seismic refraction surveys, air photointrepretation and geophysical logging performed in 1980 are included in Appendices A through F.

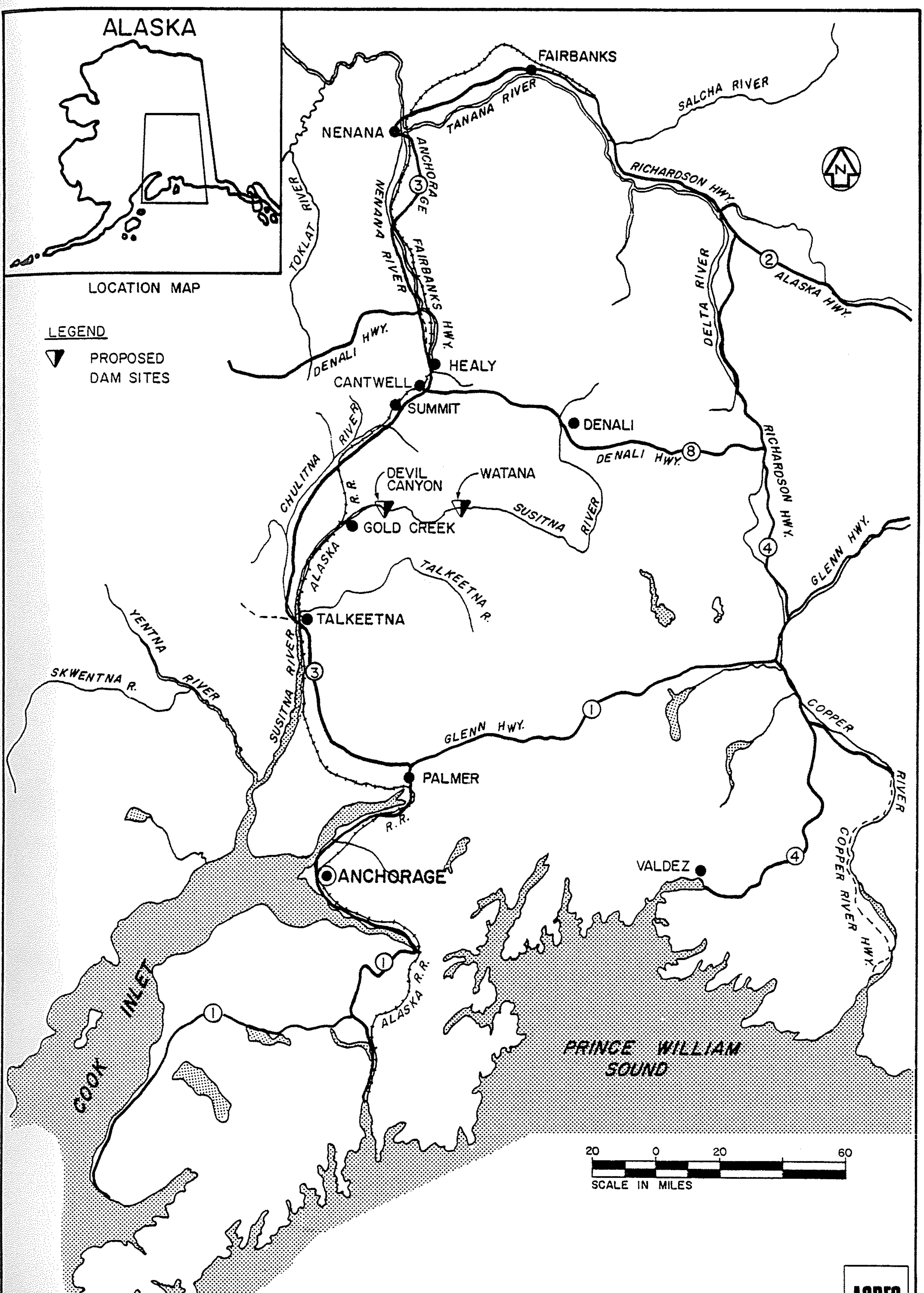
1.5 - Acknowledgments

Material presented in this report has been obtained from reports previously published by the USBR and the COE. The cooperation of the COE in providing access to records and data and opinions on interpretation is gratefully acknowledged.

Drilling at the sites was performed under the direct supervision and direction of Acres staff, by the Drilling Company under subcontract to R&M Consultants of Anchorage, Alaska. Seismic refraction surveys were performed by Woodward-Clyde Consultants, also under subcontract to R&M Consultants. In-hole geophysical logging work was performed by EDCON (Exploration Data Consultants, Inc., of Denver, Colorado) under subcontract to R&M Consultants. Air photointerpretation was performed by R&M Consultants. All work undertaken by R&M, directly or subcontracted, was directed by Acres.

Logistical support during field activities was provided by KNIK/ADC - Joint Venture under its subcontract with Cook Inlet Region, Inc./Holmes & Narver, Inc. and Acres for camp accommodations, and by Akland Helicopters and ERA Helicopters, also under subcontract with Acres for personnel and equipment transportation requirements.

The results of these activities were presented to the Acres External Review Panel (Dr. Peck, Dr. Hendron, Mr. Copen), to APA, and to the APA Review Board Members (Dr. Seed, Dr. Merritt) during technical meetings and discussions. Acres is very grateful for their critical and very objective review of the information. Thanks are due to Mr. Rivard for his contributions to Subtask 5.02 - Air Photointerpretation.



LOCATION OF DAM SITES

FIGURE 1.1

ACRES

SECTION 2

SUMMARY AND CONCLUSIONS

2 - SUMMARY AND CONCLUSIONS

2.1 - Introduction

The summary and preliminary conclusions presented herein are based on a review of previous investigations completed by other agencies and the data developed by Acres during 1980. It is emphasized that the conclusions presented are subject to revisions following further studies to be performed in 1981.

Comprehensive field exploration programs were undertaken at Watana by the Corps of Engineers in 1978 and Acres in 1980, and at Devil Canyon by the USBR in the 1950's and Acres in 1980. The scope of these programs is indicated in Table 2.1.

2.2 - Watana Site

(a) Preliminary Study Results

The following technical conditions have been identified regarding the Watana dam site:

(i) The dam site is underlain principally by a diorite/quartz diorite intrusive rock which is partially overlain by an extrusive andesitic rock exposed downstream of the proposed dam axis.

(ii) On the basis of drilling to date, rock weathering extends up to 40 feet in depth below top of rock. Bedrock quality is generally good to excellent below the weathered zone.

(iii) Two prominent shear zones, "The Fins" and "Fingerbuster" are exposed on the right bank upstream and downstream of the proposed dam axis, respectively. Lack of bedrock exposures has prevented the mapping of these features on the left bank to date.

(iv) Geologic mapping infers the continuation of "The Fins" in a northwesterly direction, outcropping along Tsusena Creek north of the site.

(v) Localized shear and fracture zones were encountered at various depths in several of the borings. These zones generally ranged from 1 to 30 feet in thickness.

(vi) The contact between the extrusive andesite and the diorite was drilled in two of the 1980 borings. The nature of this contact is not clearly defined but appears to be associated with a decrease in rock quality and increased weathering near the contact.

(vii) No evidence of major faulting was found under the river.

(viii) The rock has one major and several minor joint sets. The major set strikes approximately 320° (N40°W) with dips ranging from 65°NE to 70°SW.

(ix) Overburden thickness is generally thin on the valley walls, and thickens away from the dam site to the north. Overburden generally consists of glacially derived silts, sands, gravels, boulders and glacial lacustrine clays.

(x) Depth of river alluvium beneath the proposed dam averages approximately 60 feet and consists of sand, silt, coarse gravels and boulders. The maximum depth of this overburden in COE borings BH-3 and BH-4 was 78 ft.

(xi) Several localized areas of deeper overburden were encountered on each abutment. Further studies are required to more accurately delineate these areas.

(xii) A possible relict channel identified in previous studies and reconfirmed in the 1980 program extends from approximately 9,000 feet upstream of the dam in a general northwesterly direction towards Tsusena Creek. The depth of this channel extends up to 500 feet below ground surface. Further study is required to delineate the full extent of this channel.

(xiii) The largest geologic tectonic feature mapped in the vicinity of the dam is the Talkeetna thrust fault approximately 4 miles from the dam site. No evidence of recent fault movement has been found, however, further investigation of this feature is planned for 1981. The fault crosses the Susitna River approximately seven river miles upstream of the dam site.

(xiv) Permafrost conditions exist on the left abutment. Although the depth of the permafrost has not been fully determined, measurements indicate that it penetrates to a depth of at least 200 feet. There is evidence that the ground temperatures are within one degree centigrade of freezing and therefore are marginal. Further work to delineate the extent of permafrost will be performed during 1981. Only sporadic permafrost was encountered on the right abutment.

(xv) Reconnaissance surveys of the Watana reservoir show that several areas along Watana Creek and other smaller tributaries contain thick deposits of glacially derived material.

(xvi) Adequate quantities of rock fill and soil borrow materials for embankment construction have been found within the dam area.

(b) <u>Conclusions</u>

Based on these findings, the following tentative conclusions regarding the Watana site can be made:

(i) No evidence has been found to indicate that the site is not geologically and geotechnically feasible for the construction of a large rockfill or concrete dam and associated structures.

(ii) Exploration in the abutments to date has encountered no conditions which would preclude construction of a suitably located and oriented underground powerhouse. At this time, support for underground caverns by means of conventional rock bolting and shotcrete methods may be assumed. It is not anticipated that conditions will be found to be so severe as to rule out an underground powerhouse.

(iii) On the basis of the currently available data, relatively low density of sands and silts in the river alluvium, and potential for loss of strength of these materials under seismic loading is being assumed for the current design studies.

(iv) Foundation preparation as envisaged at this time includes (on conservative assumptions) removal of existing alluvium and a significant portion of the weathered rock under the dam, and performance of consolidation and curtain grouting. Drain holes and drainage galleries in the abutments and upstream of the underground structures are being considered in the preliminary design stages.

(v) Although the relict channel on the north bank upstream warrants further study, it is not anticipated to have any major impact on the feasibility of the project. Conventional engineering methods to prevent seepage and associated phenomenon such as piping, will be investigated during 1981 and in subsequent studies.

(vi) During filling and operation, local slumping and landslides may occur in the reservoir in areas of steep slope underlain by deep soil, as well as along portions of the northfacing slopes where extensive permafrost exists. At this time, these phenomena are not considered significant enough to cause serious wave action in the reservoir or to endanger the safety of major structures.

2.3 - Devil Canyon Site

(a) Preliminary Study Results

The following technical conditions have been identified at the Devil Canyon site:

(i) The proposed dam site is underlain by argillite and graywacke (metamorphosed sedimentary rocks). The rock is generally of good to excellent quality. Overburden on the valley walls is thin to non-existent.

(ii) One major and two minor joint sets have been mapped. The major set strikes approximately 340° (N20°W) and dips 85° NE. Bedding strikes subparallel to the gorge (050-070° NE) and dips steeply (50°-80°) to the southeast.

(iii) Stress relief cracks and open joints parallel to the gorge extend up to 100 feet back from the cliff edges. Open jointing also occurs along the major joint set.

(iv) Earlier investigators have postulated the possibility of a fault on the left abutment, paralleling the river. The seismic refraction surveys have indicated an anomalous velocity zone. No conclusive evidence has been found to support or refute the existence of this feature. Additional work in 1981 will be directed in this area.

(v) The possibility of a fault along the river channel under the proposed dam was postulated by earlier investigators. No evidence has been found to support this theory, but the possibility will be further explored during the 1981 investigations.

(vi) A several hundred foot step in bedrock surface had been reported by earlier investigators upstream of the proposed dam site, under the alluvial fan where Cheechako Creek joins the Susitna River. The location of this feature is approximately 1,000 feet upstream of the dam site.

(vii) During the 1980 program no field mapping was conducted to verify the existence of the shear zones mapped by the USBR subparallel and sub-perpendicular to the river. Additional work relative to these features will be carried out in 1981.

(viii) No extensive permafrost conditions were found to exist on either abutment.

(ix) River channel alluvium appears to be composed of talus and detached blocks of rock, and is inferred to be up to 40 feet thick under the river.

(b) Conclusions

Based on the above, the following tentative conclusions have been made regarding the Devil Canyon site:

(i) The site appears geologically and geotechnically feasible for the construction of either a concrete gravity or arch dam.

(ii) No evidence has been found to suggest the infeasibility of construction of large underground power facilities at the site. Further detailed geologic studies are required to determine the appropriate location and orientation of underground caverns.

(iii) Further investigations are required to conclusively identify or disprove the potential existence of a fault along the river channel, under the dam or on the left abutment.

(iv) On the basis of available data, it is estimated that foundation treatment will include grouting and provisions for drainage adits and drain holes for the dam. Extensive foundation rock excavation and dental concrete will probably be required to treat local areas for the concrete dam foundation.

(v) Sources of construction material have been tentatively identified for the concrete aggregate and for construction of the saddle dam on the left abutment. However, a determination of suitability and quantities available has to be performed in the 1981 program.

TABLE 2.1 -SUMMARY OF GEOTECHNICAL INVESTIGATIONS

PROGRAM	YEAR	DRILLING (FT)	AUGER HOLES (FT)	TEST PIT (NO.)	SEISMIC LINES (FT)	GEOLOGIC MAPPING
USBR	1957-58					
Devil Canyon		1976	---	19	---	Yes
Watana		---	---	---	---	No
COE	1978					
Devil Canyon		---	---	---	3300	No
Watana		5030	410	27	47665	Yes
Acres/R&M	1980					
Devil Canyon		1908	34	---	3000	Yes
Watana		1892	226	---	24800	Yes

References: U.S. Army Corps of Engineers, 1979 (18)
U.S. Bureau of Reclamation, 1960 (19)

SECTION 3

REVIEW OF PREVIOUS WORK

3 - REVIEW OF PREVIOUS INVESTIGATIONS

3.1 - Introduction

The development of the Susitna Hydroelectric Project has been studied by several Federal and private agencies in the last 30 years. However, it was not until the late 1950's that any geotechnical investigations were conducted.

Between June 1957 and August 1958, the USBR performed geologic mapping and drilling investigations at the Devil Canyon site and limited geologic mapping at the Watana site (19).

Subsequently during the 1970's, the COE performed additional investigations on both sites. These included seismic refraction surveys at Devil Canyon; and detailed geologic mapping and diamond and auger drilling at the dam site and potential borrow areas at Watana.

This report briefly discusses the findings of these investigations as documented by the USBR and the COE. These reports, which are identified in the bibliography of this summary, are available from APA and Acres for reference.

3.2 - Watana

The preliminary reconnaissance work by the USBR in the 1950's was expanded during the 1970's by the COE investigations of the dam site, reservoir, and potential borrow areas. The location and extent of these investigations are shown on Figure 3.1.

In 1975, a total of 22,500 linear feet of seismic refraction survey was performed by Dames & Moore (6) for the COE. This was expanded by Shannon & Wilson (14) in 1978 with an additional 47,665 feet of survey. This work served to support the results of the drilling and mapping programs.

During the 1978 season, the site was explored with 28 diamond and rotary drill holes (both vertical and inclined) ranging from 30 to 600 feet in length (18). A summary of this program is presented in Table 3.1. Six of the diamond drill borings were located in the river bottom and reached a maximum of 520 feet into rock. Five borings were drilled on the left abutment and six on the right, reaching a maximum depth of 300 feet or an elevation of 1,560 feet. On the right bank, eleven borings were located in what was identified as a deep relict channel to determine the thickness and characteristics of the overburden, the depth of the water table, and the permafrost conditions. These holes were also designed to obtain samples of potential borrow materials in Area D, and to evaluate bedrock depth to control spillway location.

Four potential borrow areas for construction material were identified and explored using 26 backhoe test pits and 24 auger borings. Fourteen test pits were located in Borrow Area D on the right bank which was identified as a source of impervious and semi-pervious material for the embankment. Six test pits were located in Borrow Area E, identified as a potential source of filter material and concrete aggregate. This area is situated at the confluence of Tsusena Creek and the Susitna River, approximately 15,000 feet downstream of the dam site. Six test pits were located in Borrow Area F on Tsusena Creek, three miles upstream of its confluence with the Susitna River, as a potential source of granular material. The 24 shallow auger borings were drilled in Borrow Area D between Tsusena and Deadman Creeks and ranged from 3 to 59 feet deep. No definitive estimate of available quantities of materials were made but in general it is believed that adequate quantities of available materials exist at the proposed borrow areas.

Detailed geologic mapping was conducted in the dam site area to delineate major structural features.

Two potential quarry areas were identified and reconnaissance exploration was conducted. Quarry A is located on the upper part of the left abutment, and Quarry B on the right bank relatively close to the river. Both areas were mapped as a diorite that could be exploited for appropriately sized and graded embankment rockfill.

A limited laboratory testing program was conducted on potential filter, core and embankment materials from the various borrow areas to establish the indexes and engineering characteristics of the borrow materials. These tests included gradation curves, permeability, triaxial shear tests, Modified Proctor compaction tests and concrete aggregate tests.

The COE also installed a series of ten open well piezometers and thirteen temperature logging devices in the boreholes. These instruments had not stabilized by the end of the COE investigation and, therefore, no definite conclusions were drawn.

3.3 - Devil Canyon

The investigations conducted at the Devil Canyon site were not as extensive as those at Watana. The exploration plan is shown on Figure 3.2 and summarized in Table 3.2

The USBR performed the bulk of exploration at this site between June 1957 and August 1958 (19). Twenty-one diamond drill borings were drilled in the dam site area. Six holes, from 50 to 110 feet deep, were located in the left abutment within the proposed switchyard area downstream of the proposed saddle dam axis. At the deepest point, rock was encountered at 87 feet below the surface in what was interpreted as an old buried channel. Three holes were drilled upstream of this area with a maximum depth of 120 feet. The remaining twelve holes were drilled along the riverbed near the dam axis to determine the depth and nature of the bedrock under the dam. One other proposed borehole was subsequently excavated as a test pit.

Nineteen test pits were dug in the alluvial fan immediately upstream of the dam axis. This area was considered to be the only readily available source of concrete aggregate material for dam construction, but no estimates of available quantities were made. Four additional benches were dug on the dam abutments to define the rock conditions present.

Laboratory tests, including gradation determinations and petrographic analysis were conducted on samples of the borrow area materials to determine their suitability for use as concrete aggregate. Representative rock samples from the abutments were tested to determine compressive strength, elasticity, absorption, and porosity of the foundation material.

During 1978, Shannon & Wilson (14), under COE contract, ran three seismic refraction lines totaling 3,300 feet in the borrow area and along the proposed saddle dam to expand the drilling information. This, along with alluvial fan material sampling, was the only COE work performed at the site.

3.4 - Conclusions

The investigations conducted by the COE and USBR were the first detailed efforts to establish the feasibility of the project. The review of these investigations served as the basis for identifying those geological and geotechnical features that were considered to require further investigation. A brief summary of prior features and findings of those investigations follows.

(a) Watana Site

The Watana site was considered suitable for a large rockfill dam, an underground powerhouse and ancillary structures. However, before the feasibility is conclusively established, certain features were identified which required further investigation.

(i) The exploration in the riverbed (5 drill holes and one seismic line) indicated a depth of overburden of 40 to 80 feet of relatively loose alluvial gravels, cobbles and boulders. The stability of this alluvium was questioned under the seismic loading conditions being considered for the project.

(ii) Drilling results indicated the underlying rock at the dam site to be a diorite intrusion with local andesite dikes. The overall rock was found to be hard and fresh (lightly weathered) with the fractures becoming tighter with depth. Shear zones were observed both in outcrops and the drill cores but were not considered to be significant.

(iii) The weathering of the rock in the right abutment was found to be more severe than the rest of the dam foundation, averaging about 40 feet below the bedrock surface.

(iv) The rock along the left abutment was also identified as diorite; however, in a COE boring, a surface flow of andesite porphory was encountered. The relationship of these two rock types was not delineated and it was recognized that this would require resolution before design of underground structures could be undertaken.

(v) North of the right abutment, a deep bedrock depression filled with glacial material was encountered in the drilling and seismic refraction programs. Glacial tills occur in this area in three major sequences separated by layers of sandy gravel alluvial material and two major lake deposits of plastic clays. The lowest bedrock surface encountered in the drilling was 454 feet below the surface, giving the bedrock at that point an elevation of 1,775 feet, compared with the current riverbed rock elevation of about 1,395 feet.

(vi) Two prominent shear zones named "The Fins" and "Fingerbuster" were mapped as exposures in the dam site area. Both of these zones trend northwest with strikes from 300° to 320° (N60°W to N40°W) and dip to 90° SW and NE. "The Fins", located 3,400 feet upstream of the centerline, had an observable width in excess of 400 feet with rib competent rock 5 to 25 feet wide, bounded by severely altered zone The "Fingerbuster", located 2,500 feet downstream of the axis, was less well defined, with rock faces paralleling the shear zone.

(vii) The seismic refraction survey indicated a low velocity zone along right abutment that could be interpreted as a possible slide block which requires further investigation.

(viii) The foundation rock at the site was considered to be of generally quality with relatively high intact strength. Rock bolts and shot crete were considered likely to be required to provide adequate support in underground excavations.

(ix) Adequate quantities of construction material of suitable quality w identified near the dam site. Material from Borrow Area D on the right abutment was classified as semi-pervious to impervious core material. The tests indicated that this material is sensitive to iations in water content and loses strength rapidly with increasin water content. Material from the alluvial deposit downstream of t dam axis (Borrow Area E) was identified as the most likely source clean aggregate. Processing was considered necessary for all mate ials.

(x) Two potential quarry areas were identified as sources of rockfill, riprap and coarse filter materials. The rock in both areas was cl ified as diorite and of good quality. Further mapping was conside necessary to verify the suitability.

(xi) Permafrost was found to be very deep on the left abutment, or nort facing slope, while somewhat sporadic on the right abutment. Preli nary temperature readings indicated that the permafrost is relativ warm, within -1°C to 0°C, and could be easily handled during constr tion. However, these instruments had not stabilized by the end of COE investigations and further readings will be necessary.

(b) Devil Canyon Site

The investigations conducted to date indicate that the Devil Canyon site would be a feasible location for a high concrete gravity or thin arch d with an underground powerhouse. However, certain specific features were identified by both the USBR and the COE for further study to define the subsurface conditions and fully evaluate the extent and characteristics geologic features before the feasibility of concrete structures could be positively established.

(i) The bedrock at the proposed dam site was classified as a thinly bedded, fine grained phyllite. The strike of the bedding was found be generally east-west, paralleling the river, and dipping 65° to 7 to the south. The drilling indicated that weathering extends some feet below the rock surface, with penetrative weathering restricted shallow zones along the joints. Overall, the rock was found to be of good quality. One master joint set was identified striking 335° (N25°W) and dipping 80°E, with general spacing of 5 feet.

(ii) The valley walls at the dam site are very steep and were found to have only a thin cover of overburden consisting mainly of talus at the base. On the upland areas, a covering of glacial till 5 to 35 feet thick was observed.

(iii) On the left abutment, a series of small lakes were observed approximately parallel to the river channel. Deep overburden, up to 80 feet in thickness was encountered in this area. Further, it was postulated that a shear zone or a fault existed along these lakes.

(iv) A number of shear zones were encountered during the investigations both subparallel and subperpendicular to the river channel. It was considered that these shear zones were either local stress relief features and part of a more general subregional shear pattern, respectively, which could have an important effect on the design and required further investigation.

(v) Although no positive evidence was encountered, it was postulated that the site topography may indicate the existence of a possible fault or major shear zone parallel to the river.

(vi) The rock conditions were considered adequate for underground excavation. Conventional rock support systems including shotcrete were considered adequate to provide support except at the portals and within zones of very poor quality rock. Further investigation was considered necessary to define the conditions present for the most advantageous alignment of the structures.

(vii) A large fan area near Cheechako Creek, immediately upstream of the proposed dam site, was explored for the availability of materials for concrete aggregate and the saddle dam construction. The material within this alluvial fan was found to be suitable for concrete aggregate except for a deficiency of 3/4 to 1-1/2 inch size that could come from local morainal material. Laboratory tests conducted on the collected samples confirmed their general suitability provided proper processing was employed. However, the resistance of the material to effects of the cold weather was not fully evaluated. At this time no estimate of available quantities has been made, but it is likely that sufficient quantities are available for construction requirements.

(viii) The explorations in the fan area also indicated the existence of a step in the bedrock surface from depths of 100 on the west to 350 feet on the east side, within 500 feet horizontally. The significance of this step has not yet been determined, but the geologic setting and form of this feature will be considered in subsequent investigations, to ascertain if it is an erosional or fault-caused phenomenon. The step is also coincident with a sharp bend in the river course.

(ix) Permafrost as encountered was sporadic and shallow. Thin lenses and pockets were encountered during road construction on the left abutment. It was considered doubtful that permafrost would be a problem.

(x) It was concluded that grouting and drainage under the structure and in the abutments would be required. Recommended foundation preparation included approximately 40 feet of rock excavation to sound rock, consolidation grouting and dental concrete work to treat local shear zones and poor rock zones.

TABLE 3.1 - SUMMARY OF PREVIOUS DRILLING - WATANA

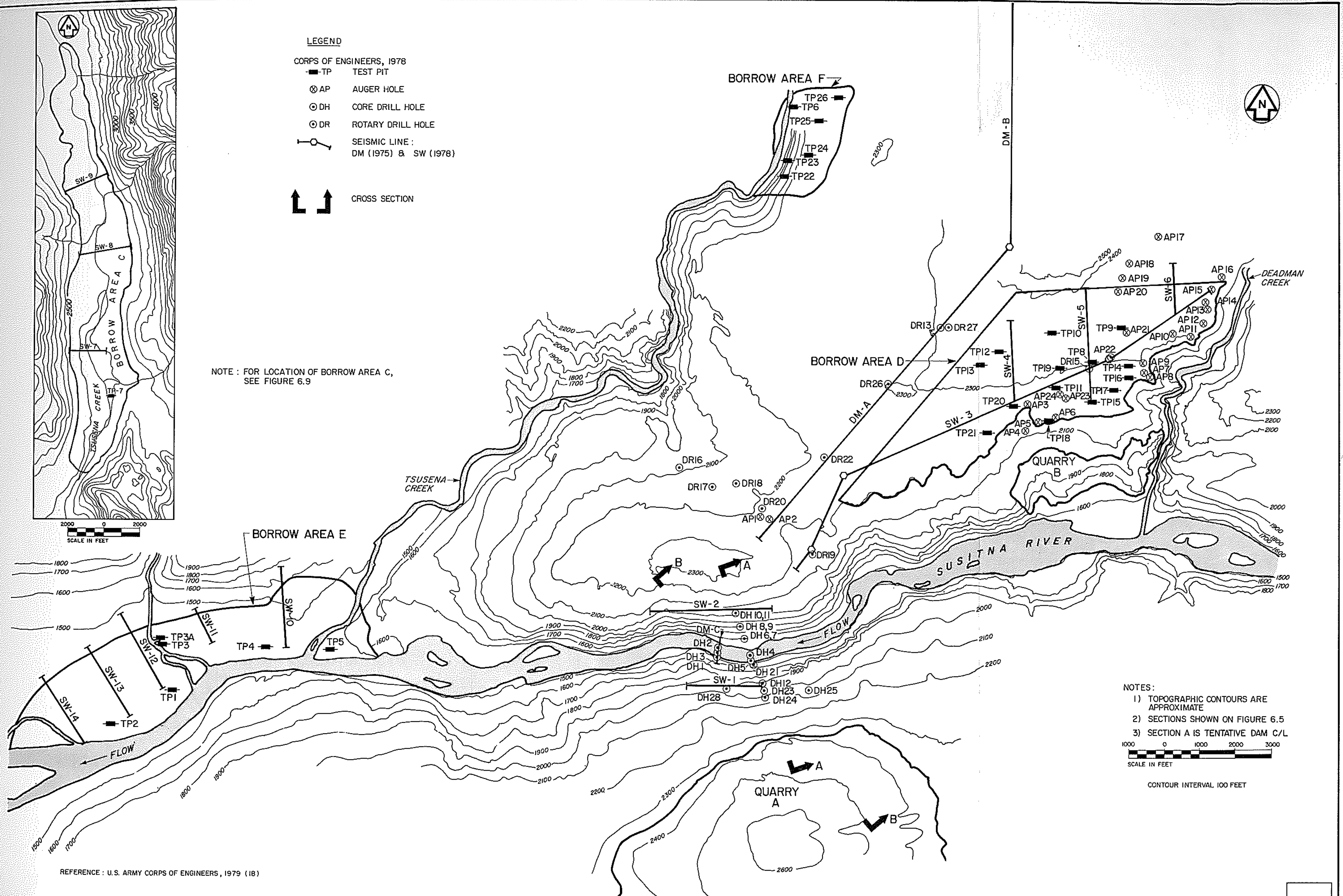
Drill Hole Number	Location	Depth of Boring, ft. Measured Down Axis of Hole (Overburden)	Angle W/Vertical	Orientation
DH-1	River Valley	122.8 (43.8)	Vertical	--
DH-2	River Valley	29.0 (29.0)	Vertical	--
DH-3	River Valley	174.5 (77.6)	Vertical	--
DH-4	River Valley	122.9 (77.7)	Vertical	--
DH-5	River Valley	176.9 (59.6)	Vertical	--
DH-6	Right Abutment	149.5 (3.5)	Vertical	--
DH-7	Right Abutment	122.2 (8.5)	31°	S30°W
DH-8	Right Abutment	150.0 (16.2)	Vertical	--
DH-9	Right Abutment	283.8 (5.6)	45°	N43°W
DH-10	Right Abutment	203.5 (19.6)	Vertical	--
DH-11	Right Abutment	300.0 (22.7)	45°	N32°E
DH-12	Left Abutment	301.1 (9.5)	Vertical	--
DR-13	Relict Channel	84.0 (84.0)	Vertical	--
DR-14	Relict Channel	75.0 (75.0)	Vertical	--
DR-15	Relict Channel	316.5 (286.0)	Vertical	--
DR-16	Left Abutment	91.5 (67.0)	Vertical	--
DR-17	Left Abutment	35.7 (9.0)	Vertical	--
DR-18	Left Abutment	248.3 (231.0)	Vertical	--
DR-19	Relict Channel	78.3 (55.0)	Vertical	--
DR-20	Outlet Structure	252.6 (210.0)	Vertical	--
DH-21	River Valley	603.7 (84.5)	32.4°	N4°E
DR-22	Relict Channel	493.6 (454.0)	Vertical	--
DH-23	Left Abutment	119.2 (7.0)	45°	S30°W
DH-24	Left Abutment	139.9 (6.9)	Vertical	--
DH-25	Left Abutment	79.9 (79.9)	46°	N47°E
DR-26	Relict Channel	94.8 (94.8)	Vertical	--
DR-27	Relict Channel	44.0 (44.0)	Vertical	--
DH-28	Left Abutment	125.2 (9.2)	Vertical	--

Reference: U.S. Army Corps of Engineers, 1979 (18)

TABLE 3.2 - SUMMARY OF PREVIOUS DRILLING - DEVIL CANYON

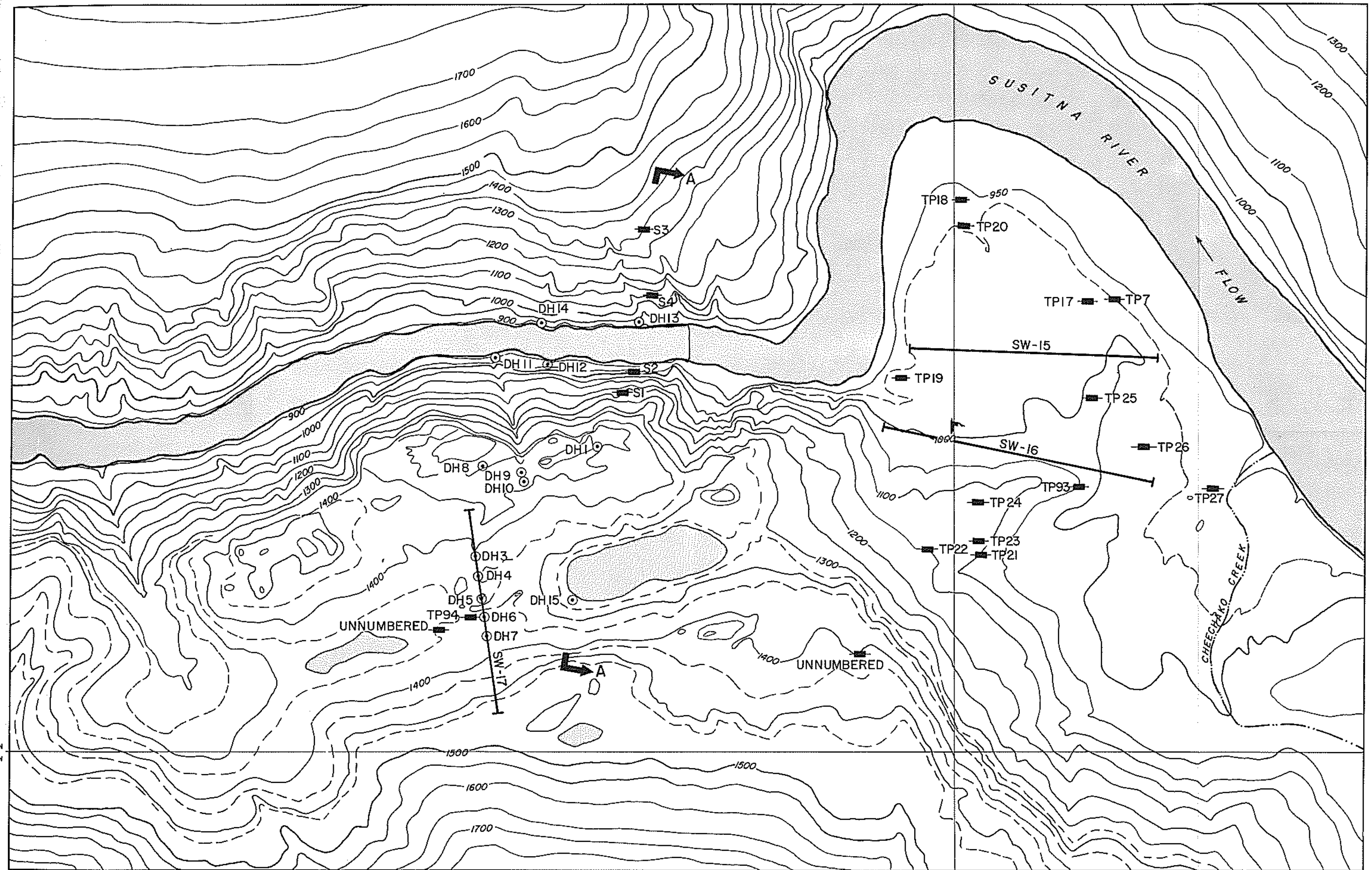
Drill Hole Number	Location	Depth of Boring, ft. Measured Down Axis of Hole (Overburden)	Angle W/Vertical	Orientation
DH-1	Left Abutment	117.3 (0.0)	45°	S23° E
DH-3	Left Abutment	(Hole Trenched)	Vertical	--
DH-4	Left Abutment	52.5 (24.7)	Vertical	--
DH-5	Left Abutment	86.2 (55.5)	Vertical	--
DH-6	Left Abutment	107.3 (86.9)	Vertical	--
DH-7	Left Abutment	59.5 (33.9)	Vertical	--
DH-8	Left Abutment	150.4 (0.0)	60°	N9°W
DH-9	Left Abutment	87.0 (0.0)	45°	Due North
DH-10	Left Abutment	121.7 (0.0)	38°	N65°E
DH-11	Left Abutment	30.5 (0.0)	48°	N5°W
DH-11A	Left Abutment	29.1 (0.0)	45°	N5°W
DH-11B	Left Abutment	33.9 (0.0)	39°	N5°W
DH-11C	Left Abutment	150.1 (0.0)	33°	N5°W
DH-12	Left Abutment	127.5 (0.0)	30°	N45°E
DH-12A	Left Abutment	149.3 (0.0)	45°	N45°E
DH-13	Right Abutment	137.0 (0.0)	45°	S18°E
DH-13A	Right Abutment	80.7 (0.0)	37°	S18°E
DH-14	Right Abutment	50.0 (0.0)	45°	S45°W
DH-14A	Right Abutment	130.4 (0.0)	37°	S45°W
DH-14B	Right Abutment	146.2 (0.0)	60°	S45°W
DH-14C	Right Abutment	82.0 (0.0)	35°	S4°E
DH-15	Right Abutment	68.3 (47.6)	Vertical	--

Reference : U.S. Bureau of Reclamation, 1960 (19)



WATANA - PREVIOUS EXPLORATION MAP

FIGURE 3.1



REFERENCES :
1) USGS, TALKEETNA MOUNTAINS, (D-5), ALASKA QUADRANGLE SEWARD MERIDIAN : T32N, R1E, S32 AND 33.
2) U.S. ARMY CORPS OF ENGINEERS, 1979 (18)
3) U.S. BUREAU OF RECLAMATION, 1960. (19)

LEGEND

USBR, 1958
⊙ DH — BORE HOLE
TP, S, — TEST PITS AND TRENCHES

CORPS OF ENGINEERS, 1978
SW — SEISMIC LINES

CROSS SECTION

NOTES:
1) TOPOGRAPHIC CONTOURS ARE APPROXIMATE
2) SECTION SHOWN ON FIGURE 6.13

200 0 200 400 600
SCALE IN FEET

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

DEVIL CANYON - PREVIOUS EXPLORATION MAP

FIGURE 3.2

ACRES

SECTION 4

REGIONAL GEOLOGY

4 - REGIONAL GEOLOGY

4.1 - General

The geology of the Talkeetna Mountains and the adjacent Susitna River basin is extremely complex due to the occurrence of several periods of intense folding and faulting, intrusion of volcanics and plutons, regional metamorphism, differential uplift and repeated glaciations (Figure 4.1). The following is a brief summary of the geologic setting of the region. A discussion of the regional geology has also been compiled by Woodward-Clyde Consultants (21).

4.2 - Geologic Setting

The oldest rocks which outcrop in the region are an upper Paleozoic (Table 4.1) metavolcanic rock sequence consisting of coarse to fine grained clastic flows and tuffs of basaltic to andesitic composition, locally containing limestone interbeds (2). This old volcanic system is exposed as a continuous northeastward trending belt across the eastern part of the Susitna River basin. This system is unconformably overlain by Triassic and Jurassic volcanic and sedimentary rocks and is intruded by Jurassic diorites (Figure 4.1). These rocks consist of a shallow marine sequence of metabasalt flows, interbedded with chert, argillite, marble and volcaniclastic rocks. The best exposures are in the Portage and Watana Creeks area. The intrusive rocks of Jurassic age include amphibolites, greenschists, diorites and granodiorites of the intruding batholithic complexes of the Talkeetna Mountains (2). The uplift and subsequent rapid erosion associated with these plutonic events was followed by the marine deposition of a turbidite sequence of lower Cretaceous argillites and lithic graywackes (4). These rocks were subsequently faulted and compressed into tight isoclinal folds and subjected to low grade metamorphism during the late Cretaceous. This sequence of rock outcrops in the Devil Canyon area.

During the early Tertiary, the country rock was again intruded by plutons comprised of biotite granodiorite and other small granitic bodies. Concurrent with and following these intrusions, a thick sequence of felsic to mafic volcanics and shallow intrusives of Paleocene to Miocene age were deposited.

4.3 - Tectonic History

At least three major periods of deformation are recognized (4) for the project area:

- a period of intense metamorphism, plutonism, and uplifting in the Jurassic;
- an orogeny during the middle to late Cretaceous;
- a period of extensive uplift and denudation in the middle Tertiary to Quaternary.

The first period (early to Middle Jurassic) was the first major orogenic event in the Susitna basin as it now exists. It was characterized by the intrusion of plutons and accompanied by crustal uplift and regional metamorphism. The rapid erosional period following this uplift was accompanied by marine deposition within the narrowing Cretaceous basin.

This period was followed by complex faulting and folding of the rocks during middle to late Cretaceous that produced a pronounced northeast-southwest str tural grain across the region (4, 5, 8, 9, 13). The majority of the structu features, of which the Talkeetna Thrust fault is the most prominent in the Talkeetna Mountains, are a consequence of this orogeny. The Talkeetna Thrus postulated as representing an old suture zone, involving the thrusting of Paleozoic, Triassic and Jurassic rocks over the Cretaceous sedimentary rocks 5, 8). Other compressional structures related to this orogeny are evident i the intense shear zones roughly parallel to and southeast of the Talkeetna Thrust.

The third major series of events shaping the region involved a period of ext sive uplift and denudation from the middle Tertiary to Quaternary (4). Two prominent tectonic features of this period bracket the basin area. The Dena fault, a right-lateral strike-slip fault 25 miles north of the Susitna River exhibits evidence of fault displacement during Cenozoic time (3) and the Cas Mountain-Caribou fault system, which borders the Talkeetna Mountains approxi mately 70 miles southeast of the sites, is a normal fault which has had faul displacement during the Holocene (7).

4.4 - Glacial History

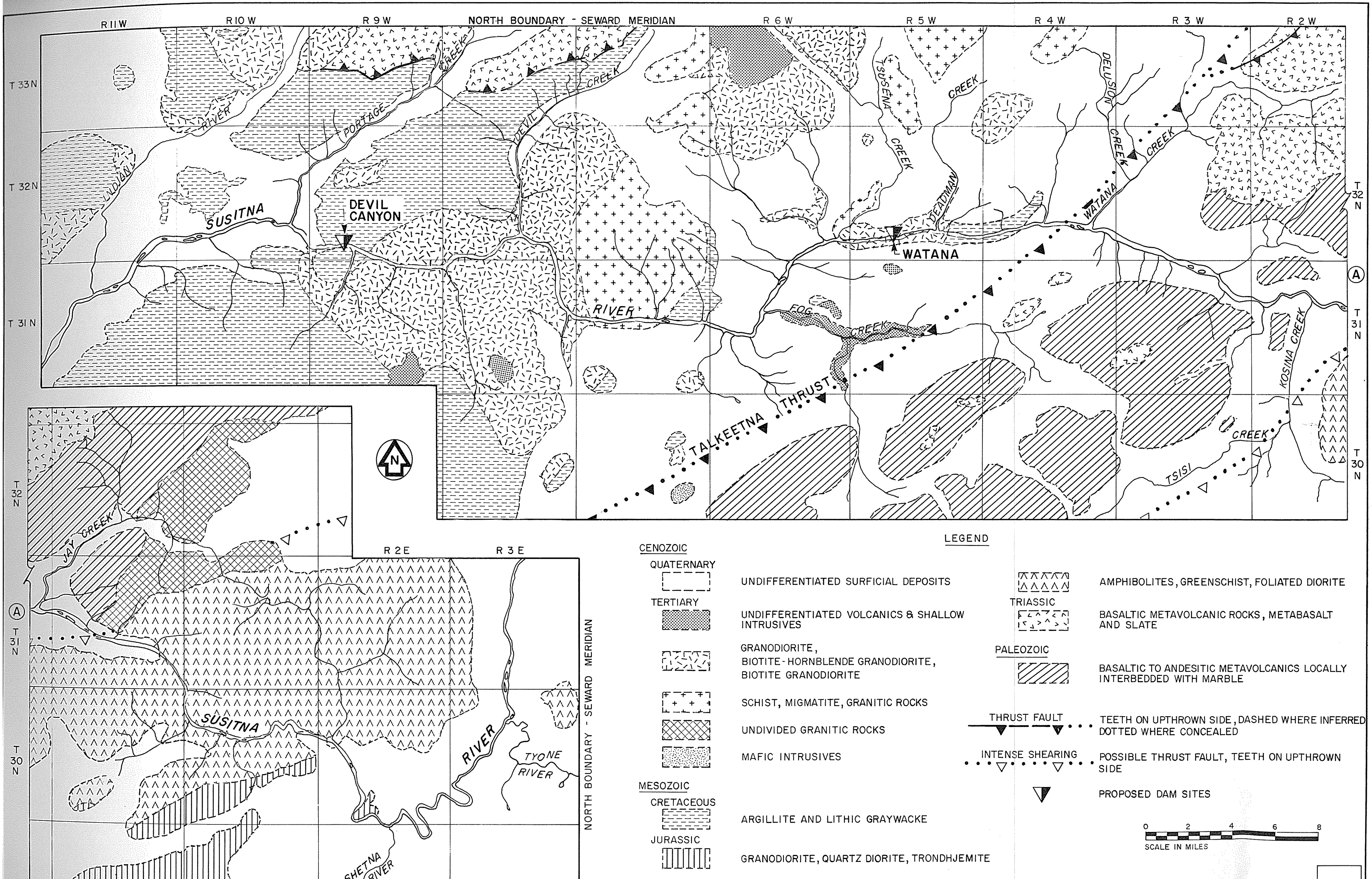
A period of cyclic climatic cooling during the Quaternary resulted in repeat glaciation of southern Alaska. Little information is available regarding th glacial history in the upper Susitna River basin. Unlike the north side of Alaska Range which is characterized by alpine-type glaciation, the Susitna b experienced coalescing glaciers from both the Alaska Range and the Talkeetna Mountains that merged and filled the upper basin area.

At least three periods of glaciation have been delineated for the region bas on the glacial stratigraphy (11, 12). During the most recent period, (late Wisconsin glaciation) glaciers filled the adjoining lowland basins and sprea onto the continental shelf (11). Waning of the ice masses from the Alaska R and Talkeetna Mountains formed ice barriers which blocked the drainage of gl cial meltwater and produced proglacial lakes. As a consequence of this repe glaciation, the Susitna and Copper River basins are covered by varying thicknesses of tills and lacustrine deposits.

TABLE 4.1 - GEOLOGIC TIME SCALE

ERA	PERIOD	EPOCH	GLACIATION	Millions of Years Ago
	Quaternary	Holocene		
		Pleistocene	Wisconsinian Illinoian Kansan Nebraskan	1.8
Cenozoic	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene		70
Mesozoic	Cretaceous Jurassic Triassic			230
Paleozoic	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian			600
Precambrian				

Reference: VanEysinga, F.W.B., Geologic Time Table, 3rd Edition, Elsevier Scientific Publishing Co., Amsterdam, 1975.



REGIONAL GEOLOGY

FIGURE 4.1

SECTION 5

1980 GEOTECHNICAL INVESTIGATION

5 - 1980 GEOTECHNICAL INVESTIGATION

5.1 - Approach

The 1980 investigation program was developed to define the geologic and subsurface features identified by previous investigators at the Watana and Devil Canyon dam sites. In addition to the review of information published, discussions were held with people knowledgeable of the area. In particular, meetings were held with the COE to discuss details of their 1978 program and the experiences of those people directly involved with the investigations.

The overall geotechnical investigation program for the Watana and Devil Canyon Sites was intended to provide the maximum of information relative to site geologic and geotechnical conditions aimed towards establishing the feasibility of the project consistent with overall study objectives and schedules.

The 1980 program was developed as the first phase of this overall investigation, and consisted of appropriate air photointerpretation, surficial geological mapping, diamond core drilling, permeability testing, in-hole geophysical logging, installation of piezometers and thermal probes, auger drilling, seismic refraction surveys and laboratory testing.

The scope of the program was principally directed towards effectively initiating the work necessary to investigate:

- Site geology.
- Rock type and quality.
- Engineering evaluation of rock conditions.
- Borrow sources for construction material.
- Groundwater regime.
- Permafrost.

Specific geologic and/or geotechnical features or conditions that were delineated during previous studies and considered to warrant further investigation have been discussed earlier in this report. The particular features selected for study during the 1980 program were:

(a) Watana Site

- Shear zones called "The Fins" and "Fingerbuster" located immediately upstream and downstream of the proposed dam site.
- A "relict channel" located on the right bank (northeast of the dam site).
- An andesite flow structure on the left bank of the dam site.
- A potential shear zone beneath the river channel.

(b) Devil Canyon Site

- Possible stress relief joints and shear zones on the left (south) bank of the river at the dam site.

- Possible shear zones or buried channel beneath the saddle dam location on the left bank of the river.

Detailed scope and methodology for the work performed are presented in the following paragraphs. A detailed discussion of the results of the program are presented in Section 6. Delays in the completion of the air photointerpretation work prevented the use of this data in planning of the 1980 exploration program. The exploration program was therefore developed only on the basis of field reconnaissance and review of previous work by others.

5.2 - Scope and Methodology

(a) Geologic Mapping

The 1980 field geologic mapping program was directed to the dam sites to expand and verify the previous geologic mapping. Geologic mapping of each of the proposed dam sites included walking selected ground traverses, noting all bedrock outcrops and unconsolidated material. Aerial photographic base maps at scales of 1:6,000 and 1:24,000 were used in mapping the Watana and Devil Canyon dam sites respectively. At each exposure, the lithology, type of material, bedding, jointing, weathering, outcrop size and elevation were noted and plotted on the base maps.

Geologic reconnaissance of the Devil Canyon reservoir and potential tunnel routes (which were studied during project definition studies) was performed between Portage and Tsusena Creeks and extended up to 5 miles north and south of the Susitna River. A helicopter reconnaissance was made within a 10-mile radius of the Watana dam site to delineate unconsolidated materials as potential borrow sources. The mapping of the reservoir areas was plotted on either a 1:12,000 aerial photographic or a 1:63,360 USGS topographic base map.

(b) Subsurface Investigations

(i) Diamond Core Drilling

Diamond core drilling was performed in the foundations and abutments of both dam sites utilizing a skid-mounted Longyear-34 diamond drill with a two or three man crew to operate and maintain the rig. A total of 3800 linear feet of drilling was performed. Three diamond core borings were drilled at each site. All logging and supervision was conducted by a geologist who described, photographed and packed the rock core and supervised permeability testing and instrument installation.

Prior to the start of diamond core drilling, all holes were cased through the overburden into sound rock. The casing was left in the hole to permit subsequent testing and installation of instrumentation.

A summary of the drilling activity for the 1980 field season is shown on Table 5.1 and Figures 5.1, and 5.2. Drilling summary logs and reports are contained in Appendix B.

(ii) Permeability Testing

Permeability testing was conducted in all the diamond drill holes upon completion of the core drilling. Prior to testing, each hole was thoroughly flushed with clear water and the drill string withdrawn. Following flushing of the hole, a packer assembly consisting of two inflatable packer elements separated by a perforated section of pipe and connected to the surface by a steel riser pipe and rubber inflation hose was lowered into the borehole to the desired depth. The test procedure involved inflating the packers with nitrogen to isolate a section of the borehole, pumping water under pressure into the test zone and recording the flow rates. Based on the flow rates, hydraulic head, hole diameter and length of test section, the permeability of the rock over the test section was calculated. In general, the packer assembly was installed to the bottom of the hole with tests being run over 16.1 foot intervals as the assembly was withdrawn.

The permeability for each test section was calculated using the following formula:

$$k = 0.0679 \frac{Q}{2 \pi LH} \ln \frac{L}{r}$$

Where: k = permeability, cm/sec
Q = constant rate of flow, gpm
L = length of test section, ft and $L \geq 10r$
H = differential head of water, ft
r = radius of hole, ft
ln = natural logarithm

A maximum test pressure equal to 1 psi per foot of vertical depth below the ground surface to the water table, plus 0.5 psi per foot of vertical depth below the water table down to the center of the test section, was used. However, in no case was the pressure allowed to exceed 200 psi. The actual gauge pressure was adjusted to take into consideration the depth of water table.

The test data and calculations are presented in Appendix B-1 and B-2 for Watana and Devil Canyon sites, respectively, and a schematic of the procedure used is in Appendix B-3.

(iii) In-Hole Geophysical Logging

In-hole geophysical logging was carried out in all three diamond drill holes at the Devil Canyon site and two holes at the Watana site. BH-2 at the Watana site caved badly and was not tested. A total of 3,225 linear feet of logging was completed. The logging procedure involved lowering a geophysical probe in the hole on a wireline with the data being returned to the surface and recorded on a self-contained loggi unit. The logs run in each hole included: temperature, caliper, resistivity and velocity.

The results of the geophysical logging are presented in Appendix E.

(iv) Borehole Photography

Scheduled borehole photography to augment core logging data proved t be impractical due to the inclination of the drill holes and the fractured nature of the rock. In three of the diamond drill holes, BH-6 and BH-8 at Watana, and BH-1 at Devil Canyon, a "dummy" camera unit which was lowered in the holes to check for any obstructions an safe passage of the unit, became lodged in the hole. The "dummy" un was recovered in all cases, but it was not considered advisable to lower the camera, as chances of it being lost in the hole or damaged were very high.

(v) Instrumentation

To monitor the groundwater and permafrost conditions in the bedrock, piezometers and thermistor strings were installed in all three bore-holes (BH-1, BH-2 and BH-4) at Devil Canyon (Figure 5.2); and BH-6 a Watana (Figure 5.1).

The piezometers used were a pneumatic type assembly manufactured by Petur Instrument Company of Seattle, WA. The pneumatic type piezo-meters were selected based on the fact that subfreezing temperatures were likely to be encountered in the upper portions of the holes whi would cause blockage in conventional standpipe piezometers. Pneumat type piezometers are also quick and easy to read as well as being accurate which is a prime consideration during winter months.

The thermistor strings were manufactured by Instrumentation Services in Fairbanks, Alaska. The thermistor strings were each 250 feet lon with redundant thermistor points installed at 3, 6, 9, 12, 15, 18, 2 25, 50, 75, 100, 125, 150, 175, 200 and 250 feet. A 40 strand cable was used to connect the thermistors to the surface where a quick connect plug on the cable was plugged into a switch box that in turn was connected to a portable readout box. The system is designed suc that two readings are obtained at each depth so readings can be cros checked. Each thermistor point was initially calibrated in the laboratory before installation and a computer program set up to con-vert readings to temperature, taking into account the correction factors for each thermistor. An accuracy of $\pm 0.05°C$ was obtained wi this equipment.

The installation details are shown on Figure 5.3 and 5.4.

(vi) Auger Drilling

Auger drilling was conducted at both sites to expand the work done b the previous investigators to define the potential borrow areas. At

Watana (Figure 5.1), four holes were drilled in Borrow Area D and nine in Borrow Area E. Two holes were drilled at Devil Canyon (Figure 5.2). A summary of auger hole locations and depths are presented in Table 5.2. The more extensive program which had been planned was curtailed because of unexpected difficulties encountered in advancing the auger through boulders, cobbles, and hard ground conditions. Grab samples were taken from Borrow Area H.

The program initially used a platform-mounted CME-45 rig that was replaced by a CME-55 for the difficult drilling conditions. Drilling was performed using a hollow stem continuous flight auger string, having an 8-inch O.D. and a 3-1/4 inch I.D., to a maximum depth of 35 feet. Material samples were collected continuously in the upper 10 feet of the hole and then at 5-foot intervals to full depth using a split-spoon sampler. The sampling procedures consisted of drilling the augers down to the required sampling depth, removing the inner plug and stem, and advancing the split-spoon sampler, 18 inches into the soil below the cutting head by driving it with a 140 lb hammer falling freely 30 inches (Standard Penetration Test). The samples were returned to the surface, logged by a geologist and prepared for transport and storage. In most cases, 4 to 6-inch long thin brass liners were used inside the split-spoon sampler, which allowed selected samples to be capped and sealed. Following completion of the hole, the auger string was withdrawn and the hole backfilled with the drill cuttings.

The logs for these holes are given in Appendix C-1. The properties of the borrow materials are discussed in Section 6.

(vii) Seismic Refraction Surveys

Seismic refraction surveys (seismic lines) were performed on the river banks at both dam sites, and in the borrow areas and relict channel near the Watana site to extend the previous studies. Eleven traverses totalling 27,800 feet were run under this program, and the results are presented in Appendix D. The locations of the lines are also shown on Figure 5.1 for Watana and Figure 5.2 for Devil Canyon.

At the Watana dam site, four traverses were shot in the immediate dam site. Two of these lines crossed the right abutment and the relict channel area. A third line is located upstream of the proposed axis on both abutments, and the fourth investigated a topographic depression a mile upstream of the dam axis on the north side of the river. Borrow Areas D and E at Watana were explored by four seismic lines (two within each area).

At Devil Canyon, the three seismic lines were run on the left (south) bank of the river across the small lake and adjacent slopes to investigate the overburden thickness in the proposed saddle dam area and the existence of a possible shear zone.

(c) Laboratory Testing

Representative soil samples obtained from the potential borrow areas for the Watana dam area were tested to determine their physical properties and verify field classification. A total of 21 samples were tested to determine the soil's moisture content, Atterberg limits, grain size distributio and Modified Proctor density. A summary of the testing program is given i Table 5.2. All twenty-one samples were tested using the applicable ASTM o AASHTO standard procedures. The results of the testing program are summarized and the data is presented in Appendix C-2.

TABLE 5.1 - SUMMARY OF DIAMOND DRILLING ACTIVITY - 1980

HOLE NO.	LOCATION	GROUND ELEVATION, FT	LENGTH FT	ORIENTATION	ANGLE FROM HORIZONTAL	PURPOSE
Watana						
BH-2	Right Abutment	1,835	401.0	N45E	55°	Fingerbuster shear zone
BH-6	Right Abutment	1,605	740.4	S45W	60°	Potential fault under river
BH-8	Left Abutment	1,976	750.55	N60E	60°	Powerhouse geology, andesite flows
Devil Canyon						
BH-1	Right Abutment	1,415	750.3	S45W	67°	Powerhouse geology
BH-2	Right Abutment	1,214	656.2	N	60°	Dam foundation
BH-4	Left Abutment	1,353	501.0	S15W	60°	Suspected shear zone

Note: Drill hole locations are shown on Figure 5.1 (Watana) and Figure 5.2 (Devil Canyon)

TABLE 5.2 - SUMMARY OF AUGER DRILLING ACTIVITY-1980

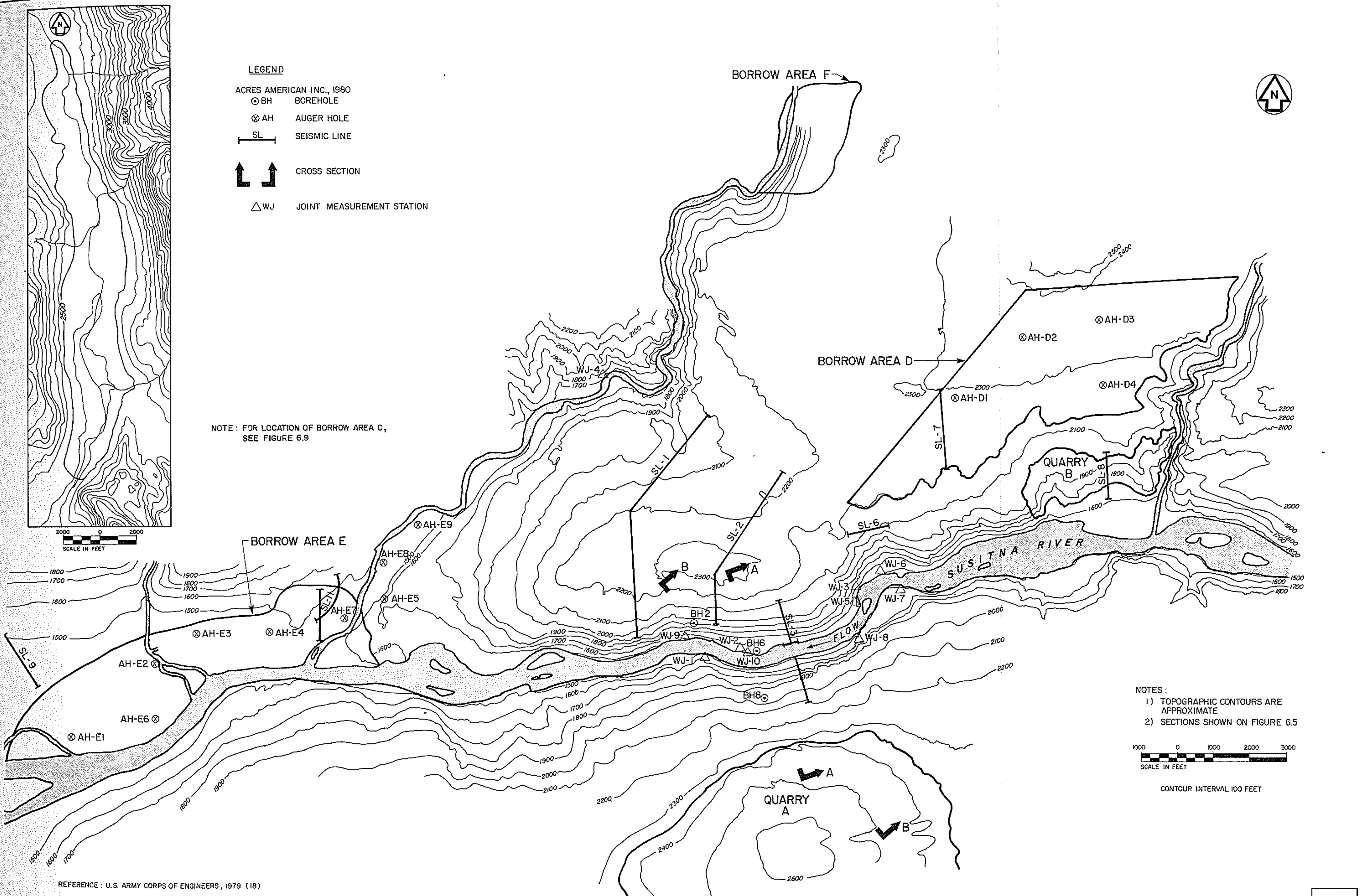
	Borrow Area	Hole No.	Depth Ft.	Purpose
Watana	D	AH-D1	20	Impervious and semi-pervious core material
		AH-D2	29	
		AH-D3	30.5	
		AH-D4	15	
	E	AH-E1	25	Filter and concrete aggregate
		AH-E2	10	
		AH-E3	20	
		AH-E4	20	
		AH-E5	10	
		AH-E6	26.5	
		AH-E7	5.5	
		AH-E8	6	
		AH-E9	8	
Devil Canyon	G	AH-G1	23	Concrete aggregate
		AH-G4	11	

NOTE: Auger hole locations are shown on Figure 5.1 (Watana) and Figure 5.2 (Devil Canyon).

TABLE 5.3 - SUMMARY OF LABORATORY TESTING

TEST (PROCEDURE)	NUMBER OF TESTS				
	Watana Dam Site Borrow Area				
	D	E	H	Deadman Creek	River Channel
Grain Size Distribution (ASTM: D422-63)	8	8	2	2	1
Natural Moisture Content (ASTM: D2216-71)	8	8	2	2	1
Liquid Limit (ASTM: D423-66)	6	--	2	2	--
Plasticity Index (ASTM: D424-59)	6	--	2	2	--
Modified Proctor Density (AASHTO T-180 Method "A")	--	--	--	1	--
(AASHTO T-180 Method "D")	--	--	1	1	--

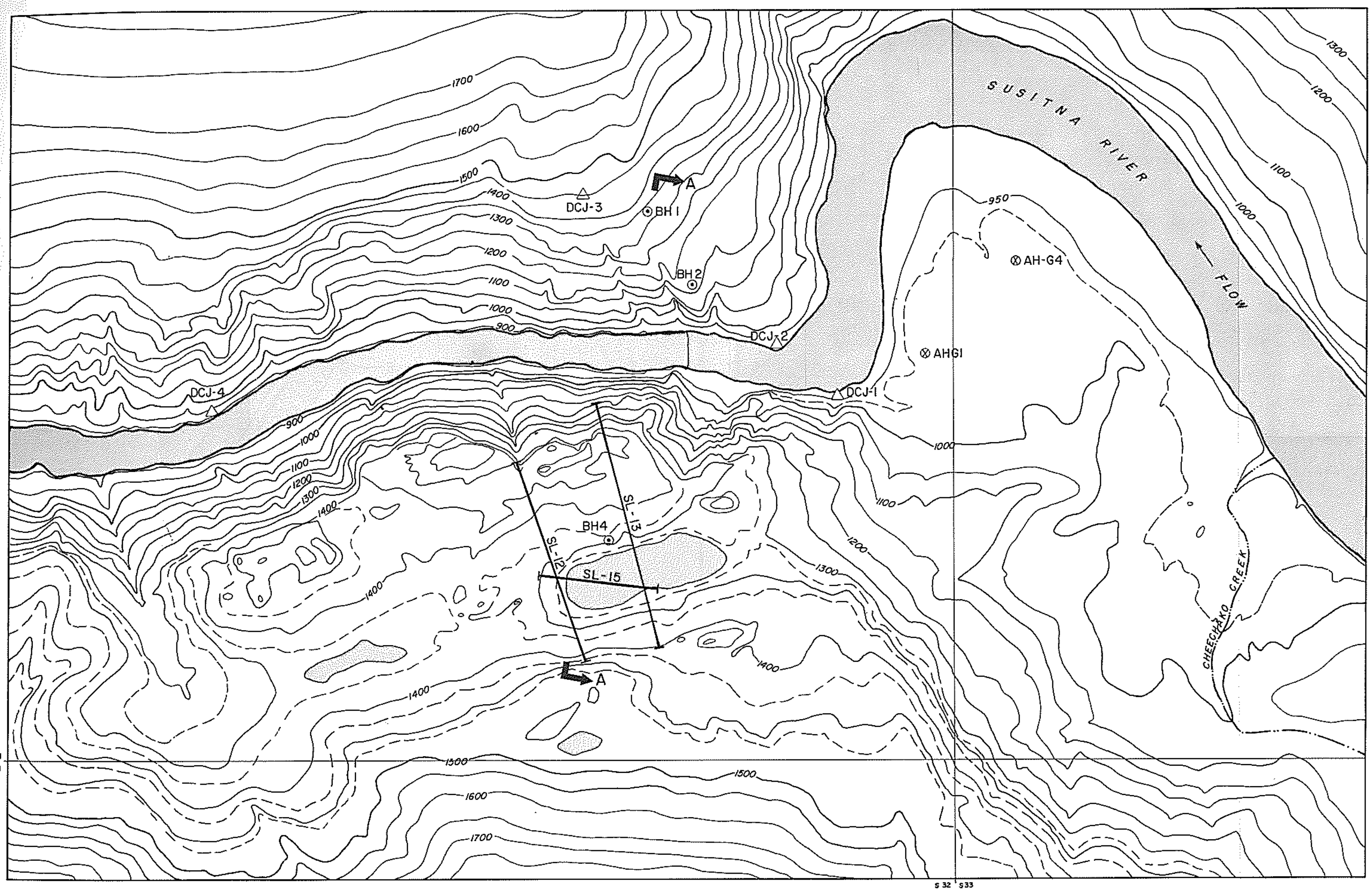
NOTE: Laboratory test results are included in Appendix C-2.



WATANA - 1980 EXPLORATION MAP

FIGURE 5.1

ACRES



REFERENCE: USGS, TALKEETNA MOUNTAINS, (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN: T 32 N, RIE, S 32 AND 33.

LEGEND

ACRES AMERICAN INC., 1980

- BH — BORE HOLE
- AH — AUGER HOLE
- SL — SEISMIC LINES
- DCJ — JOINT MEASUREMENT STATION
- CROSS SECTION

NOTES:

1) TOPOGRAPHIC CONTOURS ARE APPROXIMATE
2) SECTION SHOWN ON FIGURE 6.13

200 0 200 400 600

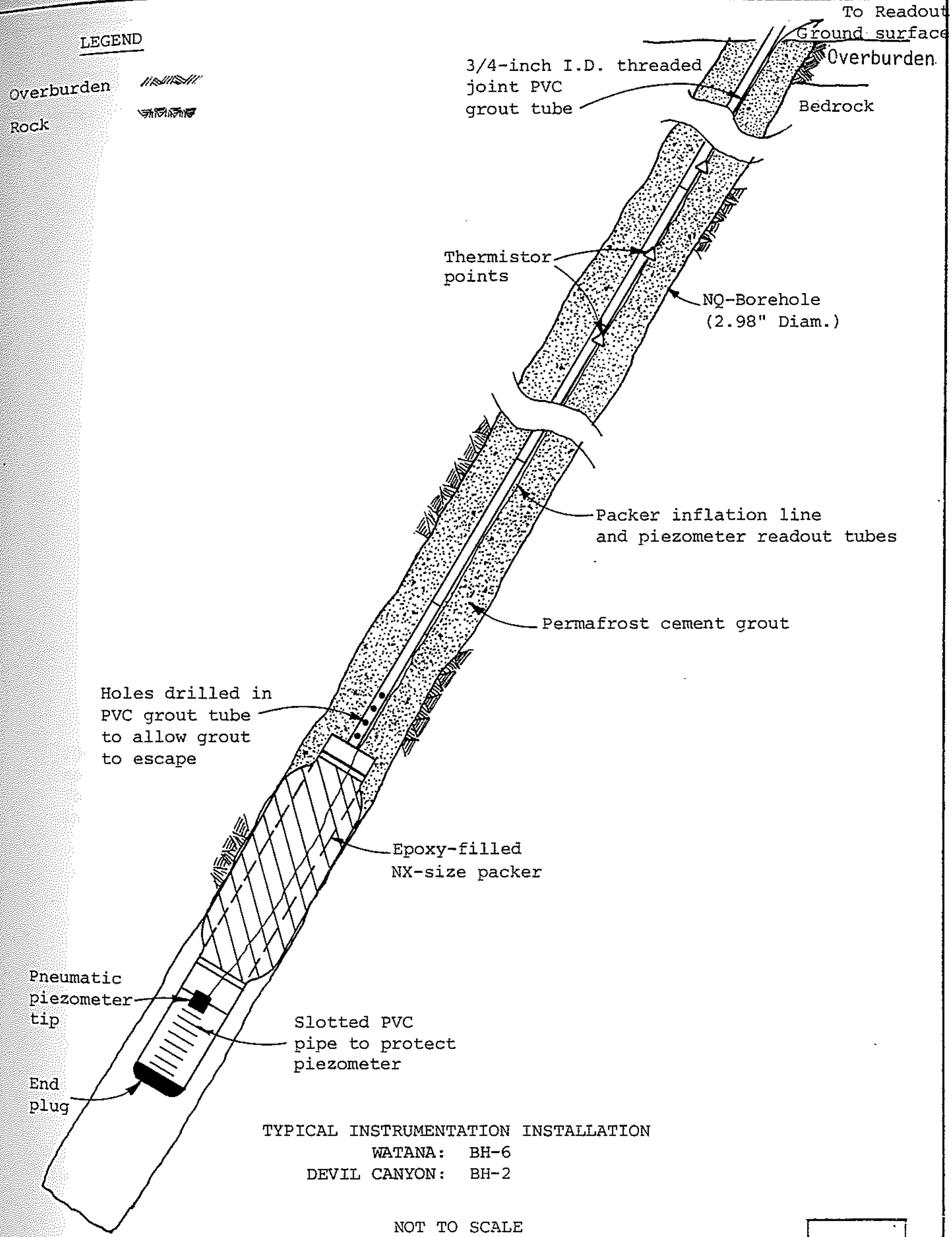
SCALE IN FEET

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

DEVIL CANYON - 1980 EXPLORATION MAP

FIGURE 5.2

ACRES



TYPICAL INSTRUMENTATION INSTALLATION
WATANA: BH-6
DEVIL CANYON: BH-2

NOT TO SCALE

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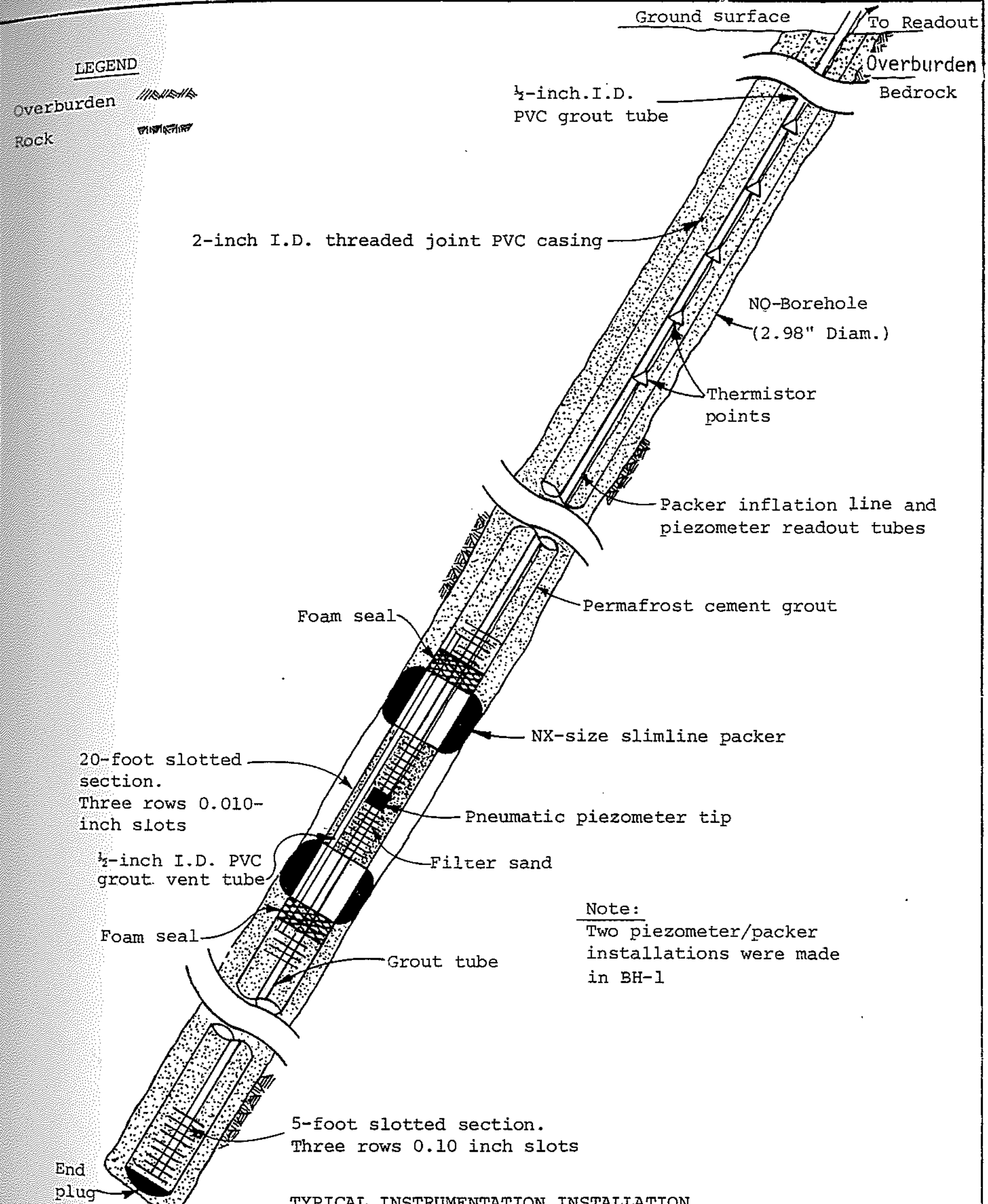
FIGURE 5.3

ACRES



TYPICAL INSTRUMENTATION INSTALLATION
DEVIL CANYON: BH-1 and BH-4

NOT TO SCALE

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FIGURE 5.4

ACRES

SECTION 6

RESULTS OF THE GEOTECHNICAL INVESTIGATIONS

6 - RESULTS OF THE GEOTECHNICAL INVESTIGATIONS

6.1 - Watana

As discussed in Section 3, the Watana dam site had been explored by previous investigators (5, 6, 18, 19). This information was then expanded by the 1980 program using detailed geologic mapping, three diamond drill holes, auger holes and seismic refraction surveys. In addition, air photointerpretation was performed, covering the entire dam site and reservoir area. The location of all explorations are shown on Figure 6.1. Discussion of results of investigations of overburden conditions, bedrock geology, groundwater, permafrost, borrow material and reservoir geology are presented in the following sections.

(a) Overburden Conditions

Overburden thickness in the dam site area ranges from nonexistent along portions of the valley slope, to greater than 450 feet away from the valley walls. The type of overburden varies from weathered rock and talus to glacially derived tills, outwash, and lacustrine clays to organic materials. The type and thickness of overburden in the site area has been delineated by geologic mapping, drilling, excavation of test pits and seismic refraction surveys. A detailed discussion of soil conditions and properties in selected borrow source areas is presented in Section 6.1(e).

An isopach map of overburden thickness is shown in Figure 6.2. In general, the overburden on the valley walls and abutments at the Watana site is thin, varying in thickness from 0 to about 10 feet. On the lower slopes, in the V-shaped portion of the valley, overburden is almost nonexistent, consisting primarily of talus. Above the break in slope on the north side of the river, the overburden thickens and consists primarily of glacial material.

Borings in DH-1 through DH-5 were drilled to bedrock by the COE in the river channel within the dam area, and show alluvium thickness on the order of 40 to 80 feet. The material consists of coarse sands, gravels and boulders. Several boulders more than three feet in diameter were encountered during the investigation. The relative density and distribution of the material is not properly known. It is suspected that these materials may become unstable during a seismic event. Further investigations will be necessary to properly explore these deposits.

Several local areas of thick overburden were encountered on both dam abutments during the various phases of investigation. Seismic line SW-2 (Figure 6.1) shows a thickening of overburden to approximately 100 feet upslope of BH-2. A similar thick pocket of overburden was found on the south abutment at DH-25 (COE, 1978) (Figure 6.1) where a depth of over 55 feet of glacial and alluvial materials were drilled without reaching bedrock.

Away from the valley, the overburden consists principally of glacial silts, sands, gravels and boulders. Where drilled, the contact between the overburden and bedrock is sharp. Seismic velocity of the unconsolidated silts, sands and gravels generally average 6,000 to 7,000 ft/sec whereas the denser tills, boulders, and weathered rock range between 13,000 to 14,00 ft/sec.

A deep bedrock depression has been delineated on the north side of the river extending from about 2,500 feet west of Deadman Creek northwest toward Tsusena Creek. The evidence for this channel is based on seismic refraction studies (14, 18, 20) and several drill holes as shown on Figu 6.1. The lowest bedrock elevation encountered in the channel was 1,775 feet or 454 feet below the surface (DR-22). The overburden in the burie channel consists of three major sequences of till, lacustrine and alluvi (including outwash) materials. At least two sequences of fine grained lacustrine material have been encountered. In DR-13, the COE reported encountering a significant artesian condition. However, the source of th artesian pressure and water pressure relief springs on the cliffs was no addressed. In another boring, DR-22, a 200-foot interval of pervious sa and gravels was encountered at elevation 2,000 (230 feet below ground surface). Discussions with the COE revealed that during a falling head permeability test on the interval composed of these materials, takes as high as 50 gpm/foot of head were recorded. Based on limited information the stratigraphy, it is very difficult to draw conclusions on whether th till, glacial material or outwash deposits are continuous over large are A reasonable assessment of the overall permeability of the channel materials is not possible at this time. Further exploration in this are is necessary.

(b) Bedrock Geology

(i) Lithology

The Watana site is underlain by a series of sedimentary, volcanic a plutonic rocks. These rocks have not been assigned formational nam but rather have been given lithologic names for mapping and correlation.

The dam site is primarily underlain by an intrusive dioritic body which ranges in composition from granodiorite to quartz diorite to diorite (Figure 6.3, sheet 1). The volcanic rocks (dacite and andesite) are generally finer grained equivalents of these intrusiv rocks with a few more silicic varieties (rhyolite). The sedimentar rocks consist of tuffaceous siltstones, sandstones and graywackes.

Igneous Intrusives

The quartz diorite is light gray in color and is found primarily up stream from the dam centerline. Grain size is medium (1-5 mm) but variable within this range. The quartz diorite is composed of 60 t 80 percent plagioclase feldspar with approximately 5 percent quartz Mafic minerals are predominantly biotite with partially chloritized hornblende. The texture is massive, with no planar structures. Th rock is hard, competent and fresh, except within the shear zones (s

Bedrock Structure). There is generally a very thin weathering rind on exposed surfaces. Inclusions of argillite, volcanics and fine grained diorite are found in this unit, particularly east of "The Fins".

The diorite is dark grayish green, medium grained and massive. The rock is 80 to 90 percent plagioclase feldspar with 10 to 20 percent biotite. The diorite is hard, competent and generally fresh with a very thin weathering rind on exposed surfaces. No inclusions have been seen in the diorite. The quartz diorite and diorite appear to occur in alternating zones on the order of several hundred feet wide. One contact is exposed on the river and is gradational over about 20 feet with no fracturing, although at another outcrop, the contact is coincident with a fracture.

Both the diorite and quartz diorite have been intruded by a few felsic and mafic dikes. The felsic dikes are fine grained granodiorite and are less than two feet wide. Both deformed and undeformed dikes were mapped. The contact with the surrounding rock is tight. Neither the dikes or the contacts are fractured; although some dikes have been offset by healed shears (see Bedrock Structure).

A mafic dike was mapped downstream of "The Fins" on the south abutment at river level. The dike is approximately 5 feet wide and consists of fine grained diorite. The dike is highly fractured and lies within a talus-filled gully. The dike trends northwest-southeast, parallel to the major joint set. A large mafic structure (350 to 400 feet wide) dioritic in composition intruded the quartz diorite in "The Fins" area. The texture is porphyritic with a fine grained to aphanitic ground mass. Based on texture, the rock is an andesite porphyry to a diorite porphyry. To simplify terminology, the term diorite porphyry will be used. Phenocrysts consist of plagioclase feldspar and hornblende. Feldspar phenocrysts are medium grained and from 10 percent of the rock at "The Fins" to 20 to 30 percent at outcrops on the south bank. The hornblende phenocrysts are medium grained and comprise about 5 percent of the rock. The rock is generally massive with rare occurrences of compositional layering.

The diorite porphyry becomes less porphyritic and more aphanitic near the contacts with the quartz diorite. Inclusions with this unit consist of rounded quartz diorite and tabular argillite fragments from 1 to 6 inches long. Contacts with the inclusions are sharp and tight. The diorite porphyry is fresh, hard and competent. The contact between the diorite porphyry and the quartz diorite is sheared at "The Fins"; however, on the south bank, both rock types are separated by only a few feet. Since the contact is covered, no evidence of shearing could be seen. It is likely that the contact could be fractured.

Downstream from the diorite/quartz diorite, and approximately 3000 feet downstream from the proposed centerline, is a series of extrusive rocks ranging in composition from rhyolite to andesite and basalt but is predominantly andesite porphyry. Where exposed on the banks of th river, these rocks are complexly faulted. Field relationships indicate that there may be more than one episode of extrusive activity an deformation. At this phase of mapping, no stratigraphic relationship could be determined and so these rocks have all been included as one unit: andesite porphyry.

The andesite porphyry is medium to dark gray to green with an aphanitic ground mass and fine (less than 1 mm) to medium grained feldspar phenocrysts. Inclusions of quartz diorite are found in the andesite porphyry near Quarry A. Near the contact with the diorite, the rock is a monzonite in composition but because of the aphanitic texture is termed a latite. The latite is light to medium grayish green with numerous inclusions of argillite and quartz diorite, the contacts being sharp and tight. The latite is flow banded with layer striking northwest-southeast and dipping 15° west. The contact with the diorite is coincident with the main "Fingerbuster" shear zone. Other variations in this unit include rhyolitic, and basaltic units. The more mafic rocks appear to be prevalent toward the west.

The contact between the andesite flow and the diorite was encountered in BH-2 and BH-8 (Figures 6.4 and 6.5). Similarly the COE borings DH-21 and DH-24 penetrated andesite dikes on the left abutment. The nature of the contact in BH-2 is unclear, in that a secondary shear zone corresponds with this contact, resulting in poor quality rock. The contact in BH-8 was intersected at a depth of approximately 50 feet. The rock in this zone was highly fractured and jointed with clay seams extending over a distance of 10 to 15 feet. Core recovery was on the order of 70 to 80 percent.

A sequence of tuffaceous siltstone and sandstones are exposed in the cliffs approximately 5,000 feet downstream of the dam site and are overlain by the andesitic (basaltic) rocks (Figure 6.3). These sedimentary rocks are composed essentially of volcanic debris, the siltstone being a medium gray, fine grained rock that exhibits some shaly character on weathering, while the sandstone has a buff colored groundmass with inclusions of feldspar, quartz, and argillite. The rock in the area is generally sound and slightly weathered.

(ii) Bedrock Structure

Joints

Joint data was recorded at all outcrops, as well as at 10 joint stations (WJ-1 through WJ-10) which were chosen for detailed joint measurements (Figure 6.3, sheet 2). At both outcrop and joint stations, the orientation of major and minor joint sets were recorded as well as the condition of the joint surface, spacing and any mineralization or coating. At outcrops, three orientations were take of joints from each joint set and an average reading recorded.

Joint stations were chosen at representative areas having good three dimensional exposure of major structures,"The Fins" and "Fingerbuster", Tsusena Creek, and in the major rock types: quartz diorite, diorite and andesite porphyries. At stations WJ-1 through 3, readings were limited to 60 to 86 joints due to limited exposure. One hundred joints were recorded at stations WJ-4 through WJ-10. For each station, joint measurements were plotted on the lower hemisphere of a Schmidt equal-area stereonet and contoured at 3, 5, 7, 10 and 15 percent contour intervals. An example illustrating the methodology is presented on Figure 6.6a. Watana joint stations are shown on Figures 6.6(b-k). A composite stereonet of 766 joints was also compiled and is included as Figure 6.6(1). Two major and four minor joint sets were mapped at the site. Set I and Set II are major joints which occur throughout the site area. Sets III and IV are minor sets which generally are less prominent than the major sets but may locally be quite pronounced, while Sets V and VI do not show prominently over any extent. Table 6.1 is a summary of joint set orientations, spacing, surface condition and structural relations at Watana.

Joint Set I is the most prominent set at Watana. The orientation is about 320° (N40°W) throughout most of the site with dips from 65° northeast to 70° southwest and averaging near vertical. Joint surfaces are planar to slightly curved and mostly smooth, with spacing from one to two feet. Open joint surfaces in the andesite prophyry in "The Fins" are pitted and rough where feldspar and hornblende phenocysts have been weathered out. Minor carbonate coating was observed on this set only at WJ-6 and WJ-10. The joints are generally closed, except in shear and fracture zones. Set I joints are parallel to the major shear and fracture zones in the dam site area. Set I joints show a consistent trend throughout the dam site from WJ-2 upstream to "The Fins". Downstream from WJ-2, the trend changes to 335° (N25°W).

Joint Set II generally trends 45° (N45°E) and dips between 70° northwest and 70° southeast. Spacing averages 6 inches to 1 foot. Surfaces are smooth and planar to slightly curved. Minor carbonate coating is found on this set at "The Fins" and at WJ-10. The river runs parallel to this set between WJ-8 and WJ-5. No shearing has been found associated with Set II.

Joint Set III is north-south trending with moderate dips to the east and west. This set is generally present throughout the site but is not as prominent as Sets I and II. Spacing is quite variable and can range from 2 inches to 5 feet where present. Joint surfaces are planar to slightly curved and smooth to rough. No mineralization is associated with this set. Set III is parallel to the north-south trending shears found at "The Fins", Fingerbuster, WJ-10, WJ-8, and WJ-7. West dipping Set III joints predominate where the north-south shears are west dipping as at WJ-2, 6, 7, 8 and 10 on the eastern and central areas of the site. East dipping Set III joints predominate where the north-south shears are east dipping as at WJ-1 and 9 on the western area of the site.

Joint Set IV consists of numerous low angle (dipping less than 40°) joints of various orientations. Spacing is highly variable ranging from 1 inch to 10 feet with an average of 1 foot. Joint surfaces a irregular and rough with no mineralization or shearing associated w them. The joint dip directions appear related to slope dip directi with joints on the north abutment dipping south and those on the so abutment dipping north. Set IV joints are possibly stress relief joints resulting from glacial unloading. Joint Sets V and VI appea to be only locally prominent.

Joint Set V is oriented nearly east-west at 280° (N80°W). Set V is most prominent at the western end of the dam site in the "Finger-buster" area (WJ-9) and at WJ-1, 2 and 10 where "east-west" shear zones are more prevalent. Between the "Fingerbuster" and WJ-2, the river is parallel to Set V.

Joint Set VI has an average trend of about 65° (N65°E) with dips be-tween 60° northwest and 60° southeast. No shears were observed par-allel to this set. Between WJ-8 and WJ-10, the river is parallel t Set VI.

Shears and Fractures

Major and minor shears and fractures were mapped at river elevation the dam site area (Figure 6.3, sheet 2). Fractures were defined as areas of very close to close spaced (less than 2 inches to 1 foot) joints where no relative movement has occurred. Fractures range fr 6 inches to 50 feet in width but are generally less than 3 feet. O the basis of mapping completed to date, it appears that several per-iods of jointing occurred at the site, with most being formed prior the major shearing and some concurrent with or after the shearing.

Two forms of shears were mapped. The first are healed shears found the quartz diorite and diorite. These range from less than 1 inch about 1.5 feet and contain breccia which has been healed by fine grained, igneous material. Offsets measured on these features when they cross felsic dikes are up to 1 foot. The healed rock is hard competent. These minor features have two basic orientations - 35° (N35°E) dipping 45 to 70° east, and 300° (N60°W) dipping 65° south.

The second type of shear, which is more common, is found in all the rock units and consists of planar areas of crushed rock (sand-size grains) and gouge which is severely weathered. These areas are gen-erally less than 6 inches wide, but can be more than 20 feet at the major shears. The crushed rock and gouge is generally but not alwa within a zone of fractured rock from 1 to 2 feet wide. The amount offset on these shears could generally not be determined because of lack of good markers.

Major shears and fractures are oriented on a northwest trend with steep dips from 70° northeast to 80° southwest. These features ten to form deep gullies on the abutments as a result of erosion of the sheared and fractured rock. Minor shears and fractures are oriente north-south with moderate dips to the east and west, and east-west dipping steeply north and south. These orientations are parallel t major joint Sets I and II and minor Set III.

Two major shear zones which were identified in previous studies and were verified by this investigation are located upstream and downstream of the proposed dam. The upstream zone, called "The Fins" by the COE, is exposed on the north abutment approximately 3,000 feet upstream of the proposed dam axis. The feature occurs in the area of the quartz diorite and andesite porphyry contacts. "The Fins" consists of a series of shears and fractures in an 800 foot wide area. The gullies formed by the shears and fractures are separated by narrow intact rock bands or ribs, from 5 to 50 feet wide. The two primary shears are northwest trending and dip 70° east. The shear at the andesite porphyry/quartz diorite contact consists of 10 feet of crushed rock and gouge. The other shear is partially covered by talus, but appears to be a maximum of 50 to 60 feet wide, estimated by the width of the gully. It is likely that this area consists of several smaller shears rather than one shear of this width. Quartz and carbonate veins (0.5 inches) in this zone crosscut the shear without offset. Upstream from the contact shear is a series of four northwest trending shears in an 80 foot wide zone of open jointing.

East-west and north-south trending shears also occur in "The Fins". The dip and width of the east-west shears are uncertain. The north-south shears are less than 1 foot wide and dip 57° to the west. Slickensides on carbonate coating indicate an oblique sense of movement. The north-south shears appear to project across the river in the vicinity of the upstream cofferdam and align with gullies on the south abutment. Another series of north-south striking shears also occur across the river from "The Fins". The COE has inferred a continuation of "The Fins" shear zone to the southeast. This area will be investigated during the 1981 summer program. The trace of the zone to the northwest may correlate with a highly oxidized and sheared granodiorite outcrop on Tsusena Creek. This outcrop, approximately 325 feet wide, which has undergone hydrothermal alteration, is also characterized by northwest, north-south and eastwest trending shears with associated crushed rock and gouge. Other evidence which supports a northwest continuation of "The Fins" is seen in the seismic refraction surveys on the north bank, which show a lower bedrock velocity associated with the trace of this feature (14, 18, 20). The trace of the feature also closely coincides with a morphologic depression.

The second major shear zone at the site, called the "Fingerbuster" by the COE, is located 1,500 feet downstream of the proposed dam axis on the north bank (Figure 6.3). BH-2, which intersected this feature, drilled through approximately 100 feet of highly fractured, sheared rock which contains clay seams and gouge. The major shear at the "Fingerbuster" is coincident with the andesite porphyry/diorite contact. The shear trends northwest with a vertical dip. This feature is intersected by a vertical north-south shear. Both lie within a rubble filled gully approximately 40 feet wide and diverge further upslope. Rock within this zone is highly fractured and moderately weathered with several 3 inch shears consisting of silty sand material. Slicks on the north-south shear indicate a vertical movement. The extent of these shears will be determined during the 1981 summer program. Minor shears in the "Fingerbuster" trend northwest, east-west and north-south. The east-west trending shears dip from 80° south to 80° north, parallel to the stretch of the river between the "Fingerbuster" and the dam centerline.

The minor shear zones are found between "The Fins" and the "Finger buster". Near the proposed dam centerline are a series of steeply dipping northwest trending fracture zones and north-south shears w dips of 40° to 85° to the east. The shears average 1 to 2 feet wi Movement of the 40° dip shear was estimated to be about 1 foot bas on joints offset across the shear. Upstream on the south abutment another zone of predominatly northwest trending shears and fractur The extent of both this feature and the one at centerline will be traced during the 1981 summer program.

(iii) Rock Quality

The Rock Quality Designation (RQD) was determined for all rock cor and is graphically shown on the Summary Logs in Appendix B-1. The rock quality encountered in the drilling was generally good to excellent with RQD's averaging between 75 and 90 percent (see Table 6.2). In general, rock quality improves with depth, with the uppe to 80 feet of the surface being weathered and more fractured. Bel this weathered zone, rock quality tends to improve with only local zones of fractured and sheared rock. These zones generally range thickness from 1 to 5 feet, but can be up to 30 feet.

The poorest quality rock was found in BH-2 which drilled through p of the "Fingerbuster" shear zone. This boring was sited within th zone and directed N45°E at an inclination of 55°. As seen in the ing logs, the shear zone was intersected at an approximate depth o feet and continued to an approximate hole length of 100 feet (vert depth 65 to 80 feet). The zone, which corresponds with the andesi diorite contact, consists of highly fractured, severely weathered brecciated and sheared rock. Repeated grouting was required to ma tain hole stability. Below this zone, rock quality improved with localized zones of low RQD's encountered around 200 to 210 and 250 feet depths, respectively.

In general, weathering appears to be primarily physical in nature, with sand rock being affected to about 40 feet from the surface at dam site. The weathering is light to moderate in joints, with pen tration generally less than a few inches into the unbroken rock. Sheared and fractured zones are considerably more weathered, and m of the shear zones exhibit chemical weathering and hydrothermal al ation. However, the severest effects of chemical alteration appar ly are limited to the immediate shear zones, so the overall rock m quality is quite good, and appears to be entirely adequate for con struction of large hydropower structures utilizing conventional construction methods.

(iv) Rock Permeability

Water pressure tests were performed in all of the borings, however testing was performed below 650 feet in BH-6 or below 70 feet in B due to unstable hole conditions. Graphic representation of the ca lated permeabilities are shown on the Summary Logs (Appendix B-1). Overall, rock permeability is relatively low, ranging from 10^{-4} to 10^{-6} cm/sec. Water losses were somewhat higher in the shallower portion of the holes, and a few shear zones, such as those encountered in BH-2, took high quantities of water without return. However, these zones tended to cave, and therefore could not be accurately tested.

(c) Groundwater

The groundwater regime in the bedrock is confined to movement along fractures and joints within the rock. Water levels, as measured during the drilling program, ranged from 16 feet below ground surface in hole BH-8 to 147 feet in BH-6. Although very little data is currently available relative to the groundwater, it is assumed that the groundwater in the non-permafrost areas of the north bank is a subdued replica of the topography with groundwater gradients being towards the Susitna River and its tributaries. Readings of the installed piezometers will be continued in 1981 to better evaluate the ground water regime.

(d) Permafrost

A limited amount of data is currently available regarding permafrost condition at the Watana site.

Ten thermal probes, consisting of 3/4 inch galvanized steel pipes filled with diesel fuel, were installed by the COE (18) in boreholes on both sides of the river to monitor ground temperatures. Readings over a 5 month period using thermistors in several of these pipes showed permafrost conditions on the south bank. All but hole DH-21, which was drilled beneath the river, gave temperatures below freezing to the bottom of the hole. The deepest hole was DH-28, drilled to a depth of 125 feet. Minimum temperatures ranged around -0.6°C.

During the early phases of the 1980 program, an attempt was made to read these instruments, and the results are summarized in Figures 6.7 and 6.8. Most of the probes on the south bank were blocked with ice or showed sub-zero temperatures at depths of 15 to 30 feet below ground surface; and it is therefore evident that permafrost exists in the south bank at relatively shallow depths. Because of the ice blockage, and the shallow depth of installation of the probes, it was not possible to determine the depth of the bottom of the permafrost. Temperatures within this shallow zone ranged from -0.01 to -0.52°C. No evidence of permafrost was observed from probes on the north bank. However, it was determined that ground temperatures are within 0.5°C of the freezing point to considerable depths.

Auger drilling in Borrow Area D by both the COE and Acres indicates that discontinuous permafrost exists throughout the area. Visible ice was identified in several of the soil samples to depths of 10 feet or more. On the south abutment BH-8 (Acres, 1980), which had remained open from July, was observed to "freeze back". It was first noted in September during the geophysical logging that the hole was "necked down" at about 175 feet and the temperature at that depth was less than 0°C. The hole was next checked in November and found to be completely frozen. In preparation for installation of the 1980 instrumentation, warm water was pumped down the hole to thaw the ice. At the start of the melting operation, ice was encountered at a depth of 50 feet. Melting proceeded to a depth of 170 feet where the hole was blocked by caving.

A thermistor string was installed in BH-6 on the north bank to a depth of 250 feet. However, temperatures have not yet stabilized in the hole. It is to be noted that this hole remained open and unfrozen from the time of its completion in July until instrumentation was installed in November. Therefore, the hole does not appear to penetrate a permafrost zone.

(e) Borrow Areas

The 1980 investigation program was planned to confirm the material sources previously identified by the COE and to provide additional information as to their geotechnical properties, thickness and areal extent. Primary emphasis was placed on defining the core and filter material sources and verifying the quantities of rock fill previously identified near the dam site. Explorations included geologic mapping, auger drilling, seismic refraction surveys, and laboratory testing. The location map for all the explorations is shown in Figure 6.1. The boring logs are included in Appendix C-1, the laboratory test program in Appendix C-2, and the seismic refraction study in Appendix D.

(i) Rockfill Material

Two quarries previously designated Quarry A and Quarry B by the COE (Figures 6.1 and 6.9) were investigated. Additional surficial mapping was performed in Quarry A on the south bank and indicated the exposed rock is primarily andesite overlying diorite. This differs from the interpretation of the earlier exploration. Additional diamond core drilling and detailed mapping will be required to confirm the thickness and extent of the various rock units. Quarry B was investigated by additional surficial mapping and a seismic line across the central section of the area (Figure 6.1). The data collected indicates that overburden in this area may reach as much as 300 feet thick which would preclude exploitation of the exposed rock face as a quarry.

(ii) Core Material - Borrow Area D

This borrow area was identified by the earlier investigations as a primary source of impervious and semi-pervious material for the dam construction. The area is located 1.5 miles upstream of the dam axis on the north bank (Figures 6.1 and 6.9). Four additional auger holes and two additional seismic lines performed during the 1980 program generally confirm the earlier findings.

Overburden throughout the area is very thick, ranging from 150 to as much as 350 feet thick (14, 20). The material in this area is composed of a surface layer of natural organic ground cover, then two to three feet of boulders and organic silts underlain by glacial tills composed of dense gravelly silty sands. The tills range from 15 to 25 feet thick and usually overlie a clay to sandy gravelly clay.

Grain size distribution curves of the till samples tested in this investigation (Appendix C-2) and the COE program (18) show that the material is well graded, consisting primarily of silty sand with some gravel and a trace of clay. The material is generally dense to very dense in-situ, and has a natural moisture content ranging from 6.6 to 25.7 percent with an average of 11 percent. Moisture content was found to be variable between samples from the same hole, as well as from hole to hole. The finer fraction of the material is generally non-plastic to very low plasticity (PI ranges 2 to 12). The shape of the compaction curves indicates that moisture content will be critical in obtaining maximum density and strength during construction, and that the shear strength of the material drops off rapidly with increases of water content over the optimum water content.

(iii) Filter Material - Borrow Area E

This borrow area was identified as the main source of filter and concrete aggregate material by the COE (18). Borrow Area E is an alluvial deposit formed at the mouth of Tsusena Creek on the right bank of the Susitna River, approximately four miles downstream of the dam site (Figures 6.1 and 6.9). Nine auger holes ranging from 5 to 31 feet deep were drilled in this area to expand the previous work (Appendix C-1). As well, additional seismic refraction lines (18) were run to confirm the thickness of the alluvial material and the limits of the proposed Borrow area.

The auger drilling indicated a thin organic and silt layer varying from 0.5 to 2.0 feet thick over most of the area. This layer is underlain by 0.5 to 3.0 feet of silty sand to clean sand, below which is a 6 foot thick layer of sandy gravel. The sandy and gravelly materials are well rounded particles up to 4 inches in diameter and are clean and well graded. The size of the particles appears to increase below 10 feet, with variable cobble and boulder content that hindered the drilling. The water table in this area is near the base of the sandy gravel layer from 7 to 16.5 feet below the ground surface.

Two holes (AH-E8 and AH-E9) were drilled on a sand bar further upstream on Tsusena Creek (Figure 6.1) in an attempt to expand the limits of Borrow Area E and confirm the availability of additional quantities of material. Both holes were terminated at less than 10 feet deep due to a high concentration of boulders. However, the overburden profiles compare favorably with the work from the main section of the borrow area. The 1980 seismic line (SL-9) in the northwest portion of the area confirms that the alluvial materials vary in thickness from 30 feet to as much as 200 feet locally, with an average thickness of 30 to 50 feet.

Grain size distribution curves (Appendix C-2) of the split spoon samples show that the upper few feet of material consists of sandy silt grading downwards to silty sand. This layer is generally poorly graded and relatively fine grained with 30 to 60 percent passing the No. 200 sieve.

The underlying material is classified as sandy gravel to gravelly s
with traces of silt. The grain size distributions for this layer s
very good correlation with the results obtained by the COE for Borr
Area E. Natural moisture content for the sandy silt layer ranges f
15.7 to 27.3 percent. The gravelly sand layer by comparison has natural moisture contents ranging from 4.4 to 9.8 percent (all samp
were taken from above the water table).

All the new data is consistent with the earlier data gathered by th
COE. Based on the additional holes and seismic lines the borrow ar
could be expanded upstream along Tsusena Creek, with adequate quant
ties apparently being readily available. Further testing will be performed in 1981 to confirm the material properties for use as concrete aggregate.

(iv) Other Potential Material Sources

During the course of the current and previous investigations within
the dam site area, several potential sources of materials, other th
those discussed above, were identified (Figure 6.9). However, cons
erable additional investigation will be required to evaluate the ty
suitability and quantities of materials available from these areas.
The various source areas are discussed below in terms of the types
materials which might be obtained from them.

- Sources of Rockfill Material

  Considerable rock excavation will be required during construction for the dam foundation, diversion facilities, underground powerhouse, penstocks and spillway. Depending on the quality of the material and the construction schedule, some of it may be useful
  fill.

- Sources of Core Material

  Based on reconnaissance mapping and exploration, three areas were identified as potential sources of core material. Several bag samples were collected to aid in the preliminary definition of th
  materials available in each area.

  The first area, designated Borrow Area H, is located southwest of Fog Lakes (Figure 6.9) and is approximately five to seven miles f
  the dam site. The topography of this area is generally flat to gently rolling. Most of the surface is covered by shallow swamps and marshes indicating poor drainage and relatively impervious underlying materials. Slump exposures along Fog Creek and the Susitna River indicate the area is underlain by a relatively thic
  layer of silt, sand and gravel with some cobbles and a trace of clay. A large ice wedge was observed in a slump exposure on the west end of the site, indicating that the till is frozen locally.
  Grab samples were taken, and gradation curves are presented. (Appendix C-2).

The second area is located to the east of Borrow Area D on Deadman Creek, one to two miles upstream from the confluence with the Susitna River and approximately three miles from the dam site. Based on cliff and slump exposures along Deadman Creek and the morphology of the site, three types of materials were identified in this area. These materials are glacial outwash, ablation till and lodgement till. The outwash consists of a relatively clean, medium to coarse grained sand with some gravel, cobbles and boulders. The ablation till is composed primarily of silt and sand with minor amounts of gravel, cobbles and clay, while the lodgement till is a sandy, clayey silt with some gravel and cobbles, generally very compact.

The topography of this area is generally flat to gently rolling with several old channels superimposed on the surface. These old channels are indicative of fluvial processes and it is therefore assumed that much of this site is blanketed with a layer of outwash material of variable thickness overlying a series of tills.

The third area is located on the west edge of Borrow Area D. A review of the previous data suggests that the percentage of tills and clay-rich material increases to the west. Further investigation would be required to verify this, should additional fine grained material sources be required.

- <u>Sources of Filter Material</u>

In the upper reaches of Tsusena Creek, the COE delineated two areas designated Borrow Area C and Borrow Area F (Figure 6.9) which may be suitable sources of filter material. To date only a limited amount of investigation, consisting of test pits in area F and three seismic lines in area C, has been performed (Figure 6.1). Additional investigations and testing will be required to verify the type and quantities of materials in each area.

Based on surficial mapping and general reconnaissance in the vicinity of the dam site, it would appear that the area surrounding the confluence of Clark Creek and Tsusena Creek, approximately five to six miles north of the dam site (Figure 6.8), may provide a potential source of filter material. This area appears to be composed primarily of alluvial materials and reworked glacial outwash.

One sample of material was also collected from a gravel bar exposed in the river channel slightly upstream of the dam. The grain size distribution curve shows that this sample is a gravel in a sand matrix with a few cobbles and few fines. Logs of DH-1 through DH-5 indicate similar material at depth. Further investigation of this material for filter, transition, aggregate or shell material is warranted, and will be conducted as part of the 1981 investigation.

(f) Reservoir Geology

Preliminary reconnaissance mapping of the Watana Reservoir was performed for the 1980 field program. Principal rock types and general types of sur ficial material were identified.

The topography of the Watana Reservoir and adjacent slopes is characterize by a narrow V-shaped stream-cut valley superimposed on a broad U-shaped glacial valley. Surficial deposits mask much of the bedrock in the area, especially in the lower and uppermost reaches of the reservoir. A surficial geology map of the reservoir, prepared by the COE, distinguishes till lacustrine and alluvial deposits, as well as general rock types (18).

(i) Surficial Deposits

Generally, the lower section of the Watana Reservoir and adjacent slopes are predominantly covered by a veneer of glacial till with scattered outwash deposits. Two main types of till have been identified in the area; ablation and basal tills. The basal till is overconsolidated, has a fine grained matrix (more silt and clay) and has low permeability. The ablation till has less fines and a somewhat higher permeability. Outwash deposits consist of cobbles, gravels, and sands that exhibit a crude stratification and are free draining.

On the south side of the Susitna River, the Fog Lake area is characteristic of a fluted ground moraine surface. Upstream in the Watana Creek area, glaciolacustrine material forms a broad, flat plain whic mantles the underlying glacial till and the semi-consolidated Tertiar sediments. This material consists predominantly of stratified, poor graded, fine grained sands and silts with lesser amounts of clay. Significant alluvial deposits exist in the river valley and consist reworked outwash and alluvium. Glaciation of the area was accompanie by the filling in of the Susitna River valley. Subsequent modification by alluvial processes during deglaciation resulted in the formation of floodplain terraces. Ice disintegration features such as kames and eskers have been observed in the river valley.

Permafrost exists in the area, as evidenced by active ice wedges, polygons, stone nets and slumping of the glacial till overlying perma frost. Numerous slumps have been identified in the Watana Reservoir area, especially in sediments comprised of basal till, and in some instances the Tertiary sediments. The majority of the slumps occur frozen glacial tills in the Watana Creek area and on an unnamed cree between Deadman and Watana Creek. In addition, numerous areas of frozen alluvium and interstitial ice crystals have been observed in outcrops and drill hole drive samples.

(ii) Bedrock Geology

As previously discussed, the Watana dam site is underlain by a diori pluton. Approximately three miles upstream of the Watana dam site, non-conformable contact between argillite and the dioritic pluton crosses the Susitna River. An approximate location of this contact has also been delineated on Fog Creek, 4 miles to the south of the dam site. Just downstream of the confluence of Watana Creek and the Susitna River, the bedrock consists of semi-consolidated, Tertiary, sedimentary rocks (15) and volcanics of Triassic age (Figure 4.1). These Triassic volcanics consist of metabasalt flows with minor thin interbeds of metachert, argillite, metavolcaniclastic rocks and marble (5). From just upstream of Watana Creek to Jay Creek, the rock unit consists of a metavolcanogenic sequence dominantly composed of metamorphosed flows and tuffs of basaltic to andesitic composition. From Jay Creek to just downstream of the Oshetna River, the reservoir is underlain by a metamorphic terrain of amphibolite and minor amounts of greenchist and foliated diorite. To the east of the Oshetna River, glacial deposits predominate.

The main structural feature of the Watana Reservoir is a thrust which trends northeast-southwest and is known as the Talkeetna Thrust (4). This thrust fault crosses the Susitna River approximately eight miles upstream of the Watana dam site. The dip of this fault is uncertain as Csejtey and others (4) have interpreted it to have a southeast dip, while Turner and Smith (16, 17) suggest a northwest dip. To date, no evidence has been found for recent displacement along this fault. At the southwest end of the fault, unfaulted Tertiary volcanics overlie the fault (4). Evidence of possible faulting has been observed in the sedimentary and volcanic rock of Jurassic age, north of Watana Creek (4, 17). Investigations of the Tertiary sediments in Watana Creek by members of the University of Alaska Geology Department did not, however, uncover any direct evidence of faulting.

Additional work on the reservoir geology is planned for the 1981 program.

6.2 - Devil Canyon

This section discusses the geology and geotechnical conditions of the Devil Canyon site as investigated during the 1980 program and by earlier investigators.

(a) Overburden Conditions

Devil Canyon has steep walls which are generally covered by a thin vene of overburden. The overburden varies from a few inches to several feet thickness. The overburden consists primarily of talus on or at the bas the steep to vertical valley walls. On the flat upland areas above 1,3 feet, the slopes are covered by glacial till that varies from 5 to 35 f thick. An overburden isopach map constructed from seismic survey and boring data is shown on Figure 6.11. On the left bank of the river (south), there is a topographic depression paralleling the elongated la in this region. The overburden in this area reaches a depth of more th 85 feet and consists principally of glacial material. A terrace or poi bar deposit is located approximately 900 feet upstream of the proposed axis at the confluence of the Susitna River and Cheechako Creek. The thickness of alluvial material approaches 350 feet (Figure 6.11). Over burden along this point bar thickens rapidly from 100 feet to more than feet over a distance of less than 400 feet. This steep dropoff in bedr was identified in previous studies and requires further investigation.

(b) Bedrock Geology

(i) Lithology

The bedrock at Devil Canyon is well exposed along the canyon walls in scattered outcrops throughout the area (Figure 6.12). Bedrock sists primarily of a Cretaceous argillite interbedded with graywac (Figure 4.1) which has been metamorphosed and intruded by felsic a mafic dikes. The argillite is medium to dark gray, hard and sligh weathered. The major constituents are quartz and biotite with min pyrite and organic material (19). The argillite is very thinly be with grain size generally very fine but ranging up to medium grain depending on the proportion of sand-size particles. Where present sand grains are aligned parallel to the foliation.

The texture varies from massive and non-foliated to a well develop foliation. Where present, the foliation ranges from slaty to phyllitic and rarely schistose. The texture appears to be depende on the relation of bedding to fold axes (see Bedrock Structure).

Interbedded with the argillite are thin beds of light gray graywac This is characteristic of turbidity deposits which is the inferred origin of this unit (5). This rock consists of fine and medium sa grains which are generally graded within the beds. The major const tuents of the graywacke are feldspar, quartz and biotite with mino iron oxides, pyrite and organic material (19). The contacts betwe the argillite and graywacke beds are sharp and tight.

Approximately 3,500 feet southeast of the dam site, the argillite unit is in contact with granodiorite/quartz diorite (Figure 4.1). The rock is medium grained and consists of quartz, plagioclase feldspar and biotite. The contact between the granodiorite/diorite and the argillite is irregular with the granodiorite/diorite intruding the argillite. The extent of the intrusion beneath the site has not been determined, although diorite was encountered in BH-2 (Figure 6.13).

Dikes and veins have intruded all rocks in the site area. The argillite contains numerous folded and faulted quartz veins and has been intruded by both felsic and mafic dikes. The granodiorite/ diorite appears to have been intruded only by mafic dikes. The felsic dikes are light yellowish-gray to gray and consist of aplite, rhyolite and other unidentified silicic varieties. The textures vary from aphanitic to fine grained. Mafic dikes are fine grained, dark gray, and appear to be diorite to basalt (diabase) in composition.

Dikes range from less than 1 inch to 60 feet wide, but are generally about 20 feet wide. Dikes strike from northwest to north with steep to vertical dips. They generally form gullies, and occasionally ridges where exposed in the canyon walls. There appears to be no correlation between lithology and morphologic expression. Dikes which form gullies tend to be very close to closely fractured. Some are sheared at the contact with the surrounding rock. Numerous dikes have been mapped in Devil Canyon. Steep slopes in the immediate area have limited mapping; however, it appears likely that dikes will also be found there. This area will be further investigated in 1981 using technical climbers to map the slopes.

(ii) Bedrock Structure

The argillite at Devil Canyon has been subjected to more than one period of tectonic deformation as evidenced by refolded folds and the development of multiple foliations. Foliation is coincident with bedding planes. Where two or more foliations are nearly parallel, the resulting combined foliation can be quite pronounced with a slaty to phyllitic appearance as seen in the dam site area. Where two foliations are oblique to each other, neither foliation predominates and the rock appears massive.

The strike of the bedding plane foliation which varies from 035° to 090° (N35°E to East) is subparallel to the river and dips from 45° to 80° SE (Figure 6.11). Slopes on the north bank tend to be parallel with the bedding, dipping at about 60° and are steeper than those on the south bank (45°).

As at the Watana site, joint measurements were taken at all outcrops, as well as at four joint stations (Figure 6.12). Stations DCJ-1 and 2 were taken at river level on the south and north banks at the dam site, respectively. Station DCJ-3 is also on the river approximately 3,000 feet downstream. DCJ-4 is on the north bank about 750 feet from the river. All stations are in argillite. For each station, joint measurements were plotted on the lower hemisphere of a Schmidt equa area stereonet and contoured at 3, 5, 7, 10 and 15 percent contour intervals. Stereonets for each station are shown on Figures 6.14(a-d).

One major and three minor joint sets were mapped at Devil Canyon. These sets appear to be similar to those mapped by WPRS (19). Tabl 6.3 summarizes the joint characteristics. The major joint set, Set strikes approximately northwest with an average dip of 85°NE. It i prominent at all outcrops and joint stations. This set is planar w a smooth to rough surface. On the left bank, on the upper canyon walls, Set I joints are open as much as 6 inches; however, the vertical extent of the openness is unknown.

Joint Set II strikes approximately northeast and dips 75° to 85° NW The spacing ranges from 3 to 15 feet. Like Set I, Set II also has open joints on the south bank (Figure 6.12). These joints dip towa the river and may be potential planes for slope failure.

Joint Set III is bedding plane foliation or cleavage. The joint surface condition is variable from plane and smooth to irregular an rough.

Joint Set IV is a combination of several low angle joint sets. The vary in orientation from northeast, east and northwest with dips le than 30° to the northwest, south and northeast respectively. Surfa condition ranges from plane and smooth to irregular and rough.

Joint spacing in the borings ranges from less than one foot to 10 f with spacing and tightness increasing with depth. Iron staining is common along the joint surfaces and numerous calcite "healed" joint were also encountered.

Several fracture and shear zones have been mapped along the canyon walls and in the drill holes (Figure 6.12 and Appendix B-2). In general, these zones are characterized by highly fractured and crus rock, moderate to high weathering depending on location, clay gouge higher permeability and core loss during drilling. With depth, the zones become considerably narrower, tighter and more widely spaced. The trend of these zones are approximately northwest and northeast, parallel to joint Sets I and II. The 1981 program will delineate these zones in more detail. These zones are marked by highly fractured and sheared rock with clay gouge. Of the three holes drilled the poorest quality rock was encountered in BH-4 (Table 6.4), which was drilled beneath the lake on the south bank. Although the quali of the rock in this hole was not as high as the other holes, no evidence could be found in the boring from any major shearing, althoug minor shear was encountered from 293 to 296 feet. Additional drill will, however, be required in this area.

(iii) Rock Quality

The overall nature of the rock is that of a very hard, brittle rock mass, resembling that of higher-grade metamorphic rocks. The joint and fracturing appears to be controlled more by the direction of regional stress and foliation than by the bedding structure. As at Watana, the weathering penetration is limited to the percolation paths afforded by open joints and fracture zones. A more complete evaluation of weathering mechanisms and extent of chemical and hydrothermal attention will be attempted in the 1981 program. Indications to date are that the rock is suitable for construction of large structures, although some deteriorated zones will require significant remedial work.

(iv) Rock Permeability

The values computed from the water pressure tests show relatively low permeabilities on the order of 10^{-4} to 10^{-6} cm/sec (Appendix B-2). In most cases, the zones of higher permeability correlate with the upper weathered zones and the more fractured zones at depth. Examination of the data from tests performed in BH-4 showed minimal water losses even in more highly fractured ones, indicating the overall tightness of the rock mass.

(c) Groundwater

Groundwater migration within the rock is restricted to joints and fractures. As described in Section 5, several piezometers have been installed to define the site groundwater regime. Data collected thus far at the site has been insufficient to accurately define the groundwater conditions; however, it is assumed that the groundwater level is a subdued replica of the surface topography with the gradients being towards the river and lakes.

(d) Permafrost

Preliminary temperature measurements made in the borings showed no permafrost conditions on either side of the river. Additional monitoring of the instrumentation will be carried out throughout the project to accurately define a temperature profile.

(e) Borrow Areas

The 1980 investigations at the Devil Canyon site were designed to confirm the concrete aggregate source near Cheechako Creek previously identified by the USBR. Reconnaissance mapping of the surrounding area was also conducted to identify sources of impervious materials for the cofferdam and the saddle dam.

(i) Concrete Aggregate

The previous investigations had identified the alluvial fan near the Cheechako Creek confluence, approximately 1,000 feet upstream of the proposed dam, as the primary source of concrete aggregate. However, due to limitations on access at the site, only two auger holes were drilled during the 1980 investigation.

These holes, located in the western side of the fan, were drilled to depths of 11 and 23 feet respectively. Data from these holes indica that a thin mantle of organic material overlies three to four feet o silty sand. Below the sand is a layer of sandy gravel with a trace silt and scattered boulders and cobbles that hinder the drilling pro cess. Seismic lines run by Shannon & Wilson for the COE (14, 18) indicate that this layer is as much as 80 feet thick, extending to approximately elevation 870 feet.

Results of the laboratory testing conducted by the USBR (19) indicat that the material from this fan is of adequate quality for use as co crete aggregate. The gravel particles are stream worn and generally rounded, with accompanying subangular sands. Petrographic analyses the sand and gravel indicates that the fan composition includes quar diorites, granites, andesites, diorites, dacites, metavolcanic rocks aplites, breccias, schists, phyllites, argillites, and amphibolites. Generally the material is of good quality with less than 2 percent deleterious constituents such as chert, muscovite, and argillite. T particles are generally fresh with 13 percent of the material tested showing deterioration or weathering effects.

From the USBR tests, there appears to be a deficiency of 3/4 to 1-1/ inch gravel. However, this could be accommodated by the selective processing of local morainal materials.

(ii) Impervious Material

Reconnaissance mapping of the areas adjacent to the canyon by this a previous investigations has shown that the area is mantled with out- wash and till materials several feet thick. In addition, the buried channel area on the south abutment is filled with some 90 feet of gl cial material. This material was described during the field program as generally dense, well graded and composed of particles ranging in size from rock flour to boulders. This material may provide a sourc of impervious fill, but will require testing to determine suitability.

(iii) Additional Material Source

Two terraces have been mapped on the east side of Cheechako Creek southeast of the proposed dam axis. The gravel in these terraces is coarser than in the alluvial fan, but may provide additional granula material after processing.

(f) Reservoir Geology

The Devil Canyon Reservoir will be confined to the narrow canyon of the Susitna River. The topography in and around the reservoir is bedrock controlled. Overburden is thin to absent, except in the upper reaches of the proposed reservoir where alluvial deposits cover the valley floor.

The large intrusive plutonic body which underlies the Watana site (see Section 6.1) also extends beneath adjacent slopes. It is predominantly a biotite granodiorite with local areas of quartz diorite and diorite. It is light gray to pink, medium grained and composed of quartz, feldspar, biotite and hornblende. The most common mafic mineral is biotite. When weathered, the rock has a light yellow-gray or pinkish yellow-gray color, except where it is highly oxidized and iron stained. The granodiorite is generally massive, competent, and hard witn the exception of the rock exposed on the upland north of the Susitna River where the biotite granodiorite has been badly decomposed as a result of physical weathering.

The other principal rock types in the reservoir area are the argillite and graywacke, which are exposed at the Devil Canyon dam site. In summary, the argillite has been intruded by the massive granodiorite and as a result, large isolated roof pendants of the argillite and graywacke are found locally throughout the reservoir and surrounding areas. The argillite/graywacke varies to a phyllite of low metamorphic grade, with possible isolated schist outcrops.

The rock has been isoclinally folded into steeply dipping structures which generally strike northeast-southwest. The contact between the argillite and the biotite granodiorite crosses the Susitna River just upstream of the Devil Canyon dam site. It is non-conformable and characterized by an almost aphanitic texture with an apparent wide chilled zone. The trend of the contact is roughly northeast-southwest as it crosses the river. Several large outcrop areas of the argillite which are completely surrounded by the biotite granodiorite are located in the Devil Creek area (Figure 4.1).

Preliminary joint measurements made in the reservoir area indicate structural trends similar to those encountered at the dam site (Table 6.3). Joint spacing at these stations ranged up to 3 feet.

TABLE 6.1: WATANA - JOINT CHARACTERISTICS

Joint Set	Strike (Range/Av)	Dip (Range/Av)	Spacing (Range/Av)	Surface	Coating	Remarks
I (excluding WJ-1 and WJ-9)	294°-345°/320°	65°NE-70°SW/90°	1"-15'/1-2'	Planar to slightly curved, smooth, occasionally rough, closed; but open in fracture zones	Minor carbonate	Parallel to major shears
WJ-1 and WJ-9	310°-0°/335°	70°NE-70°SW/90°	1"-15/1-2'	Same as above	None	Parallel to major shears
II	20°-60°/45°	70°NW-70°SE/90°	3"-2'/6"-1'	Planar to slightly curved, smooth	Minor carbonate	No shearing
III	345°-25°/10°	50°-60°W 50°-85°E	Variable 2"-5'	Planar to slightly curved, smooth to rough	None	Parallel to minor shears
IV	East-West and others	Less than 40°	Variable, 1"-10'	Irregular, rough	None	No shearing
V	260°-325°/280°	65°N-70°S/ mostly north	6"-1'	Planar smooth to rough	Minor carbonate	Parallel to minor shears
VI	60°-80°/65°	60°NW/60°SE	6"-4'/1/2'	Planar to slightly curved, rough	Minor carbonate	No shearing

TABLE 6.2: WATANA - BOREHOLE ROCK QUALITY DISTRIBUTION

BOREHOLE NUMBER	PERCENTAGE OF RECOVERED CORE IN SPECIFIC RQD RANGES					
	0-25%	25-50%	50-75%	75-90%	90-95%	95-100%
BH-2	19	15	22	17	13	14
BH-6	5	2	13	22	15	43
BH-8	4	7	18	16	18	38

ROCK QUALITY CLASSIFICATION (MODIFIED FROM DEERE, 1963)

0-25%	-	Very Poor
25-50%	-	Poor
50-75%	-	Fair
75-90%	-	Good
90-95%	-	Very Good
95-100%	-	Excellent

TABLE 6.3: DEVIL CANYON - JOINT CHARACTERISTICS

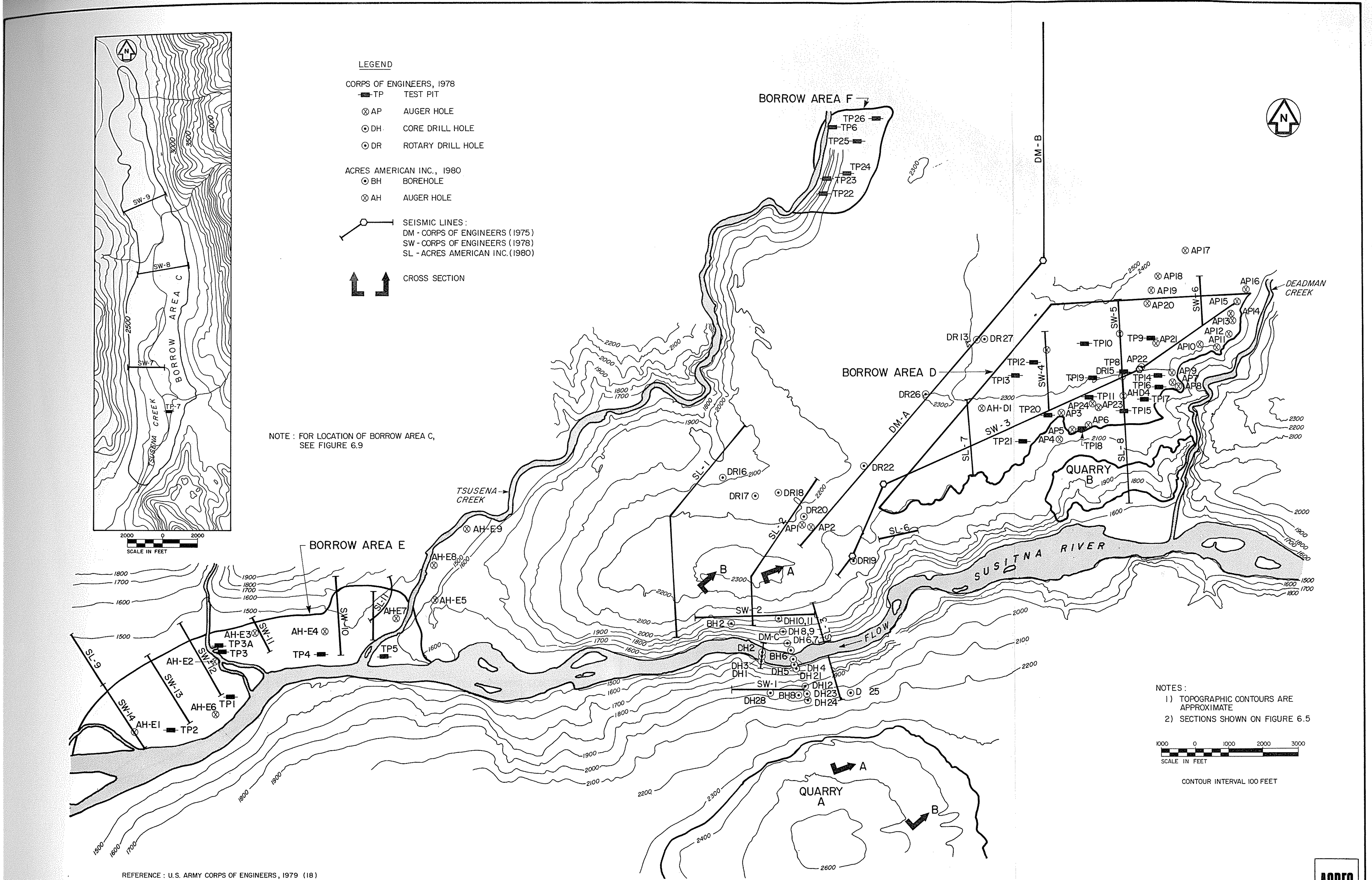
Joint Set	Strike (Range/Av)	Dip (Range/Av)	Spacing (Range)	Surface	Coating	Remarks
I	320° to 350°/ 335°	78°NE to 77°SW/ 85°NE	1" to 2'/6"	Planar, smooth to rough, some open	Iron oxide, quartz	Parallel to dikes and shears
II	030° to 060°	75° to 85°NW	6" to 15'/1'	Planar, smooth		Open on south bank, minor shears
III	035° to 090°/ 80°	45° to 80°SE	2" to 2'	Planar to irregular, smooth to rough		Bedding plane foliation
IV	040° to 060°	25° to 30°NW	2" to 4'/1'	Planar to irregular, smooth to rough		
	90°	5°S				
	340°	20°NE				

TABLE 6.4: DEVIL CANYON - BOREHOLE ROCK QUALITY DISTRIBUTION

BOREHOLE NUMBER	PERCENTAGE OF RECOVERED CORE IN SPECIFIC RQD RANGES					
	0-25%	25-50%	50-75%	75-90%	90-95%	95-100%
BH-1	2	2	9	21	15	51
BH-2	3	1	7	14	20	55
BH-4	1	8	16	22	16	37

ROCK QUALITY CLASSIFICATION (MODIFIED FROM DEERE, 1963)

0-25%	-	Very Poor
25-50%	-	Poor
50-75%	-	Fair
75-90%	-	Good
90-95%	-	Very Good
95-100%	-	Excellent

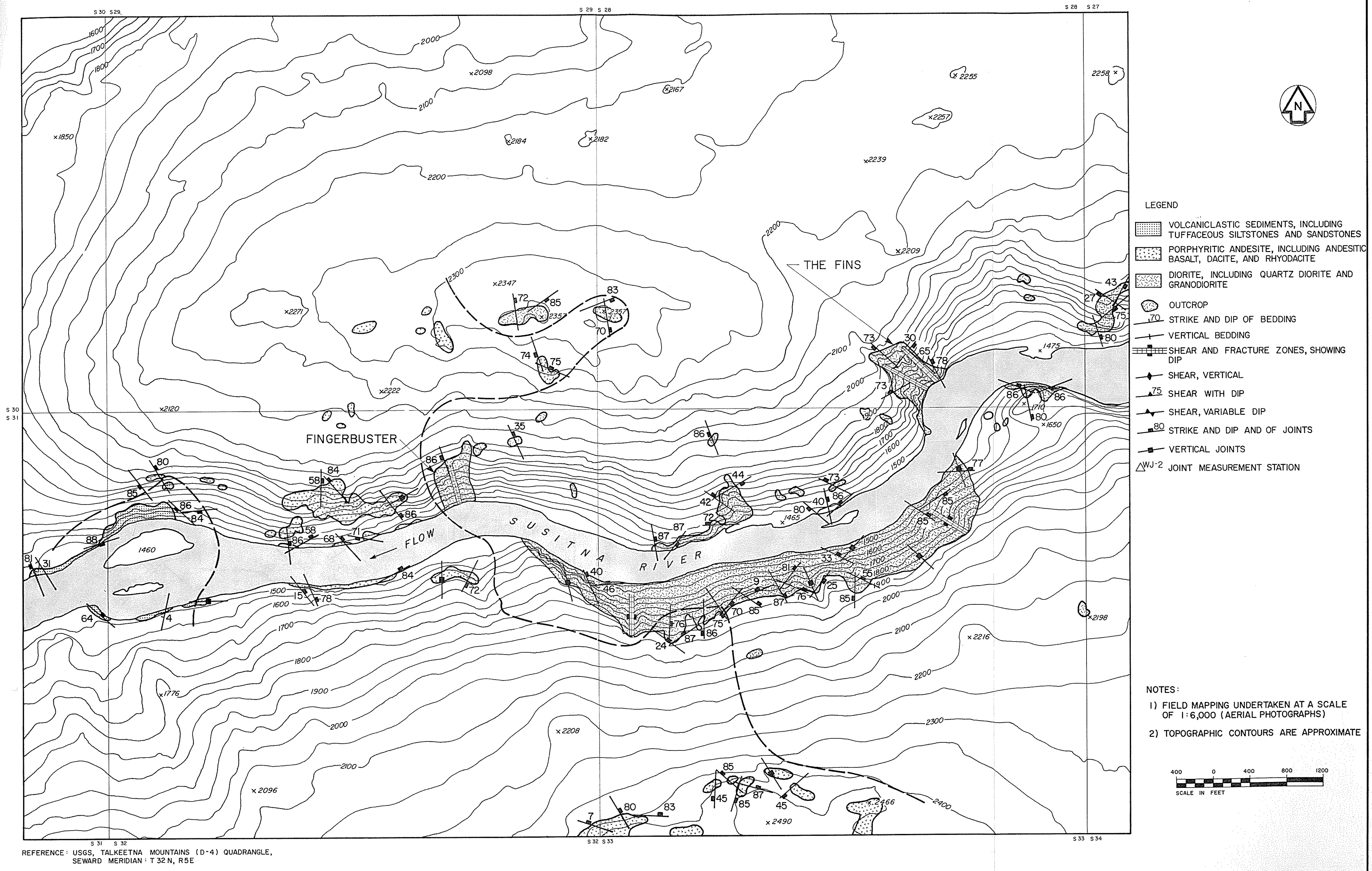


WATANA - EXPLORATION LOCATION MAP

FIGURE 6.1

WATANA - OVERBURDEN ISOPACH MAP

FIGURE 6.2

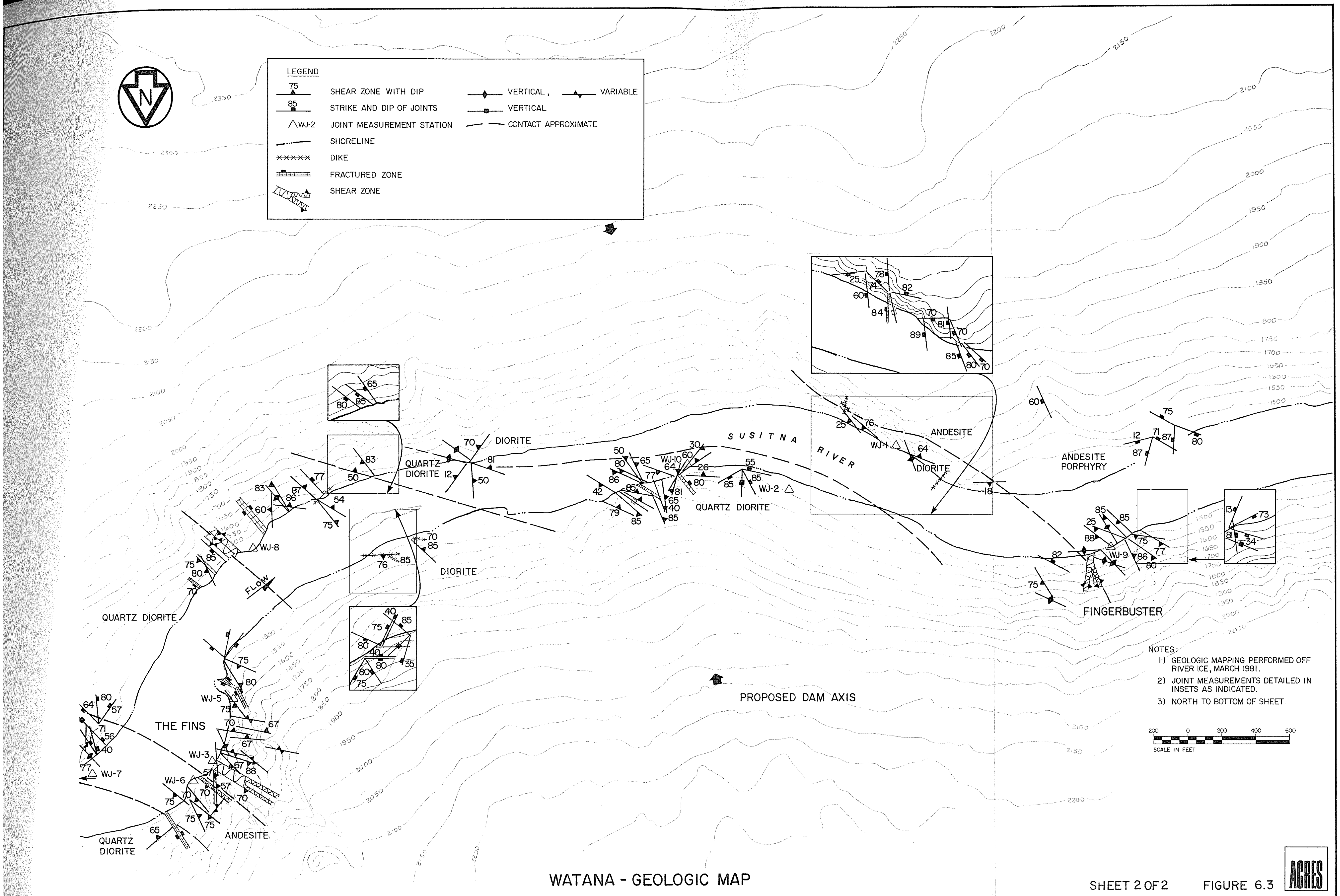


WATANA - GEOLOGIC MAP

SHEET 1 OF 2

FIGURE 6.3

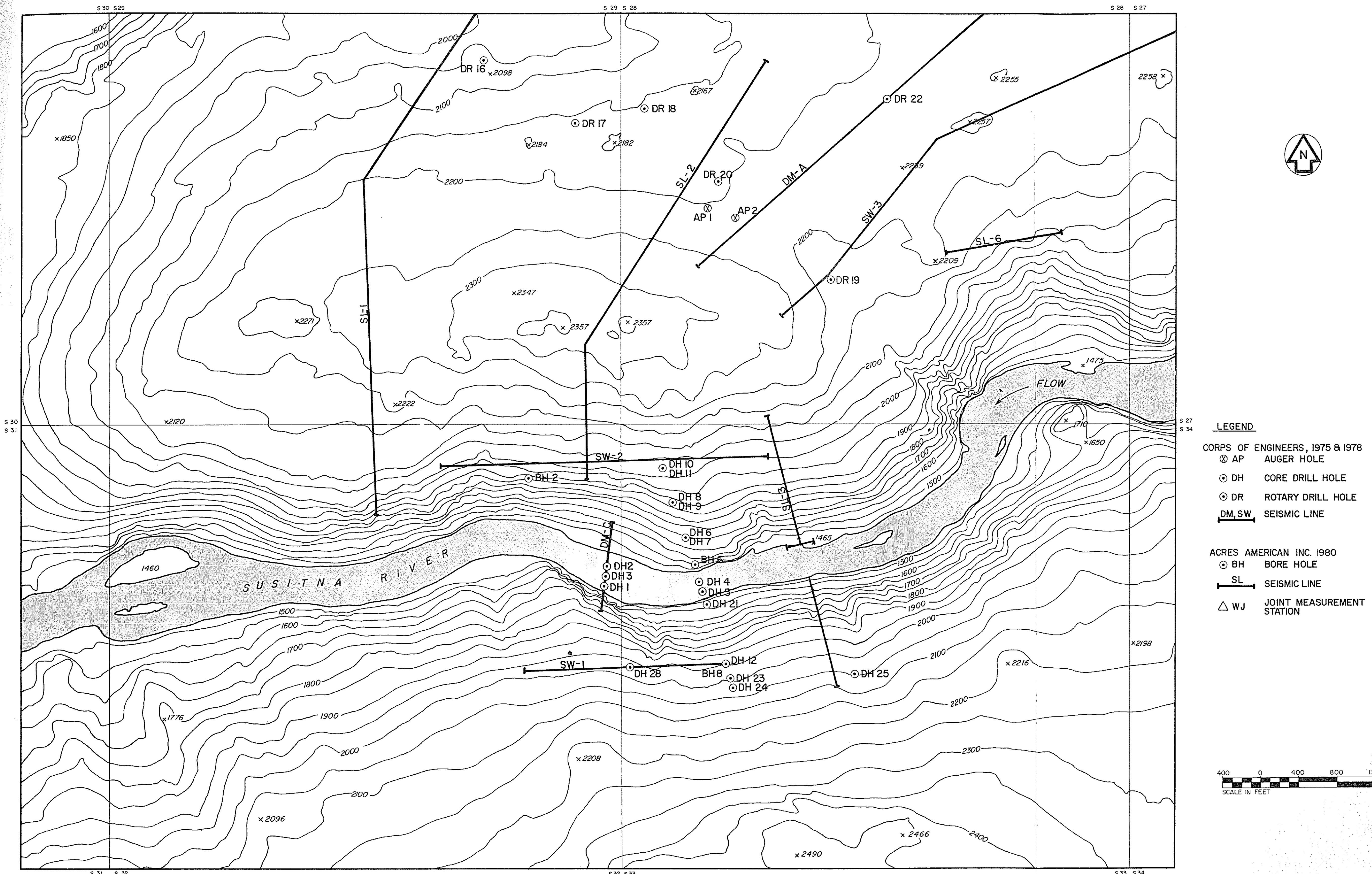
ACRES



WATANA - GEOLOGIC MAP

SHEET 2 OF 2

FIGURE 6.3

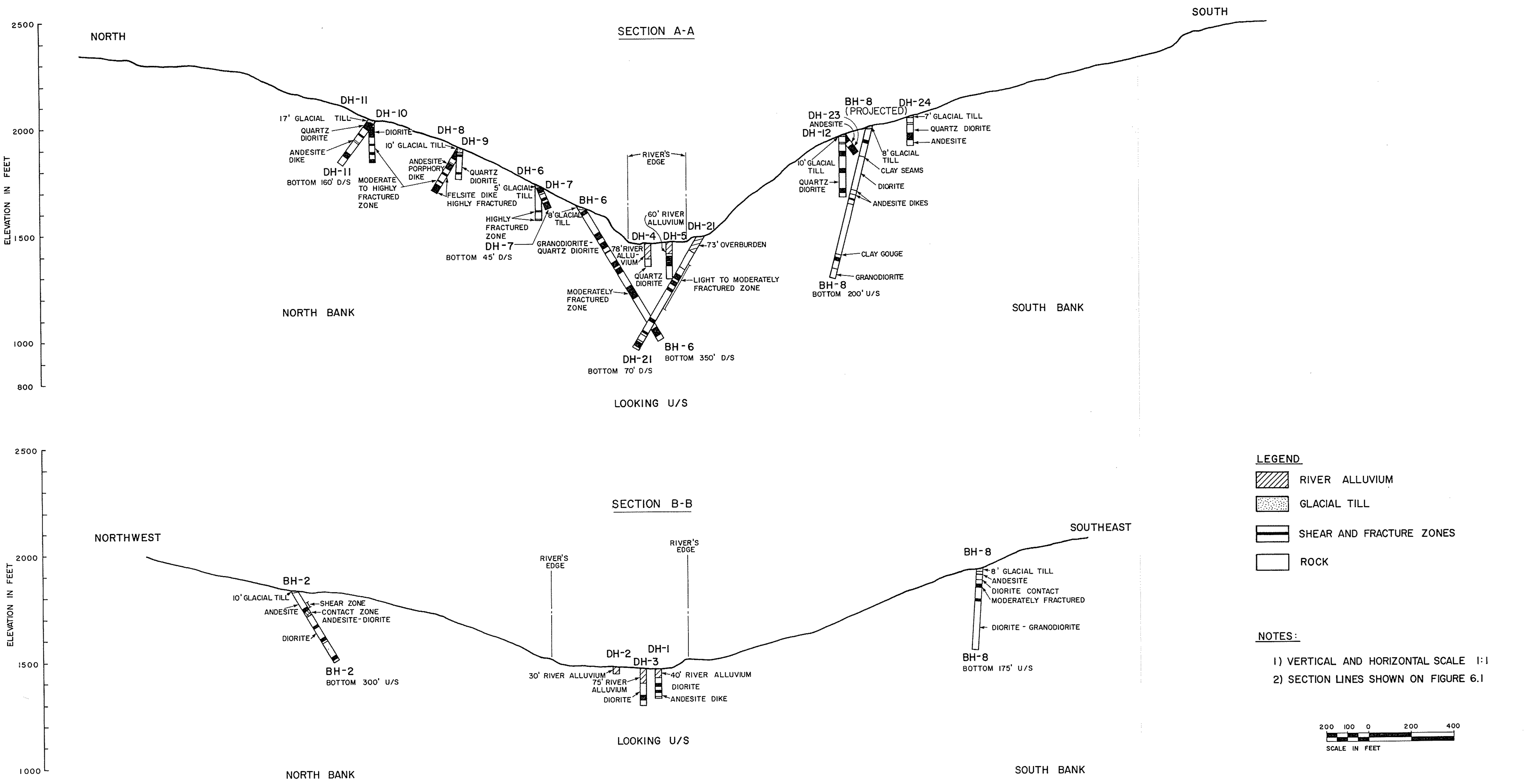


REFERENCE: USGS, TALKEETNA MOUNTAINS (D-4) QUADRANGLE,
SEWARD MERIDIAN: T 32 N, R5E

WATANA - SITE EXPLORATION MAP

FIGURE 6.4

ACRES

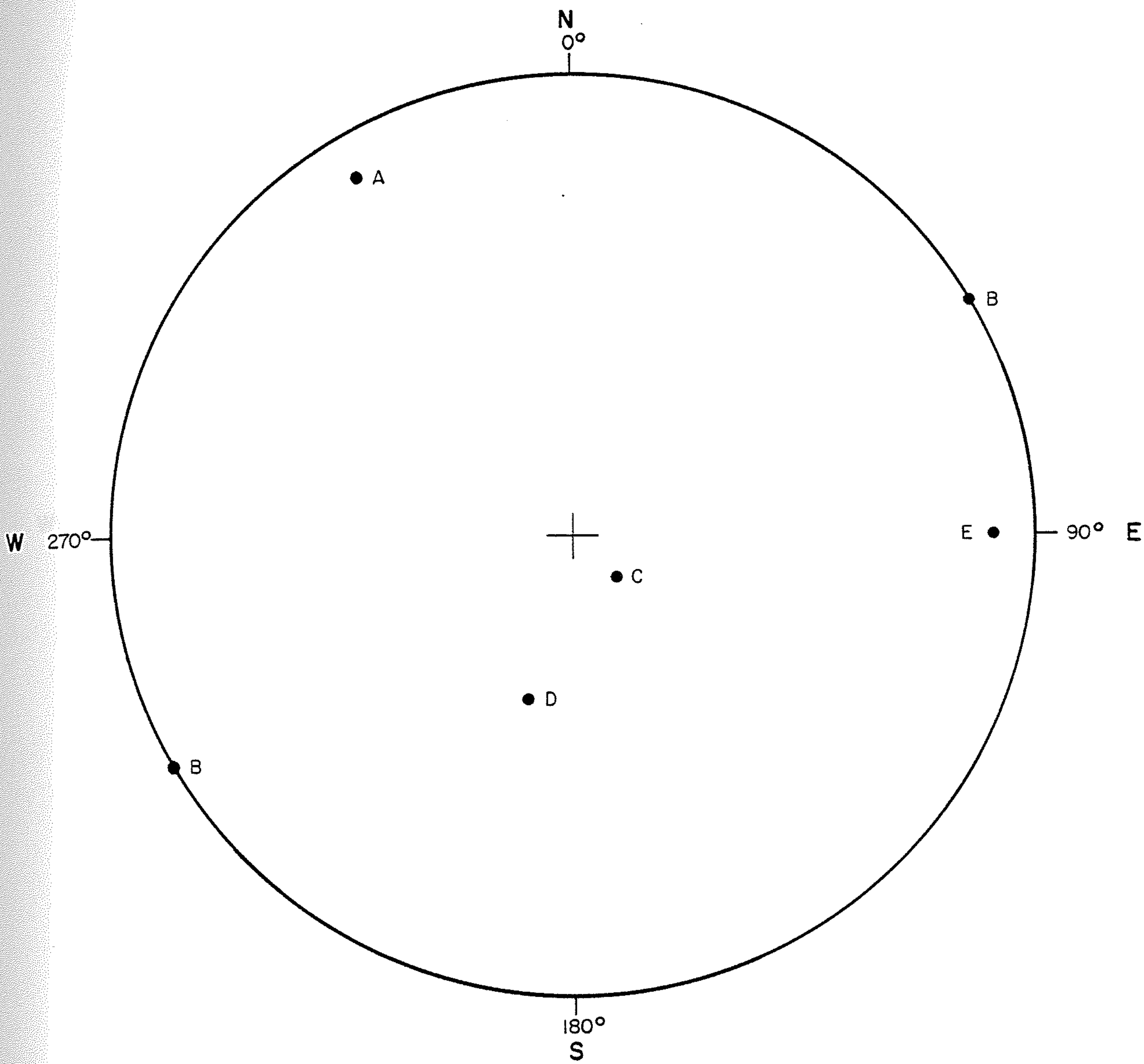


REFERENCE : CORPS OF ENGINEERS, 1979 (18)

WATANA - GEOLOGIC CROSS SECTIONS

FIGURE 6.5

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

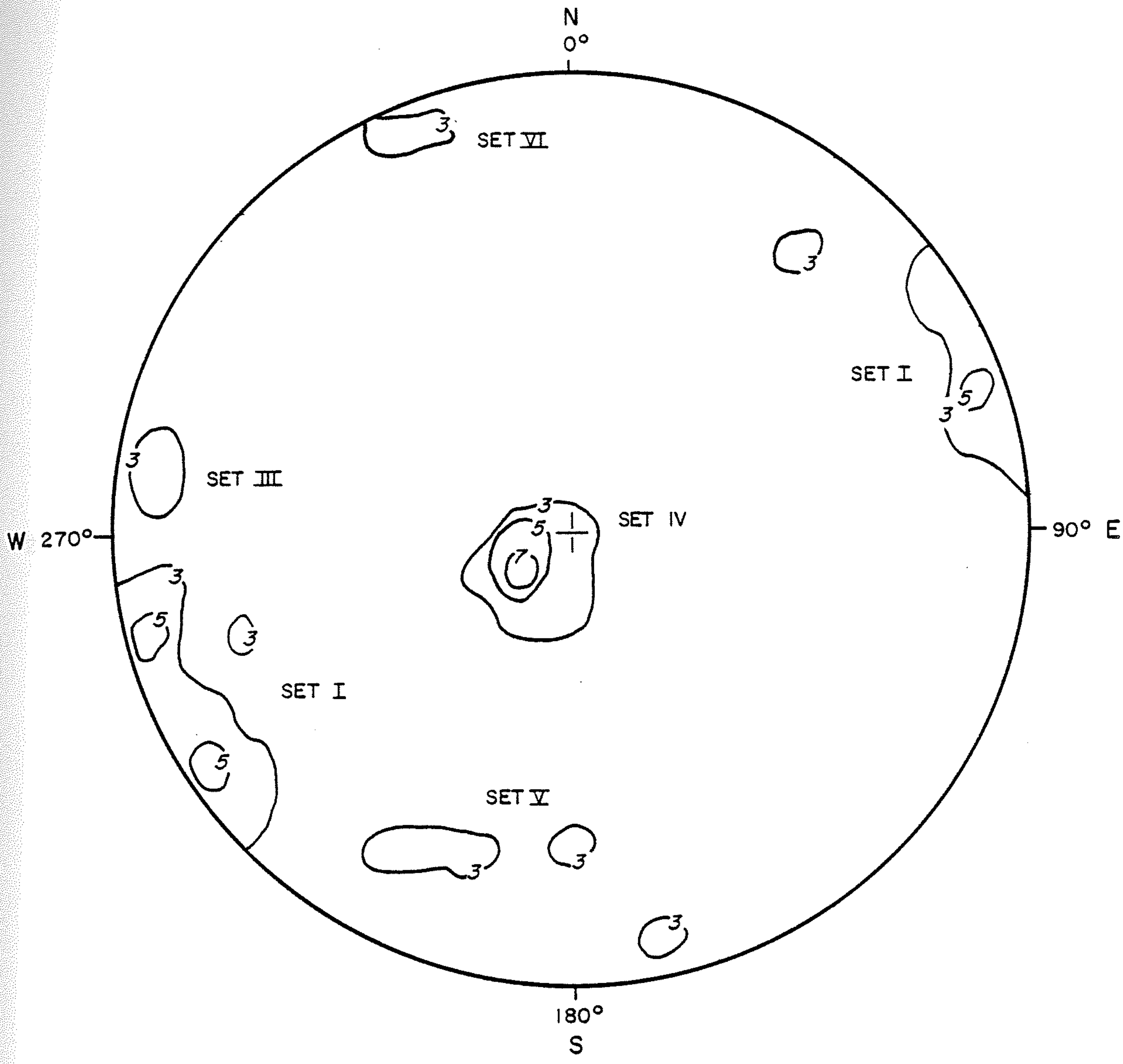
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

SAMPLE POINT PLOTS

POINT	STRIKE	DIP
A	N60°E	80°SE
B	N30°W	90°
C	N45°E	10°NW
D	N75°W	30°NE
E	N-S	80°W

JOINT PLOTTING METHOD

FIGURE 6.6a



NOTES:

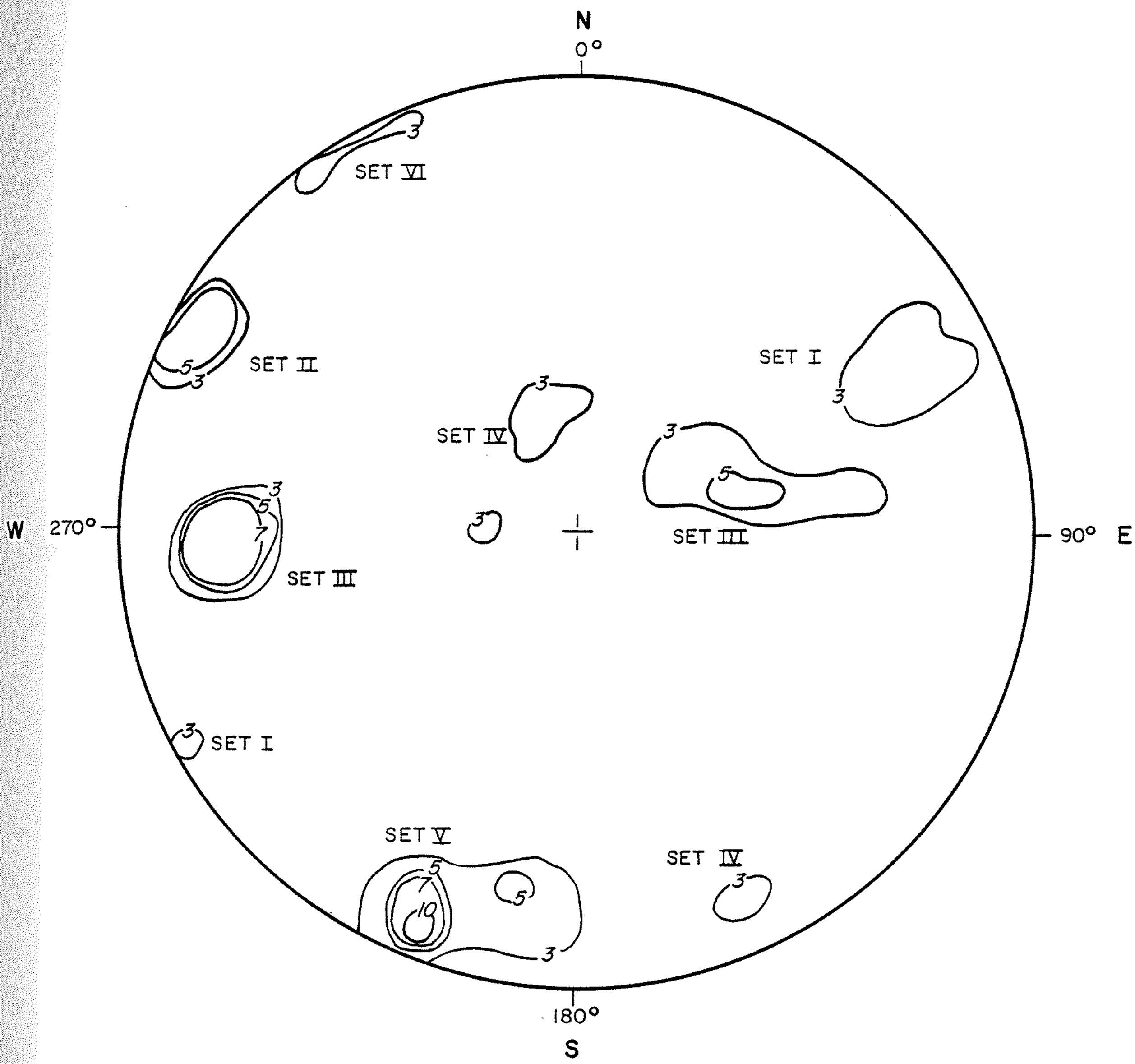
1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 86.

JOINT STEREOGRAPHIC PLOTS - WATANA
WJ-1

FIGURE 6.6b



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

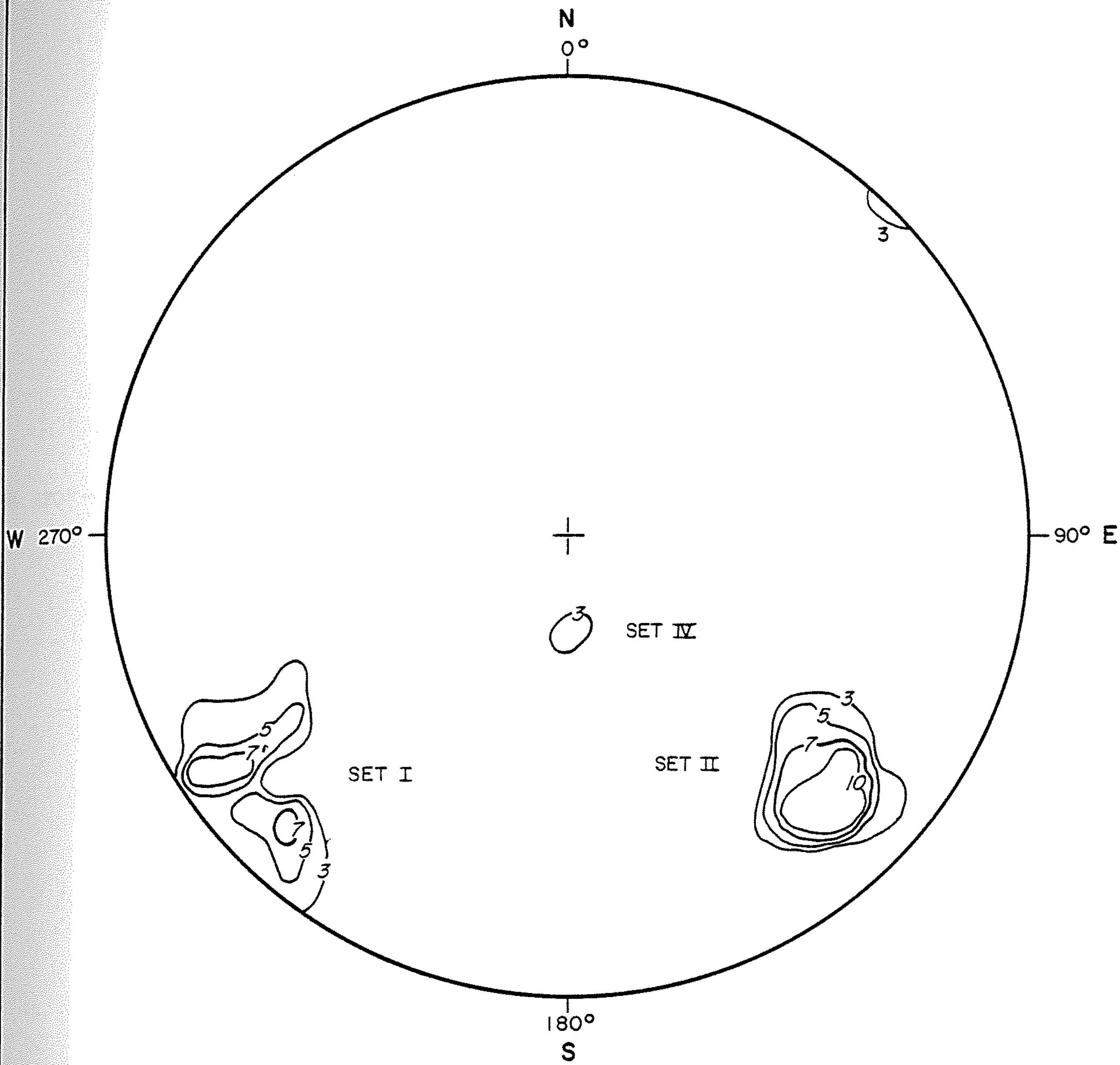
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 60.

WATANA - JOINT CONTOUR PLOT
STATION WJ-2

FIGURE 6.6c

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

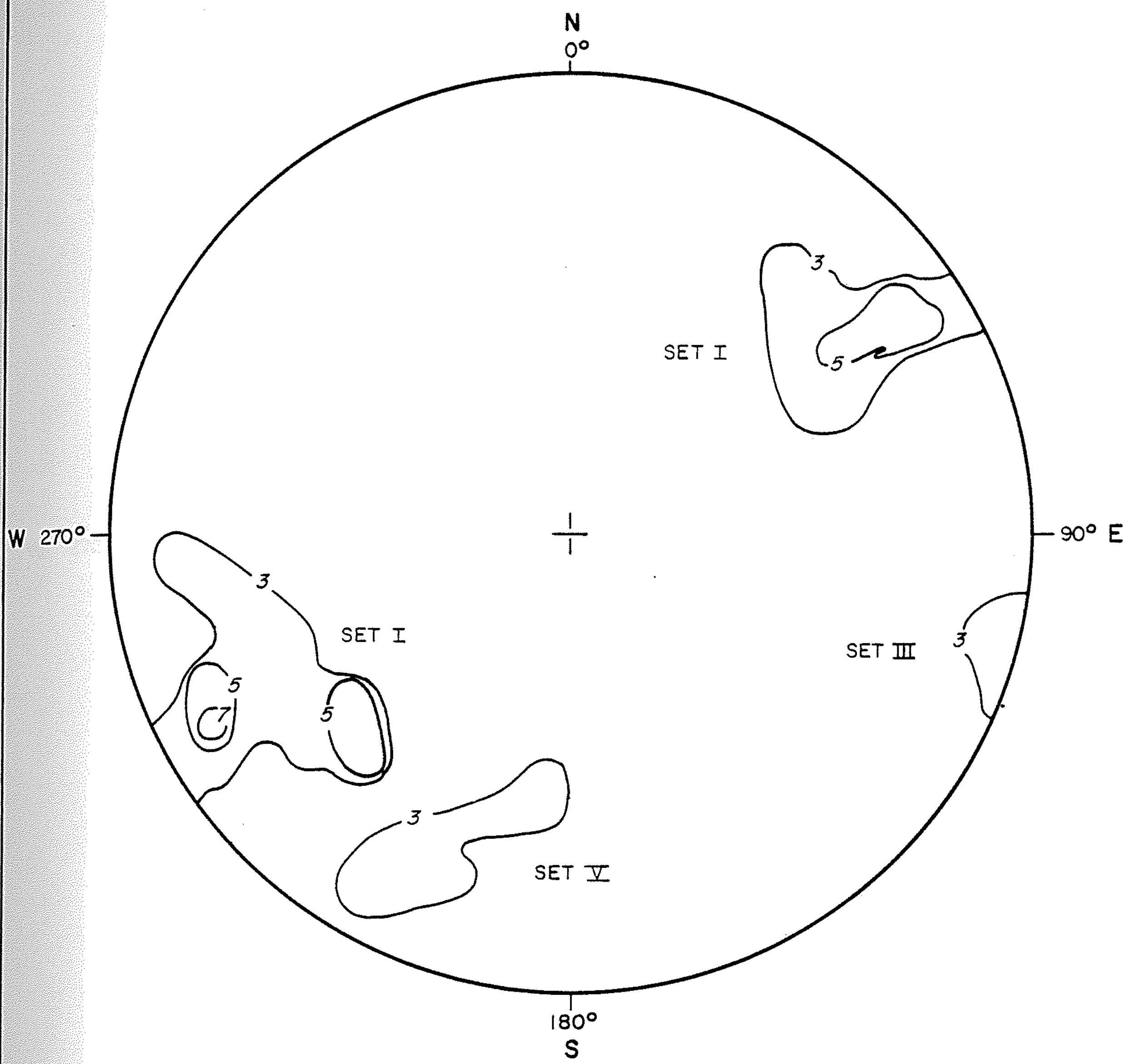
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 80.

WATANA - JOINT CONTOUR PLOT
STATION WJ-3

FIGURE 6.6d

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

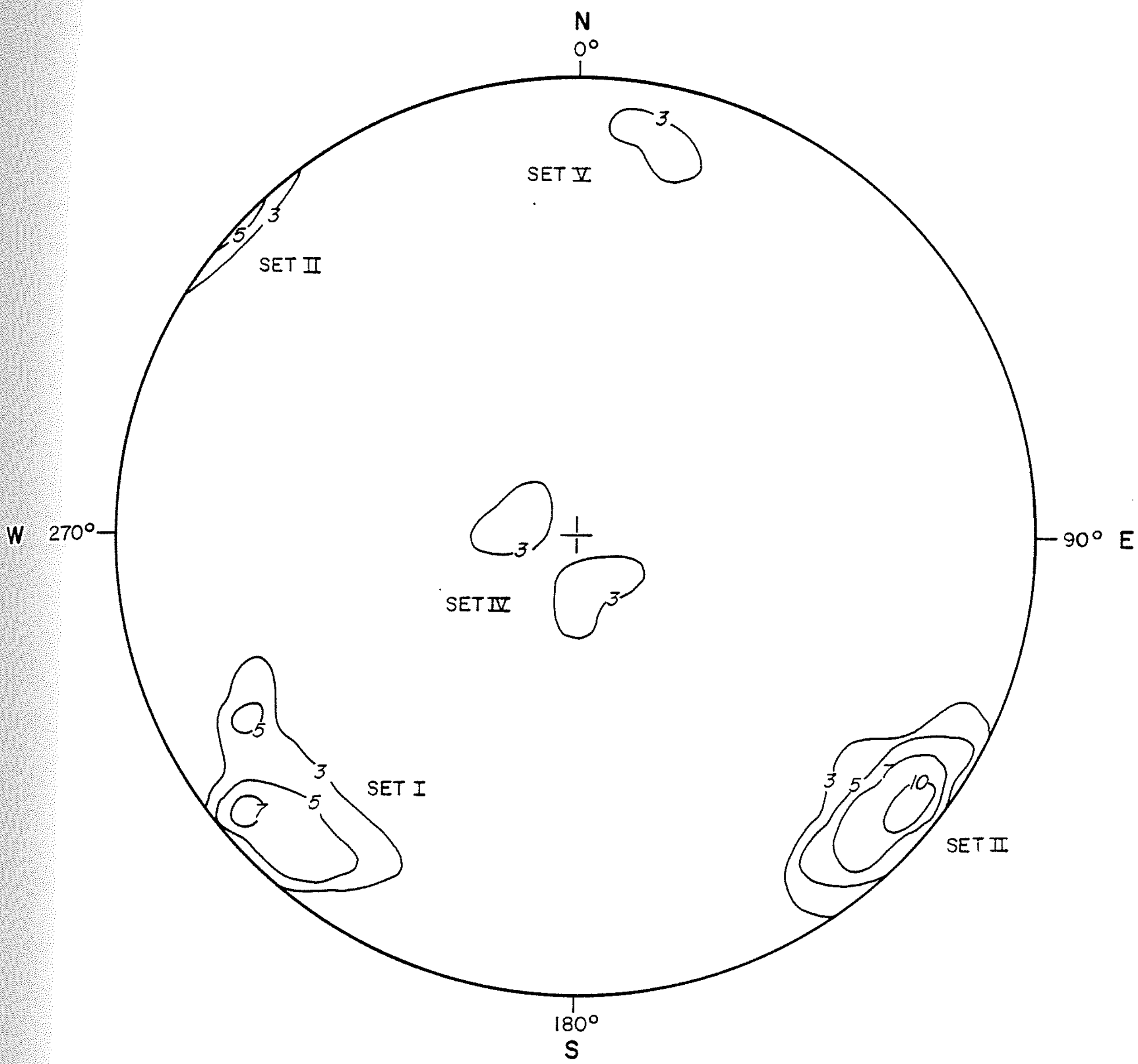
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-4

FIGURE 6.6e

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

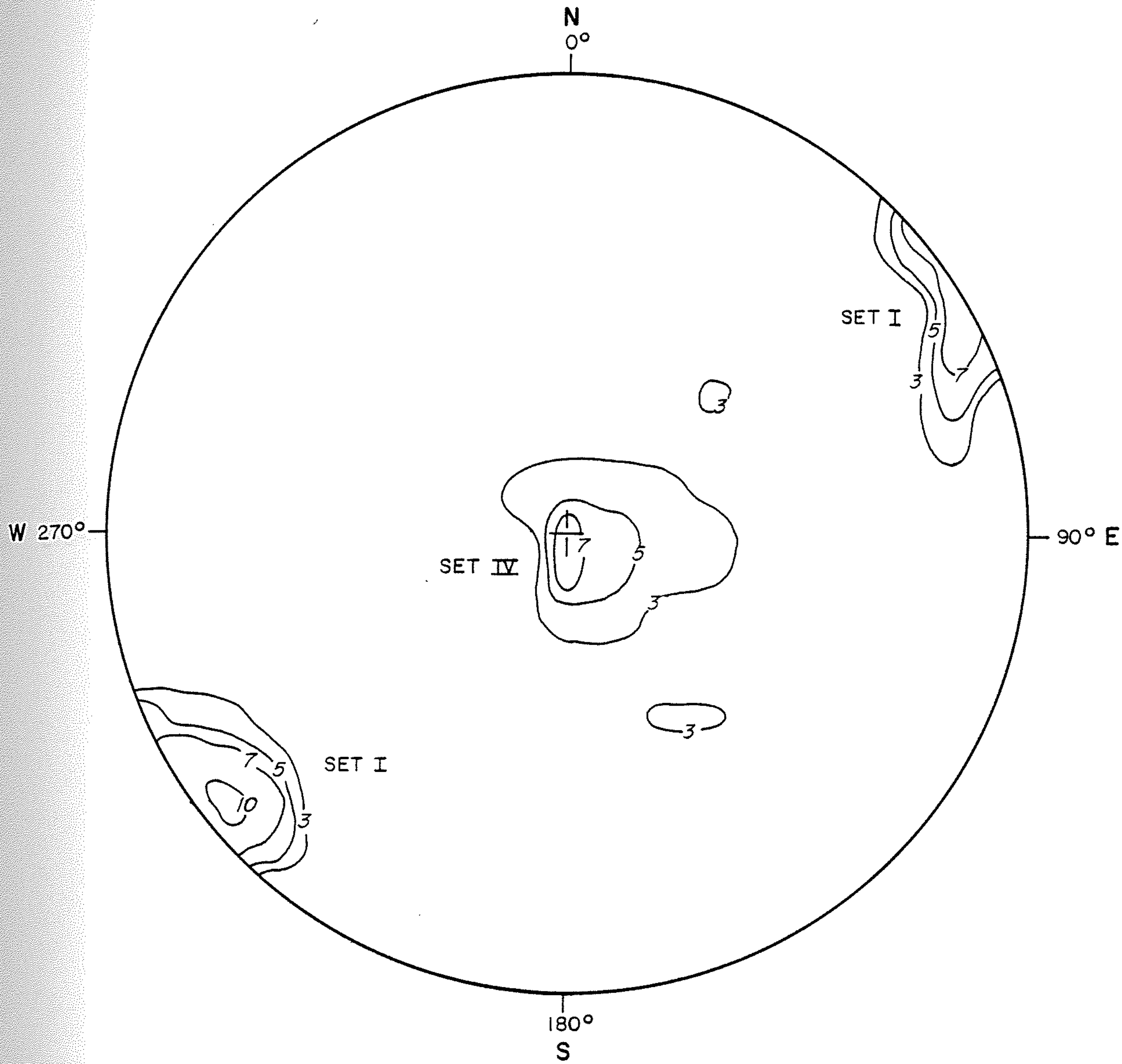
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA-JOINT CONTOUR PLOT
STATION WJ-5

FIGURE 6.6f

ACRES



<u>NOTES</u>:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

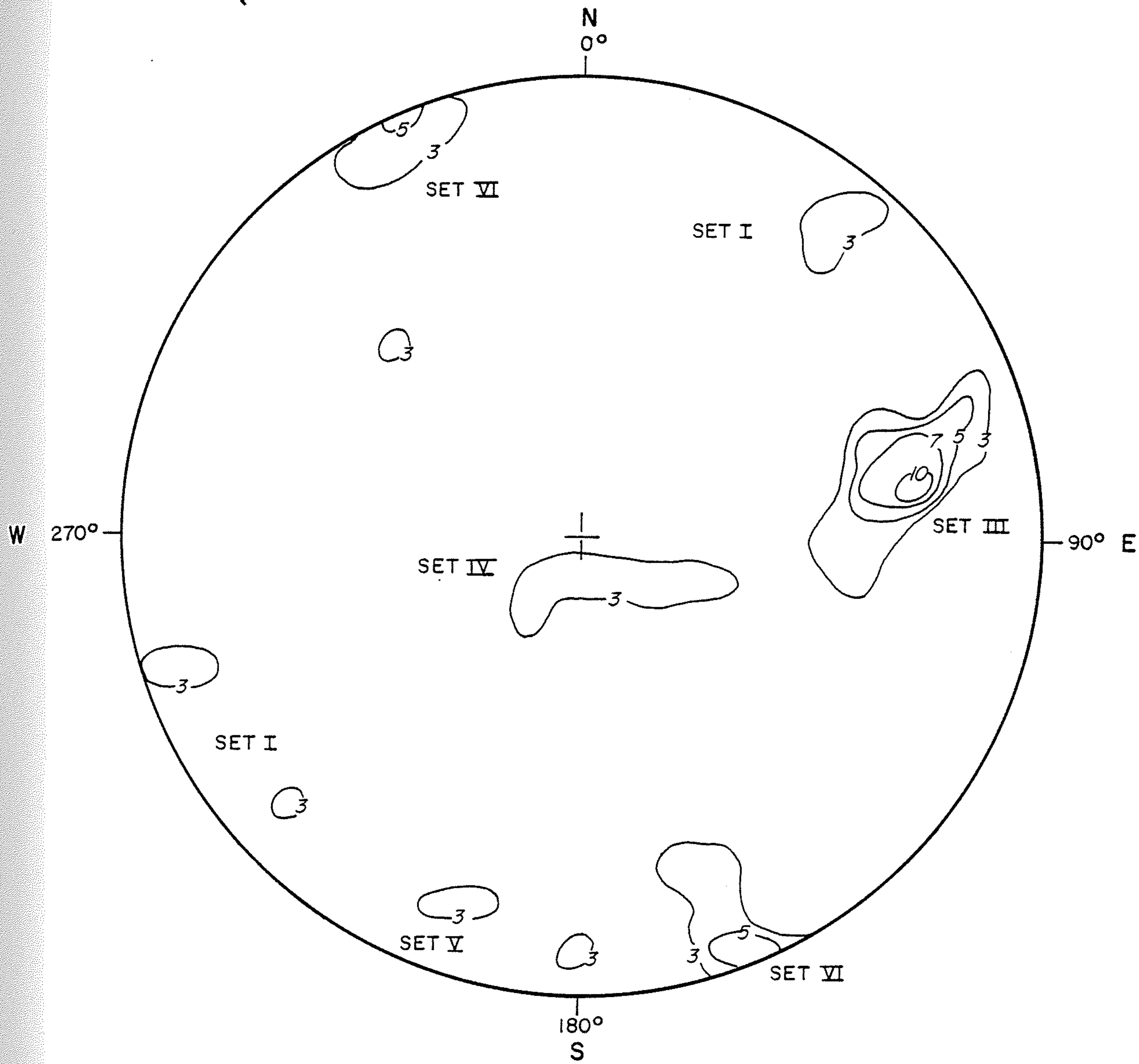
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

JOINT STEREOGRAPHIC PLOTS - WATANA
WJ-6

FIGURE 6.6g

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

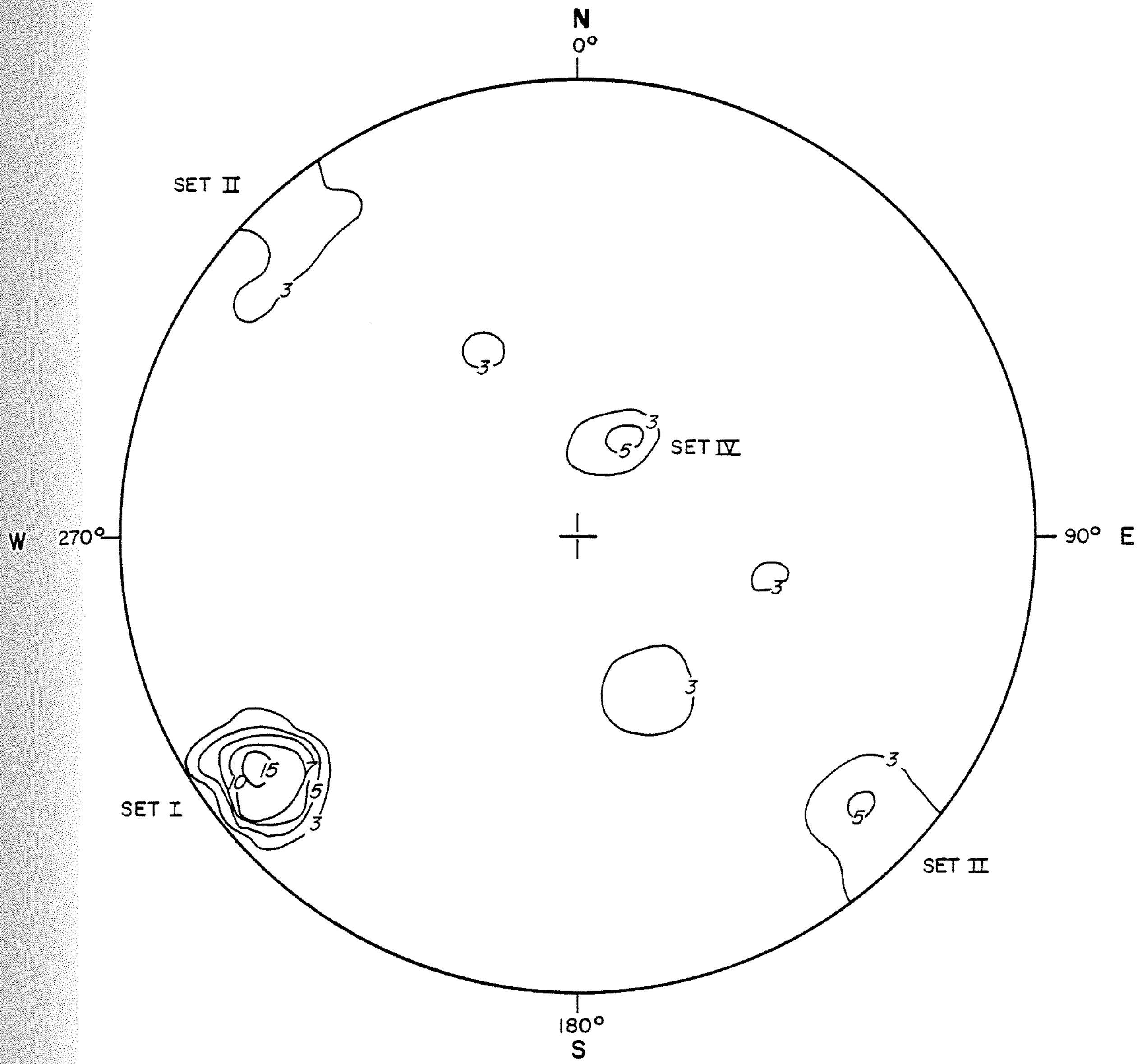
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-7

FIGURE 6.6h

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

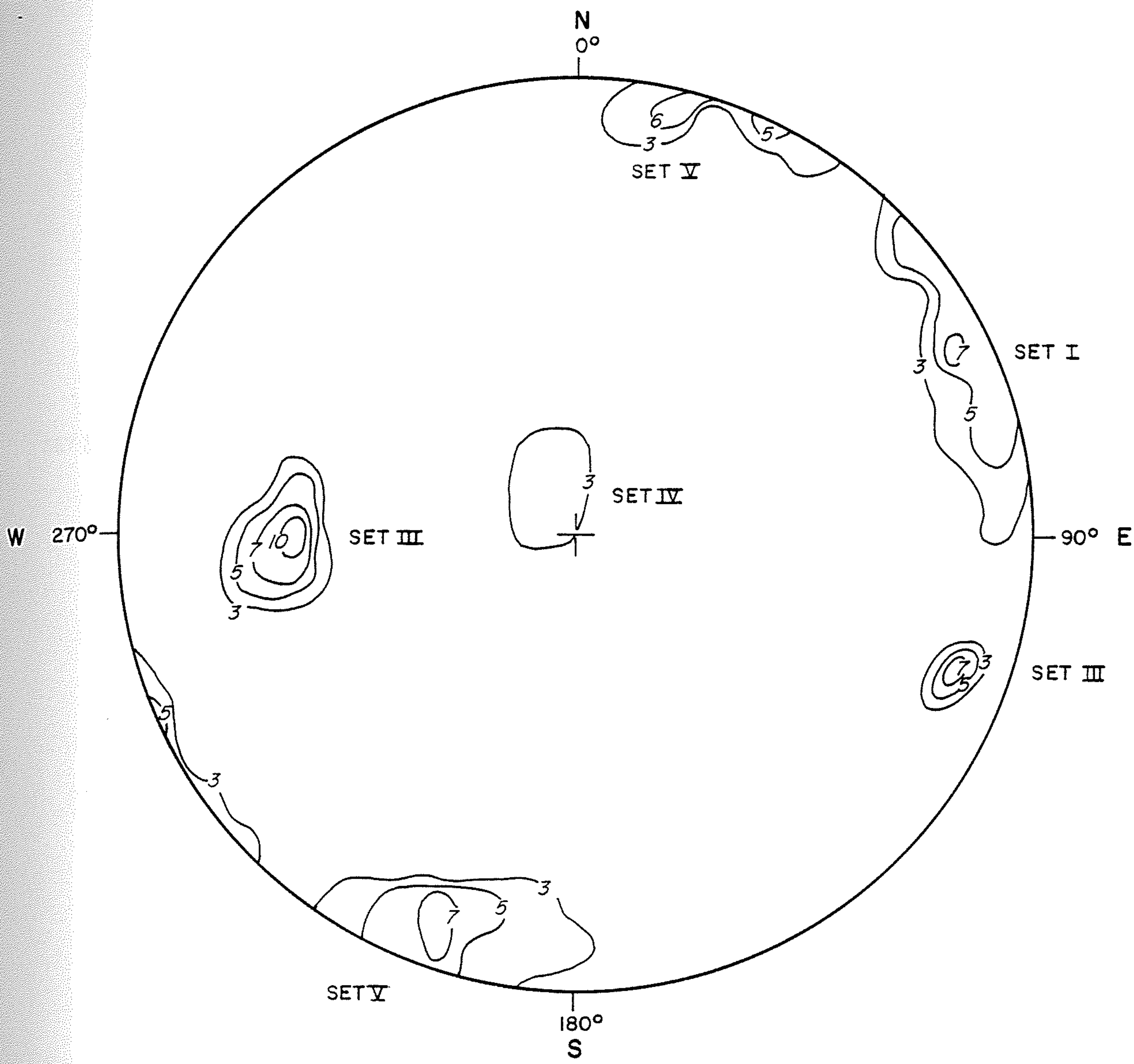
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-8

FIGURE 6.6i

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

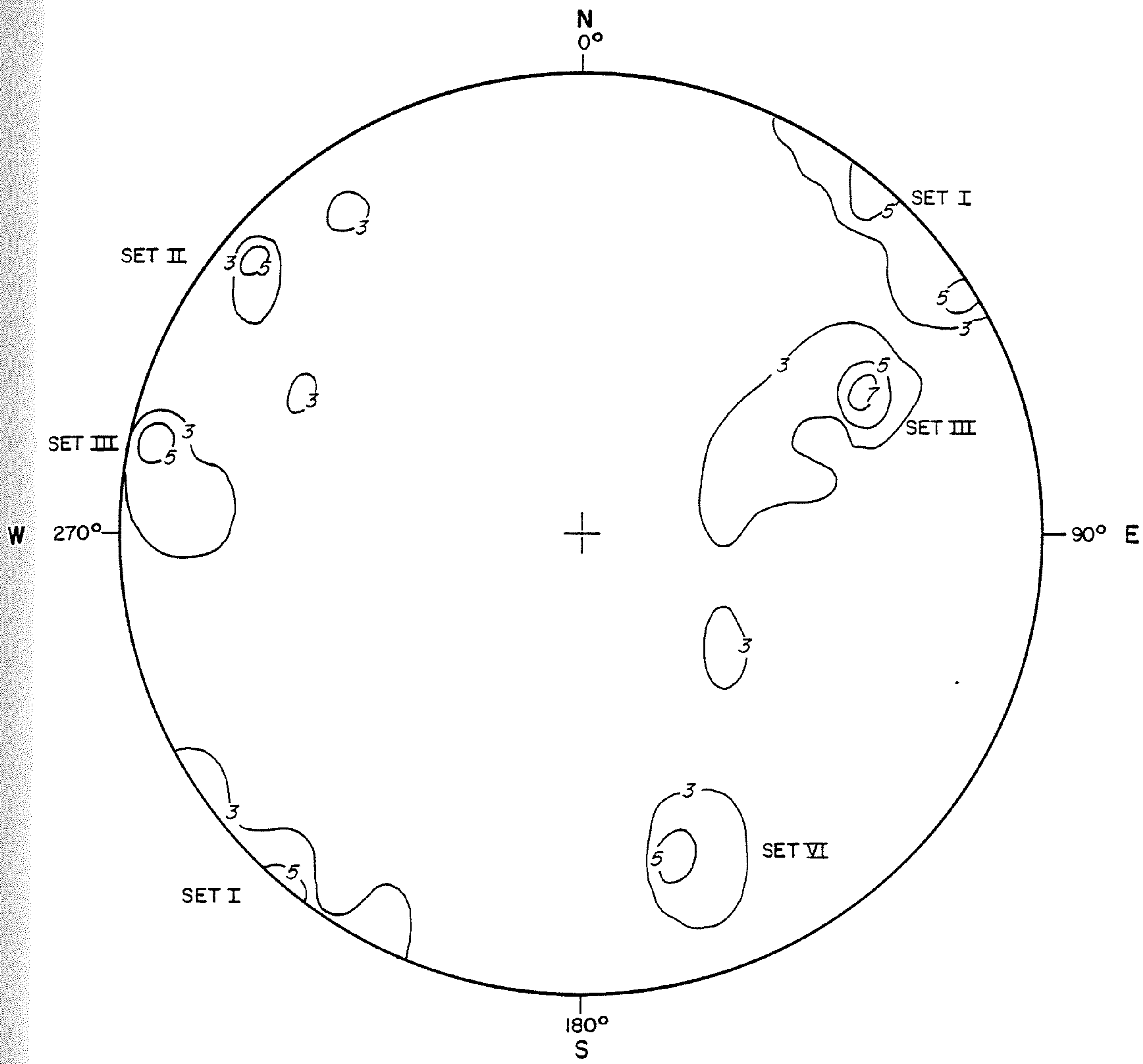
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-9

FIGURE 6.6j

ACRES



NOTES:

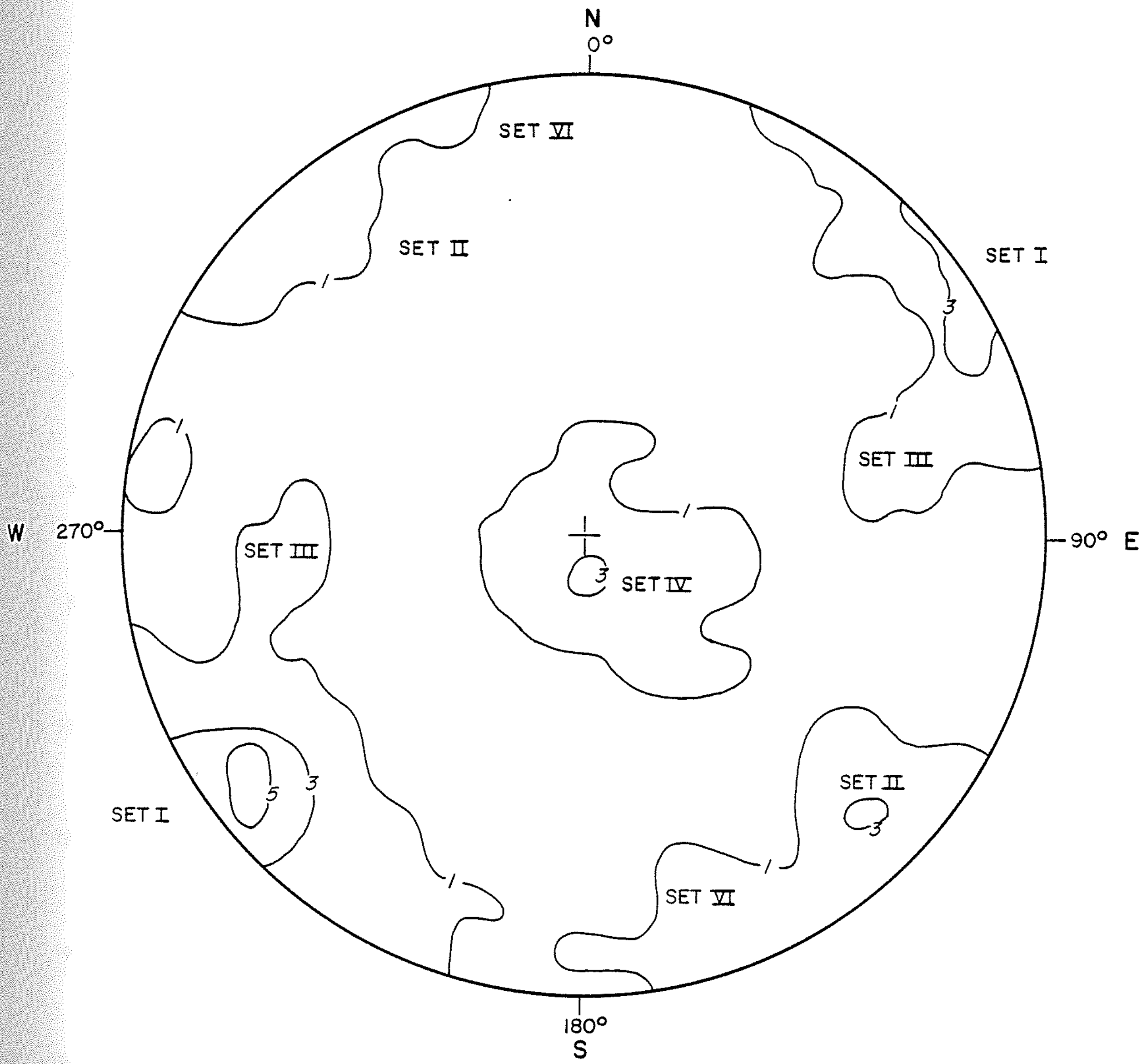
1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-10

FIGURE 6.6 k



NOTES:

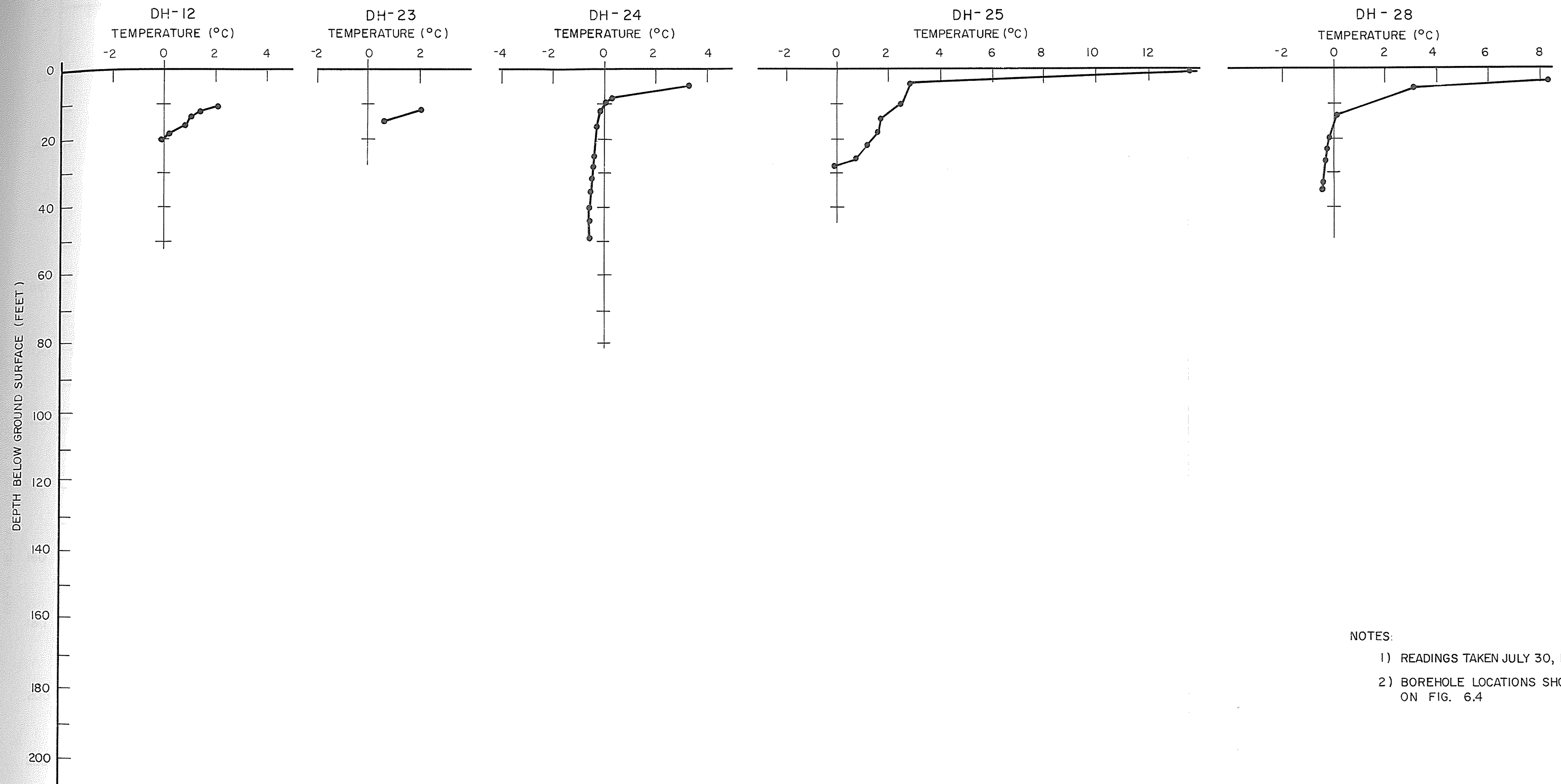
1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

WATANA - JOINT CONTOUR PLOT
COMPOSITE

FIGURE 6.6 L

ACRES



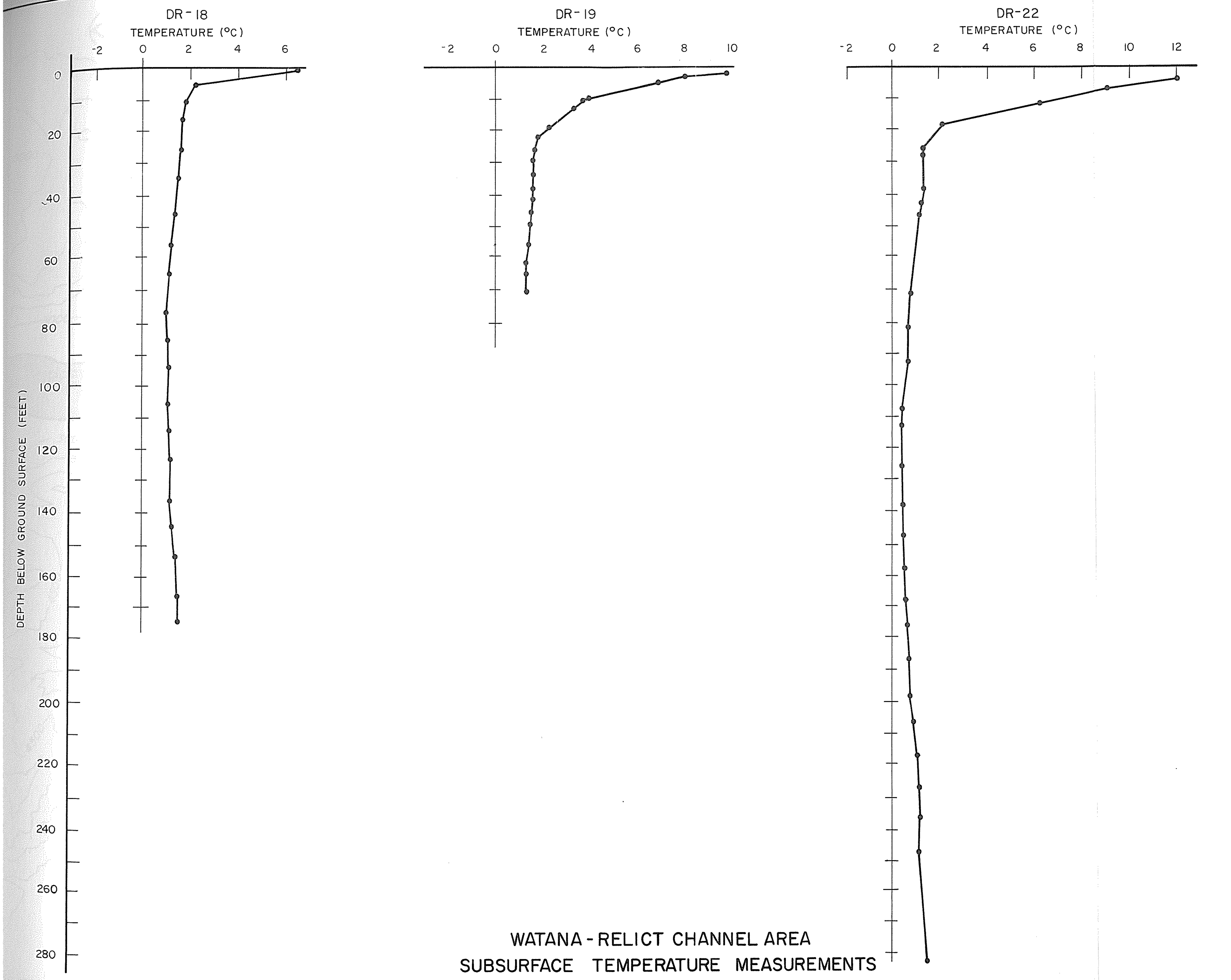
NOTES:

1) READINGS TAKEN JULY 30, 1980

2) BOREHOLE LOCATIONS SHOWN ON FIG. 6.4

WATANA DAM SITE –
SUBSURFACE TEMPERATURE MEASUREMENTS

FIGURE 6.7



NOTES:

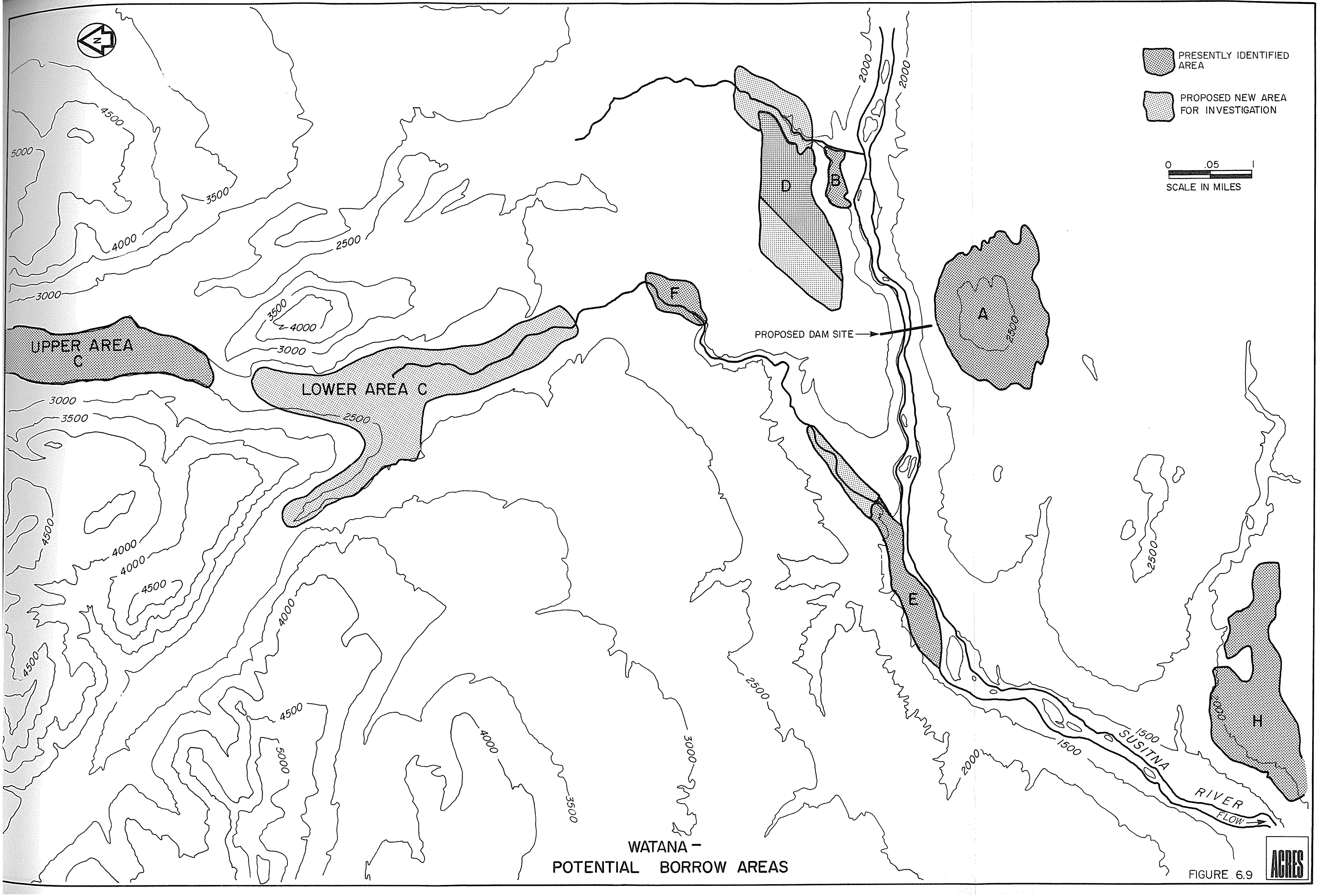
1) READINGS TAKEN JULY 30, 1980

2) BOREHOLE LOCATIONS SHOWN ON FIG. 6.4

WATANA - RELICT CHANNEL AREA
SUBSURFACE TEMPERATURE MEASUREMENTS

ACRES

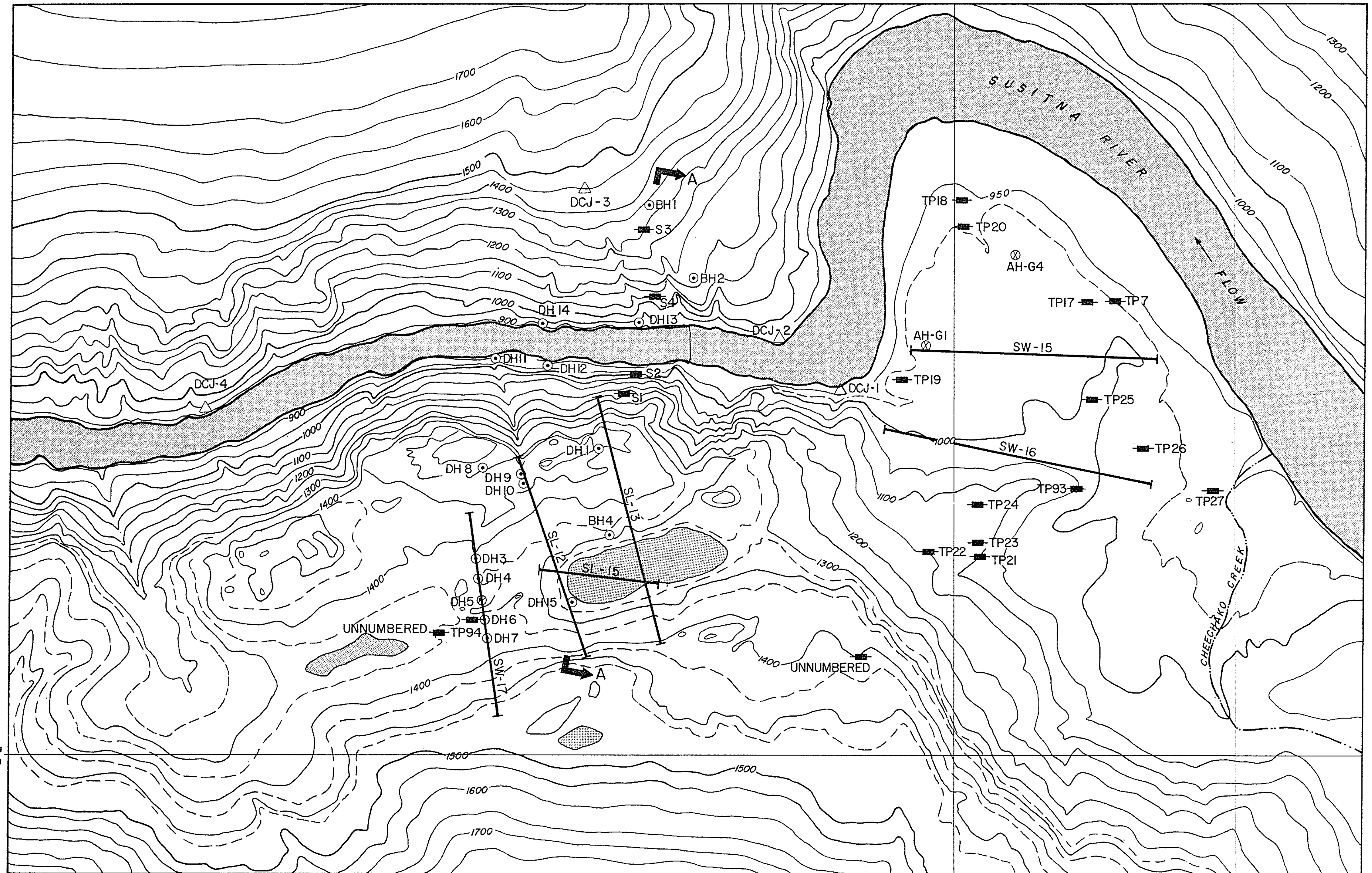
FIGURE 6.8



WATANA –
POTENTIAL BORROW AREAS

ACRES

FIGURE 6.9



REFERENCES :
1) USGS, TALKEETNA MOUNTAINS, (D-5), ALASKA QUADRANGLE SEWARD MERIDIAN : T32N, R1E, S32 AND 33.
2) U.S. ARMY CORPS OF ENGINEERS, 1979. (18)
3) U.S. BUREAU OF RECLAMATION, 1960. (19)

LEGEND

USBR, 1958
DH BORE HOLE
TP,S, TEST PITS AND TRENCHES

CORPS OF ENGINEERS, 1978
SW SEISMIC LINES

ACRES AMERICAN INC., 1980
BH BORE HOLE
AH AUGER HOLE
SL SEISMIC LINES

DCJ JOINT MEASUREMENT STATION

CROSS SECTION

NOTES:
1) TOPOGRAPHIC CONTOURS ARE APPROXIMATE
2) SECTION SHOWN ON FIGURE 6.13

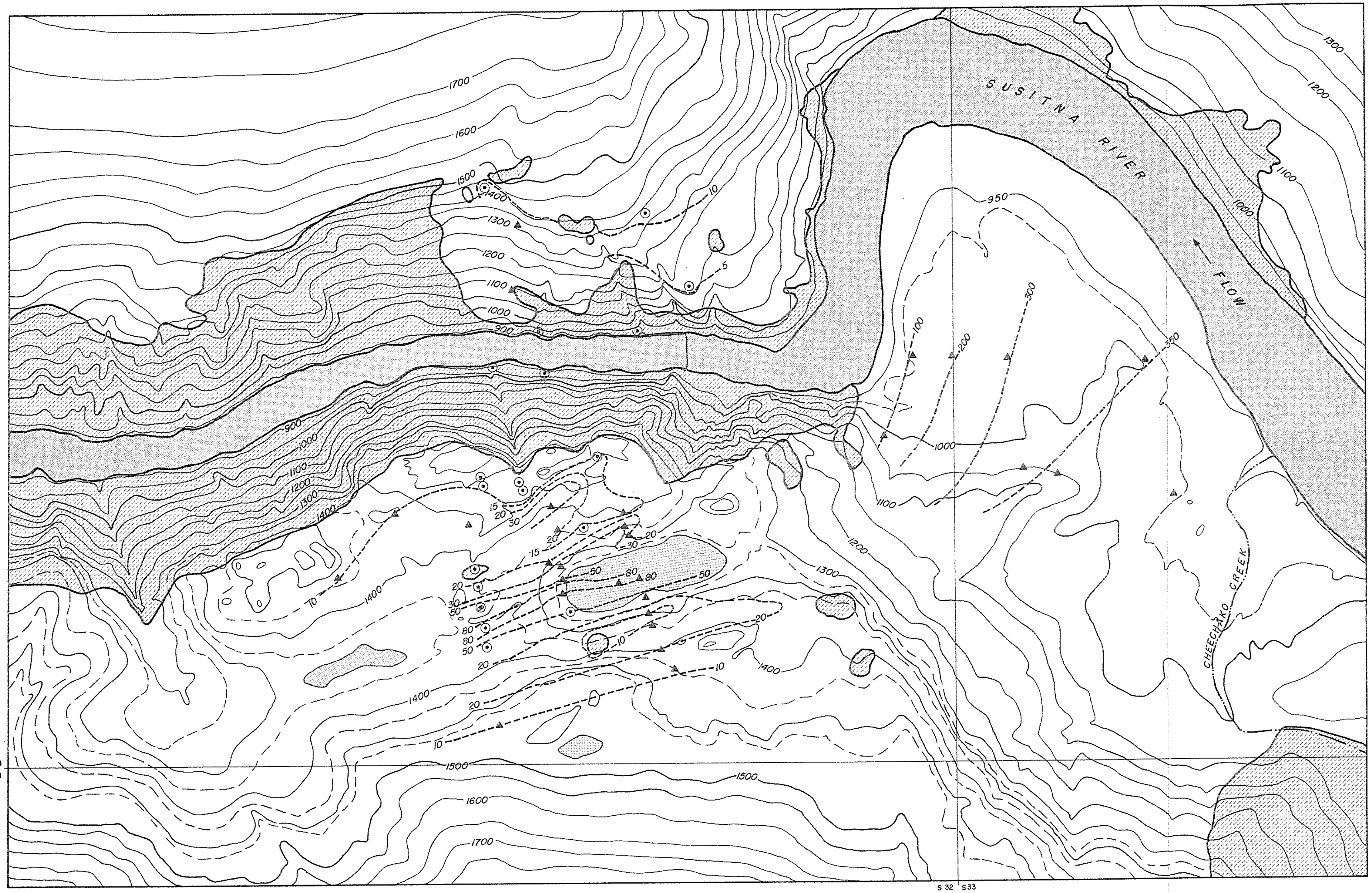
200 0 200 400 600
SCALE IN FEET

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

DEVIL CANYON- EXPLORATION LOCATION MAP

FIGURE 6.10

ACRES



REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN: T 32N, R1E, S32 AND 33.

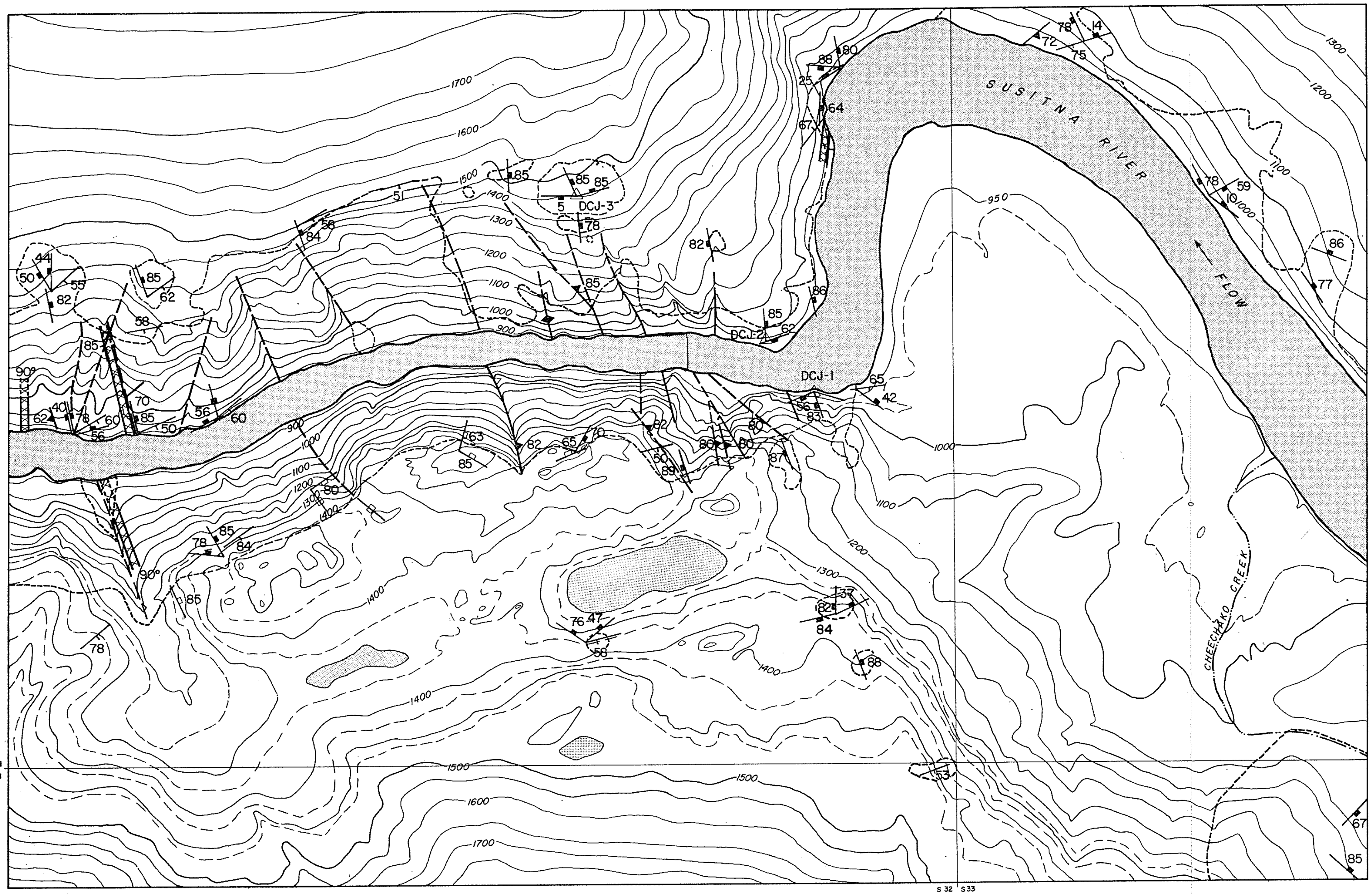
NOTES:
1) TOPOGRAPHIC CONTOURS ARE APPROXIMATE
2) ISOPACH CONTOURS ARE IN FEET BELOW GROUND SURFACE

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

DEVIL CANYON - OVERBURDEN ISOPACH MAP

FIGURE 6.11

ACRES



REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE,
SEWARD MERIDAN: T32N, R1E, S32, AND 33.

LEGEND

- 65 STRIKE AND DIP OF BEDS
- 75 STRIKE AND DIP OF JOINTS
- 85 STRIKE AND DIP OF OPEN JOINTS
- MAJOR OUTCROPS OF ARGILLITE, GRAYWACKE
- DIKE, FELSIC
- SHEAR ZONE, (DASHED WHERE INDEFINITE)
- △DCJ-2 JOINT MEASUREMENT STATION

NOTES:

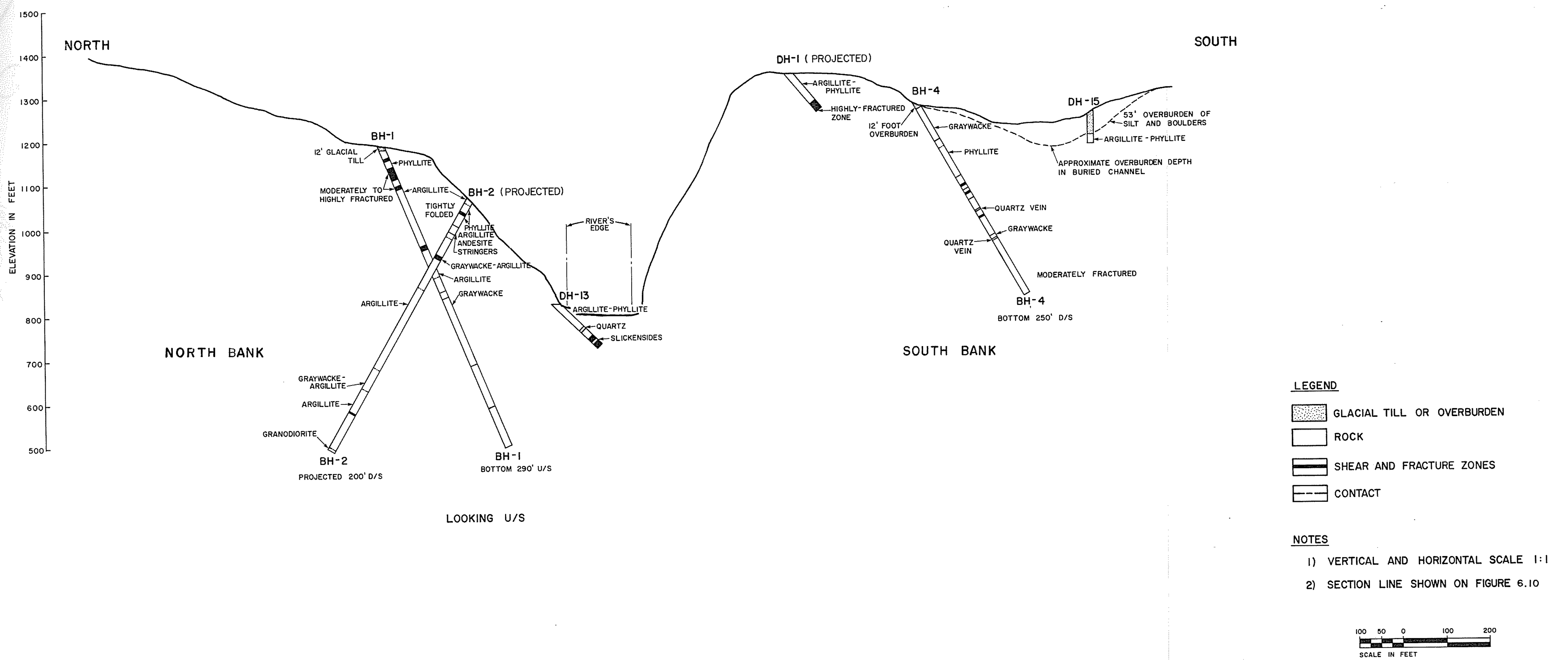
1) GEOLOGIC MAPPING UNDERTAKEN AT THE SCALE OF 1:24,000 (AERIAL PHOTOGRAPHS)
2) TOPOGRAPHIC CONTOURS ARE APPROXIMATE
3) MODIFIED FROM: KACHADOORIAN, 1974(10)

200 0 200 400 600
SCALE IN FEET

DEVIL CANYON - GEOLOGIC MAP

FIGURE 6.12

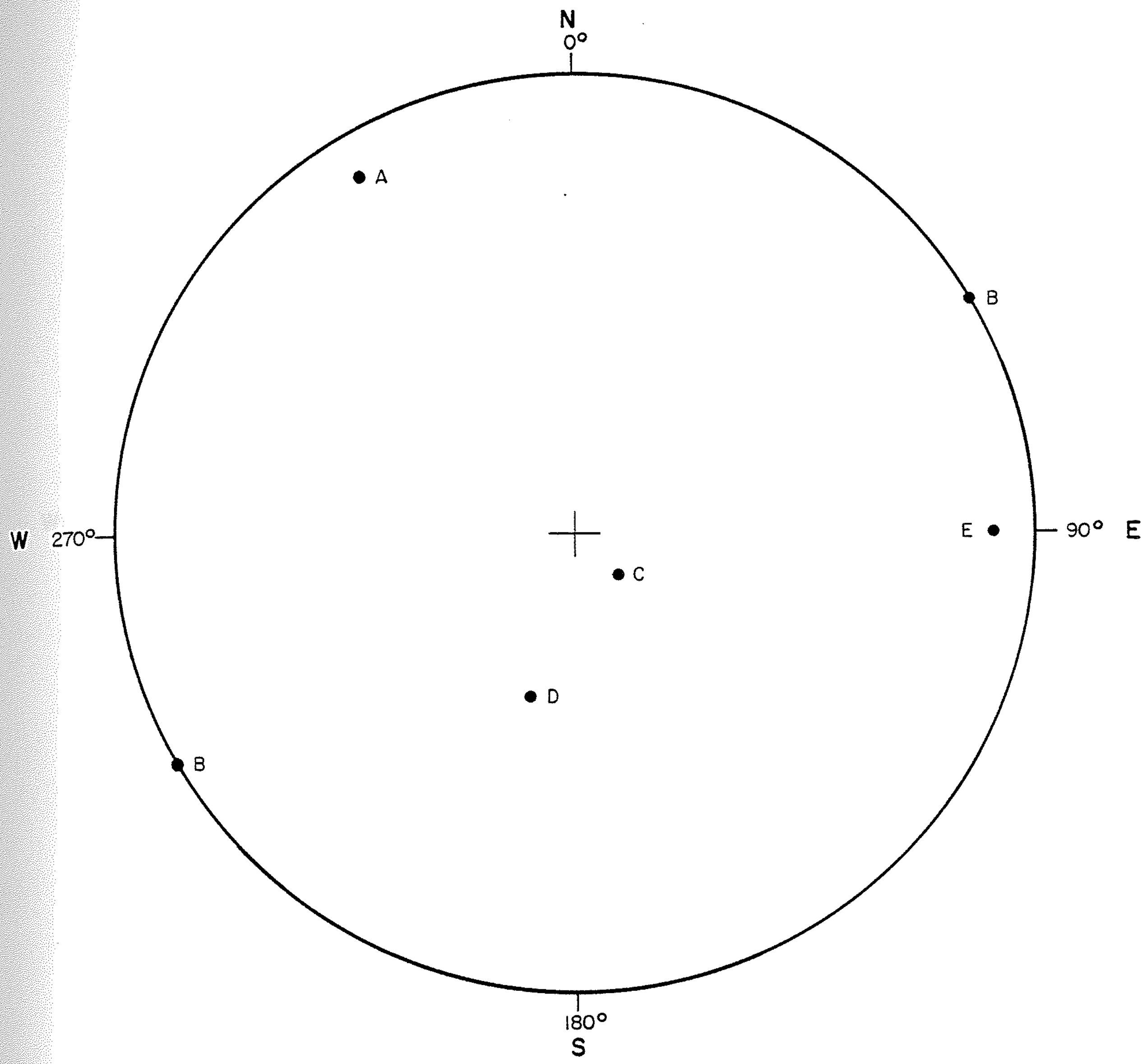
ACRES



REFERENCES : 1. WPRS, 1960
2. CORPS OF ENGINEERS, 1978
3. ACRES AMERICAN INC., 1980

DEVIL CANYON GEOLOGIC CROSS SECTION

FIGURE 6.13



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

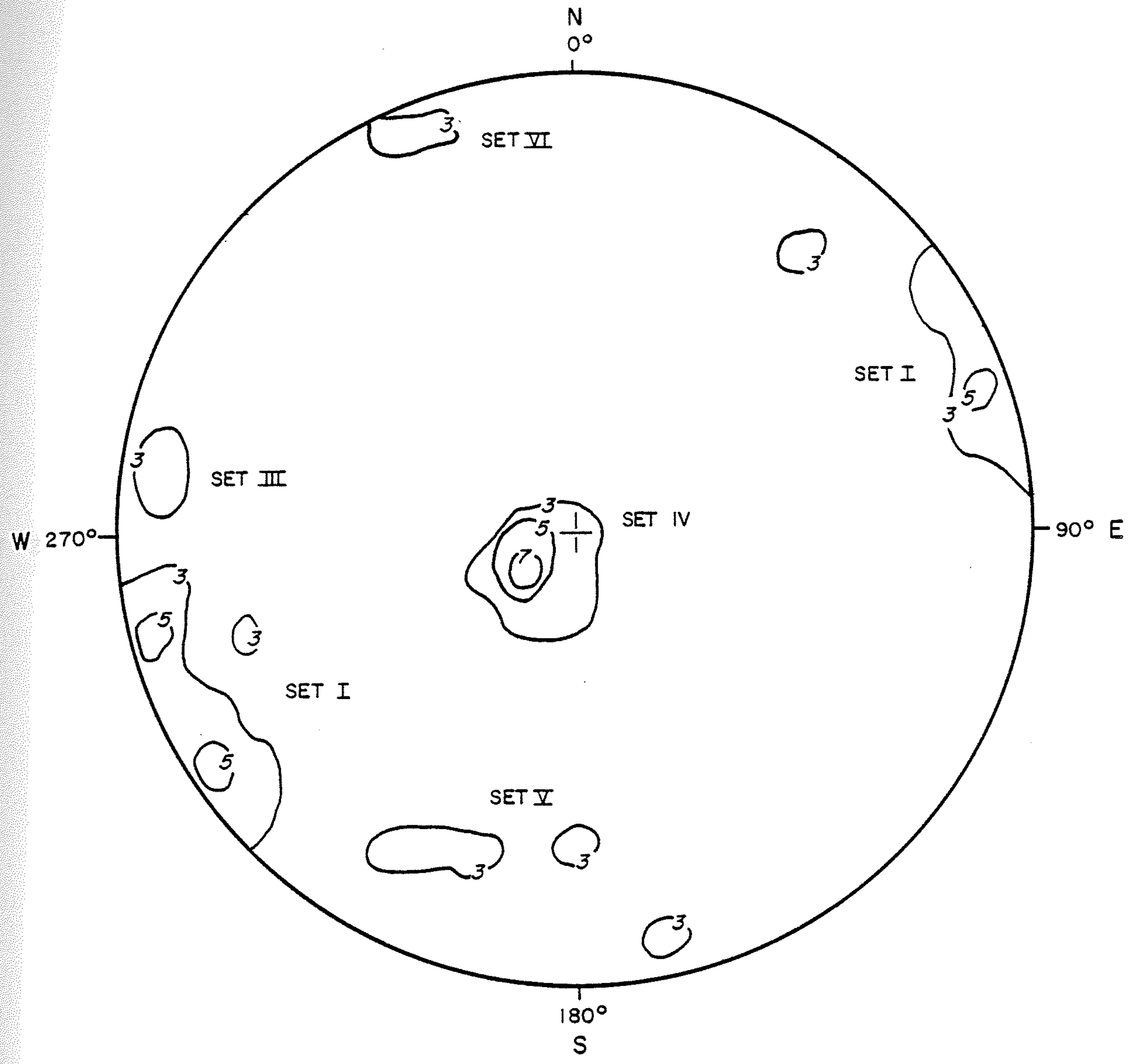
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

SAMPLE POINT PLOTS

POINT	STRIKE	DIP
A	N60°E	80°SE
B	N30°W	90°
C	N45°E	10°NW
D	N75°W	30°NE
E	N-S	80°W

JOINT PLOTTING METHOD

FIGURE 6.6a



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

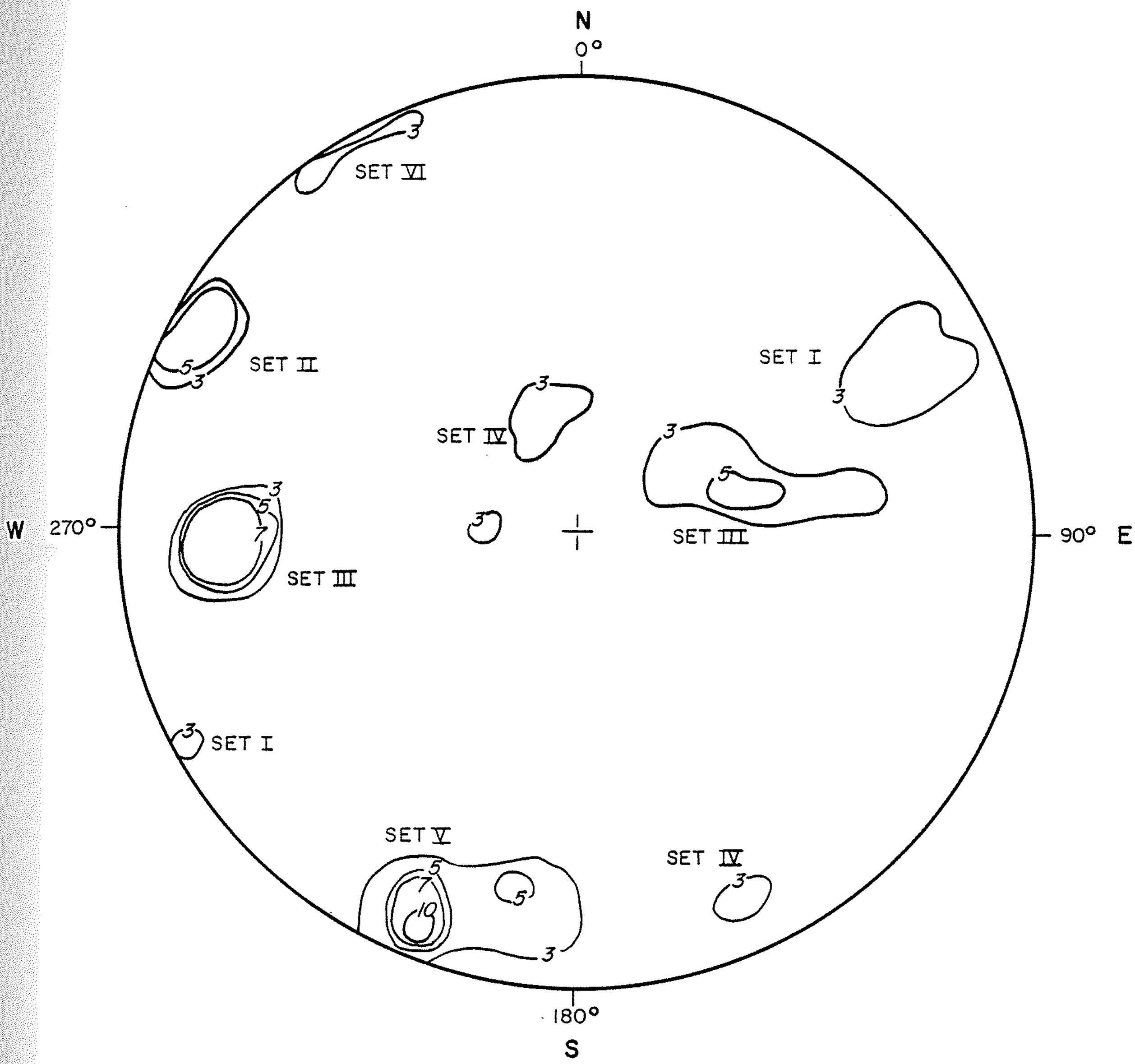
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 86.

JOINT STEREOGRAPHIC PLOTS - WATANA
WJ-1

FIGURE 6.6b

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

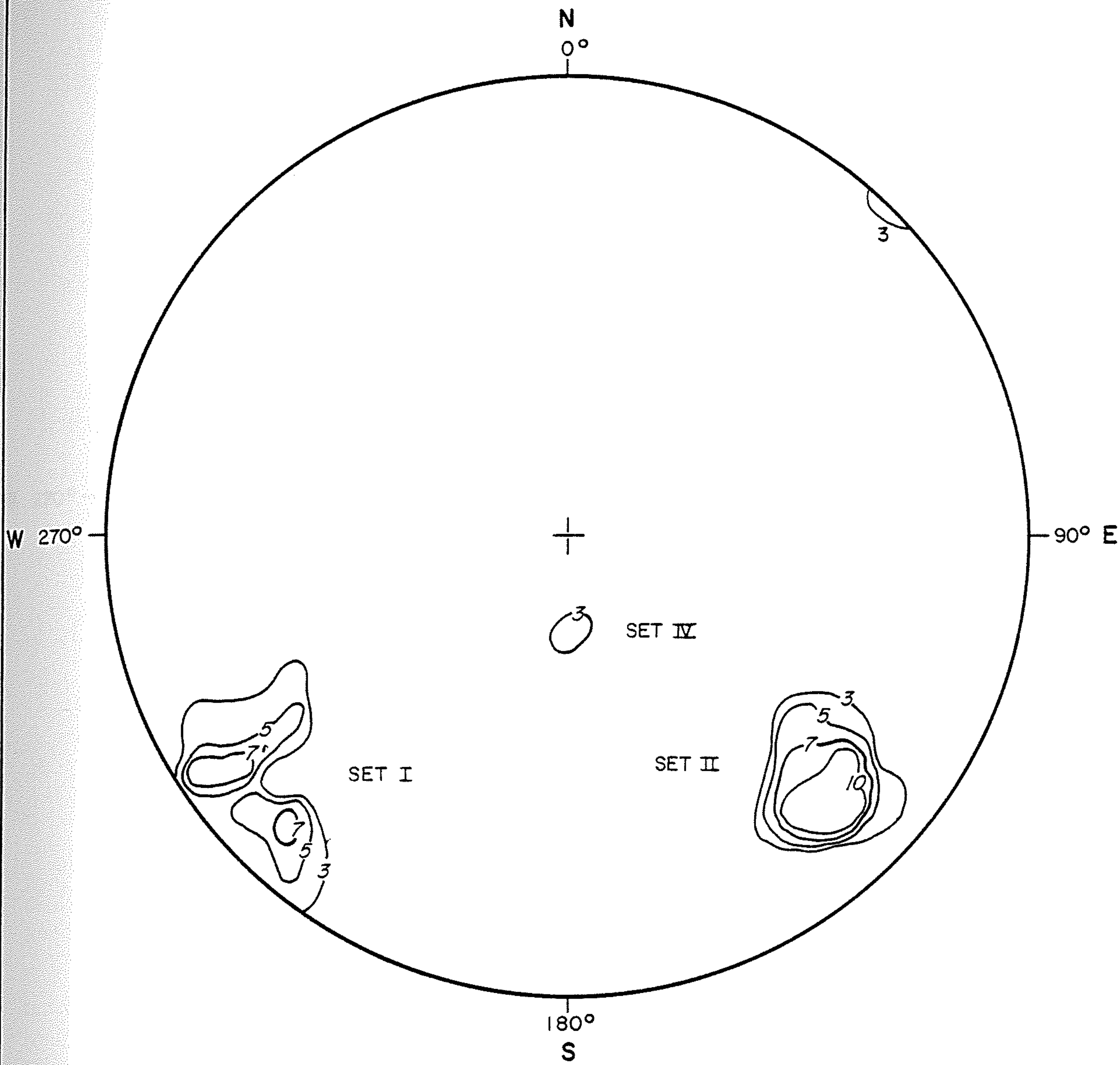
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 60.

WATANA - JOINT CONTOUR PLOT
STATION WJ-2

FIGURE 6.6c

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

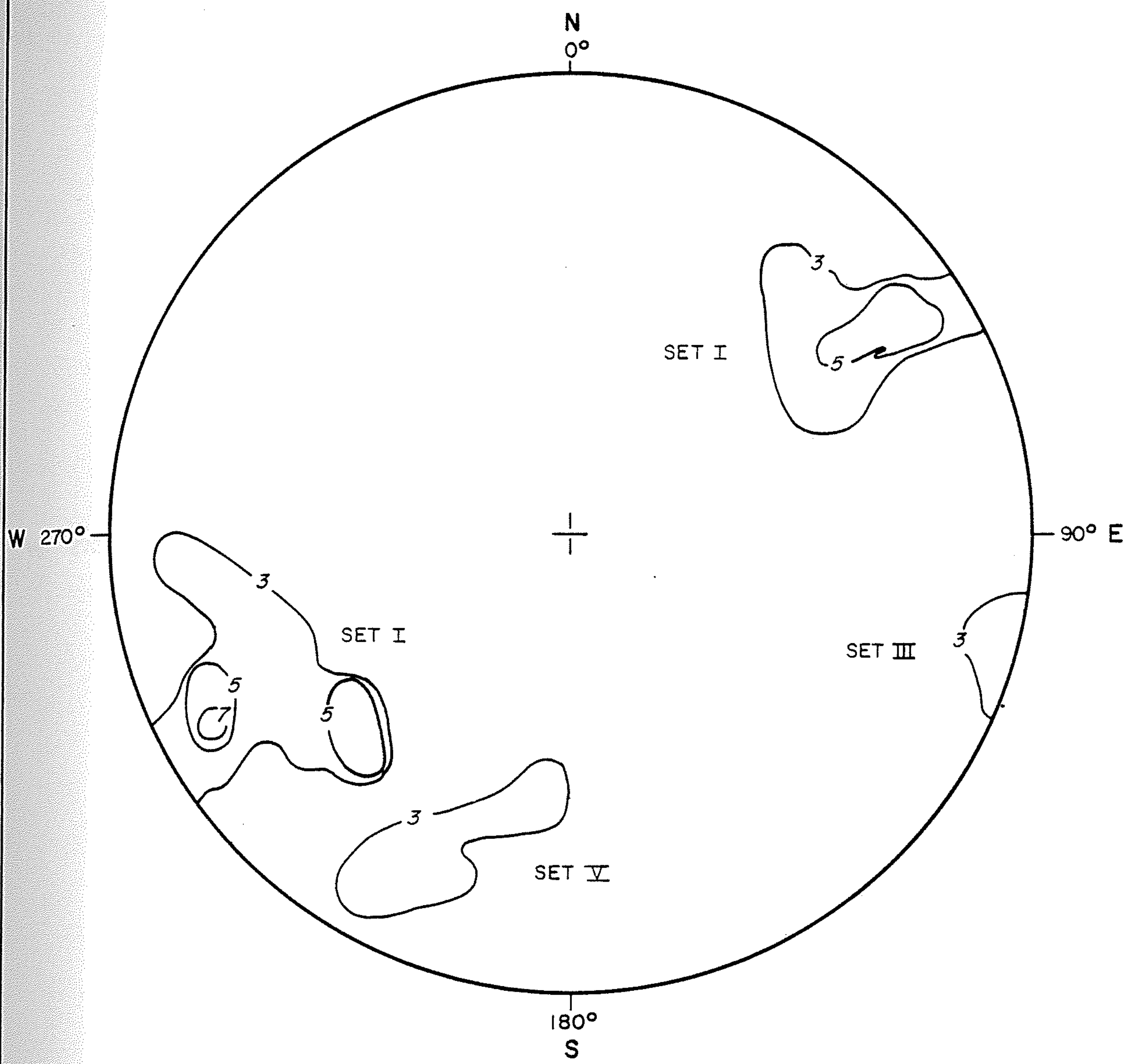
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 80.

WATANA - JOINT CONTOUR PLOT
STATION WJ-3

FIGURE 6.6d

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

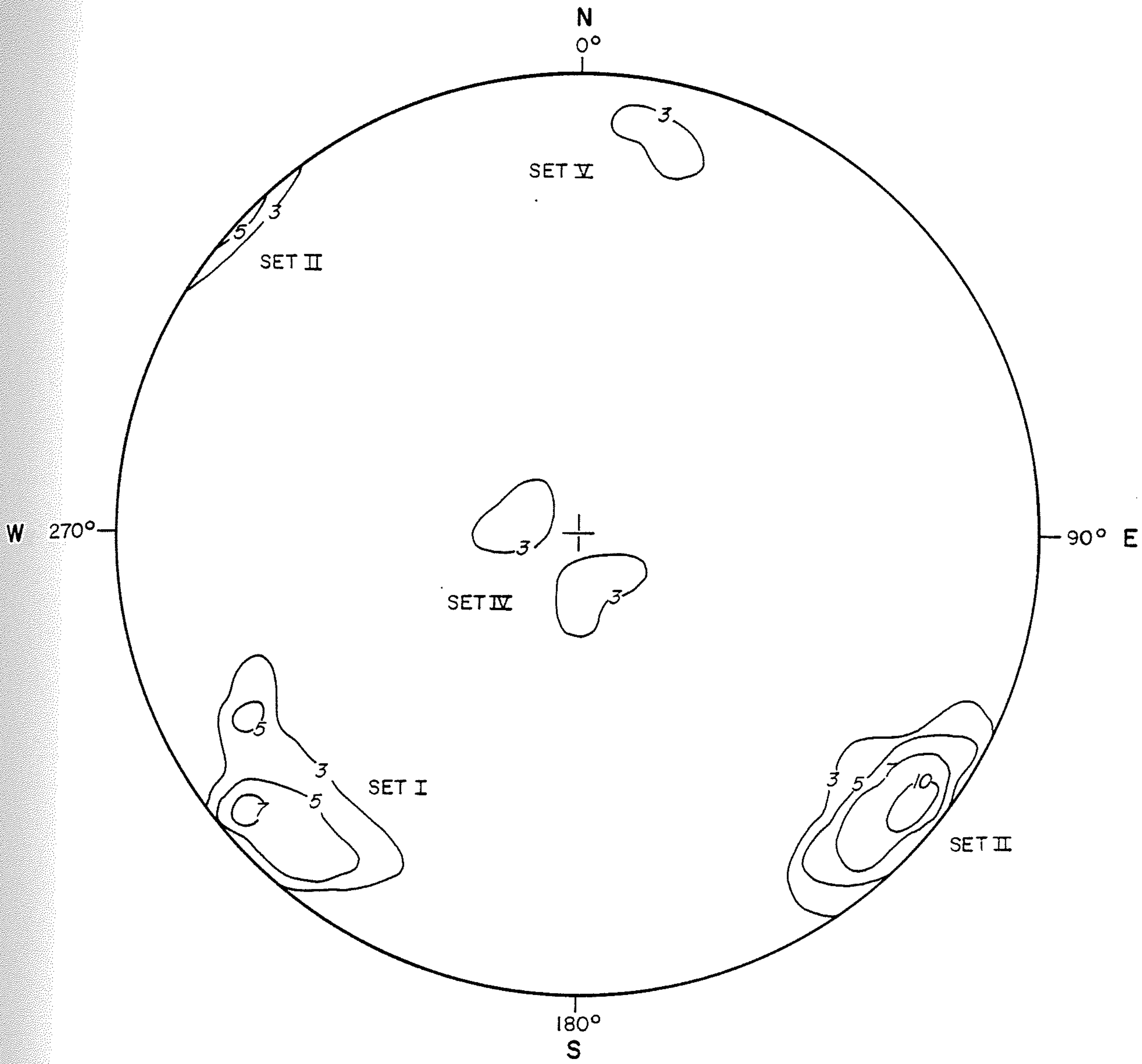
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-4

FIGURE 6.6e

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

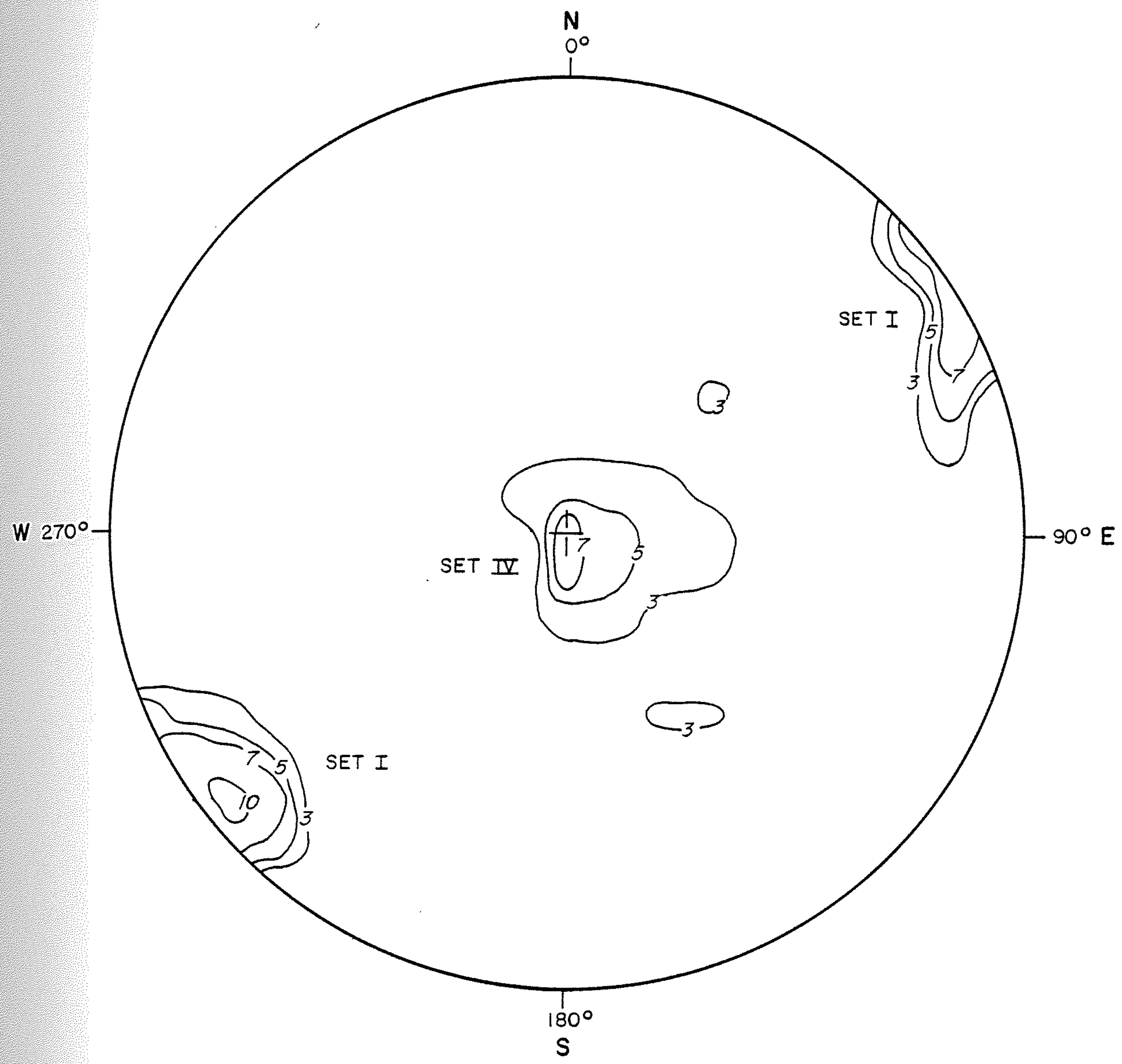
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA-JOINT CONTOUR PLOT
STATION WJ-5

FIGURE 6.6f

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

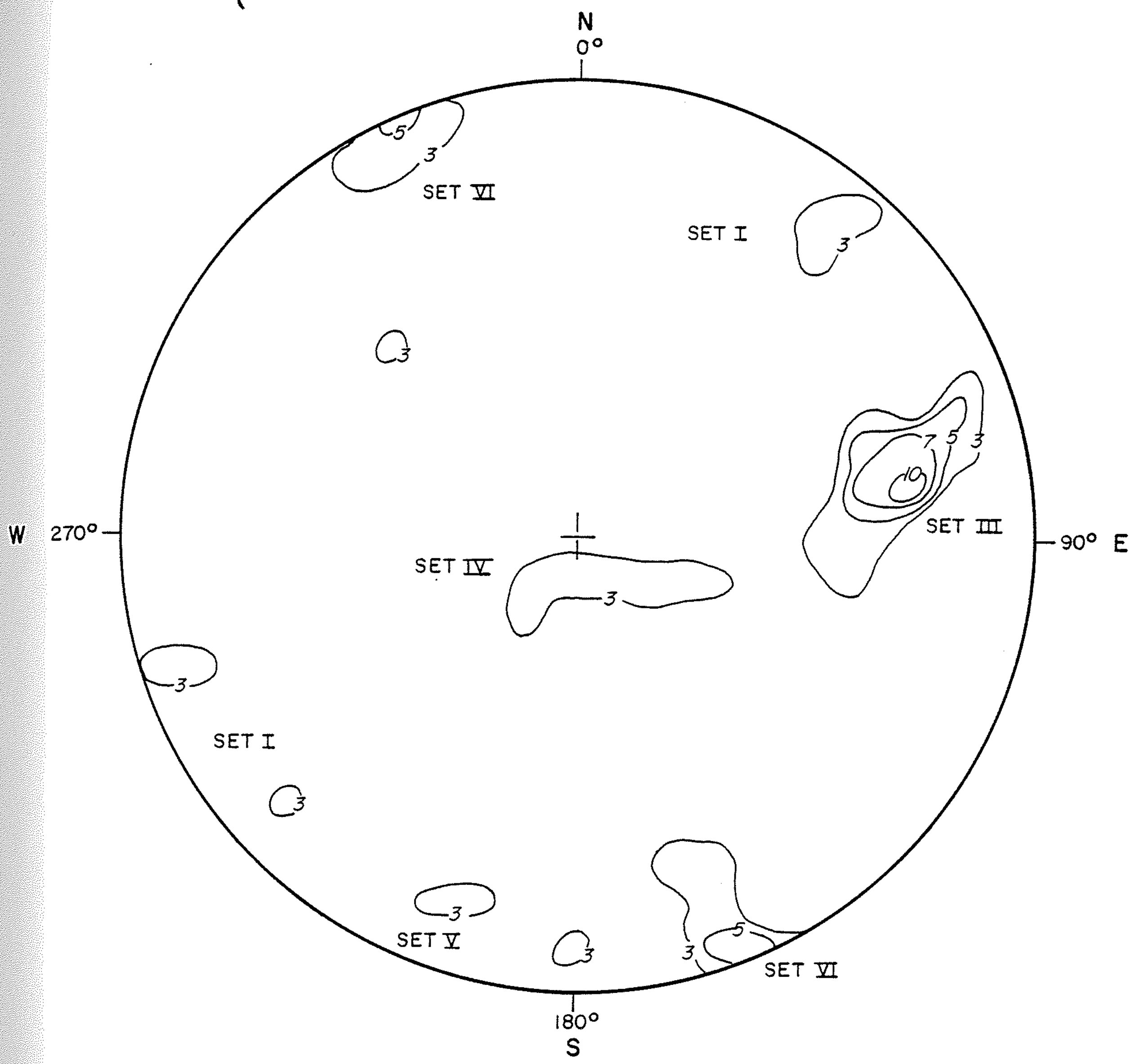
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

JOINT STEREOGRAPHIC PLOTS - WATANA
WJ-6

FIGURE 6.6g

ACRES



NOTES:

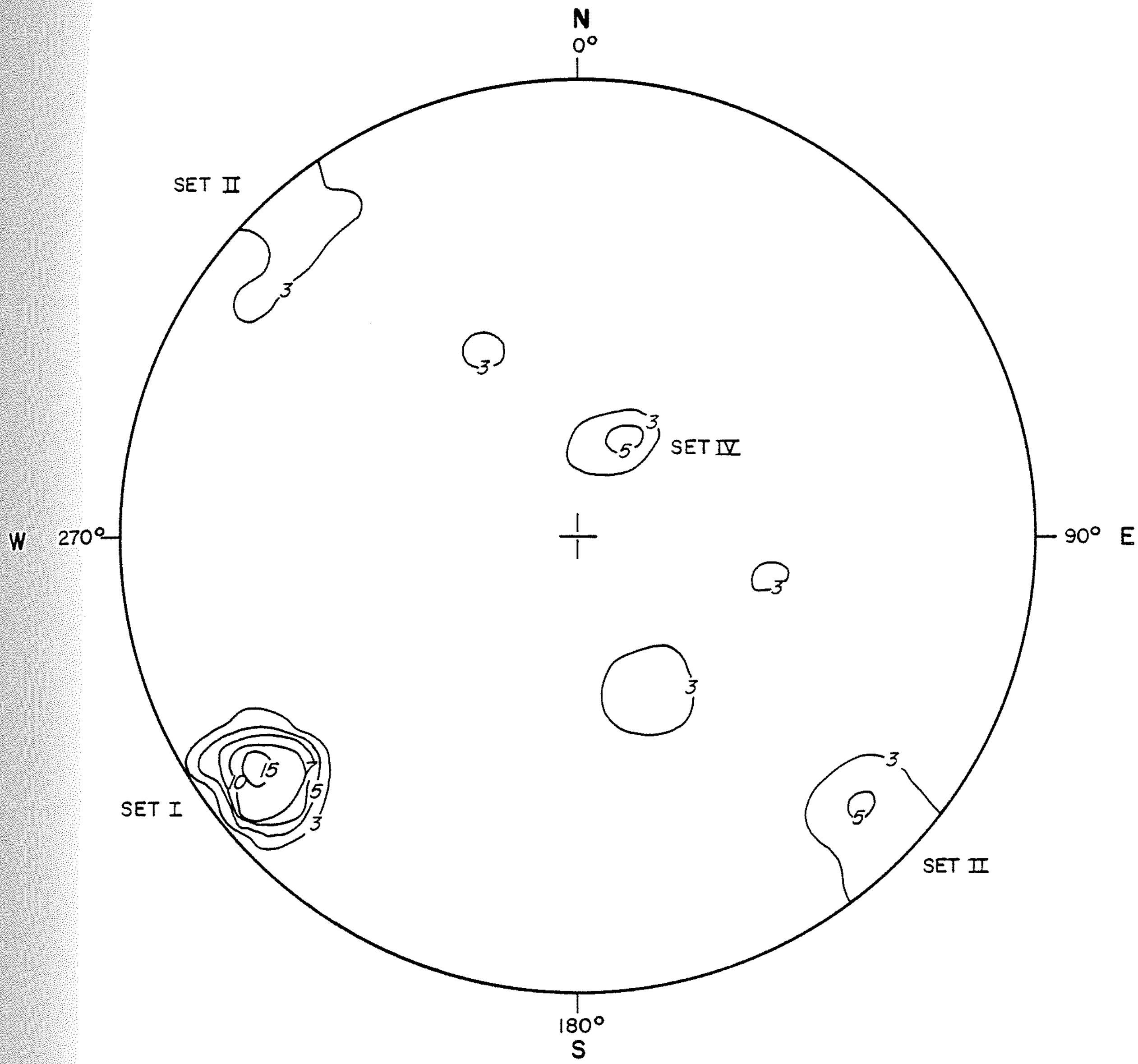
1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-7

FIGURE 6.6h



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

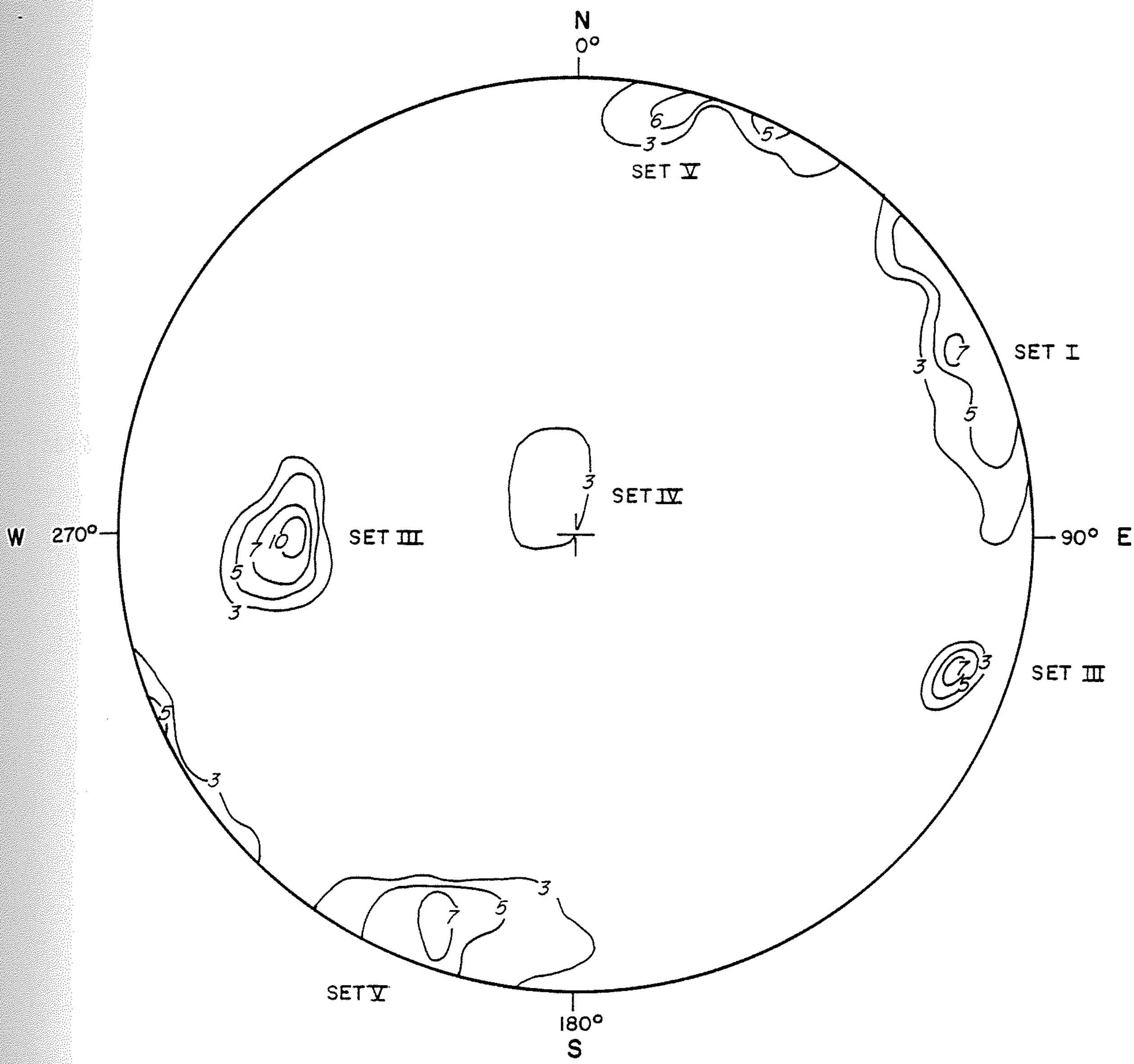
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-8

FIGURE 6.6i

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

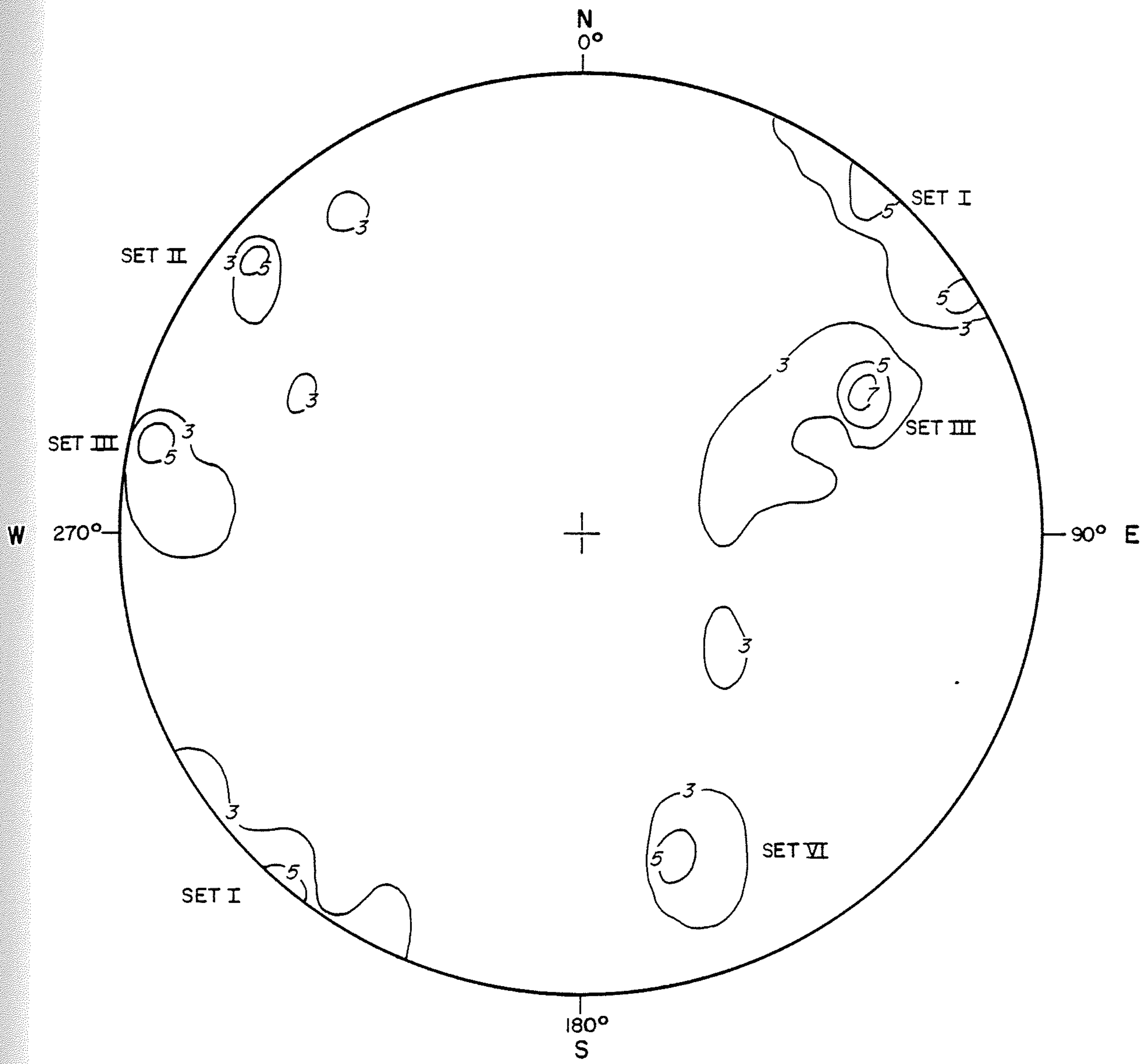
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-9

FIGURE 6.6j

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

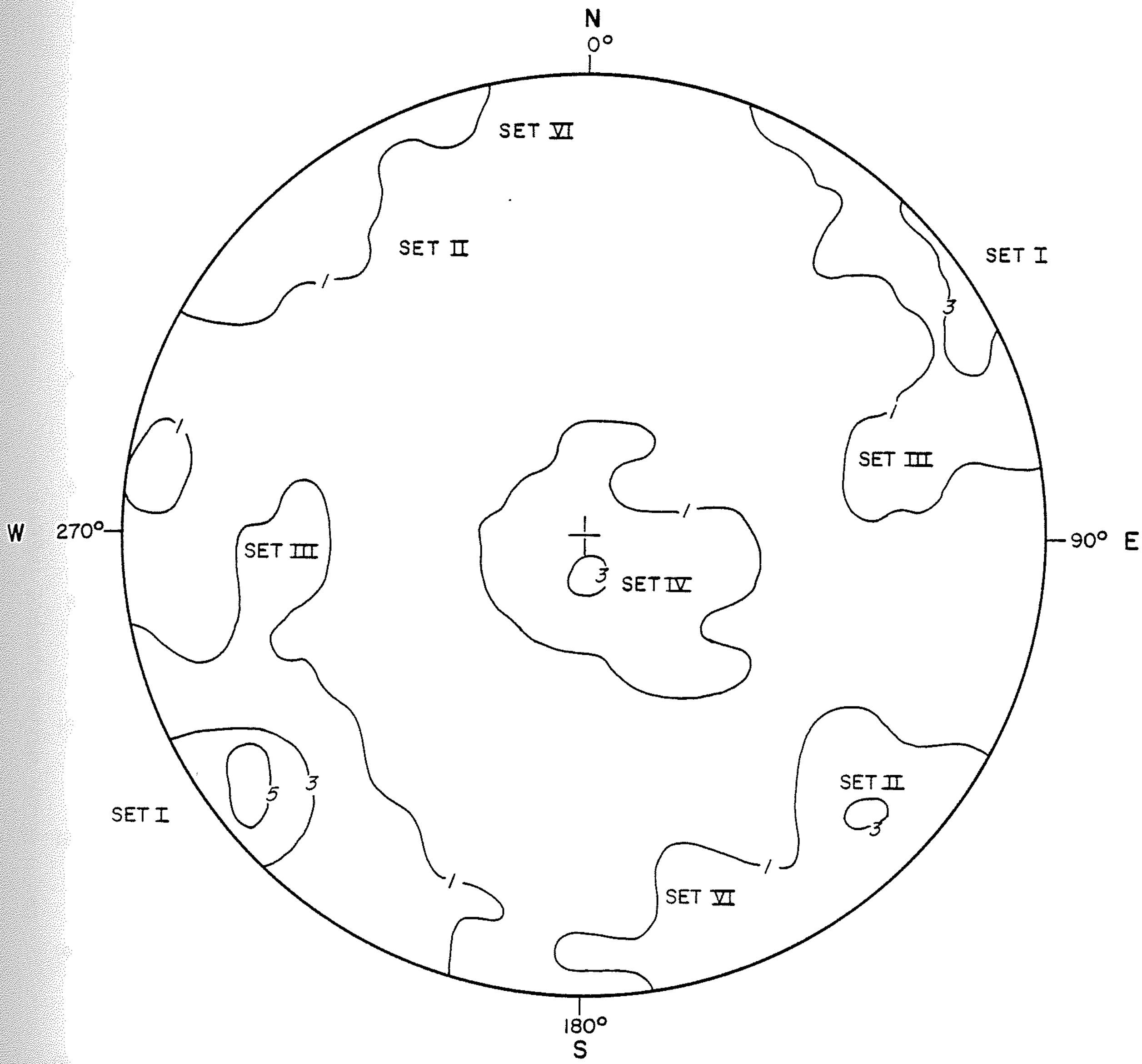
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

WATANA - JOINT CONTOUR PLOT
STATION WJ-10

FIGURE 6.6 k

ACRES



NOTES:

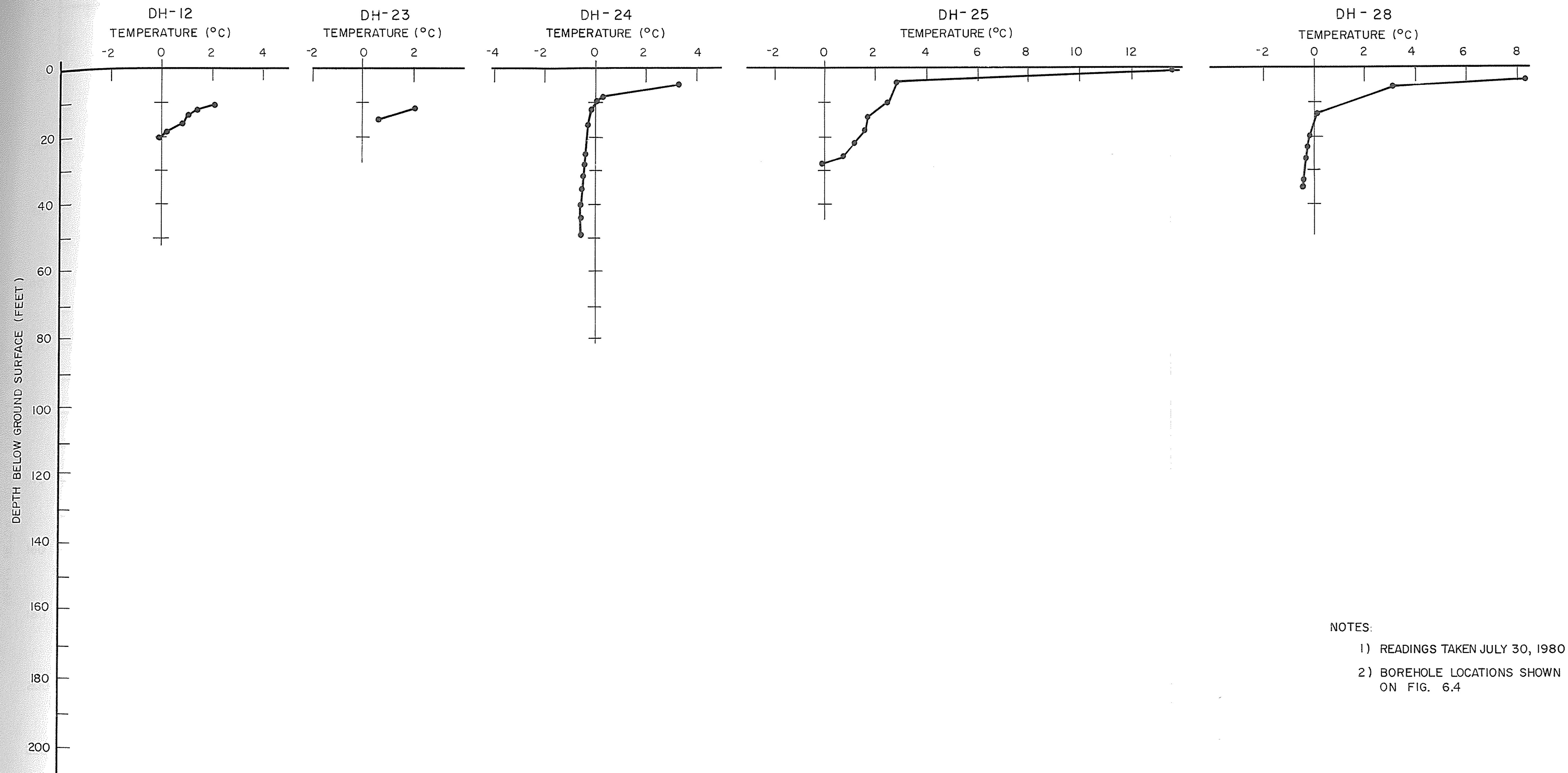
1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

WATANA - JOINT CONTOUR PLOT
COMPOSITE

FIGURE 6.6 L

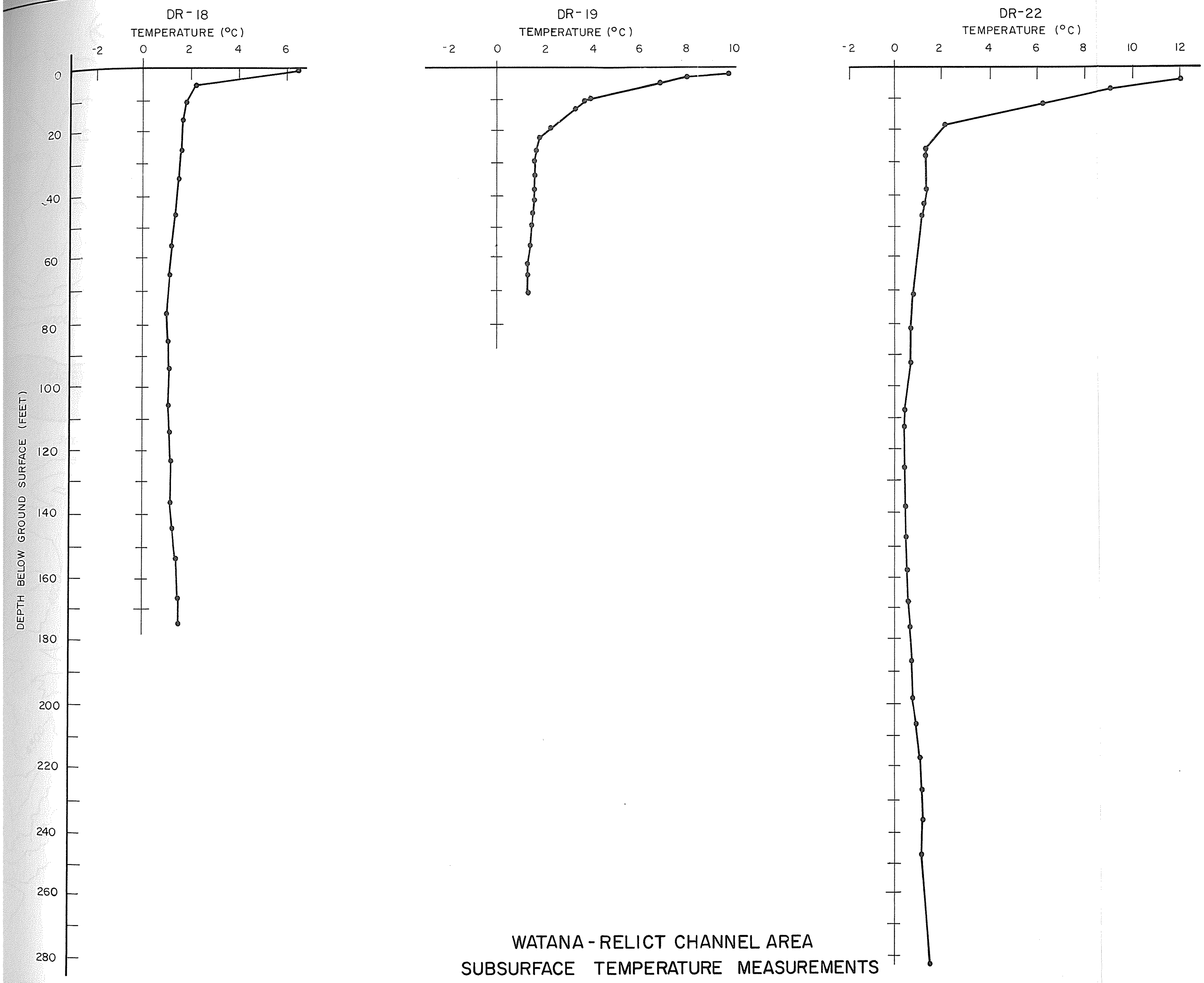
ACRES



WATANA DAM SITE –
SUBSURFACE TEMPERATURE MEASUREMENTS

ACRES

FIGURE 6.7

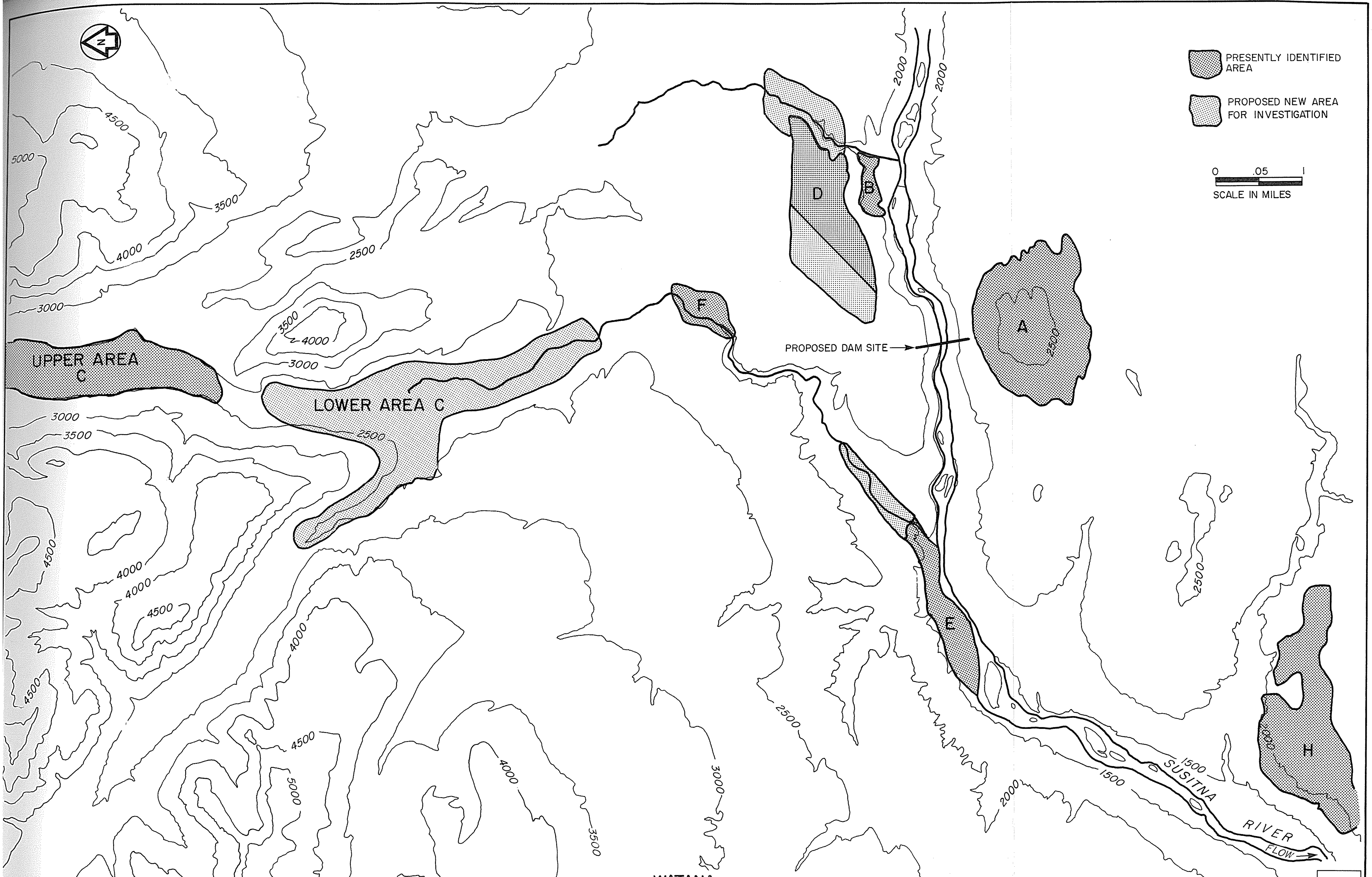


NOTES:
1) READINGS TAKEN JULY 30, 1980
2) BOREHOLE LOCATIONS SHOWN ON FIG. 6.4

WATANA - RELICT CHANNEL AREA
SUBSURFACE TEMPERATURE MEASUREMENTS

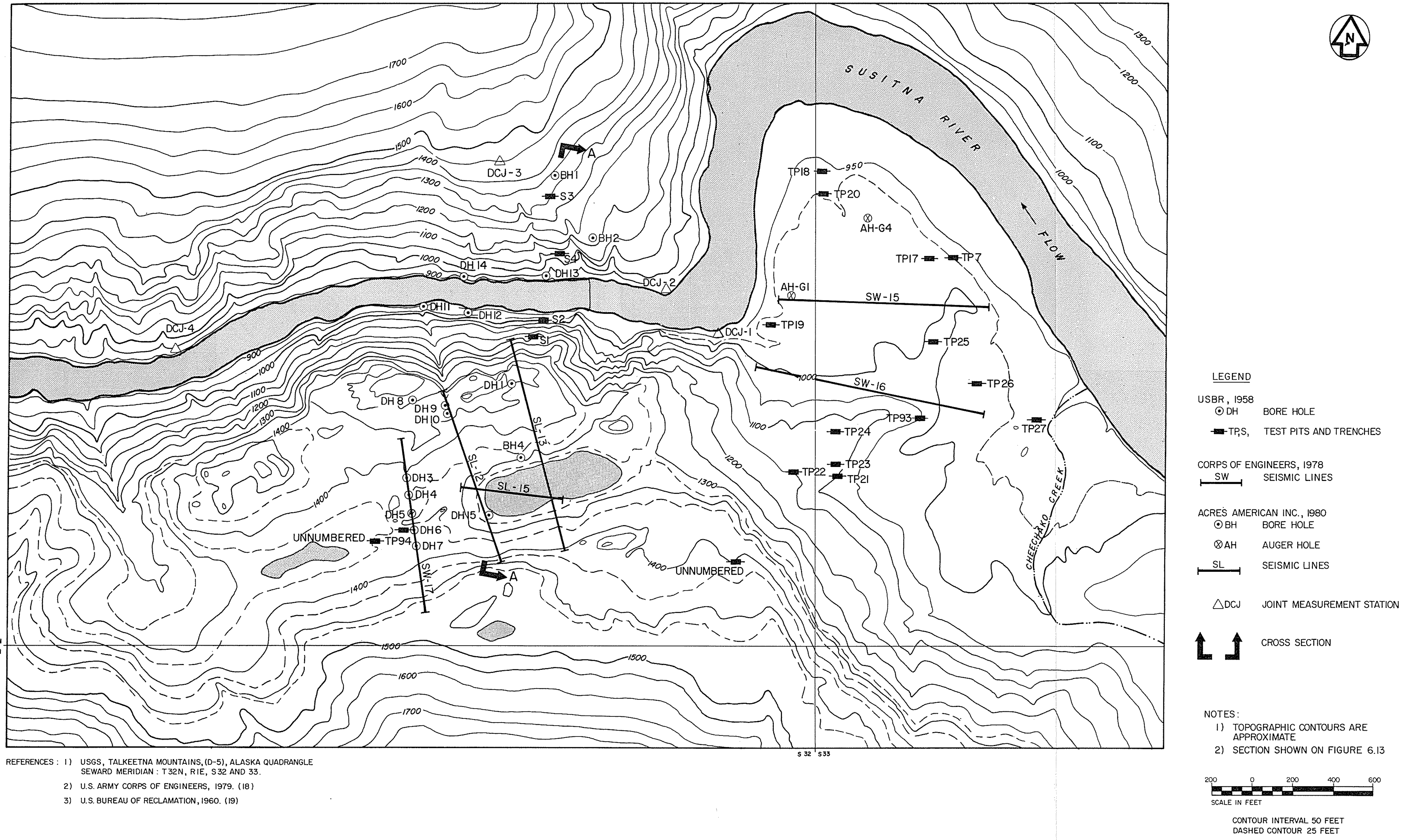
ACRES

FIGURE 6.8



WATANA - POTENTIAL BORROW AREAS

FIGURE 6.9

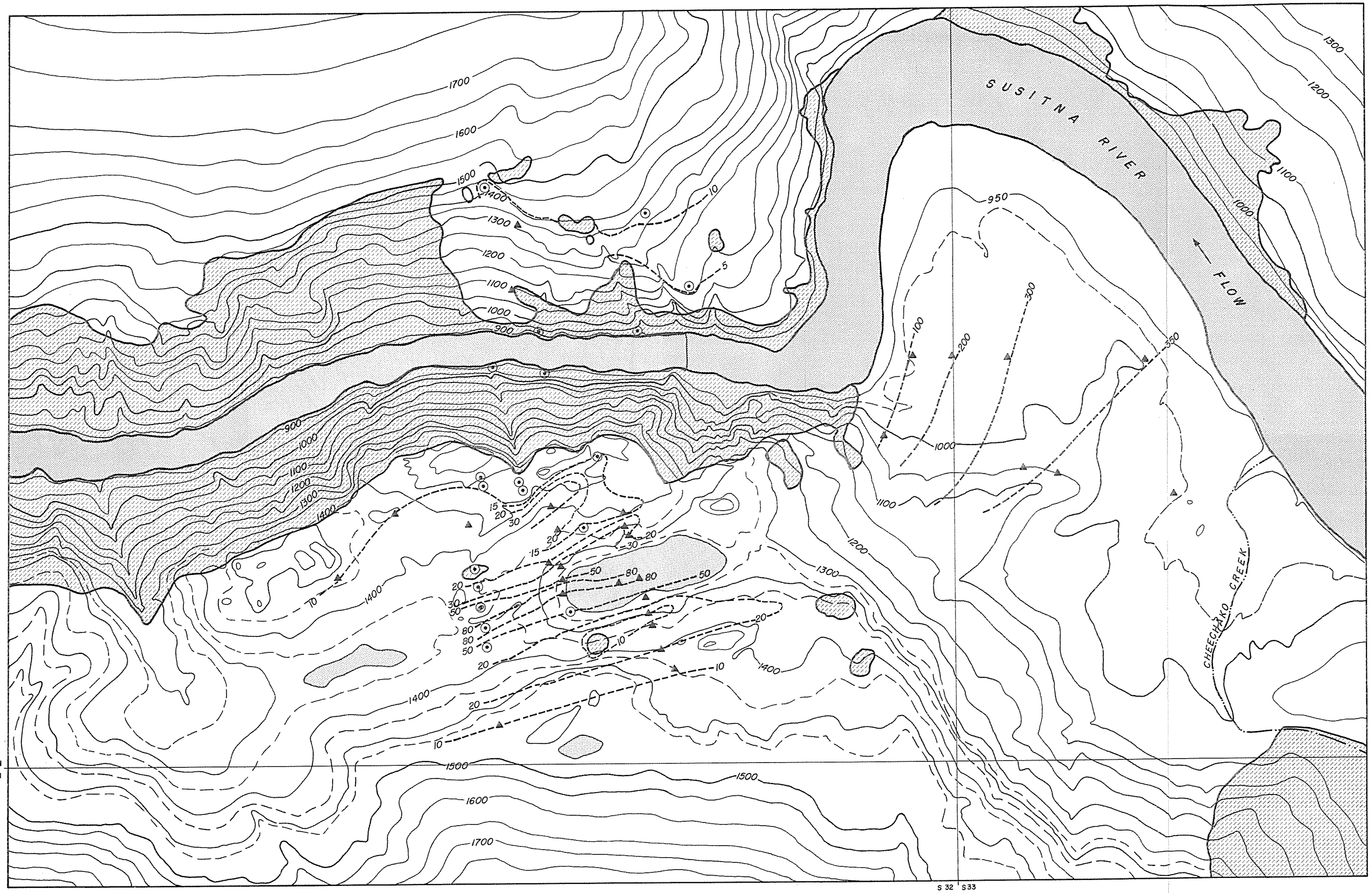


REFERENCES :
1) USGS, TALKEETNA MOUNTAINS, (D-5), ALASKA QUADRANGLE SEWARD MERIDIAN : T32N, R1E, S32 AND 33.
2) U.S. ARMY CORPS OF ENGINEERS, 1979. (18)
3) U.S. BUREAU OF RECLAMATION, 1960. (19)

DEVIL CANYON - EXPLORATION LOCATION MAP

FIGURE 6.10

ACRES



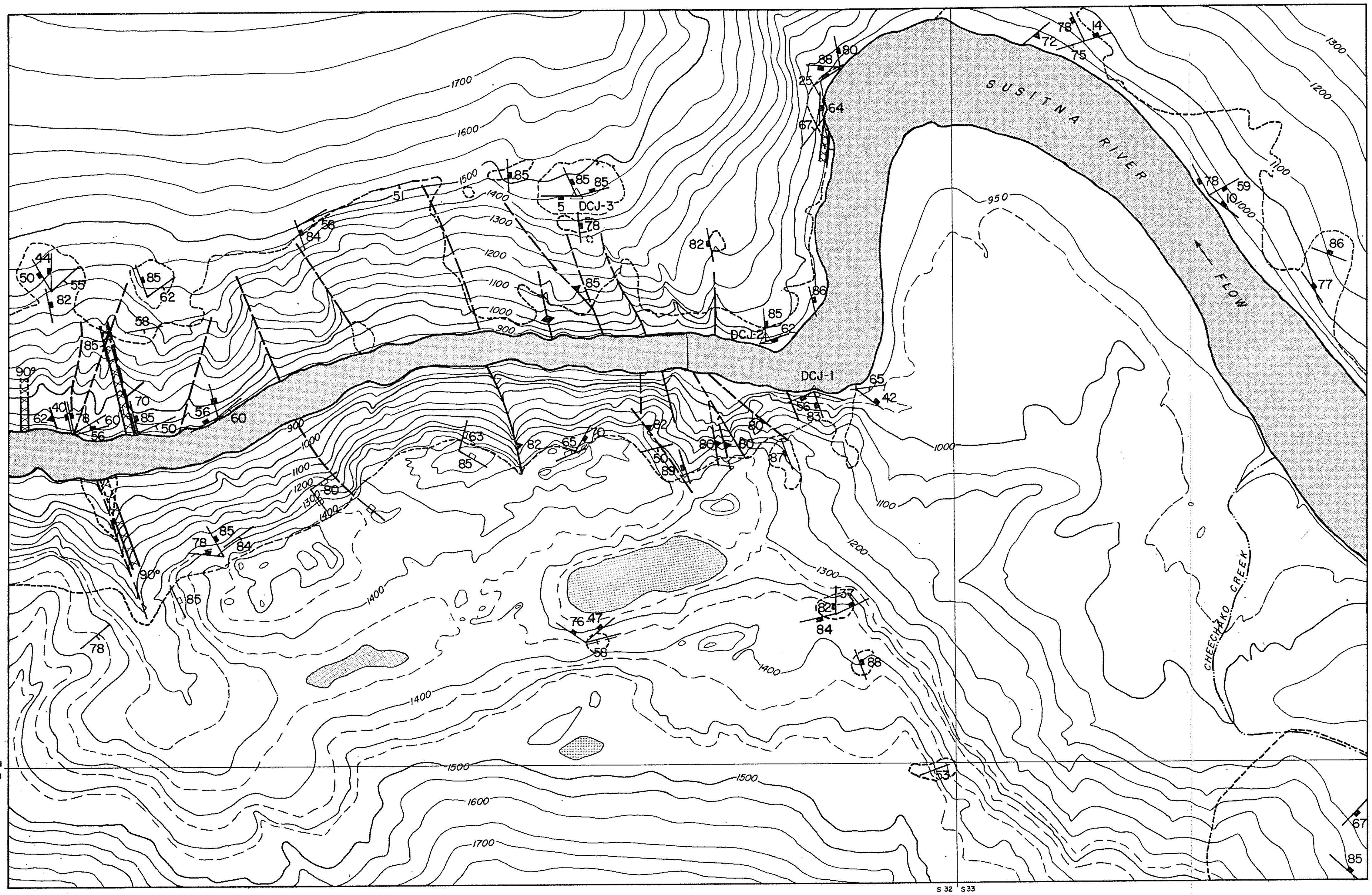
REFERENCE : USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN : T 32N, R1E, S32 AND 33.

NOTES:
1) TOPOGRAPHIC CONTOURS ARE APPROXIMATE
2) ISOPACH CONTOURS ARE IN FEET BELOW GROUND SURFACE

DEVIL CANYON - OVERBURDEN ISOPACH MAP

FIGURE 6.11

ACRES



REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDAN: T32N, R1E, S32, AND 33.

LEGEND

- 65 — STRIKE AND DIP OF BEDS
- 75 — STRIKE AND DIP OF JOINTS
- 85 — STRIKE AND DIP OF OPEN JOINTS
- MAJOR OUTCROPS OF ARGILLITE, GRAYWACKE
- DIKE, FELSIC
- SHEAR ZONE, (DASHED WHERE INDEFINITE)
- △DCJ-2 JOINT MEASUREMENT STATION

NOTES:

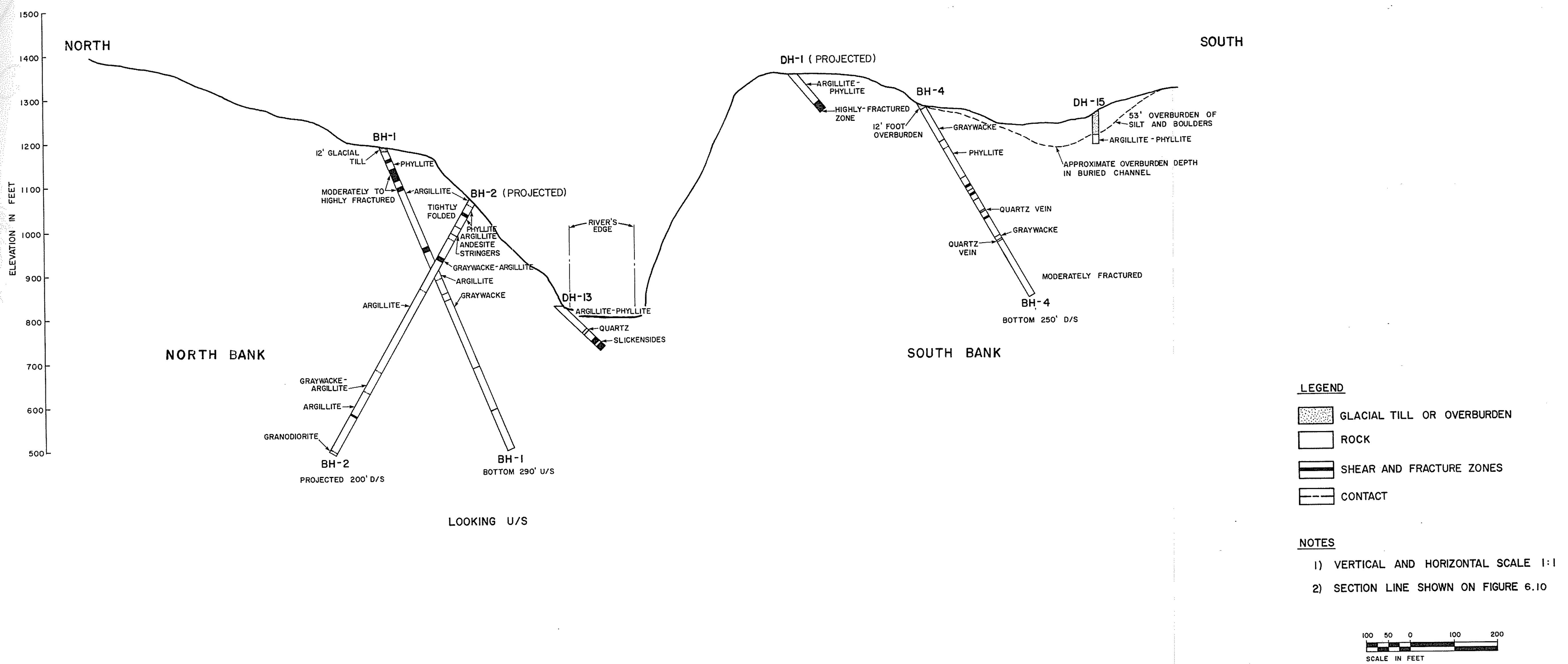
1) GEOLOGIC MAPPING UNDERTAKEN AT THE SCALE OF 1:24,000 (AERIAL PHOTOGRAPHS)
2) TOPOGRAPHIC CONTOURS ARE APPROXIMATE
3) MODIFIED FROM: KACHADOORIAN, 1974 (10)

200 0 200 400 600
SCALE IN FEET

DEVIL CANYON - GEOLOGIC MAP

FIGURE 6.12

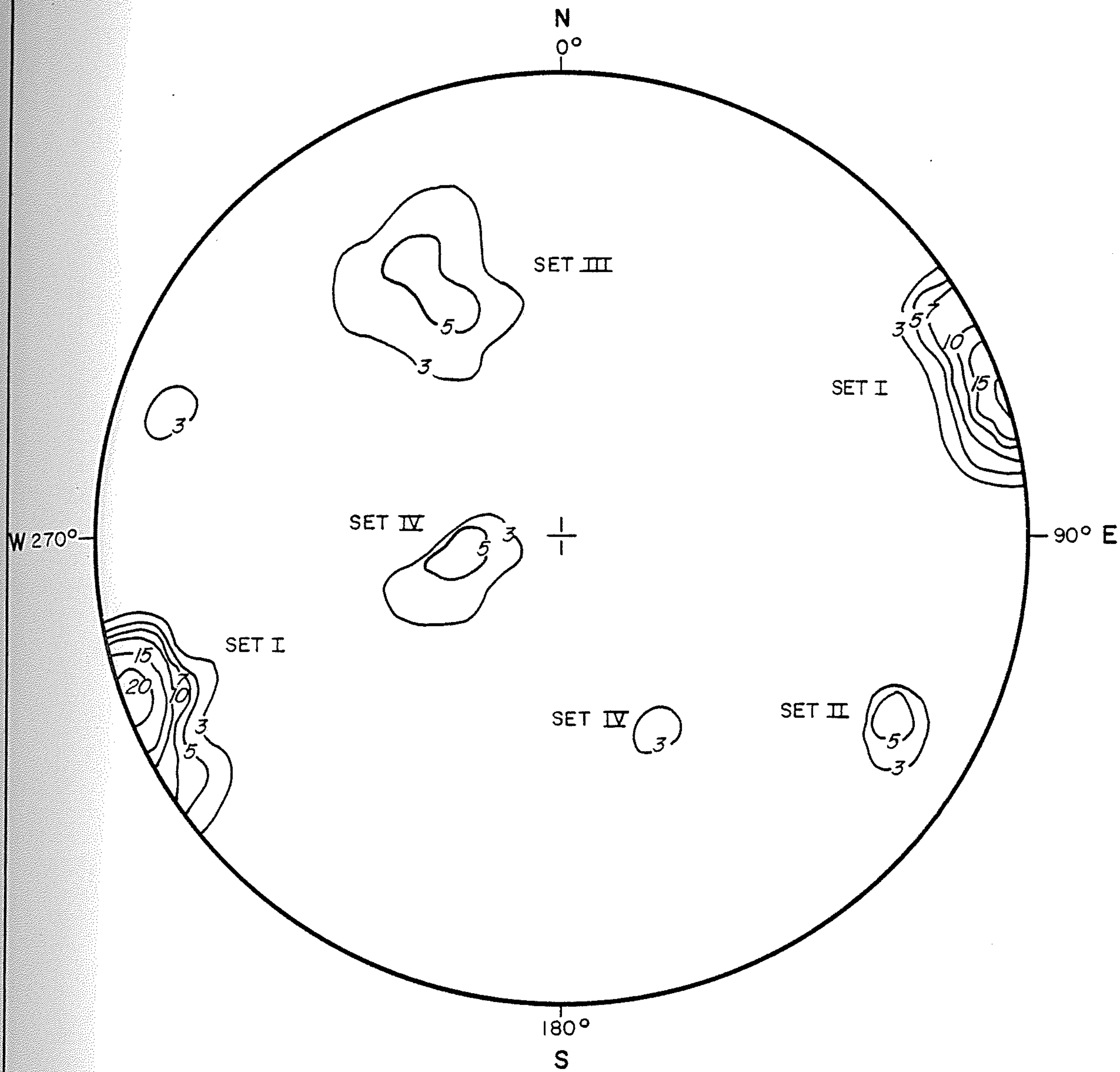
ACRES



REFERENCES : 1. WPRS, 1960
2. CORPS OF ENGINEERS, 1978
3. ACRES AMERICAN INC., 1980

DEVIL CANYON GEOLOGIC CROSS SECTION

FIGURE 6.13



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

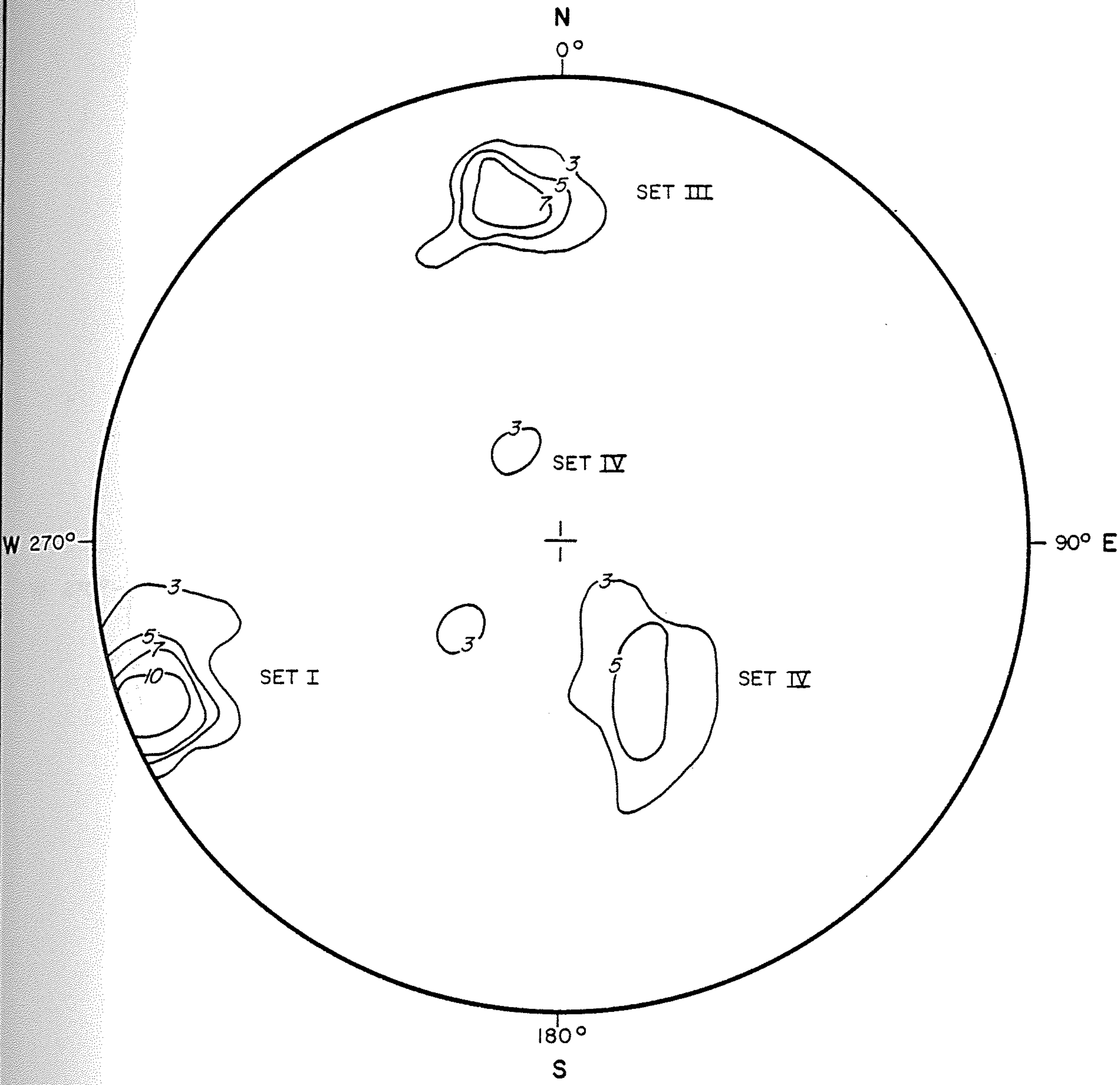
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 93.

DEVIL CANYON - JOINT CONTOUR PLOT
STATION DCJ-1

FIGURE 6.14 a

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

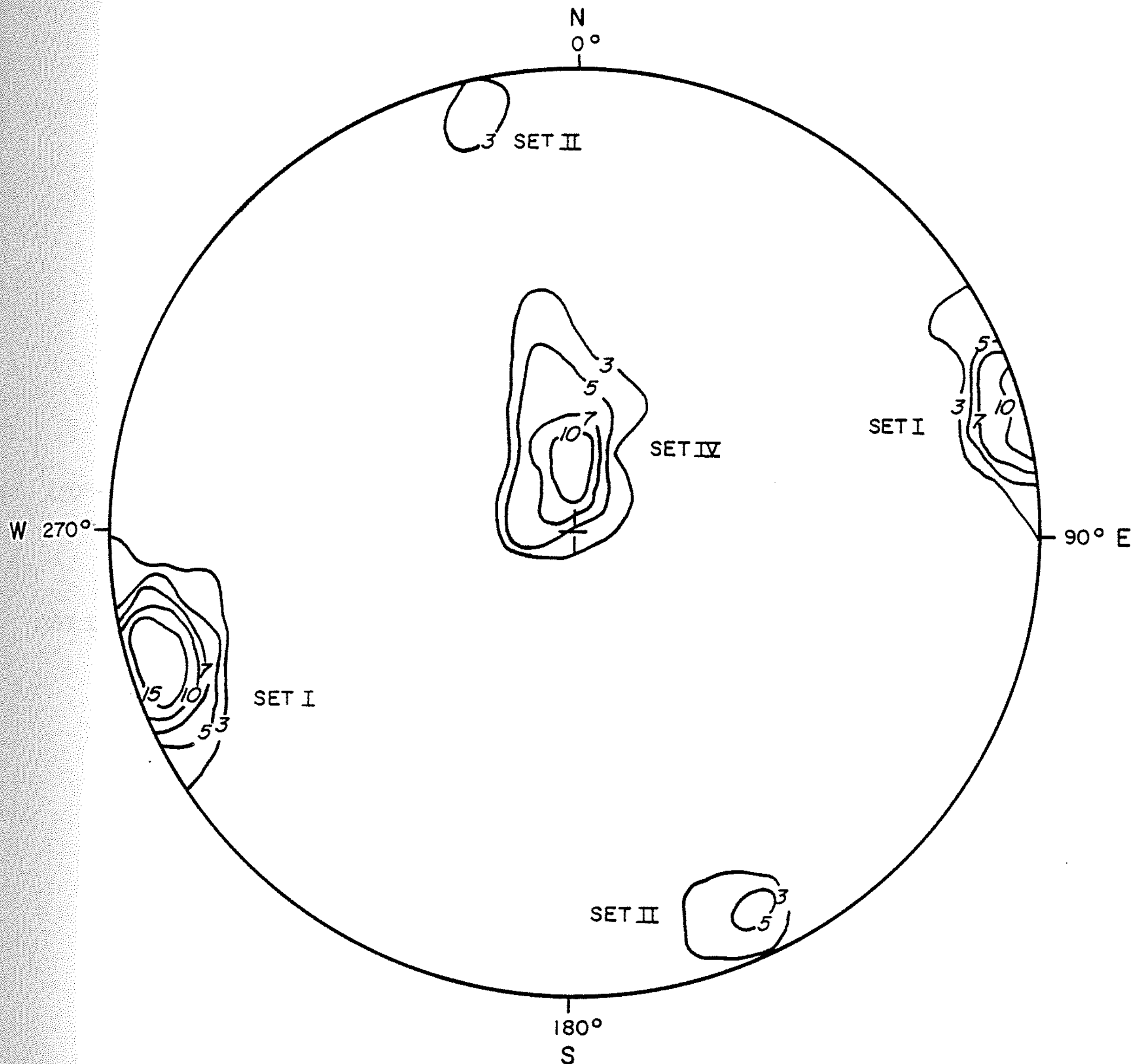
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

DEVIL CANYON - JOINT CONTOUR PLOT
STATION DCJ-2

FIGURE 6.14 b

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

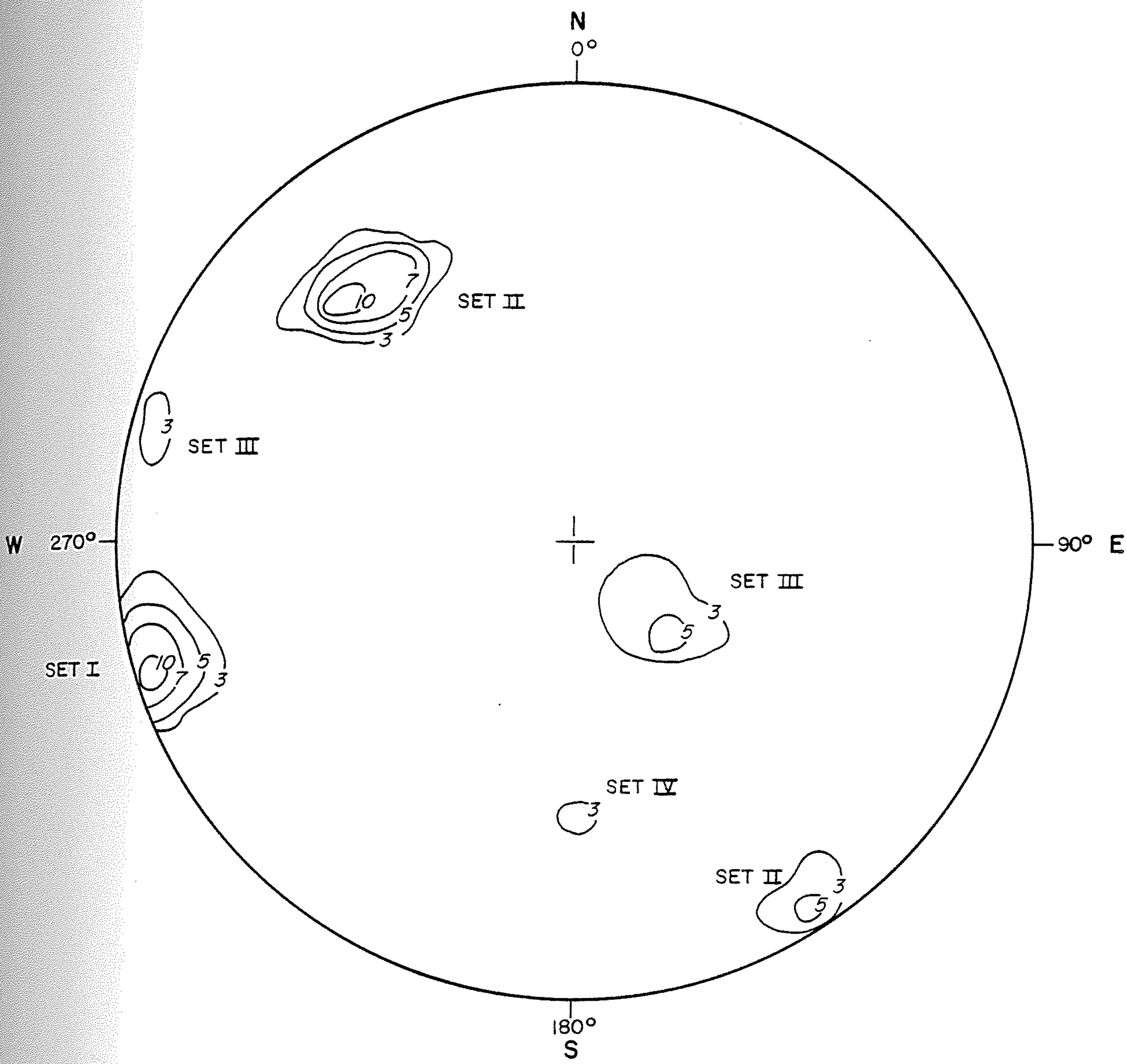
2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

DEVIL CANYON - JOINT CONTOUR PLOT
STATION DCJ-3

FIGURE 6.14 c

ACRES



NOTES:

1. PLOTTING BY PROJECTION OF PERPENDICULARS TO JOINT PLANES ON SURFACE OF LOWER HEMISPHERE. POINTS ARE PLOTTED ON AN EQUAL-AREA NET.

2. CONTOURS ARE NUMBER OF JOINTS PER 1% OF AREA.

3. NUMBER OF POINTS IS 100.

DEVIL CANYON - JOINT CONTOUR PLOT
STATION DCJ-4

FIGURE 6.14d

ACRES

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APPENDIX A

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APPENDIX B

DIAMOND CORE DRILLING

Prepared By: R&M Consultants, Inc.

APPENDIX B-1

WATANA REPORTS

ACRES AMERICAN INCORPORATED
CONSULTING ENGINEERS
BUFFALO, NEW YORK

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS
ANCHORAGE, ALASKA

DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2

SITE WATANA NORTH ABUTMENT — JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR THE DRILLING COMPANY — STARTED 11:30 P.M. July 14 1980 — FINISHED 4:00 P.M. July 27 1980

DRILLING METHOD — SOIL CASING ADVANCER — CASING DIAM. NW (3.5" O.D.)
ROCK DIAMOND CORE DRILL — CORE DIAM. NQ - 3(1.75")

LOCATION:
LATITUDE N 62° 49' 33.281"
DEPARTURE W 148° 33' 9.157"
BEARING 45°
INITIAL DIP 55°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1835 ft.
ROCK SURFACE 1826.8 ft.
BOTTOM OF HOLE 1506.5 ft.
WATER TABLE 1765 ft. (7-28-80)

NOTE: All depths are along hole.

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN (ft)	% CORE REC. (RQD.)
0.0	Overburden	Soil containing fragments of green igneous rock, fine to medium grained with small white crystals. Grades downward to residual, highly weathered bedrock. 0.0 - 10.0' No samples taken.		
10.0	Andesite	Greenish to dark bluish-gray, fine to medium grained groundmass with white plagioclase phenocrysts. Flow structures. Very hard. Fresh to slightly weathered. Joint spacing very close to close. Joint and fracture surfaces rough, with Iron-oxide staining, often thin clay coatings. Disseminated sulfides throughout. 16.7 Gouge. Core loss 0.2'.	Run 1 10.0 to 15.0 Run 2 15.0 to 20.0 Run 3 20.0 to 25.0 Run 4 25.0 to 25.5	100 (50) 96 (50) 100 (66) 100 (0)

LOGGED BY Rahaim - Hagen (R&M)
Summary by Feldman
(ACRES)

APPROVED (R&M)
DATE
APPROVED (ACRES)
DATE

ACRES AMERICAN INCORPORATED
CONSULTING ENGINEERS
BUFFALO, NEW YORK

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS
ANCHORAGE, ALASKA

DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 2 OF 1

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
25.5	Andesite (cont'd)	29.6 Fracture with clay.	R 5 25.5 to 30.5
			R 6 30.5 to 35.5
			R 7 35.5 to 40.5
		40.5 - 60.8 Mafic and ultramafic inclusions. Calcite coatings common on fracture surfaces.	R 8 40.5 to 45.7
			R 9 45.7 to 50.5
			R 10 50.5 to 55.7
		(55.7 - 60.8) Core loss 0.7'.	R 11 55.7 to 60.8
		60.8 - 71.2 Incompetent, highly fractured. Many fractures healed with carbonate. (62.2) Faint slickensides.	R 12 60.8 to 63.7
			R 13 63.7 to 66.9
66.9			

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ANCHORAGE, ALASKA

DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 3 OF 13

SITE WATANA NORTH ABUTMENT
JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
66.9	Andesite (cont'd)		R 14 66.9 to 68.9	100 (50)
			R 15 68.9 to 71.2	113 (73)
		71.2 - 72.0 Altered. Clay zone. 71.2 - 81.0 Highly fractured and sheared, core loss 4.7'. Highly weathered and altered. Hole caving, core badly ground during drilling. Core loss 5.3'.	R 16 71.2 to 72.0	75 (0)
			R 17 72.0 to 75.5	26 (0)
			R 18 75.5 to 77.5	35 (0)
			R 19 77.5 to 81.0	66 (46)
		81.0 - 97.8 Highly fractured throughout, moderately hard to soft and friable locally, moderately to slightly weathered, more competent than rock above.	R 20 81.0 to 84.5	100 (71)
			R 21 84.5 to 85.0	100 (0)
			R 22 85.0 to 90.2	100 (77)
90.2				

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ANCHORAGE , ALASKA

DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 4 OF

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
90.2	Andesite (cont'd)		R 23 90.2 to 92.0
		(92.0 - 95.0) Core loss 0.5'.	R 24 92.0 to 95.0
		(95.0) Brecciated zone with clay and carbonate. Soft.	R 25 95.0 to 96.5
		(96.8) Slickensides	R 26 96.5 to 97.8
		97.8 - 121.0 Highly fractured and sheared, core loss 8.4'. Zone is highly altered and weathered throughout, moderately hard to soft and friable, clay gouge and slickensides throughout. Permeated by carbonate.	R 27 97.8 to 100.1
			R 28 100.1 to 101.8
		(101.8 - 109.6) Shear zone. Core loss 7.2'. Calcareous clay gouge with angular rock fragments.	R 29 101.8 to 108.0
			R 30 108.0 to 109.6
			R 31 109.6 to 115.2
115.2			

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DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2
SHEET NO. 5 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
115.2	Andesite (cont'd)	(118.2) Highly oxidized.	R 32 115.2 to 118.2	80 (30)
118.2	Andesite and Diorite (Transitional Zone)	Light green to gray, fine grained andesite (as described above) interlayered with light to dark green, fine to medium grained diorite (with hornblende, plagioclase, biotite, orthoclase). Rock types alternate throughout. Locally competent, slightly weathered. Very close joint spacing, numerous healed fractures. Iron staining on fracture surfaces. Calcite present in joints and fractures.	R 33 118.2 to 121.0	82 (54)
		121.0 - 141.9' Highly fractured and sheared locally. More competent than rock above, slightly to moderately weathered, with iron staining on joint surfaces.	R 34 121.0 to 125.7	89 (70)
		(123 - 128.4) Possible shear zone.	R 35 125.7 to 128.4	100 (30)
			R 36 128.4 to 131.0	100 (54)
		(131.0 - 134.8) Core loss 0.2'.	R 37 131.0 to 134.8	95 (0)
			R 38 134.8 to 139.8	100 (84)
			R 39 139.8 to 141.9	100 (0)
		141.9 - 167.9 Highly fractured and sheared, moderately hard to soft and friable locally. Generally incompetent, slightly to highly weathered, iron stained throughout.	R 40 141.9 to 144.4	80 (60)
		(141.9 - 153.7) Shear zone, core loss greater than 3 feet.		
144.4				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 6 OF

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
144.4	Andesite-Diorite (cont'd)	(144.4 - 148.0) No core recovered. Triconed through caved section.	R 41 144.4 to 148.0
		(148.0 - 151.0) Very hard but incompetent. Core loss 2.0'.	R 42 148.0 to 151.0
151.0	Diorite	Greenish gray, very fined to medium grained with porphyritic texture. Visible compositional zoning. Moderately hard to soft, moderately competent to weak and friable locally. Fresh to slightly weathered with iron staining on joint surfaces. Carbonate common throughout. Joint spacing very close to wide. Numerous fractures cemented with calcite.	R 43 151.0 to 153.7
		(151.0 - 153.7) Highly fractured and weathered, with 0.9' clay seam. Core loss 0.9'.	R 44 153.7 to 155.7
		(155.7 - 158.2) Core loss 0.5'.	R 45 155.7 to 158.2
		(158.2 - 159.5) Highly fractured and weathered. Extensive oxidation within fractures.	R 46 158.2 to 160.2
		160.2 - 167.9 Core loss 0.4'.	R 47 160.2 to 162.2
			R 48 162.2 to 167.9
		167.9 - 170.5 Abundant calcite within fractures and joints. Rock becoming more competent.	R 49 167.9 to 170.5
170.5			

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for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 7 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
170.5	Diorite (cont'd)	170.5 - 172.5 Altered. Coarse grained, friable, highly fractured and sheared. Chloritized. 172.5 - 175.8 More competent. Fine to medium grained, joint spacing moderately close. Numerous fractures healed with calcite.	R 50 170.5 to 175.8	100 (47)
		175.8 - 177.0 Sheared, incompetent, calcareous.	R 51 175.8 to 177.0	100 (0)
		177.0 - 196.4 Light green to light blue-gray. Very hard, competent, fresh. Joint spacing moderately close with occasional calcite fillings. Minor sulfide mineralization throughout.	R 52 177.0 to 181.0	90 (87)
		(177.0 - 181.0) Core loss 0.4'.	R 53 181.0 to 182.8	100 (100)
			R 54 182.8 to 186.9	100 (100)
			R 55 186.9 to 189.2	100 (100)
			R 56 189.2 to 191.0	100 (100)
		(191 - 196.4) Core loss 0.7'.	R 57 191.0 to 196.4	89 (74)
		196.4 - 197.4 Alteration zone. Highly weathered, sheared. Core loss 0.3'.	R 58 196.4 to 201.0	94 (48)
201.0				

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for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 8 OF 1

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
201.0	Diorite (cont'd)		R 59 201.0 to 203.8
		205.0 - 205.3 Highly fractured.	R 60 203.8 to 207.1
		207.1 - 209.3 Brecciated, healed. Core loss 0.4'.	R 61 207.1 to 209.3
			R 62 209.3 to 214.4
		214.4 - 218.5 Core loss 0.3'.	R 63 214.4 to 218.5
			R 64 218.5 to 223.7
		223.7 - 228.7 Medium grained. Joint spacing close. Iron staining and calcite on fracture surfaces. Core loss 0.2'.	R 65 223.7 to 228.7
		228.7 - 230.7 Joint spacing moderately close, rock more competent.	R 66 228.7 to 232.5
		230.7 - 241.0 Altered, bleached. Soft. Joint spacing close, slightly to moderately weathered. Penetrative (to approximately 1 cm) iron staining along joints. Sulfide mineralization.	R 67 232.5 to 237.7
237.7			

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HOLE NO. BH-2

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
237.7	Diorite (cont'd)	241.0 - 241.9 Altered, very soft, slick clay.	R 68 237.7 to 241.9	105 (57)
		241.9 - 252.2 Highly fractured and altered. Contains numerous soft, friable zones throughout with calcareous clay common. Many joints weakly healed with carbonate. Zone is generally incompetent (possible shear zone).	R 69 241.9 to 247.2	111 (20)
			R 70 247.2 to 252.2	104 (38)
		252.2 - 257.2 Slightly more competent.	R 71 252.2 to 257.2	100 (82)
		257.2 - 262.2 Rock weakened and slightly friable. Fractures filled with carbonate and/or clay.	R 72 257.2 to 262.2	96 (80)
		262.2 - 285.8 Light green to white. Very hard, competent, fresh. Joint spacing very close to close, calcite and pyrite on joint surfaces.	R 73 262.2 to 265.0	100 (71)
		(265.0 - 271.0) Core loss 0.5'.	R 74 265.0 to 269.0	93 (75)
			R 75 269.0 to 271.0	90 (90)
			R 76 271.0 to 276.1	100 (100)
276.1				

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HOLE NO. BH-2
SHEET NO. 10 OF 1

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
276.1	Diorite (cont'd)		R 77 276.1 to 280.6
			R 78 280.6 to 285.8
		285.8 - 287.8 Highly fractured, incompetent. Core loss 0.1'.	R 79 285.8 to 287.8
			R 80 287.8 to 291.1
			R 81 291.1 to 296.1
			R 82 296.1 to 301.1
		301.1 - 306.1 Core loss 0.4'.	R 83 301.1 to 306.1
		306.1 - 310.0 Joint spacing moderately close to wide.	R 84 306.1 to 310.2
			R 85 310.2 to 315.4
315.4			

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 11 OF 13

SITE WATANA NORTH ABUTMENT   JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION: *	LENGTH OF RUN	% CORE. REC. (RQD)
315.4	Diorite (cont'd)		R 86 315.4 to 320.6	100 (98)
		322.0 Highly altered zone. Friable.	R 87 320.6 to 325.3	100 (91)
			R 88 325.3 to 328.0	100 (85)
		328.0 - 348.6 Alteration zone, joint spacing very close to moderately close, moderately hard to soft and friable locally. Sulfide mineralization throughout. Minor calcite and chlorite on joints.	R 89 328.0 to 332.4	100 (62)
		(328.0, 331.4) Slickensides. (334.4 - 335.8) Highly altered and friable.	R 90 332.4 to 337.5	100 (90)
			R 91 337.5 to 341.0	100 (97)
			R 92 341.0 to 341.4	100 (100)
			R 93 341.4 to 346.6	100 (100)
		348.6 - 362.5 Fresh to slightly weathered, hard to very hard. Joint spacing moderately close to wide.	R 94 346.6 to 351.0	100 (84)
351.0				

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SUSITNA HYDROELECTRIC PROJECT
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HOLE NO. BH-2
SHEET NO. 12 OF

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
351.0	Diorite (cont'd)		R 95 351.0 to 356.0 R 96 356.0 to 361.0
362.5 396.3	Diorite and Andesite	Intermixed, transitional rock types. Pale green or white, to gray. Phaneritic to aphanitic texture. Fresh with some alteration zones as noted below. Hard. Joints very closely spaced. 361.0 - 366.0 Core loss 0.4'. 362.5 - 363.5 Quartz vein. 370.3 - 381.0 Calcite and sulfides in joints. (375.8 - 318.0) Core loss 0.3'. 386.2 - 386.8 Highly altered and soft. 386.8 - 401.0 Hard, fairly competent. Joint spacing very close to close. Numerous healed joints throughout.	R 97 361.0 to 366.0 R 98 366.0 to 370.6 R 99 370.6 to 375.8 R 100 375.8 to 381.0 R 101 381.0 to 386.2 R 102 386.2 to 391.2 R 103 391.2 to 396.3

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HOLE NO. BH-2
SHEET NO. 13 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
396.3	Diorite and Andersite (cont'd)		R 104 396.3 to 398.8	100 (80)
			R 105 398.8 to 401.0	100 (100)
401.0		End of Hole		

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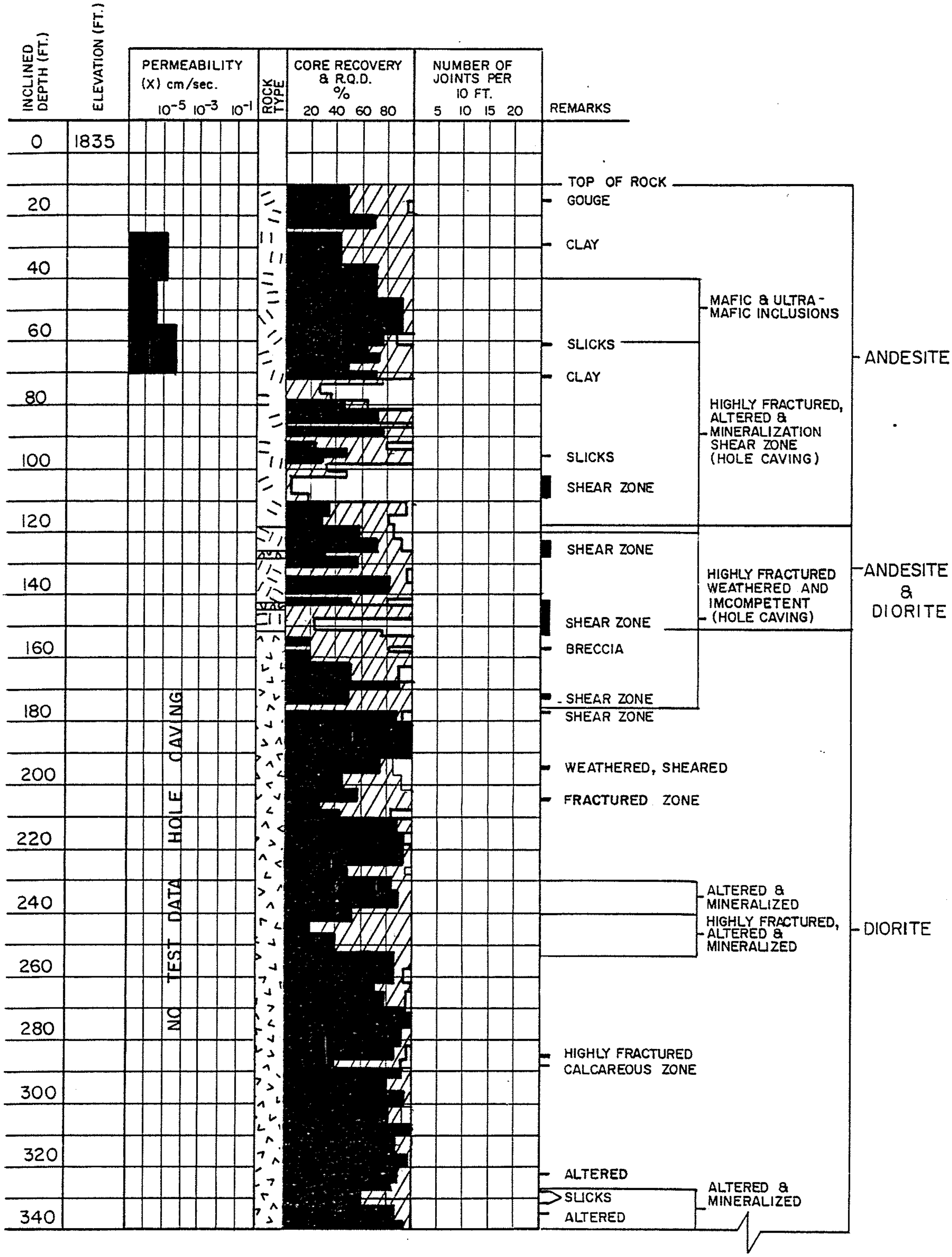
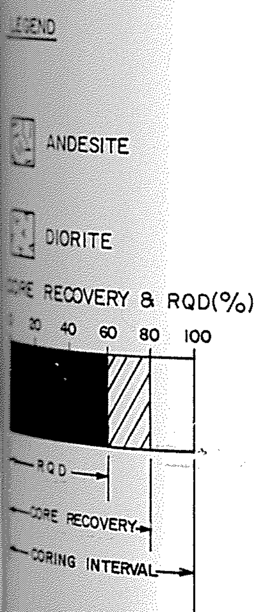
SUMMARY
BEDROCK LOGS

HOLE NO. BH-2 DATE JULY 1980
LOCATION NORTH ABUTMENT - WATANA





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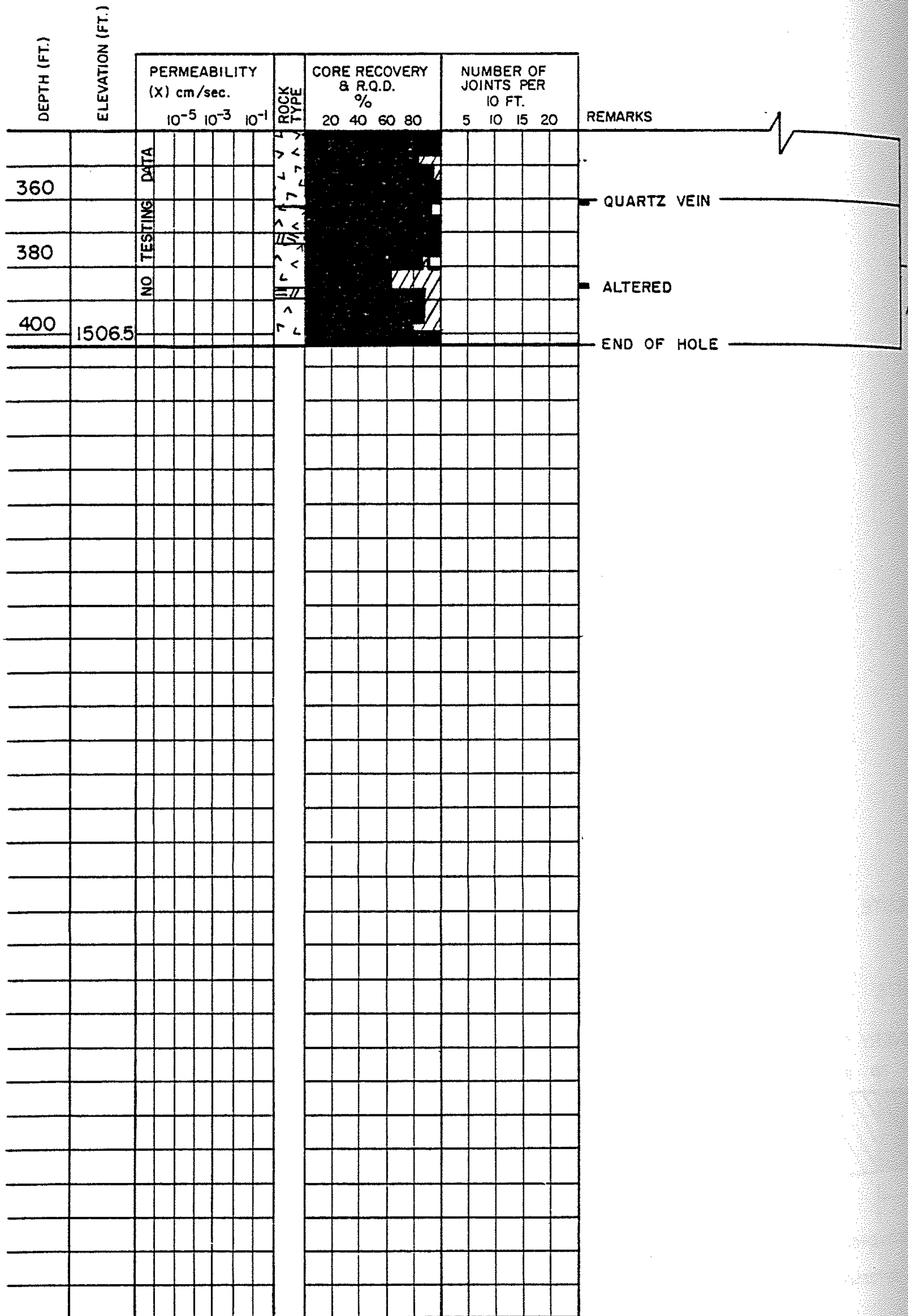
BEDROCK LOGS

HOLE NO. BH-2 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA



SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number B.H. - 2

Location Watana

Ground Surface Elevation 1835

Static Water Level Greater than 70' below surface

Dip of Hole 55°

Stickup None

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
23.9	40	20	20	.32	2.26×10^{-5}
38.9	55	26	10	.18	9.80×10^{-6}
53.9	70	30	20	.42 to 2.5	1.98×10^{-5} to 1.17×10^{-4}

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DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. B.H. 6
SHEET NO. 1 OF 20

SITE Watana North Abutment
JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR The Drilling Company
STARTED 07:00 .M. June 26 19 80
FINISHED - .M. July 9 19 80

DRILLING METHOD
SOIL Casing Advancer — CASING DIAM. NW -(4" I.D.)
ROCK Diamond Core Drilling — CORE DIAM. NQ -3- (1.75")

LOCATION:
LATITUDE N62° 49' 24.891
DEPARTURE W148° 32' 21.862
BEARING 225°
INITIAL DIP 60°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1605 ft.
ROCK SURFACE 1598.1 ft.
BOTTOM OF HOLE 963.8 ft.
WATER TABLE 1458 ft. 12-06-80

NOTE: All depths are along hole.

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN (ft)	% CORE. REC. (RQD.)
0.0	Overburden	Brown sandy gravel with cobbles and boulders.		
8.0	Quartz Diorite	Pale green to gray biotite, hornblende, Quartz Diorite. Mafics approximately 30%, medium grained, nonfoliated. Slightly to moderately weathered. Joint spacing very close to moderately close. Iron staining present along some joints, occasional healed fractures. 8.0 - 10.7 Core loss 0.7'.	Run 1 8.0 to 10.7 Run 2 10.7 to 15.0	74 (74) 93 (74)
16.5	Quartz Monzonite	Light tan to light grey, hornblende, Quartz Monzonite. Fine to medium grained, nonfoliated. Slightly to highly weathered, locally friable, and porous. Iron staining and solution cavities common. Rock generally incompetent. Joint spacing very close to close. 17.2 - 18.0 Highly fractured. 19.6 - 27 Highly fractured, core loss 0.7'.	Run 3 15.0 to 19.6 Run 4 19.6 to 23.8 Run 5 23.8 to 26.8	102 (57) 83 (0) 100 (0)
24.5	Granodiorite	Pale green to gray biotite hornblende quartz Granodiorite. Mafics average approximately 20%. Fine to medium grained. Moderately hard to very		

LOGGED BY R. RAHAIM - J. HAGAN (R&M)
SUMMARY - L. ACOMB
(ACRES)

APPROVED (R&M)
DATE
APPROVED (ACRES)
DATE

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 2 OF

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN (ft)
26.8	Granodiorite (cont'd)	hard, fresh to slightly weathered. Limonite staining and clay residue on some joint surfaces. Joint spacing very close to moderately close with joints oriented approximately 40° to 55° to core axis. Occasional highly fractured zones 0.1' to 1.1' thick, with clay gouge. Healed fractures throughout.	R 6 26.8 to 30.0
		26.8 - 30.0 Core loss 0.5'.	R 7 30.0 to 32.8
		29.5 - 30.0 Highly fractured and weathered. Clay filling common.	R 8 32.8 to 37.8
			R 9 37.8 to 40.5
		40.5 - 45.0 Core loss 0.2'.	R 10 40.5 to 45.0
		45.0 - 49.1 Highly fractured zone.	R 11 45.0 to 49.1
		49.1 - 51.4 Shear zone, highly fractured with clay gouge.	R 12 49.1 to 50.4
			R 13 50.4 to 51.4
			R 14 51.4 to 55.5
55.5			

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 3 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
55.5	Granodiorite (cont'd)		R 15 55.5 to 59.3	100 (53)
			R 16 59.3 to 63.2	100 (79)
		65.3 - 75.3 Highly fractured and sheared zone slight to highly weathered, moderately hard to soft and friable locally. Joint spacing very close to close. Hole caving during drilling.	R 17 63.2 to 66.5	100 (52)
		(65.5) Very friable. (66.5 -67.3) Core loss 0.8'.	R 18 66.5 to 67.3	0 (0)
			R 19 67.3 to 67.7	100 (0)
			R 20 67.7 to 70.4	100 (59)
		(71.5 - 73.0) Shear zone, slickenslides and clay gouge.	R 21 70.4 to 75.3	104 (59)
		75.3 - 149.4 Competent, hard to very hard fresh to slightly weathered. Joint spacing very close to wide.	R 22 75.3 to 80.3	100 (88)
			R 23 80.3 to 84.2	100 (92)
84.2				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 4 OF 2[illegible]

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO RE (R
81.2	Granodiorite (cont'd)		R 24 84.2 to 89.3	1 (
		89.3 - 94.6 Core loss 0.2'.	R 25 89.3 to 94.6	(
			R 26 94.6 to 98.5	1 (
		98.5 - 100.3 Core loss 0.1'.	R 27 98.5 to 100.3	(
			R 28 100.3 to 101.5	1 (
			R 29 101.5 to 102.5	1 (1
			R 30 102.5 to 103.1	1
			R 31 103.1 to 108.2	
		108.2 - 111.7 Core loss 0.1'.	R 32 108.2 to 111.7	
111.7				

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HOLE NO. BH-6
SHEET NO. 5 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
111.7	Granodiorite (cont'd)		R 33 111.7 to 112.7	100 (91)
		112.7 - 122.1 Core loss 0.4'.	R 34 112.7 to 117.2	93 (91)
			R 35 117.2 to 122.1	98 (98)
			R 36 122.1 to 127.2	100 (100)
			R 37 127.2 to 128.7	100 (100)
			R 38 128.7 to 130.8	100 (100)
			R 39 130.8 to 135.8	100 (86)
			R 40 135.8 to 140.8	100 (78)
			R 41 140.8 to 145.6	104 (98)
145.6				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 6 OF 2

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
145.6	Granodiorite (cont'd)	149.4 - 149.6 Highly fractured.	R 42 145.6 to 150.6
		152.5, 154.5 Altered, weathered zones, friable.	R 43 150.6 to 155.6
			R 44 155.6 to 160.6
		160.6 - 187.0 Highly altered and weathered. Moderately hard to soft and very friable locally. Joint spacing very close to close. Minor sulfide mineralization and carbonate throughout.	R 45 160.6 to 165.6
		165.6 - 175.2 Core loss 0.3'.	R 46 165.6 to 170.0
			R 47 170.0 to 175.2
			R 48 175.2 to 179.8
			R 49 179.8 to 184.9
		187.0 - 240.3 Generally hard and fresh except for very slight weathering along joints and fractures.	R 50 184.9 to 190.0
190.0			

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SUSITNA HYDROELECTRIC PROJECT
for **ALASKA POWER AUTHORITY**

HOLE NO. BH-6
SHEET NO. 7 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
190.0	Granodiroite (cont'd)		R 51 190.0 to 195.1	100 (100)
			R 52 195.1 to 200.2	100 (100)
			R 53 200.2 to 205.0	100 (88)
			R 54 205.0 to 210.0	100 (100)
		210.0 - 215.0 Core loss 0.3'.	R 55 210.0 to 215.0	94 (96)
		215.4 - 215.7 Highly fractured and moderately weathered.	R 56 215.0 to 220.0	100 (90)
			R 57 220.0 to 225.2	100 (100)
			R 58 225.2 to 230.1	100 (98)
			R 59 230.1 to 235.4	100 (100)
235.4				

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DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 8 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO RE (RQ
235.4	Granodiorite (cont'd)		R 60 235.4 to 240.3	1((1(
		240.3 - 260.0 Transitional zone into underlying quartz diorite. Contains thin altered friable zones locally. Numerous very thin veins of calcite throughout.	R 61 240.3 to 245.5	1((9
			R 62 245.5 to 249.7	1((9
			R 63 249.7 to 255.0	1((8
		(256.0 - 256.7) Highly altered, very friable. Clay filling (possible shear zone). (256.8) Slickensides.	R 64 255.0 to 260.0	1(((
260	Quartz Diorite	Light green, to pink and gray hornblende Quartz Diorite. Fine to medium grained, nonfoliated with approximately 30% mafics. Generally hard and fresh, clay and pyrite crystals common on fractured surfaces. Occasional thin (less than 0.1') calcite veins and healed joints throughout. Joint spacing close to moderately close.	R 65 260.0 to 265.1	1 (1
			R 66 265.1 to 270.2	1 (1
		273 -273.7 Altered zone, friable, sandy locally.	R 67 270.2 to 275.0	1 (
		275 -325.6 Generally hard, fresh and competent. Joint spacing close to moderately close.	R 68 275.0 to 280.3	1 (
280.3				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
280.3	Quartz Diorite (cont'd)		R 69 280.3 to 281.6	100 (100)
			R 70 281.6 to 284.6	100 (100)
		284.6 - 290.6 Core loss 0.2'.	R 71 284.6 to 286.6	95 (95)
			R 72 286.6 to 290.6	98 (98)
			R 73 290.6 to 295.6	100 (100)
			R 74 295.6 to 300.7	100 (96)
			R 75 300.7 to 305.0	100 (100)
			R 76 305.0 to 310.2	100 (100)
			R 77 310.2 to 315.4	100 (96)
315.4				

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SUSITNA HYDROELECTRIC PROJECT

for ALASKA POWER AUTHORITY

HOLE NO. BH-6

SHEET NO. 10 OF 2

SITE Watana North Abutment   JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
315.4	Quartz Diorite (cont'd)	318.6 - 320.1 Altered zone, chalky, bleached, friable along joints.	R 78 315.4 to 320.6
		320.6 - 325.6 Core loss 0.2'.	R 79 320.6 to 325.6
		325.6 - 332.7 Highly fractured and altered, very soft and friable. Core loss 3.0'.	R 80 325.6 to 330.2
			R 81 330.2 to 332.7
			R 82 332.7 to 337.9
		342.0 Altered zone, friable, weakly healed with carbonate.	R 83 337.9 to 342.9
		343.0 - 343.2 Highly fractured. Core loss 0.2'.	R 84 342.9 to 348.8
		352.9 - 362.5 Highly fractured, friable, soft.	R 85 348.8 to 353.8
			R 86 353.8 to 358.9
358.9			

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
358.9	Quartz Diorite (cont'd)		R 87 358.9 to 363.9	100 (52)
		367.9 Highly fractured, friable, soft.	R 88 363.9 to 368.2	107 (98)
		368.2 - 373.2 Core loss 0.2'.	R 89 368.2 to 373.2	96 (96)
		374.5, 377.0, 380.4, and 382.0 Highly fractured, friable, soft.	R 90 373.2 to 378.4	100 (77)
		382 - 490.5 Generally hard fresh and competent. Joint spacing close to wide.	R 91 378.4 to 383.3	100 (94)
		(383.3 - 388.3) Core loss 0.1'.	R 92 383.3 to 388.3	98 (98)
			R 93 388.3 to 393.3	100 (100)
			R 94 393.3 to 398.3	100 (92)
			R 95 398.3 to 400.6	100 (100)
400.6				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 12 OF 2[illegible]

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&[illegible]

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO RE (R
400.6	Quartz Diorite (cont'd)		R 96 400.6 to 403.4	1[illegible] (1[illegible]
			R 97 403.4 to 406.2	1[illegible] (1[illegible]
			R 98 406.2 to 411.1	1[illegible] (1[illegible]
			R 99 411.1 to 416.3	1[illegible] (1[illegible]
			R 100 416.3 to 421.1	1[illegible] (1[illegible]
			R 101 421.1 to 425.6	1[illegible] (1[illegible]
			R 102 425.6 to 430.2	1[illegible] ([illegible]
			R 103 430.2 to 435.4	1[illegible] (1[illegible]
			R 104 435.4 to 440.4	1[illegible] (1[illegible]
440.4				

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SUSITNA HYDROELECTRIC PROJECT
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HOLE NO. BH-6
SHEET NO. 13 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
440.4	Quartz Diorite (cont'd)		R 105 440.4 to 445.6	100 (100)
			R 106 445.6 to 450.4	100 (100)
		454.5 -454.9 Highly fractured, friable, minor sulfide mineralization.	R 107 450.4 to 455.8	101 (91)
			R 108 455.8 to 458.2	100 (100)
		461.6 Fractured zone.	R 109 458.2 to 463.2	100 (100)
		463.2 - 464 Mineralized zone, very soft, core loss 0.4'.	R 110 463.2 to 464.0	13 (0)
			R 111 464.0 to 468.4	100 (100)
			R 112 468.4 to 473.3	100 (100)
		476.2 - 476.4 Fractured zone.	R 113 473.3 to 477.8	100 (98)
477.8				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 14 OF 2

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
477.8	Quartz Diorite (cont'd)	479.1 Slickensides.	R 114 477.8 to 480.3
			R 115 480.3 to 485.3
		485.3 - 490.5 Core barrel mislatched during drilling. Had to. pull rods and redrill; core loss 1.4'.	R 116 485.3 to 490.5
		490.5 - 650.0 Generally fresh, hard, competent.	R 117 490.5 to 495.5
		498.5, 502.1 Joints filled with calcareous clay.	R 118 495.5 to 500.5
			R 119 500.5 to 505.6
			R 120 505.6 to 510.6
			R 121 510.6 to 515.6
			R 122 515.6 to 520.2
520.2			

DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 15 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
520.2	Quartz Diorite (cont'd)	520.2 - 521.0 Slightly friable. Core loss 0.1'.	R 123 520.2 to 525.6	98 (83)
			R 124 525.6 to 530.4	104 (92)
		530.5 - 532.5 Altered zone, soft, clayey; hole caved during drilling.	R 125 530.4 to 531.8	100 (50)
			R 126 531.8 to 532.0	100 (0)
			R 127 532.0 to 533.5	100 (67)
		533.5 - 539.5 Core loss 0.8'.	R 128 533.5 to 539.5	87 (87)
		539.5 - 547.5 Core loss 0.4'.	R 129 539.5 to 544.6	96 (86)
			R 130 544.6 to 547.5	93 (66)
			R 131 547.5 to 550.4	100 (83)
550.4				

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HOLE NO. BH-6
SHEET NO. 16 OF

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
550.4	Quartz Diorite (cont'd)		R 132 550.4 to 555.4
			R 133 555.4 to 560.4
		562.7, 565.0 Slickensides.	R 134 560.4 to 565.7
		565.7 - 570.7 Core loss 0.8'. (569.0) Highly fractured and sheared, clay gouge.	R 135 565.7 to 570.7
		572.3 - 573.1 Brecciated, clay gouge.	R 136 570.7 to 575.9
			R 137 575.9 to 580.7
			R 138 580.7 to 585.8
			R 139 585.8 to 590.8
		590.8 - 592.8 Core barrel mislatched during drilling, had to pull rods, core loss 0.5.	R 140 590.8 to 592.8
592.8			

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HOLE NO. BH-6
SHEET NO. 17 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
592.8	Quartz Diorite (cont'd)		R 141 592.8 to 597.8	100 (80)
			R 142 597.8 to 602.6	100 (83)
			R 143 602.6 to 608.3	100 (65)
			R 144 608.3 to 611.5	100 (97)
		613 - 615 Altered and friable, soft, numerous healed joints. Core loss 0.9'.	R 145 611.5 to 615.4	77 (64)
			R 146 615.4 to 620.2	100 (96)
			R 147 620.2 to 625.2	100 (100)
		625.2 - 630.2 Core loss 0.2'.	R 148 625.2 to 630.2	96 (92)
			R 149 630.2 to 631.8	100 (88)
631.8				

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SUSITNA HYDROELECTRIC PROJECT for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 18 OF 2

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
631.8	Quartz Diorite (cont'd)		R 150 631.8 to 636.7
			R 151 636.7 to 640.5
			R 152 640.5 to 645.6
		646.7 Joint filled with crushed rock.	R 153 645.6 to 650.0
650	Granite	Light gray to white, fine to medium grained, nonfoliated with approximately 5% to 10% mafics. Hard, fresh and competent. Minor sulfide mineralization throughout. Numerous healed fractures and joints, carbonate coating on joints common. Joint spacing close to moderately close with joints oriented approximately 40° to 60° to core axis.	R 154 650.0 to 655.8
			R 155 655.8 to 660.6
			R 156 660.6 to 665.8
			R 157 665.8 to 670.8
			R 158 670.8 to 676.0
676.0			

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
676.0	Granite (cont'd)		R 159 676.0 to 680.6	100 (98)
			R 160 680.6 to 685.4	100 (94)
		686.2 - 712.2 Shear zone, joint spacing very close to close, moderately hard to soft and friable locally. Rock generally less competent, minor sulfide mineralization throughout. Carbonate common.	R 161 685.4 to 687.9	84 (80)
		686.2 - 687.9 Core loss 0.4'.	R 162 687.9 to 692.5	104 (89)
		(686.2, 690.0, 695.7, 699.3, 704.0, 708.2) Slickensides with clay gouge, soft, friable.		
			R 163 692.5 to 697.5	104 (74)
			R 164 697.5 to 702.5	100 (92)
			R 165 702.5 to 707.4	100 (67)
			R 166 707.4 to 712.2	100 (94)
			R 167 712.2 to 717.1	102 (100)
717.7				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-6
SHEET NO. 20 OF 2

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO RE (R
717.1	Grantie (cont'd)		R 168 717.1 to 722.0	1 (
		722.0 - 727.1 Core loss 0.1'.	R 169 722.0 to 727.1	(
			R 170 727.1 to 730.5	1 (1
			R 171 730.5 to 735.4	1 (
			R 172 735.4 to 740.4	1 (
740.4		End of hole		

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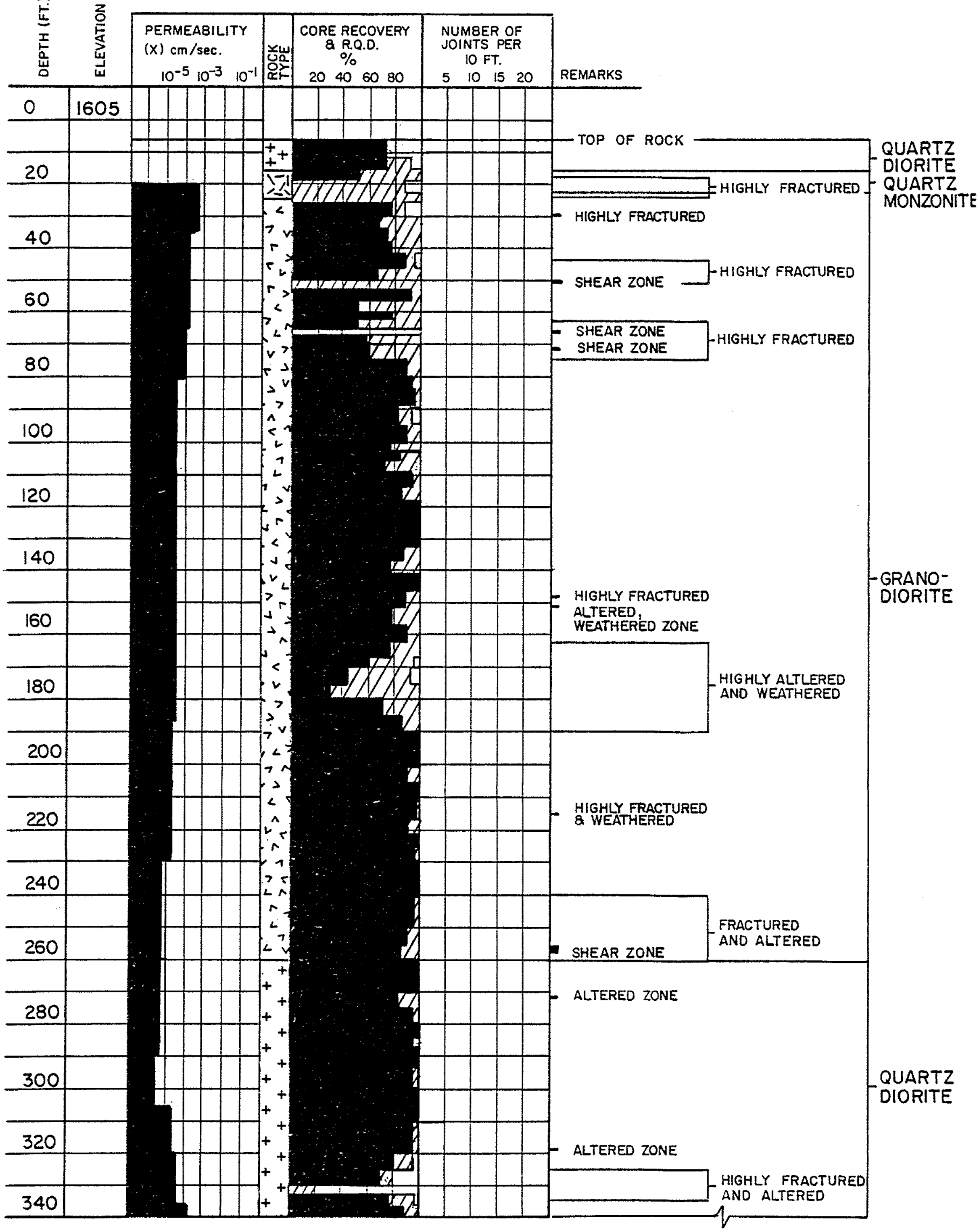
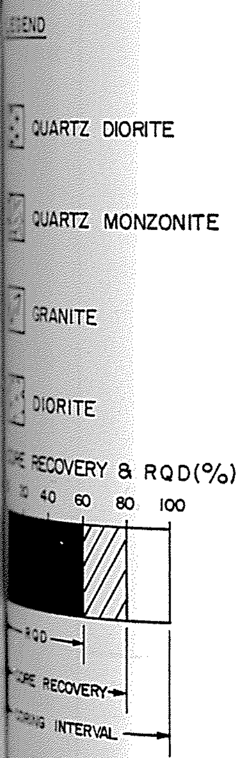
BEDROCK LOGS

HOLE NO. BH-6 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA





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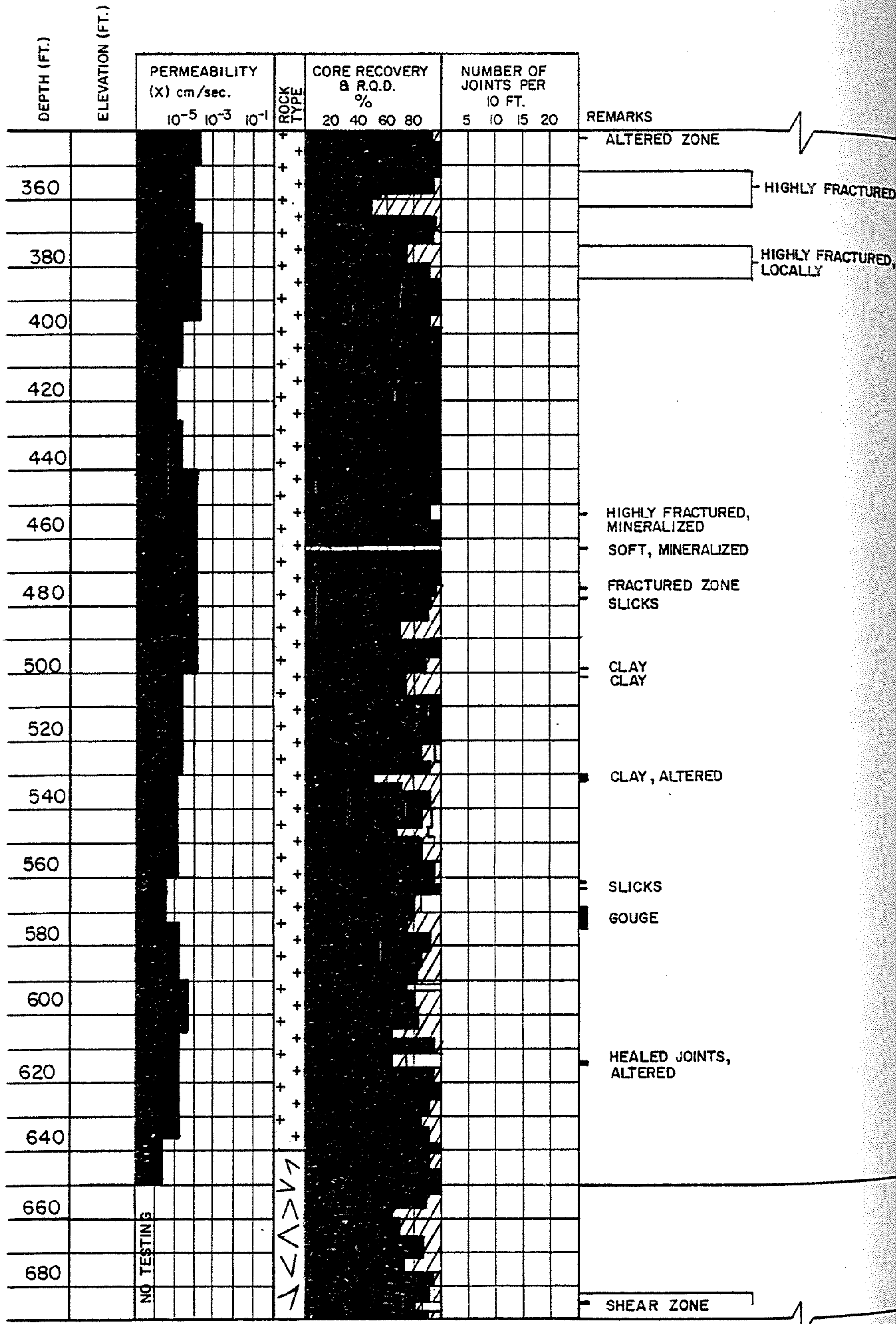
BEDROCK LOGS

HOLE NO. BH-6 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA



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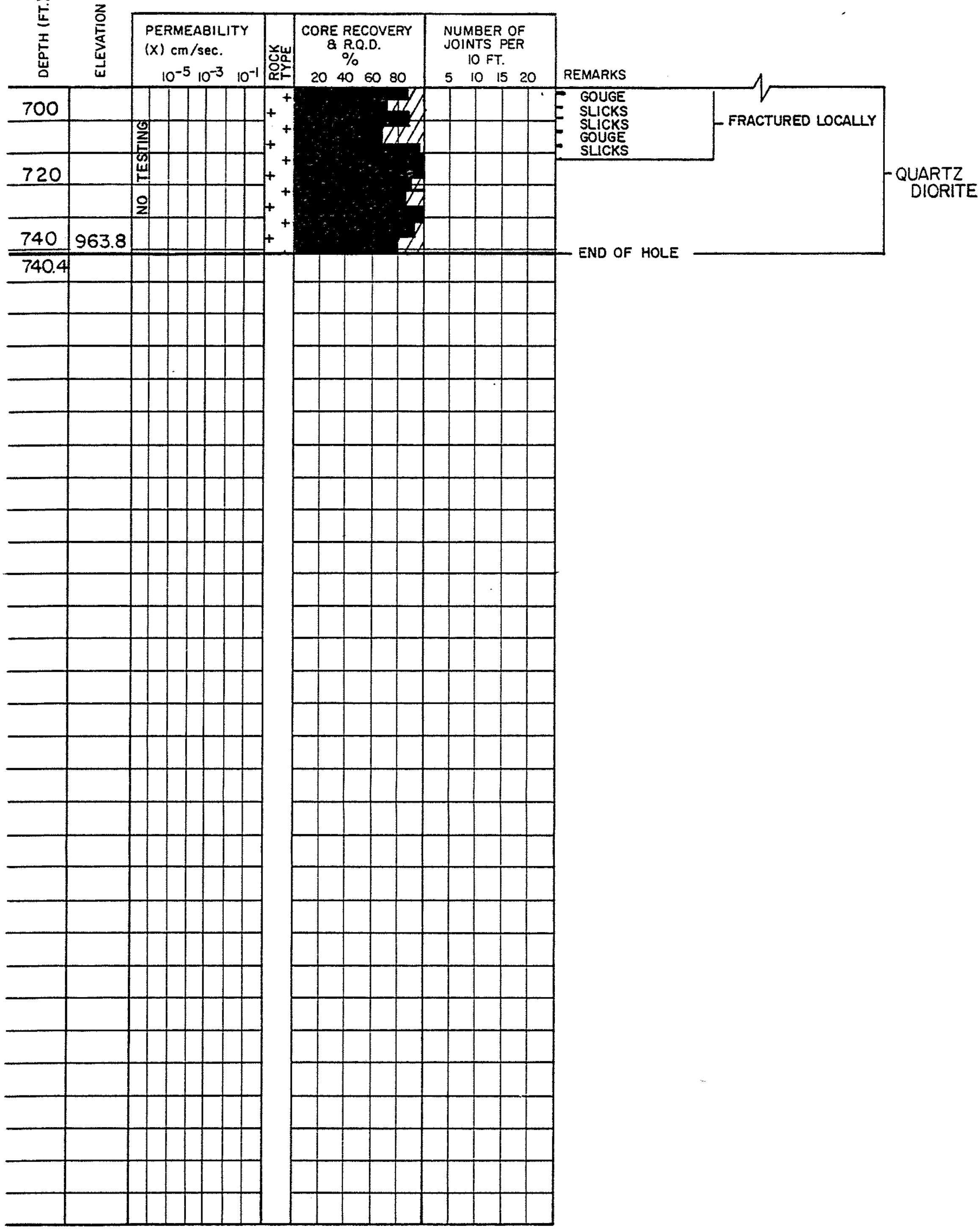
BEDROCK LOGS

HOLE NO. BH-6 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA



SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number B.H.- 6

Location Watana

Ground Surface Elevation 1605

Static Water Level 147 feet Below Surface

Dip of Hole 60°

Stickup None

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
33.9	50	16 to 18	10	11	1.93×10^{-4}
48.9	65	22 to 24	10	10.8	1.76×10^{-4}
63.9	80	28 to 30	10	6.4 to 8	9.77×10^{-5} To 1.22×10^{-4}
78.9	95	35 to 36	10	2.4	3.44×10^{-5}
93.9	110	41 to 44	10	2.2	2.97×10^{-5}
108.9	125	48 to 50	10	2.9	3.64×10^{-5}
123.9	140	54 to 58	10	4.4	5.11×10^{-5} To 5.29×10^{-5}
138.9	155	61 to 62	10	3.7 to 3.8	4.28×10^{-5}
153.9	170	66 to 68	10	4.3	4.65×10^{-5}
168.9	185	76 to 78	10	4.0	4.02×10^{-5}
183.9	200	82 to 84	10	1.3	1.25×10^{-5}
198.9	215	92 to 98	15	1.7	1.54×10^{-5} To 1.49×10^{-5}

Depth Tested From (feet)	To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
213.9	230	98 to 104	10	1.4	1.22×10^{-5} To 1.18×10^{-5}
228.9	245	108	15	1.75	1.44×10^{-5}
243.9	260	114	25	1.0	7.96×10^{-6}
258.9	275	125	25	1.2	9.00×10^{-6}
273.9	290	125	45	1.2	9.00×10^{-6}
288.9	305	130	145	.54	3.94×10^{-6}
303.9	320	140	25	4.9	3.40×10^{-5}
318.9	335	140	10	6.2	4.31×10^{-5}
333.9	350	200	10	10 to 30	5.36×10^{-5} To 1.61×10^{-4}
348.9	365	200	50	.31 to 14.7	1.66×10^{-6} To 7.89×10^{-5}
363.9	380	204	10	15 to 30	7.93×10^{-5} To 1.59×10^{-4}
378.9	395	202	10	15 to 30	7.99×10^{-5} To 1.60×10^{-4}
393.9	410	204	10	6.6	3.49×10^{-5}
408.9	425	202	10	3.75	2.00×10^{-5}
423.9	440	202	10	5.7	3.03×10^{-5}
438.9	455	200	15	11 to 30	5.90×10^{-5} To 1.61×10^{-4}
453.9	470	200	10	11 to 30	5.90×10^{-5} To 1.61×10^{-4}

Borehole BH-6 Watana - (Continued)

Depth Tested From (feet)	To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
468.9	485	202	15	11 to 30	5.86×10^{-5} To 1.60×10^{-4}
483.9	500	200	10	11 to 30	5.90×10^{-5} To 1.61×10^{-4}
498.9	515	202	15	7.8	4.15×10^{-5}
513.9	530	204	15	7.5	3.96×10^{-5}
528.9	545	195	15	5.2	2.84×10^{-5}
543.9	560	205	15	3.8	2.00×10^{-5}
558.9	575	200	15	1.45	7.78×10^{-6}
573.9	590	195	10	5.2	2.84 x 10-5
588.9	605	200	15	8.5	4.56×10^{-5}
603.9	620	205	10	2.95	1.55×10^{-5}
618.9	635	203	10	3.35	1.78×10^{-5}
633.9	650	198	20	.55	2.97×10^{-6}

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DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 1 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR The Drilling Company STARTED 1:00 P.M. 7/29 19 80
FINISHED .M. 8/9 19 80

DRILLING METHOD: SOIL Casing Advancer CASING DIAM. NW 4" I.D.
ROCK Diamond Core Drilling CORE DIAM. NQ-3 (1.75")

LOCATION:
LATITUDE N62° 49' 11.686
DEPARTURE W148° 32' 17.664
BEARING 60°
INITIAL DIP 60°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1976 ft.
ROCK SURFACE 1964 ft.
BOTTOM OF HOLE 1326 ft.
WATER TABLE 1960 ft.

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN (ft)	% CORE REC. (RQD.)
0.0 8.0-13.8	Overburden	0.0 - 1.0 Organic materials. 1.0 - 8.0 Brown sandy gravel with silt and boulders, grading into angular cobbles. Not sampled. Weathered bedrock.		
13.8 33.8	Porphyritic Andesite	Pale tan to gray, very fine to fine grained groundmass with numerous light colored phenocrysts. Generally hard to very hard, friable locally. Slightly to moderately weathered with iron staining on joint surfaces and penetrative staining and weakening up to 1 cm immediately adjacent to joints. Less weathering with depth. Joint spacing very close to close. Occasional joints healed with carbonate. 13.8 - 28.8 Core loss 2.0'. 13.8 - 33.8 Moderately to highly weathered, friable locally. Penetrative iron staining throughout. (13.8 - 18.0) Some residual interstitial sand and silt.	Run 1 13.8 to 18.0 Run 2 18.0 to 23.8 Run 3 23.8 to 28.8 Run 4 28.8 to 33.8	71 (10) 91 (22) 94 (54) 100 (30)

LOGGED BY Hagen - Rahaim (R&M)
Summary by Feldman, Acomb
(ACRES)

APPROVED (R&M)
DATE
APPROVED (ACRES)
DATE

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SUSITNA HYDROELECTRIC PROJECT

for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 2 OF 1

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
33.8		33.8 - 49.6 Rock becoming more competent. Slightly to moderately weathered with iron staining on joint surfaces. 33.8 - 38.8 Core loss 0.3'.	Run 5 33.8 to 38.8 Run 6 38.8 to 43.9 Run 7 43.9 to 45.6
		(48.3 - 50.6) Sandy clay material along contact with underlying diorite. Soft and friable. Core loss 1.5 feet.	Run 8 45.6 to 49.6
49.6	Diorite	Pale pink to greenish gray, fine to medium grained crystalline rock. Non-foliated, approximately 20% to 30% mafics. Generally hard to very hard, fresh to slightly weathered, with iron staining on some joint and fracture surfaces. Carbonate common throughout. Joint spacing very close to moderately close. Occasional joints healed with carbonate. 49.6 - 65.0 Moderately weathered and altered with some bleaching. Locally soft, clayey zones. 59.5 - 63.6 Dark gray fine grained basalt dike containing inclusions of brecciated, altered diorite, and carbonate veins. Core loss 0.1'.	Run 9 49.6 to 52.5 Run 10 52.5 to 56.5 Run 11 56.5 to 59.5 Run 12 59.5 to 63.6 Run 13 63.6 to 68.0
68.0			

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DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 3 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
68.0	Diorite (cont'd)		Run 14 68.0 to 73.0	104 (100)
		76.0 Thin altered zone.	Run 15 73.0 to 77.7	100 (43)
		77.7 - 89.0 Highly fractured. Some faint slickensides.	Run 16 77.7 to 80.7	103 (57)
			Run 17 80.7 to 84.0	100 (57)
			Run 18 84.0 to 89.3	100 (64)
		89.3 - 91.6 Highly fractured, friable locally.	Run 19 89.3 to 91.6	100 (43)
		91.6 - 96.6 Core loss 0.2'.	Run 20 91.6 to 96.6	96 (60)
			Run 21 96.6 to 101.0	100 (100)
			Run 22 101.0 to 106.2	100 (83)
106.2				

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SUSITNA HYDROELECTRIC PROJECT for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 4 OF

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
106.2	Diorite (cont'd)		Run 23 106.2 to 111.0
			Run 24 111.0 to 116.1
		116.1 - 121.1 Core loss 0.1'.	Run 25 116.1 to 121.1
		123.0 - 124.0 Highly fractured zone. Slightly altered and bleached.	Run 26 121.1 to 126.1
		129.0 Faint slickensides.	Run 27 126.1 to 131.1
			Run 28 131.1 to 135.6
		135.6 - 140.8 Core loss 0.2'. 140.0 Rock generally fresh to bottom of hole.	Run 29 135.6 to 140.8
		140.8 - 142.9 Prominent joint sets at 25° and 35° to core axis. Core loss 2.1'.	Run 30 140.8 to 142.9
		146.0 Slickensides.	Run 31 142.9 to 148.0
148.0			

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for ALASKA POWER AUTHORITY

HOLE NO. BH-8

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
148.0	Diorite (cont'd)		Run 32 148.0 to 152.6	100 (98)
			Run 33 152.6 to 157.7	100 (100)
		157.7 - 167.5 Core loss 0.6'.	Run 34 157.7 to 162.7	96 (96)
			Run 35 162.7 to 167.5	92 (63)
			Run 36 167.5 to 171.9	100 (70)
		171.9 - 173.6 Altered and brecciated zone with clay and sand filling. Soft and friable. Calcareous. Core loss 0.6 feet.	Run 37 171.9 to 176.5	87 (52)
			Run 38 176.5 to 181.0	98 (91)
			Run 39 181.0 to 185.9	100 (100)
		185.9 - 194.2 Core loss 0.6'.	Run 40 185.9 to 189.2	91 (88)
189.2				

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DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 6 OF

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
189.2	Diorite (cont'd)		Run 41 189.2 to 194.2
			Run 42 194.2 to 199.2
			Run 43 199.2 to 201.0
			Run 44 201.0 to 206.2
		206.2 - 211.0, 213.0 Some alteration and minor sulfide mineralization.	Run 45 206.2 to 211.0
			Run 46 211.0 to 215.1
			Run 47 215.1 to 219.3
			Run 48 219.3 to 221.2
		221.2 - 225.4 Some hydrothermal alteration, locally fractured and friable.	Run 49 221.2 to 225.4
225.4			

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-8

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
225.4	Diorite (cont'd)		Run 50 225.4 to 230.6	100 (100)
		230.6 - 235.6 Core loss 0.2'.	Run 51 230.6 to 235.6	96 (96)
		238.0 Slightly altered, bleached and somewhat softer.	Run 52 235.6 to 240.9	100 (91)
			Run 53 240.9 to 245.6	100 (100)
		245.6 - 251.0 Core loss 0.1'.	Run 54 245.6 to 251.0	98 (87)
		251.0 Thin clay seam.	Run 55 251.0 to 255.2	100 (93)
			Run 56 255.2 to 260.1	100 (100)
		261.5, 270.0 Highly fractured zones.	Run 57 260.1 to 265.1	100 (84)
			Run 58 265.1 to 270.1	100 (90)
270.1				

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DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 8 OF 1

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
270.1	Diorite (cont'd)		Run 59 270.1 to 275.3
			Run 60 275.3 to 280.2
			Run 61 280.2 to 284.4
		284.4 - 287.8 Core loss 0.1'.	Run 62 284.4 to 287.8
		287.8 - 291.0 Mislatch of core barrel during drilling. Core badly ground. Core loss 0.8 feet.	Run 63 287.8 to 291.0
			Run 64 291.0 to 296.1
			Run 65 296.1 to 300.8
			Run 66 300.8 to 303.7
		307.8 - 308.8 Highly fractured, moderately weathered, soft.	Run 67 303.7 to 308.8
308.8			

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 9 OF 19

SITE Watana South Abutment   JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
308.8	Diorite (cont'd)		Run 68 308.8 to 313.2	100 (93)
			Run 69 313.2 to 318.2	100 (100)
318.8	Granodiorite	Pale green to pink and gray, fine to medium grained crystalline rock. Non-foliated with approximately 20% mafics. Hard to very hard, fresh and generally competent. Joint spacing close to moderately close. Occasional carbonate coating.	Run 70 318.2 to 321.5	100 (94)
		324.5 Thin felsic dike.	Run 71 321.5 to 326.9	100 (100)
		326.9 - 330.8 Core loss 0.1'.	Run 72 326.9 to 330.8	97 (97)
		332.4 - 332.8 Felsic dike.	Run 73 330.8 to 335.8	100 (90)
340.0	Diorite	Gray to pale green and pink, fine to medium grained crystalline rock. Non-foliated with 20% to 30% mafics. Hard to very hard, fresh. Generally competent. Minor sulfide mineralization. Joint spacing very close to moderately close. Occasional joints healed with calcite.	Run 74 335.8 to 340.1	100 (93)
		341.0 - 344.0 Highly fractured zone.	Run 75 340.1 to 343.2	100 (58)
		343.2 - 375.5 Localized dikes and veins of gray, fine grained andesite.	Run 76 343.2 to 348.4	100 (92)
348.4				

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HOLE NO. BH-8
SHEET NO. 10 OF 1

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
348.4	Diorite (cont'd)		R 77 348.4 to 351.8
			R 78 351.8 to 356.8
			R 79 356.8 to 360.9
			R 80 360.9 to 364.2
		364.2 - 365.5 Core loss 0.1'.	R 81 364.2 to 365.5
			R 82 365.5 to 370.5
			R 83 370.5 to 375.5
			R 84 375.5 to 380.4
			R 85 380.4 to 384.0
384.0			

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HOLE NO. BH-8
SHEET NO. 11 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
384.0	Diorite (cont'd)	384.0 - 386.0 Possible shear zone, soft and friable with clay and sand infilling along joints.	R 86 384.0 to 389.0	102 (46)
			R 87 389.0 to 393.4	100 (86)
			R 88 393.4 to 397.7	100 (100)
			R 89 397.7 to 402.3	100 (96)
		406.0 - 408.7 Alteration zone, soft, and friable. Core loss 0.4 feet.	R 90 402.3 to 407.8	93 (45)
			R 91 407.8 to 411.9	100 (58)
			R 92 411.9 to 417.1	100 (96)
			R 93 417.1 to 421.0	100 (90)
			R 94 421.0 to 426.4	100 (96)
426.4				

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SUSITNA HYDROELECTRIC PROJECT for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 12 OF 1

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO RE (R
426.4	Diorite (cont'd)	430.4 to 436.0 Highly fractured and altered zone, friable with some chloritized joints. Core loss 0.7 feet.	R 95 426.4 to 431.0	1 (
			R 96 431.0 to 433.6	1 (
		(435.6) Shear zone, rock brecciated with clay gouge, very soft. Core loss 0.2'.	R 97 433.6 to 436.3	(
		440.0 - 443.5 Highly fractured and sheared zone. Core loss 0.3 feet.	R 98 436.3 to 441.0	(
			R 99 441.0 to 446.0	(
		446.0 - 451.0 Core loss 0.7 feet.	R 100 446.0 to 451.0	(
			R 101 451.0 to 456.2	1 (1
			R 102 456.2 to 461.0	1 (1
			R 103 461.0 to 465.4	1 (1
465.4				

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HOLE NO. BH-8
SHEET NO. 13 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
465.4	Diorite (cont'd)		R 104 465.4 to 467.2	100 (89)
			R 105 467.2 to 470.2	100 (100)
			R 106 470.2 to 475.4	100 (90)
		476.6 - 476.9 Altered zone soft, friable.	R 107 475.4 to 480.6	100 (90)
			R 108 480.6 to 481.7	100 (100)
			R 109 481.7 to 485.5	100 (81)
			R 110 485.5 to 490.0	100 (100)
		491.5 - 495.0 Altered zone, soft, core loss 0.2 feet.	R 111 490.0 to 495.0	96 (90)
			R 112 495.0 to 499.9	100 (100)
499.9				

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SUSITNA HYDROELECTRIC PROJECT

for ALASKA POWER AUTHORITY

HOLE NO. BH-8

SHEET NO. 14 OF 1

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
465.4	Diorite (cont'd)		R 113 499.9 to 505.2
		505.2 - 520.6 Altered zone, bleached, minor sulfide mineralization.	R 114 505.2 to 510.2
		510.2 - 515.6 Core loss 0.1'.	R 115 510.2 to 515.6
		(515.6 - 518.6) Soft and friable.	R 116 515.6 to 520.6
			R 117 520.6 to 525.7
			R 118 525.7 to 530.8
			R 119 530.8 to 536.1
			R 120 536.1 to 541.1
			R 121 541.1 to 546.3
546.3			

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HOLE NO. BH-8
SHEET NO. 15 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
546.3	Diorite (cont'd)		R 122 546.3 to 551.2	100 (100)
		551.2 - 552.6, 664.0 - 556.4 Highly fractured zones.	R 123 551.2 to 552.6	100 (50)
			R 124 552.6 to 556.4	100 (50)
			R 125 556.4 to 561.2	100 (42)
			R 126 561.2 to 566.2	100 (100)
			R 127 566.2 to 571.6	100 (89)
		571.6 - 596.0 Altered zone, sulfide mineralization.	R 128 571.6 to 575.4	100 (95)
		(580.0 - 580.5, 587.6) Highly altered, soft and friable with some carbonaceous clay filling.	R 129 575.4 to 580.5	100 (100)
			R 130 580.5 to 585.6	100 (96)
585.6				

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SUSITNA HYDROELECTRIC PROJECT

for ALASKA POWER AUTHORITY

HOLE NO. BH-8
SHEET NO. 16 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CO RE (RO
585.6	Diorite (cont'd)		R 131 585.6 to 590.7	10 (7
		(592.2) Brecciated zone. Core loss 0.1'.	R 132 590.7 to 596.0	9 (7
			R 133 596.0 to 601.0	10 (8
			R 134 601.0 to 604.0	10 (8
			R 135 604.0 to 609.0	10 (9
		609.0 - 634.0 Highly fractured zone, with clayey filling along some joints, numerous joints healed with carbonate. Core loss 0.1'.	R 136 609.0 to 612.4	9 (5
			R 137 612.4 to 617.6	10 (5
		(619.6, 633.3) Slickensides.	R 138 617.6 to 621.0	10 (5
			R 139 621.0 to 626.2	10 (6
626.2				

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HOLE NO. BH-8
SHEET NO. 17 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
626.2	Diorite (cont'd)		R 140 626.2 to 628.8	100 (69)
			R 141 628.8 to 634.0	100 (75)
			R 142 634.0 to 639.3	100 (98)
			R 143 639.3 to 643.5	100 (95)
		643.5 - 648.8 Medium to coarse grained brecciated rock with clay gouge, friable and soft locally, partially healed with carbonate.	R 144 643.5 to 648.8	100 (94)
			R 145 648.8 to 653.8	100 (100)
			R 146 653.8 to 659.1	100 (100)
			R 147 659.1 to 664.1	100 (94)
			R 148 664.1 to 669.4	100 (100)
669.4				

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HOLE NO. BH-8
SHEET NO. 18 OF 1

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
669.4	Diorite (cont'd)	669.4 - 674.7 Localized clay filling along joints. Core loss 0.3 feet.	R 149 669.4 to 674.7
			R 150 674.7 to 679.9
			R 151 679.9 to 685.2
			R 152 685.2 to 690.2
		690.2 - 693.0 Mislatch of core barrel during drilling, core badly ground. Core loss 0.4 feet.	R 153 690.2 to 693.0
			R 154 693.0 to 698.0
			R 155 698.0 to 703.1
			R 156 703.1 to 708.5
			R 157 708.5 to 713.1
713.1			

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HOLE NO. BH-8
SHEET NO. 19 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
713.1	Diorite (cont'd)	713.1 - 719.4 Mislatch of core barrel during drilling, core badly ground, core loss 0.6 feet some carbonaceous clay along joints.	R 158 713.1 to 719.4	90 (59)
		719.4 - 724.7 Altered zone, bleached, locally soft and friable, pitted. Core loss 0.2'.	R 159 719.4 to 724.7	96 (79)
			R 160 724.7 to 729.3	100 (98)
			R 161 729.3 to 734.3	100 (100)
			R 162 734.3 to 739.3	102 (98)
			R 163 739.3 to 744.3	104 (90)
			R 164 744.3 to 749.4	100 (80)
		749.4 Soft, friable zone.	R 165 749.4 to 750.5	100 (82)
750.5		End of Hole		

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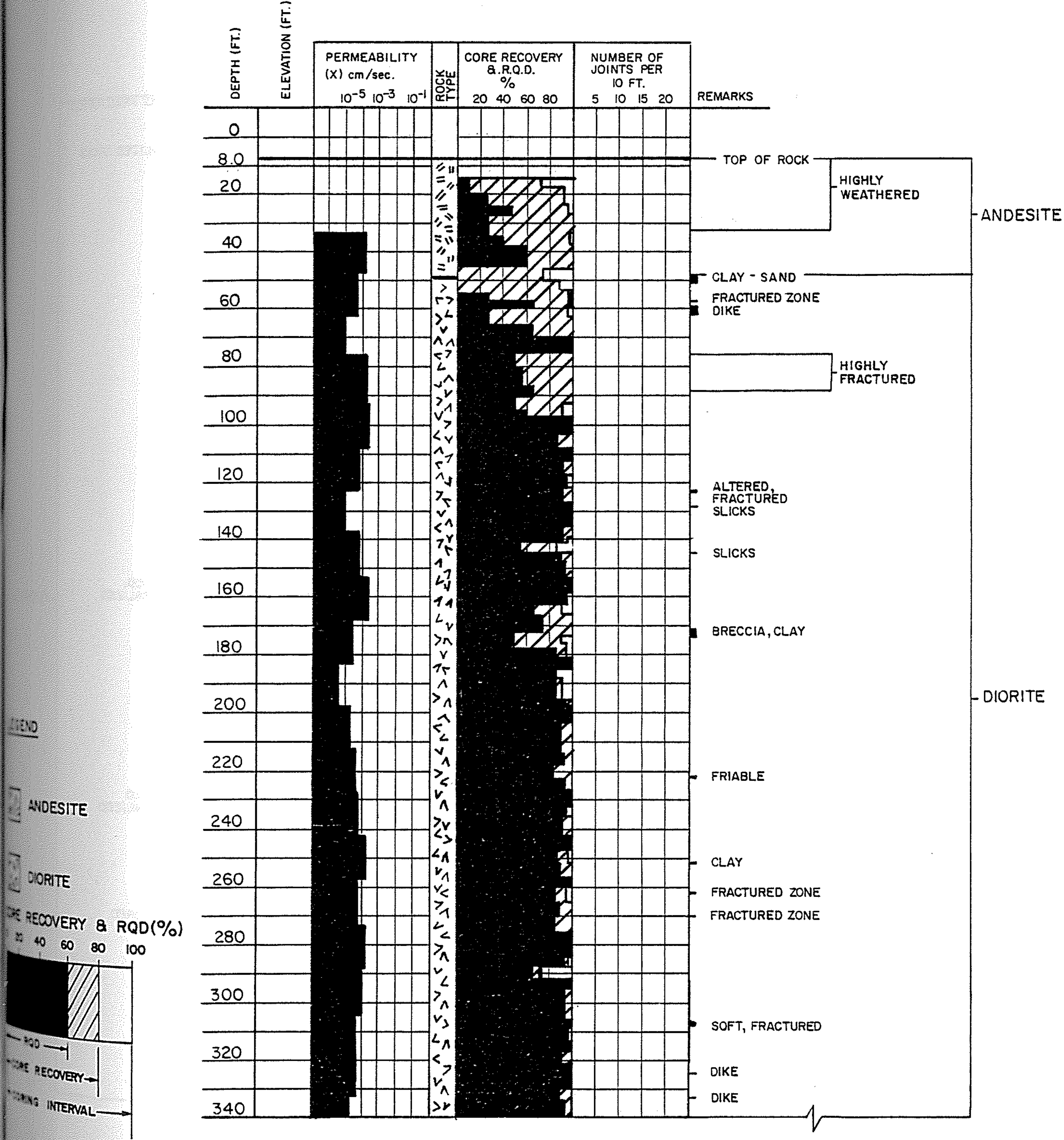
BEDROCK LOGS

HOLE NO. BH-8 DATE JULY 1980

LOCATION SOUTH ABUTMENT - WATANA



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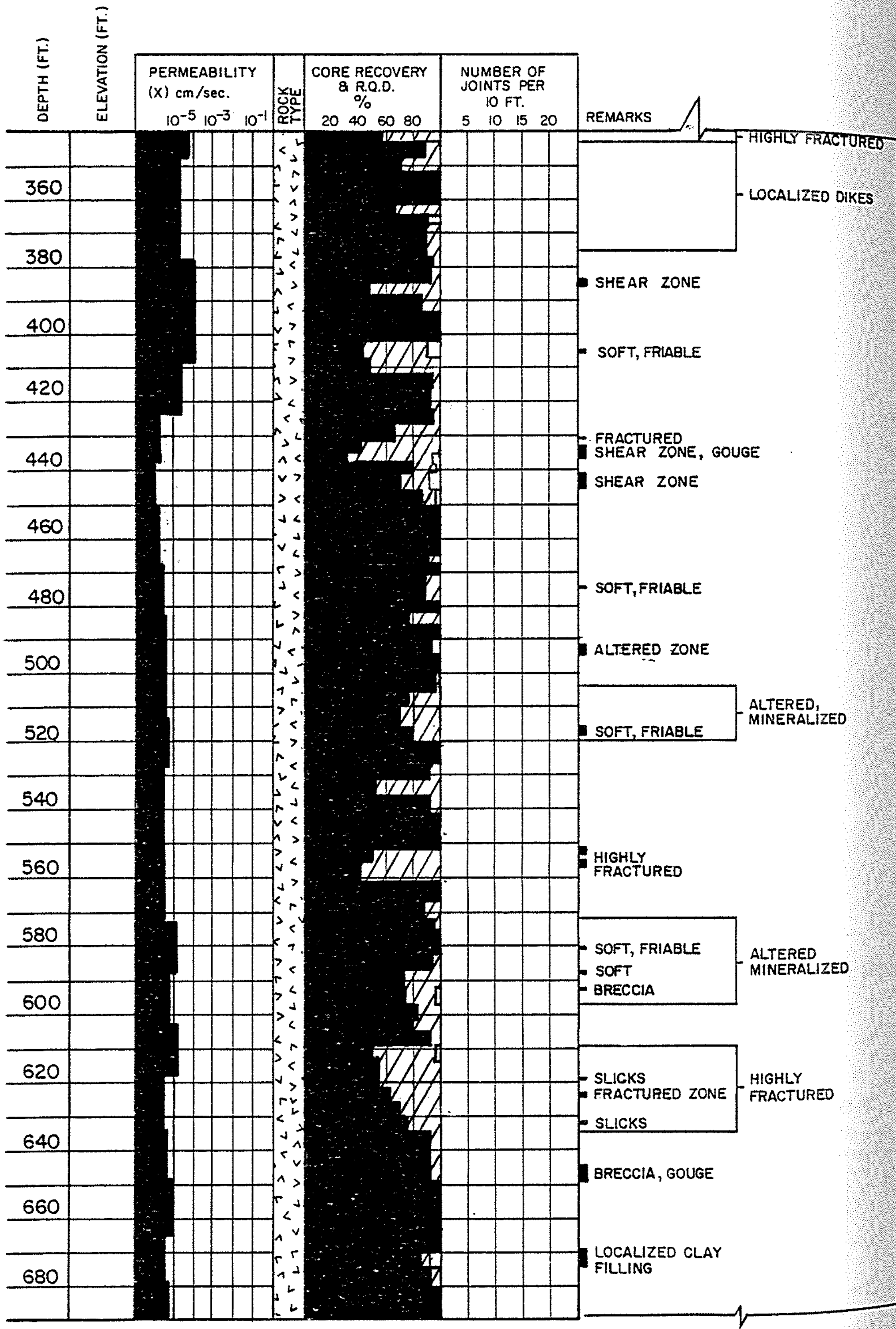
BEDROCK LOGS

HOLE NO. BH-8 DATE JULY 1980

LOCATION SOUTH ABUTMENT - WATANA



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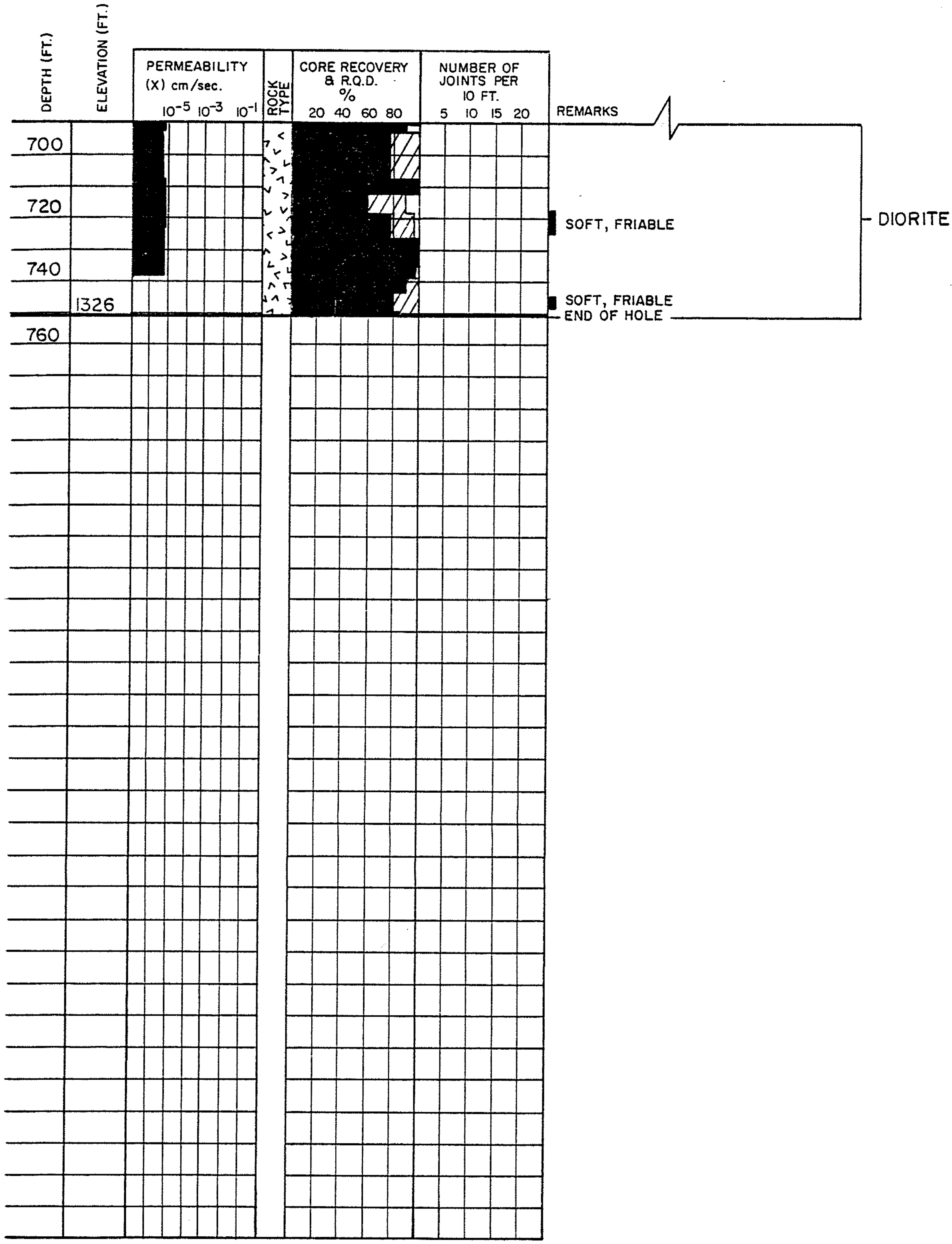
BEDROCK LOGS

HOLE NO. BH-8 DATE JULY 1980

LOCATION SOUTH ABUTMENT - WATANA



SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number: B.H. - 8

Location: Watana

Ground Surface Elevation: 1976

Static Water Level: 15 feet (vertical)

Dip of Hole: 60°

Stickup: None

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
31.9	48	20	13	4.55	2.41×10^{-4}
46.9	63	25	20	2.1	9.36×10^{-5}
61.9	78	31	5	.34	1.27×10^{-5}
76.9	93	38	10	4.0	1.26×10^{-4}
91.9	108	45	15	6.2	1.69×10^{-4}
106.9	123	51	20	3.2	7.84×10^{-5}
121.9	138	57	10	.8	1.78×10^{-5}
136.9	153	64	5	3.2	6.40×10^{-5}
151.9	168	70	9	6.6	1.22×10^{-4}
166.9	183	77	10	3.0	5.07×10^{-5}
181.9	198	84	10	.38	5.92×10^{-6}
196.9	213	90	10	1.2	1.75×10^{-5}
226.9	243	104	8	3.7	4.73×10^{-5}
241.9	258	110	6	10.3	1.25×10^{-4}
256.9	273	116	5	7.5	8.64×10^{-5}
271.9	288	50	6	7.0	1.74×10^{-4}
286.9	303	50	7	3.85	9.60×10^{-5}
301.9	318	50	6	2.95	7.35×10^{-5}
316.9	333	142	5	7.8	7.42×10^{-5}

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
331.9	348	149	5	7.3	6.63×10^{-5}
346.9	363	155	6	2.45	2.14×10^{-5}
361.9	378	162	5	2.75	2.31×10^{-5}
376.9	393	150	35	12.7	1.15×10^{-4}
391.9	408	110	40	10.9	1.32×10^{-4}
406.9	423	50	5	1.7	4.24×10^{-5}
421.9	438	188	6	.4	2.91×10^{-6}
436.9	453	195	5	.24	1.68×10^{-6}
451.9	468	200	8	.36	2.46×10^{-6}
466.9	483	200	6	.54	3.70×10^{-6}
481.9	498	200	7	.54	3.70×10^{-6}
496.9	513	200	7	.60	4.11×10^{-6}
511.9	528	200	5	.55	3.76×10^{-6}
526.9	543	200	5	.96	6.57×10^{-6}
541.9	558	200	6	.85	5.82×10^{-6}
556.9	573	200	6	.76	5.20×10^{-6}
571.9	588	200	7	2.05	1.40×10^{-5}
586.9	603	200	6	.85	5.82×10^{-6}
601.9	618	200	7	2.8	1.92×10^{-5}
616.9	633	200	6	.75	5.13×10^{-6}
631.9	648	200	6	.82	5.61×10^{-6}
646.9	663	225	8	1.60	9.77×10^{-6}
661.9	678	200	6	.80	5.47×10^{-6}
669.9	671	200	7	1.1	7.53×10^{-6}
691.9	708	200	6	1.08	7.39×10^{-6}
706.9	723	200	6	1.2	8.21×10^{-6}
721.9	738	200	12	1.0	6.84×10^{-6}

APPENDIX B-2

DEVIL CANYON REPORTS

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DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 1 OF 20

SITE DEVIL CANYON NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR THE DRILLING COMPANY STARTED 12:00 P.M. AUG. 23 1980
FINISHED .M. AUG. 31 1980

DRILLING METHOD
SOIL Casing Advancer CASING DIAM. NW (3.5" O.D.)
ROCK DIAMOND CORE DRILL CORE DIAM. NQ-3 (1.875")

LOCATION:
LATITUDE N 62° 49' 11.427
DEPARTURE W 149° 18' 24.797
BEARING 225°
INITIAL DIP 67°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1415 ft.
ROCK SURFACE 1404.1 ft.
BOTTOM OF HOLE 724.4 ft.
WATER TABLE 1223 ft. (11-21-80)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD.)
0.0	Overburden	Sandy gravel with some silt and scattered cobbles. Not sampled.		
11.8	Phyllite	Gray-brown with intercalated quartz stringers forming 30% of rock. Foliation regular to swirling at 60° to 90° to core axis. Moderately hard to hard; slightly to moderately weathered. fractured and friable throughout. Becomes less weathered with depth. Limonite staining and minor clay or sand along discontinuities. 12.8 - 14.8 Highly fractured. Core loss 0.6'. 17.5 - 18.3 Highly fractured.	Run 1 11.8 to 15.8 Run 2 15.8 to 20.8	85 (20) 100 (88)
20.8	Argillite	Medium gray to dark gray, very fine to medium grained. Laminae oriented approximately 30° to core axis. Contorted quartz stringers and irregular bedding throughout. Generally hard to soft and friable locally. Fresh to slightly weathered along joints and fractures with limonite staining common and occasional clay filling. Minor sulfide mineralization and carbonate throughout. Joint spacing close to very close.	Run 3 20.8 to 26.2 Run 4 26.2 to 31.3	85 (59) 86 (82)

LOGGED BY R. RAHAIM - J HAGAN (R&M)
SUMMARY - B. HOLM
(ACRES)

APPROVED (R&M)
DATE
APPROVED (ACRES)
DATE

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 2 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
31.3	Argillite (cont'd)	20.8 - 31.3 Core loss 1.5'. (21.8 - 22.3) Quartz-carbonate-pyrite mineralization with bleaching from weathering. (25.0, 26.4 - 26.6) Soft zones. 31.3 - 35.0 Slightly fissile. Core loss 0.3'.	R 5 31.3 to 35.0 R 6 35.0 to 40.0 R 7 40.0 to 45.0 R 8 45.0 to 49.0
49.0 68.9	Meta-Argillite	Dark gray pelitic rock with occasional bluish gray laminae. Sheen along irregular fracture surfaces. Very fine to fine grained. Laminae oriented at approximately 0° to 30° to core axis. Moderately hard to very hard. Well indurated with slight fissility locally. Fresh to slightly weathered with limonite staining on joints common. Elongated quartz grains scattered throughout. Euhedral pyrite commonly associated with bluish zones. Some open voids from leached sulfides. Joint spacing very close to moderately close, with occassional chlorite or clay filling. Numerous old fractures rehealed by quartz throughout. 49.0 - 84.0 Quartz, irregular veins and cement along old partings, 4% to 12% of rock. 63.5 - 68.9 Highly fractured. Core loss 1.1'. 68.1 - 69.2 Quartz vein with sulfides and some voids from sulfide leaching.	R 9 49.0 to 53.2 R 10 53.2 to 58.3 R 11 58.3 to 63.5 R 12 63.5 to 64.5 R 13 64.5 to 68.9

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SUSITNA HYDROELECTRIC PROJECT for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 3 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
68.9	Meta-argillite (cont'd)			
			R 14 68.9 to 72.3	100 (88)
			R 15 72.3 to 77.2	100 (92)
		79.0 - 109.1 Highly fractured and sheared zone. Poor core recovery with core loss of 4.6 feet. Slightly to highly weathered throughout, residual soil locally.	R 16 77.2 to 80.7	94 (83)
			R 17 80.7 to 84.0	94 (48)
		84.0 - 101.5 Quartz stringers and veins forming 40% to 60% of rock. Numerous small cavities.	R 18 84.0 to 90.0	87 (70)
			R 19 90.0 to 94.4	91 (50)
			R 20 94.4 to 97.8	88 (29)
			R 21 97.8 to 101.5	54 (0)
			R 22 101.5 to 105.0	71 (23)
105.0				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 4 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
105.0	Argillite	Medium to dark gray, very fine to fine grained laminae oriented approximately 0° to 20° to core axis. Contorted quartz stringers and irregular bedding throughout. Generally hard; soft and friable locally. Fresh to slightly weathered, with limonite staining on joint and fracture surfaces. Minor sulfide mineralization throughout. Joint spacing very close to moderately close.	R 23 105.0 to 109.1
		109.1 - 265.6 Sulfides 3% to 8% of rock.	R 24 109.1 to 112.5
		109.1 - 175.0 Most joints at 60° to core axis. Limonite common along joints. Numerous drilling breaks.	R 25 112.5 to 117.6
		112.5 - 117.6 Core loss 0.7'.	R 26 117.6 to 120.9
		114.0 - 114.8 Quartz vein.	
		117.6 - 118.6 Vertical quartz inclusion.	R 27 120.9 to 125.0
		120.9 - 129.0 Clay filling in joints. (Possible gouge).	
		125.0 - 129.0 Joints and fractures open to 0.05' within run. Core loss 0.5'.	R 28 125.0 to 129.0
		129.0 - 148.0 Joint spacing very close to close.	R 29 129.0 to 134.0
			R 30 134.0 to 139.2
			R 31 139.2 to 144.3
144.3			

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 5 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
144.3	Argillite	(144.3 - 148.3) Core loss 0.4'.	R 32 144.3 to 148.0	89 (81)
		148.0 - 166.3 Joint spacing very close to moderately close.	R 33 148.0 to 153.2	100 (92)
			R 34 153.2 to 156.2	100 (83)
		(156.2 - 161.5) Core loss 0.2'.	R 35 156.2 to 161.5	96 (89)
			R 36 161.5 to 166.3	100 (100)
			R 37 166.3 to 171.5	100 (100)
		175.0 - 276.1 Numerous fractures cemented with calcite, minor chlorite. Core frequently broken along these surfaces by drilling.	R 38 171.5 to 176.3	100 (100)
			R 39 176.3 to 181.4	100 (100)
			R 40 181.4 to 186.3	100 (100)
186.3				

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HOLE NO. BH-1
SHEET NO. 6 OF

SITE DEVIL CANYON N. ABUTMENT   JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
186.3	Argillite (cont'd)		R 41 186.3 to 191.5
			R 42 191.5 to 196.4
			R 43 196.4 to 201.5
			R 44 201.5 to 204.9
			R 45 204.9 to 209.9
			R 46 209.9 to 214.9
			R 47 214.9 to 220.0
		220.0 - 221.2 Joints oriented parallel to core axis, with clay gouge.	R 48 220.0 to 225.1
			R 49 225.1 to 230.0
230.0			

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ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 7 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
230.0	Argillite (cont'd)		R 50 230.0 to 235.0	100 (100)
			R 51 235.0 to 240.1	100 (98)
		240.1 - 241.0. Minor clay along partings within run.	R 52 240.1 to 241.8	100 (94)
		241.8 Core is fresh below this point.	R 53 241.8 to 246.9	100 (100)
			R 54 246.9 to 251.5	100 (100)
			R 55 251.5 to 255.9	100 (91)
			R 56 255.9 to 260.5	100 (100)
		260.5 - 276.1 Joint spacing very close to close.	R 57 260.5 to 262.5	100 (100)
			R 58 262.5 to 265.6	100 (87)
265.6				

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HOLE NO. BH-1
SHEET NO. 8 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft0	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
265.6	Argillite (cont'd)	(270.3 - 274.2) Core loss 0.8'.	R 59 265.6 to 270.3 R 60 270.3 to 274.2 R 61 274.2 to 276.1
276.2 298.9	Lithic Graywacke	Dark gray to black; fine to medium grained with crystalline like texture. 3% to 7% green carbonate crystals, quartz rich. Fresh to moderately weathered hard to very hard. Joint spacing very close to moderately close. 276.1 - 280.3 Slickensided partings. 285.2 - 286.6 Core loss 0.2'. 285.3 0.1' layer of clay gouge.	R 62 276.1 to 280.3 R 63 280.3 to 285.2 R 64 285.2 to 286.6 R 65 286.6 to 291.5 R 66 291.5 to 296.0
296.5	Meta Argillite	Medium to dark gray, mottled bluish-gray locally. Fine grained; moderately hard to very hard, fresh and competent. Minor sulfide mineralization. Carbonates common. Joint spacing very close to moderately close. Numerous healed joints throughout.	R 67 296.0 to 298.9

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SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
298.0	Meta-argillite (cont'd)	296.0 - 298.9 Shear zone, highly fractured, weathered and slickensided. Core loss 0.6'	R 68 298.0 to 303.0	100 (85)
			R 69 303.0 to 305.0	100 (90)
		305.0 - 311.0 Core loss 0.3'.	R 70 305.0 to 306.1	82 (68)
		306.1 - 311.0 Joint spacing very close.	R 71 306.1 to 311.0	98 (71)
			R 72 311.0 to 315.7	100 (85)
			R 73 315.7 to 320.0	100 (100)
		320.0 - 325.0 Core loss 0.3'.	R 74 320.0 to 325.0	94 (92)
329.0	Graywacke (Breccia-Conglomerate)	Medium to dark gray clayey matrix containing coarse, angular and sub-rounded clasts of quartz, phyllite, argillite, and other rock types ranging in size from 0.01' to 0.1' and constituting 50% to 60% of rock mass. Well indurated, hard to very hard, competent, fresh. Contains thin layers (1 to 2 feet thick) of Argillite locally. Joint spacing very close to moderately close. Chlorite and carbonate coating on joints common. Occasional healed joints.	R 75 325.0 to 329.7	100 (85)
			R 76 329.7 to 334.7	100 (80)
334.7				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 10 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
334.7	Graywacke (cont'd)		R 77 334.7 to 339.8	100 (88)
		343.0 Joint with clay gouge.	R 78 339.8 to 345.0	100 (96)
			R 79 345.0 to 349.7	(100) (94)
			R 80 349.7 to 355.0	100 (100)
			R 81 355.0 to 359.6	100 (100)
			R 82 359.6 to 361.3	100 (100)
			R 83 361.3 to 363.4	100 (100)
			R 84 363.4 to 364.4	100 (100)
			R 85 364.4 to 369.3	100 (98)
369.3				

DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 11 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
.3	Graywacke (cont'd)	373.3 to 373.6 Shear zone with clay gouge.	R 86 369.3 to 373.6	100 (93)
			R 87 373.6 to 378.6	100 (100)
		378.7 Clay filled joint.	R 88 378.6 to 381.5	100 (86)
		381.5 - 401.5 Numerous healed joints broken by drilling.	R 89 381.5 to 386.5	100 (100)
		386.5 - 391.4 Core loss 0.2'.	R 90 386.5 to 391.4	95 (94)
			R 91 391.4 to 396.5	100 (98)
			R 92 396.5 to 401.5	100 (90)
		406.0 - 424.0 Joint spacing very close to close.	R 93 401.5 to 406.6	100 (96)
			R 94 406.6 to 411.5	100 (82)
5				

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for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 12 OF 2

SITE DEVIL CANYON N. ABUTMENT   JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO R (R
411.5	Graywacke (cont'd)	413.3 - 415.3 Highly fractured zone.	R 95 411.5 to 415.3	1 (
			R 96 415.3 to 420.3	1 (
		423.9 - 424.1 Highly fractured zone, trace of clay gouge.	R 97 420.3 to 424.1	1 (
			R 98 424.1 to 429.3	1 (
			R 99 429.3 to 434.3	1 (1
			R 100 434.3 to 439.4	1 (
			R 101 439.4 to 444.4	1 (
			R 102 444.4 to 449.5	1 (1
			R 103 449.5 to 454.7	1 (1
454.7				

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SUSITNA HYDROELECTRIC PROJECT for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 13 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
454.7	Graywacke (cont'd)		R 104 454.7 to 459.8	100 (100
			R 105 459.8 to 463.8	100 (100)
			R 106 463.8 to 468.6	100 (100)
			R 107 468.6 to 473.1	100 (100)
			R 108 473.1 to 475.4	100 (100)
			R 109 475.4 to 480.5	100 (82)
			R 110 480.5 to 485.5	100 (100)
			R 111 485.5 to 488.8	100 (85)
		488.8 - 491.5 Core loss 0.1'.	R 112 488.8 to 491.5	96 (70)
491.5				

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for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 14 OF 2

SITE DEVIL CANYON N. ABUTMENT   JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO RE (R
491.5	Graywacke (cont'd)		R 113 491.5 to 496.7	1 (
			R 114 496.7 to 501.2	1 (
			R 115 501.2 to 506.5	1 (1
			R 116 506.5 to 511.5	1 (1
			R 117 511.5 to 514.8	1 (
			R 118 514.8 to 519.9	1 (
			R 119 519.9 to 525.1	1 (
			R 120 525.1 to 530.4	1 (1
		530.4 - 534.0 Core loss 0.2'. (533.5) Joint with carbonate and clay gouge.	R 121 530.4 to 534.0	(
534.0				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-I
SHEET NO. 15 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
534.0	Graywacke (cont'd)		R 122 534.0 to 539.0	100 (98)
		540 - 750.2 Generally hard, fresh, competent.	R 123 539.0 to 544.3	100 (89)
			R 124 544.3 to 549.5	100 (100)
			R 125 549.5 to 554.5	100 (100)
			R 126 554.5 to 559.7	100 (90)
			R 127 559.7 to 564.8	100 (100)
			R 128 564.8 to 569.7	100 (100)
			R 129 569.7 to 575.1	100 (100)
			R 130 575.1 to 579.9	100 (92)
579.9				

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SUSITNA HYDROELECTRIC PROJECT

for ALASKA POWER AUTHORITY

HOLE NO. BH-1

SHEET NO. 16 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
579.9	Graywacke (cont'd)		R 131 579.9 to 585.1
			R 132 585.1 to 590.1
			R 133 590.1 to 595.1
		598.7 - 599.1 Core shattered.	R 134 595.1 to 599.1
			R 135 599.1 to 604.2
			R 136 604.2 to 609.1
			R 137 609.1 to 610.5
			R 138 610.5 to 614.8
			R 139 614.8 to 619.8
619.8			

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SUSITNA HYDROELECTRIC PROJECT
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HOLE NO. BH-1
SHEET NO. 17 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
619.8	Graywacke (cont'd)	(621.6 - 621.7) Core shattered.	R 140 619.8 to 621.7	100 (95)
			R 141 621.7 to 626.8	100 (98)
			R 142 626.8 to 631.7	100 (100)
			R 143 631.7 to 636.7	100 (100)
			R 144 636.7 to 641.6	100 (100)
			R 145 641.6 to 645.2	100 (100)
			R 146 645.2 to 650.0	100 (100)
			R 147 650.0 to 655.2	100 (100)
			R 148 655.2 to 660.4	100 (96)
660.4				

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DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 18 OF 2

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
660.4	Graywacke (cont'd)		R 149 660.4 to 665.6
			R 150 665.6 to 670.8
			R 151 670.8 to 675.8
			R 152 675.8 to 680.5
			R 153 680.5 to 683.9
		683.9 - 690.0 Core loss 0.7'.	R 154 683.9 to 690.0
			R 155 690.0 to 695.2
			R 156 695.2 to 700.5
			R 157 700.5 to 705.7
705.7			

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HOLE NO. BH-1
SHEET NO. 19 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
705.7	Graywacke (cont'd)		R 158 705.7 to 710.6	100 (100)
			R 159 710.6 to 715.7	100 (100)
			R 160 715.7 to 721.0	100 (98)
			R 161 721.0 to 725.4	100 (100)
		727.1 Joint with clay coating.	R 162 725.4 to 727.4	100 (95)
			R 163 727.4 to 731.8	100 (91)
		731.8 - 732.5 Highly fractured zone. 733.0 Joint with clay gouge.	R 164 731.8 to 737.1	100 (85)
		737.4 Joint with ¼" clay gouge.	R 165 737.1 to 741.5	100 (91)
			R 166 741.5 to 745.7	100 (98)
745.7				

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for ALASKA POWER AUTHORITY

HOLE NO. BH-1
SHEET NO. 20 OF 2

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO RE (R
745.7	Graywacke (cont'd)		R 167 745.7 to 750.2	1 (
750.2		End of Hole		

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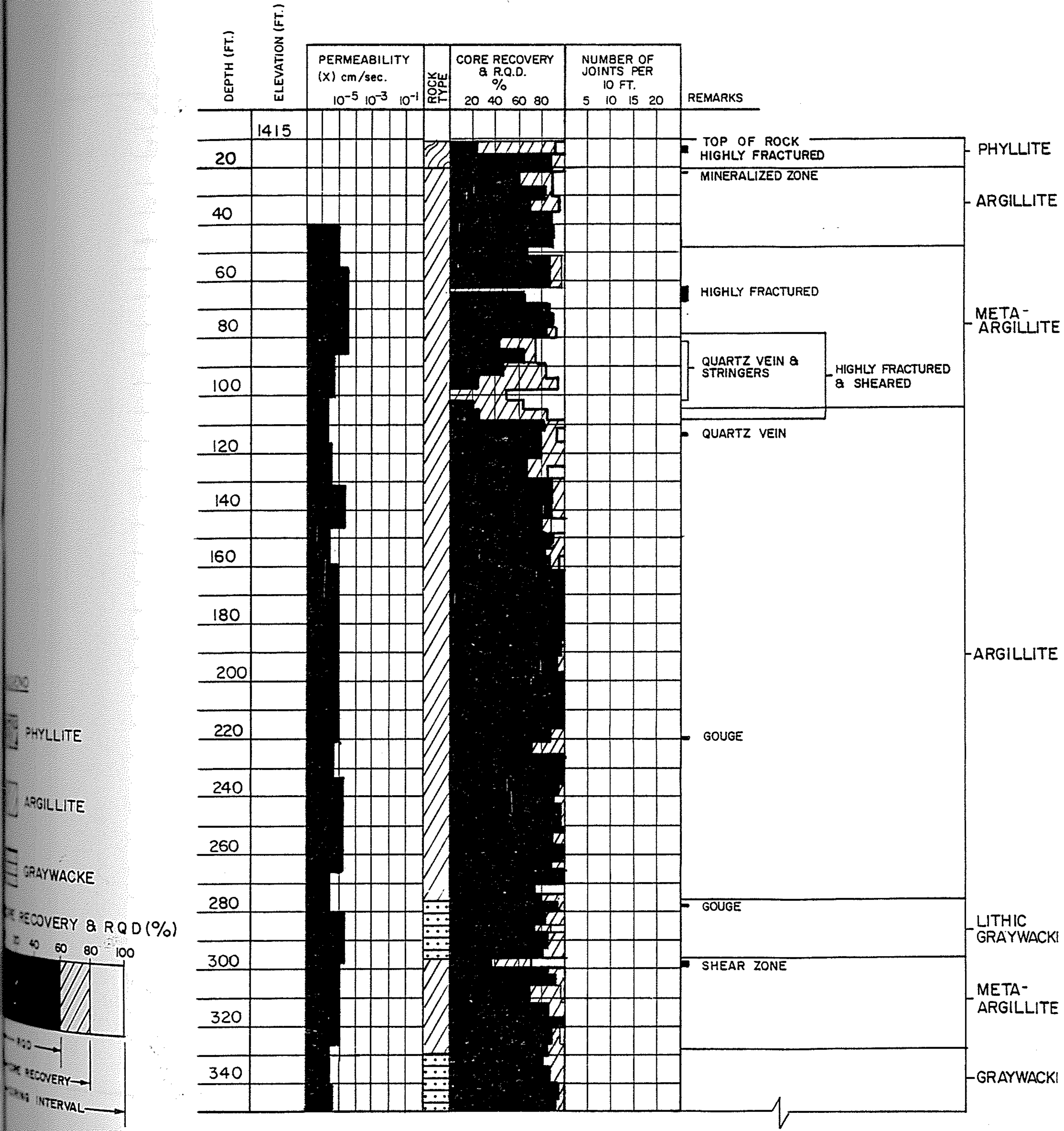
BEDROCK LOGS

HOLE NO. BH-1 DATE AUG 1980

LOCATION DEVIL CANYON



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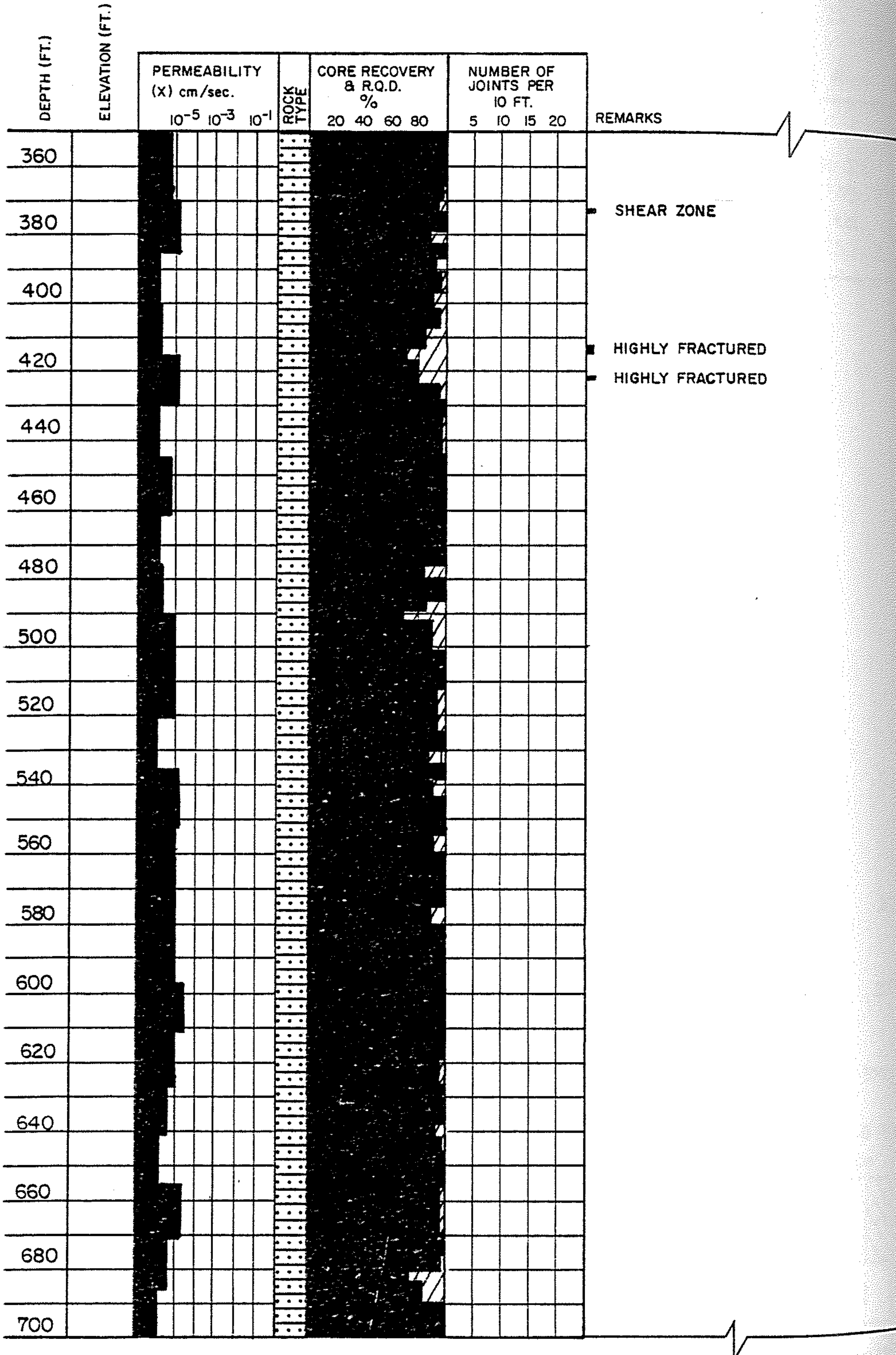
BEDROCK LOGS

HOLE NO. BH - I DATE AUGUST,80

LOCATION DEVIL CANYON



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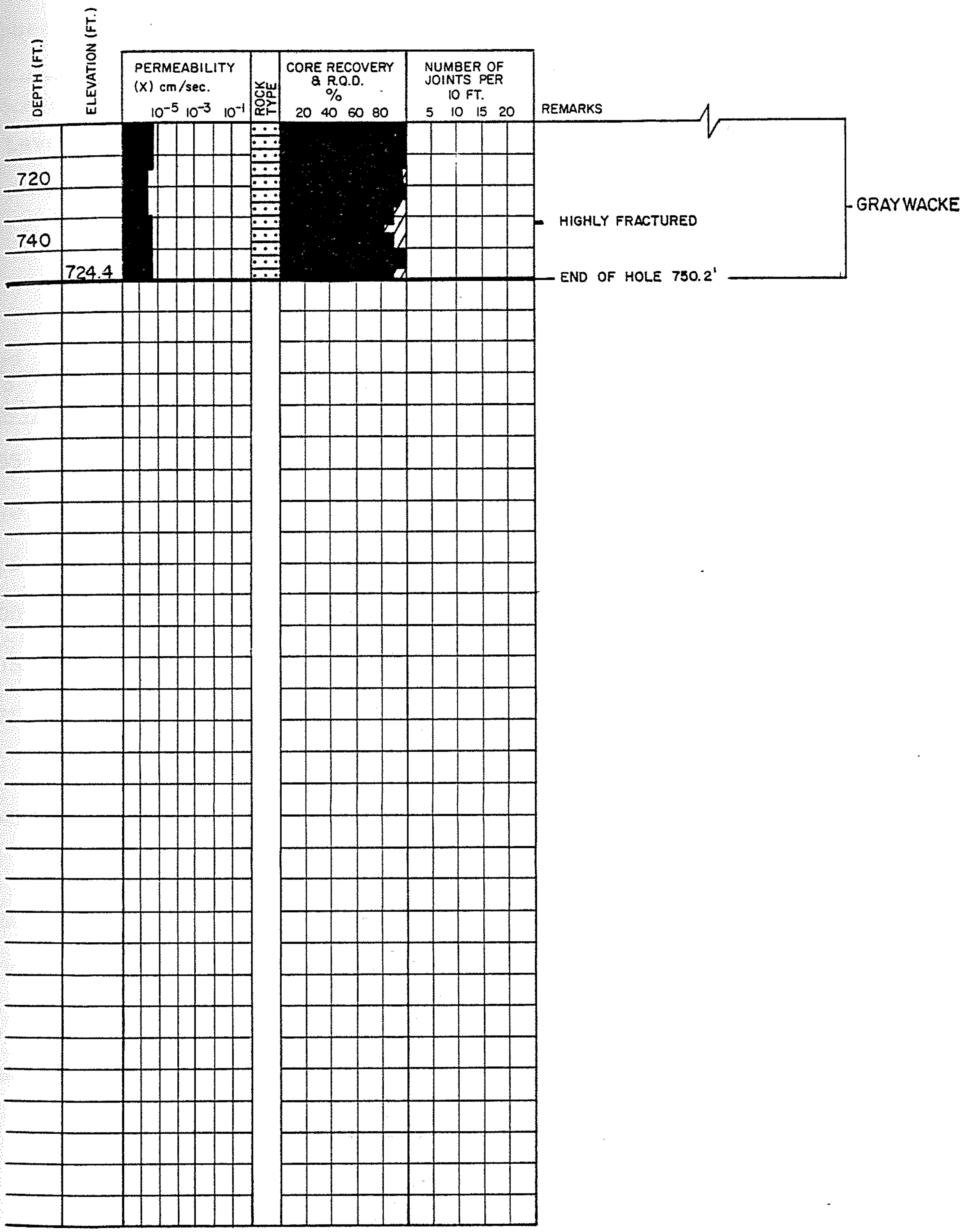
BEDROCK LOGS

HOLE NO. BH-1 DATE AUG 1980

LOCATION DEVIL CANYON



SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number BH-1

Location Devil Canyon

Ground Surface Elevation 1415

Static Water Level 192 feet (Vertical)

Dip of Hole 67°

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
38.9	55	8	20	11	.70	9.31×10^{-6}
53.9	70	3	30	11	4.1	5.07×10^{-5}
68.9	85	8	40	10	6.2	6.94×10^{-5}
83.9	100	3	45	10	.78	8.53×10^{-6}
98.9	115	8	55	10	.50	5.00×10^{-6}
113.9	130	3	60	46	.90 to 5.40	8.82×10^{-6} To 5.29×10^{-5}
128.9	145	8	70	21	.65 to .95	5.88×10^{-6} To 8.59×10^{-6}
143.9	160	3	75	14	.80	7.10×10^{-6}
158.9	175	8	85	10	.84 to 1.25	6.93×10^{-6} To 1.03×10^{-5}
173.9	190	3	90	10	.02 to .15	1.62×10^{-7} To 1.22×10^{-6}

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficie Permeal (cm/se
188.9	205	8	100	10	1.65 to 2.45	1.25 x To 1.86 x
203.9	220	3	105	10	2.1	1.57 x
218.9	235	8	115	10	.6 to 1.2	4.21 x To 8.43 x
233.9	250	3	120	10	2.3 to 3.0	1.59 x To 2.08 x
248.9	265	8	130	10	5.25	3.43 x
263.9	280	3	135	10	.1 to .4	6.45 x To 2.58 x
278.9	295	8	145	10	2 to 5.8	1.22 x To 3.55 x
293.9	310	3	150	10	1.1 to 2.8	6.64 x To 1.69 x
308.9	325	8	160	10	.26 to 2.2	1.49 x To 1.26 x
323.9	340	3	165	10	.40	2.27 x
338.9	355	8	170	10	1.6	8.83 x
353.9	370	3	180	10	1.5	8.03 x
368.9	385	8	190	10	2.2	1.13 x
383.9	400	3	195	10	.20 to .32	1.01 x To 1.62 x
398.9	415	8	200	10	.30 to .70	1.48 x To 3.46 x

Borehole BH-1

Devil Canyon - (Continued)

Depth Tested From (feet)	To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
413.9	430	3	200	10	1.3 to 2.9	6.47×10^{-6} To 1.44×10^{-5}
428.9	445	8	200	10	.30	1.48×10^{-6}
443.9	460	3	200	10	.62 to 1.65	3.08×10^{-6} To 8.21×10^{-6}
458.9	475	8	200	10	.55	2.72×10^{-6}
473.9	490	3	200	10	.74	3.68×10^{-6}
488.9	505	8	200	10	2.6	1.28×10^{-5}
503.9	520	3	200	10	.50 to 2.0	2.49×10^{-6} To 9.95×10^{-6}
518.9	535	8	200	10	.2 to .5	9.88×10^{-7} To 2.47×10^{-6}
533.9	550	3	200	10	2.4 to 5.0	1.19×10^{-5} To 2.49×10^{-5}
548.9	565	8	200	10	4.5	2.22×10^{-5}
563.9	580	3	200	10	3.8	1.89×10^{-5}
578.9	595	8	200	1	3.9	1.93×10^{-5}
593.9	610	3	200	10	9.7	4.83×10^{-5}
608.9	625	8	150	13	2.55	1.53×10^{-5}
622.9	639	3	130	18	1.21	7.98×10^{-6}
638.9	655	8	130	11	.55	3.60×10^{-6}
653.9	670	3	200	10	7.4	3.68×10^{-5}
668.9	685	8	130	10	1.02	6.67×10^{-6}

Borehole BH-1 Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient Permeabil (cm/sec
683.9	700	3	150	27	.34 to .48	2.05 x 10 To 2.90 x 10
698.9	715	8	150	19	.4 to 1.12	2.39 x 10 To 6.70 x 10
713.9	730	3	150	13	.40	2.41 x 10
728.9	745	8	150	14	.80	4.79 x 10

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DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 1 OF 18

SITE DEVIL CANYON NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR THE DRILLING COMPANY
STARTED 11:00 A.M. Sept. 10 19 80
FINISHED .M. Sept. 15 19 80

DRILLING METHOD
SOIL CASING ADVANCER — CASING DIAM. NW (3.5" O.D.)
ROCK DIAMOND CORE DRILLING — CORE DIAM. NQ (1.875")

LOCATION:
LATITUDE N 62° 49'8.737"
DEPARTURE W 149° 18' 21.179"
BEARING 0°
INITIAL DIP 60°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1214 ft
ROCK SURFACE 1212 ft
BOTTOM OF HOLE 645.7 ft
WATER TABLE 1209 ft

NOTE: All depths are along hole.

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN (ft)	% CORE REC. (RQD.)
0.0	Overburden	Dark brown organic silt with trace light gray ash, angular cobbles. 0.0 - 2.0 No samples taken.		
2.0	Argillite	Gray, siliceous, very fine grained. Thinly bedded, with laminae oriented 55° to 60° to core axis. Very hard to moderately hard. Fresh to slightly weathered, with Iron-oxide staining on fracture and joint surfaces. Joints very close to closely spaced. Pyrite cubes common. Occasional quartz intrusions. 2.0 - 16.0 Core loss 2.9'. (6.0 - 10.5) Highly fractured interval, friable 10.5 - 16.0 Silvery sheen. Grading into phyllite. Laminae offset.	Run 1 2.0 to 6.0 Run 2 6.0 to 7.0 Run 3 7.0 to 8.1 Run 4 8.1 to 10.5 Run 5 10.5 to 16.0	95 (53) 40 (0) 73 (0) 79 (0) 76 (40)
16.0				

LOGGED BY Rahaim, Hagen - field (R&M)
Feldman - Summary
(ACRES)

APPROVED (R&M)
DATE December 1980
APPROVED (ACRES)
DATE

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 2 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
16.0	Phyllite	Dark gray, thinly bedded. Wavy laminae oriented at 40° to 60° to core axis. Very hard to hard. Fresh to moderately weathered, with Iron-staining on joints and fracture surfaces. Joint spacing very close to moderately close. Trace to frequent pyrite. Minor quartz in healed fractures.	Run 6 16.0 to 21.0
			Run 7 21.0 to 26.0
		21.0 - 26.0 Slightly fissile.	
			Run 8 26.0 to 28.0
		28.0 - 33.0 Thin quartz veins. Healed brecciated zone at approximately 31 feet.	Run 9 28.0 to 33.0
		33.0 - 38.0 Argillaceous zone. Fractures oriented at approximately 0° to core axis.	Run 10 33.0 to 38.0
			Run 11 38.0 to 42.0
		42.0 - 46.9 Joint spacing close to moderately close.	Run 12 42.0 to 46.9
			Run 13 46.9 to 51.8
		51.8 - 57.1 Graywacke intermixed with phyllite.	Run 14 51.8 to 57.1
57.1			

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 3 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
57.1	Phyllite (cont'd)		Run 15 57.1 to 62.1	100 (100)
			Run 16 62.1 to 67.0	100 (98)
			Run 17 67.0 to 71.9	100 (100)
			Run 18 71.9 to 76.8	100 (100)
		71.9 - 76.8 Intermixed argillite.	Run 19 76.8 to 81.8	100 (80)
		81.8 - 86.9 Predominantly phyllite. Wavy and irregular bedding at 50° to 60° to core axis. Closely spaced joints.	Run 20 81.8 to 86.9	100 (96)
		86.9 - 91.6 Joint spacing very close to close.	Run 21 86.9 to 91.6	100 (83)
91.6	Argillaceous Graywacke	Brown, folded, very hard and fresh. Joint spacing very close to moderately close. Pyrite common. Some quartz intrusions. Argillite, laminae oriented at 40° to 50° to core axis.	Run 22 91.6 to 96.9	100 (89)
			Run 23 96.9 to 101.7	100 (96)
101.7				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 4 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
101.7	Argillaceous Graywacke (cont'd)		Run 24 101.7 to 105.0
			Run 25 105.0 to 107.9
		107.9 - 112.0 Rock less competent, highly fractured and broken by drilling.	Run 26 107.9 to 109.5
		(109.5 - 112.0) Core loss 1.5'.	Run 27 109.5 to 112.0
112.0	Argillite	Gray, very fine grained. Generally very hard, friable locally. Fresh to slightly weathered, with trace of Iron-staining and some chlorite and calcite scale in joints and fractures. Very close to closely spaced joints. Occasional quartz intrusions.	Run 28 112.0 to 114.6
		114.6 - 119.4 Some interlayered graywacke. Slickensides at 117.5'.	Run 29 114.6 to 119.4
		119.4 - 123.2 Highly fractured. Some fractures healed with bluish quartz. Clay on vertical joint. Core loss 0.3'.	Run 30 119.4 to 123.2
			Run 31 123.2 to 125.9
		125.9 - 132.0 Poor recovery. Core badly ground by drilling. Core loss 4.1 feet.	Run 32 125.9 to 132.0
132.0			

DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 5 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
137.0	Argillite (cont'd)		Run 33 132.0 to 135.0	100 (100)
			Run 34 135.0 to 137.0	100 (90)
		137.0 - 140.3 Joints moderately close spaced.	Run 35 137.0 to 140.3	100 (76)
		140.3 - 145.4 Oolitic zone. Numerous soft, white, noncalcareous Oolites in dark gray calcareous argillite matrix. (141.3, 144.0) Slickensides.	Run 36 140.3 to 143.4	100 (81)
			Run 37 143.4 to 145.4	100 (90)
145.4	Graywacke	Dark gray, medium to coarse grained. Moderately hard to soft, fresh to moderately weathered. Numerous cream-colored, rounded, siliceous blebs (greater than 3 mm) throughout. Joint spacing very close to moderately close.	Run 38 145.4 to 147.5	100 (100)
		147.5 - 152.0 Core loss 0.2'.	Run 39 147.5 to 152.0	96 (95)
		152.0 - 155.0 Gouge zone. Moderately hard to soft, moderately weathered. Residual soil present. Very friable. Core loss 0.2'.	Run 40 152.0 to 155.0	93 (0)
		155.0 - 178.6 Dark gray to green, with crystals of gypsum(?) [up to 5 mm diameter] and quartz. Abundant biotite mica noted. Moderately hard, slightly to moderately weathered. (155.0 - 160.0) Slickensides.	Run 41 155.0 to 160.0	100 (92)
165.4			Run 42 160.0 to 165.4	100 (93)

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 6 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
165.4	Graywacke (cont'd)		Run 43 165.4 to 170.5
			Run 44 170.5 to 175.6
			Run 45 175.6 to 178.6
		178.6 - 182.8 Highly fractured, some clay gouge on joint surfaces.	Run 46 178.6 to 181.8
182.8	Interbedded Graywacke and Argillite	Interbedded graywacke and dark gray, fine grained argillite. Hard to moderately hard. Fresh. Joints closely spaced. Many healed fractures filled with calcite, some quartz.	Run 47 181.8 to 185.9
			Run 48 185.9 to 190.8
			Run 49 190.8 to 193.8
			Run 50 193.8 to 198.9
			Run 51 198.9 to 203.4
203.4			

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for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 7 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
203.4	Graywacke and Argillite (cont'd)		Run 52 203.4 to 208.6	100 (100)
			Run 53 208.6 to 211.7	100 (100)
		213.0 - 213.6 Broken and healed zone.	Run 54 211.7 to 216.9	100 (96)
			Run 55 216.9 to 220.4	100 (100)
		220.4 - 231.2 Joint spacing close to moderately close.	Run 56 220.4 to 226.0	100 (98)
			Run 57 226.0 to 231.2	100 (100)
			Run 58 231.2 to 236.3	100 (100)
236.3	Argillite	Gray, very fine grained. Laminae oriented 50° to core axis. Oriented, platy minerals evident. Very hard to moderately hard. Fresh. Joint spacing very close to moderately close. Traces of pyrite (cubes), and minor quartz in irregular veins.	Run 59 236.3 to 241.0	100 (100)
			Run 60 241.0 to 244.7	100 (97)
244.7				

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for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 8 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
244.7	Argillite (cont'd)		Run 61 244.7 to 249.8
			Run 62 249.8 to 255.0
			Run 63 255.0 to 260.0
		260.0 - 262.5 Core loss 0.2'.	Run 64 260.0 to 262.5
			Run 65 262.5 to 267.3
			Run 66 267.3 to 269.5
		270.5 Joint with clay gouge.	Run 67 269.5 to 274.7
		274.7 - 281.8 Core loss 0.4'.	Run 68 274.7 to 277.5
			Run 69 277.5 to 281.8
281.8			

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HOLE NO. BH-2
SHEET NO. 9 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
281.8	Argillite (cont'd)		Run 70 281.8 to 287.0	100 (100)
			Run 71 287.0 to 292.0	100 (100)
			Run 72 292.0 to 297.0	100 (100)
		300.0 Joint with clay gouge.	Run 73 297.0 to 301.7	100 (100)
		301.7 - 306.7 Quartz intrusion parallel to bedding - constitutes 15% of the interval.	Run 74 301.7 to 306.7	100 (100)
			Run 75 306.7 to 309.4	100 (100)
			Run 76 309.4 to 310.5	100 (100)
			Run 77 310.5 to 315.5	100 (100)
			Run 78 315.5 to 318.7	100 (100)
318.7				

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HOLE NO. BH-2
SHEET NO. 10 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
318.7	Argillite (cont'd)	318.7 - 325.8 Wavy laminae, generally oriented at 45° to 50° to core axis.	Run 79 318.7 to 322.5
			Run 80 322.5 to 325.8
		327.8 - 329.0 Interbedded graywacke numerous contorted quartz stringers throughout.	Run 81 325.8 to 329.0
		329.0 - 336.4 Contorted quartz stringers throughout.	Run 82 329.0 to 331.5
		331.5 - 336.4 Core loss 1.6'.	Run 83 331.5 to 336.4
		336.4 - 365.6 Intercalated graywacke and argillite, dark gray to light grayish brown. Irregular, wavy laminae at 50° to core axis. Very hard to hard, fresh, joint spacing very close to moderately close.	Run 84 336.4 to 338.4
		341.5 Joint with clay gouge.	Run 85 338.4 to 342.0
			Run 86 342.0 to 346.0
			Run 87 346.0 to 351.1
351.1			

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HOLE NO. BH-2
SHEET NO. 11 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
351.1	Argillite (cont'd)		Run 88 351.1 to 356.0	100 (100)
			Run 89 356.0 to 360.8	100 (100)
			Run 90 360.8 to 365.6	100 (98)
		365.6 - 385.1 Trace of pyrite with cubes to 5 mm. (365.6 - 370.9) Core loss 0.1'.	Run 91 365.6 to 370.9	98 (96)
		(374.4) Clay filled joint.	Run 92 370:9 to 375.0	100 (85)
			Run 93 375.0 to 380.0	100 (100)
			Run 94 380.0 to 385.1	100 (100)
		385.1 - 390.3 Deformed laminae.	Run 95 385.1 to 390.3	100 (98)
			Run 96 390.3 to 395.5	100 (94)
395.5				

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for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 12 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
395.5	Argillite (cont'd)		Run 97 395.5 to 400.7
		400.7 - 406.0 Core loss 0.1'.	Run 98 400.7 to 406.0
		406.3 Clay gouge on joint.	Run 99 406.0 to 411.0
		411.0 - 444.9 Argillite grading into phyllite. Quartz veins common. Chlorite mineralization.	R 100 411.0 to 416.3
			R 101 416.3 to 421.3
			R 102 421.3 to 426.6
		426.6 - 431.9 Core loss 0.4'.	R 103 426.6 to 431.9
			R 104 431.9 to 437.2
			R 105 437.2 to 442.2
442.2			

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HOLE NO. BH-2
SHEET NO. 13 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
442.2	Argillite (cont'd)		R 106 442.2 to 444.9	100 (100)
444.9	Graywacke with Argillite	Graywacke interlayered with (varying amounts) argillite. Dark gray to brown, fine grained. Very hard, fresh, joint spacing very close to close. Minor quartz intrusions with chlorite.	R 107 444.9 to 450.0	100 (100)
			R 108 450.0 to 455.3	100 (94)
			R 109 455.3 to 460.2	100 (100)
			R 110 460.2 to 465.3	100 (100)
			R 111 465.3 to 470.3	100 (100)
			R 112 470.3 to 475.0	100 (96)
		475.0 - 492.5 Numerous healed fractures filled with calcite. Argillite has wavy laminae.	R 113 475.0 to 477.3	100 (100)
			R 114 477.3 to 481.9	100 (100)
481.9				

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HOLE NO. BH-2
SHEET NO. 14 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
481.9	Graywacke with Argillite (cont'd)		R 115 481.9 to 485.4
			R 116 485.4 to 490.3
		(491.8 - 492.5) Shear zone with clay gouge.	R 117 490.3 to 492.5
		494.4 - 498.0 Joints with clay gouge.	R 118 492.5 to 495.4
495.4	Argillite	Dark gray argillite with distorted, irregular laminae oriented approximately 45° to 50° to core axis. Fresh, very hard. Joint spacing very close to close. Frequent irregular quartz intrusions with some chlorite.	R 119 495.4 to 498.5
		498.0 Joint with clay coating at 45° to core axis.	R 120 498.5 to 503.8
			R 121 503.8 509.1
		509.1 - 519.1 Irregular fragments of graywacke throughout.	R 122 509.1 to 514.0
			R 123 514.0 to 519.1
519.1			

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HOLE NO. BH-2

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
519.1	Argillite (cont'd)		R 124 519.1 to 524.3	100 (100)
		529.0 Joint with clay gouge.	R 125 524.3 to 529.5	100 (94)
		529.5 - 534.7 Slight alteration zone associated with quartz vein.	R 126 529.5 to 534.7	100 (97)
		534.7 - 538.3 Core loss 0.3'.	R 127 534.7 to 538.3	91 (83)
			R 128 538.3 to 542.0	100 (78)
		542.0 - 557.1 Laminae very irregular to core axis. (546.0, 548.7) Highly fractured with clay gouge.	R 129 542.0 to 547.2	100 (71)
			R 130 547.2 to 552.0	100 (100)
			R 131 552.0 to 557.1	100 (94)
		557.1 - 558.7, 560.5 - 562.0 Highly fractured.	R 132 557.1 to 562.0	100 (72)
562.0				

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HOLE NO. BH-2
SHEET NO. 16 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
562.0	Argillite (cont'd)	562.0 - 582.9 Many rehealed fractures filled with calcite and quartz. Irregular orientations.	R 133 562.0 to 567.0
			R 134 567.0 to 572.1
			R 135 572.1 to 574.9
			R 136 574.9 to 579.9
			R 137 579.9 to 582.9
		582.9 - 627.8 Numerous thin bands of highly fractured rock rehealed with quartz throughout. Rehealed zones are less competent and badly broken by drilling. Hard to soft and friable locally.	R 138 582.9 to 584.9
		584.9 - 589.6 Core loss 0.2'.	R 139 584.9 to 589.6
		594.2 - 594.6 Shear zone with clay gouge.	R 140 589.6 to 594.6
			R 141 594.6 to 599.6
599.6			

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HOLE NO. BH-2
SHEET NO. 17 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
599.6	Argillite (cont'd)		R 142 599.6 to 601.8	100 (91)
			R 143 601.8 to 604.0	100 (91)
			R 144 604.0 to 609.2	100 (81)
		611.2 - 611.7 Shear zone.	R 145 609.2 to 614.2	100 (80)
			R 146 614.2 to 619.5	100 (93)
			R 147 619.5 to 624.8	100 (93)
		626.8 - 627.8 Shear zone, friable, core loss 0.2'.	R 148 624.8 to 630.8	85 (70)
632.9	Granite	Light grayish brown, fine to med. grained, composed primarily of feldspars and quartz with 2 to 5% mafics. Massive, very hard. Joint spacing wide. Fairly sharp contact with overlying argillite. 1" wide contact zone with no apparent contact metamorphism in argillitte. .	R 149 630.8 to 636.0	100 (100)
			R 150 636.0 to 641.2	100 (100)
641.2				

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SUSITNA HYDROELECTRIC PROJECT

for ALASKA POWER AUTHORITY

HOLE NO. BH-2
SHEET NO. 18 OF

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R8

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
		645.3 - 650.0 Argillite, with blebs and bands of quartz throughout. No bedding structure evident. Fresh, very hard, joint spacing close to wide.	R 151 641.2 to 646.5
			R 152 646.5 to 651.5
			R 153 651.5 to 656.2
656.2		End of Hole	

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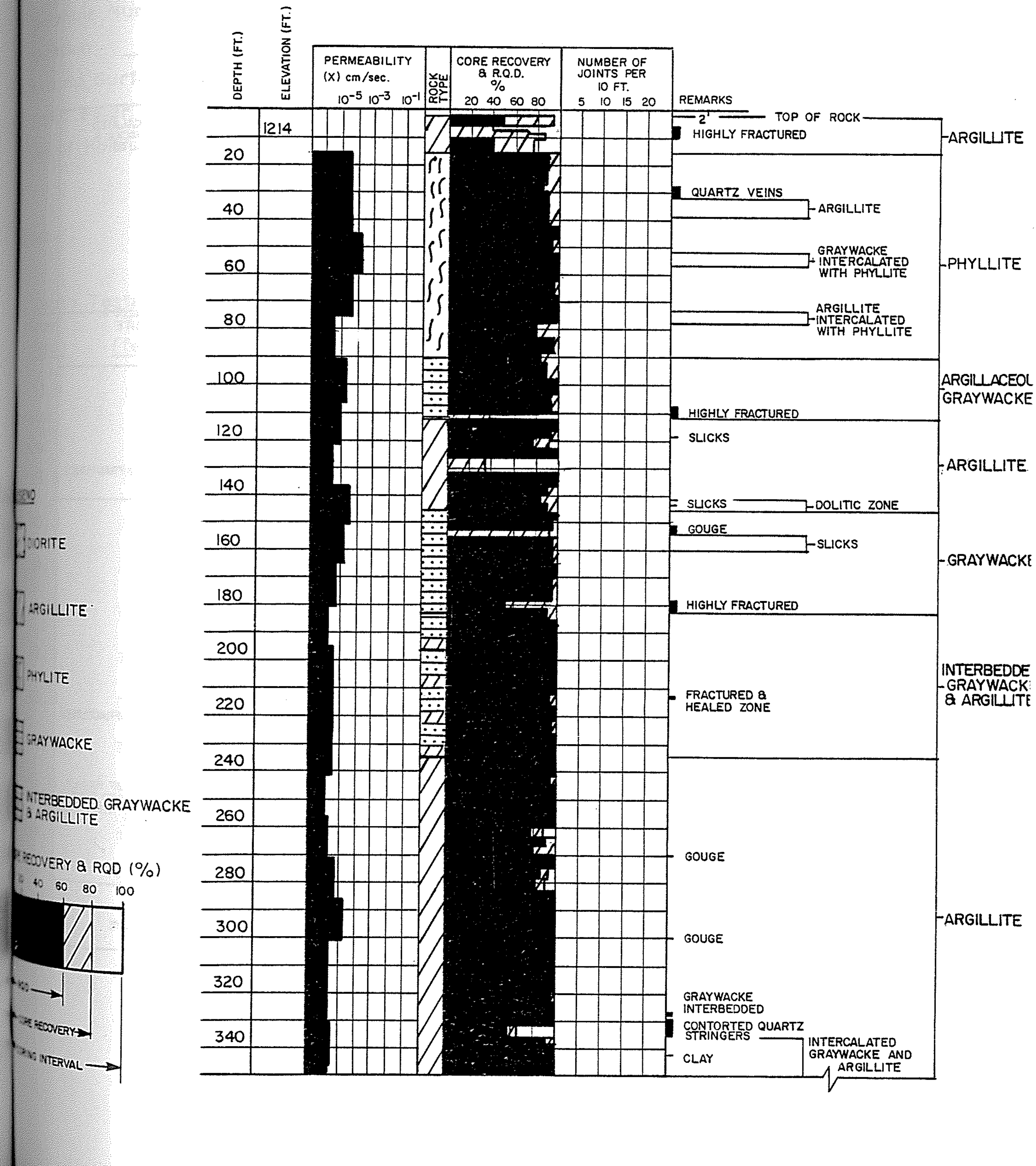
BEDROCK LOGS

HOLE NO. BH- 2 DATE SEPT 1980

LOCATION DEVIL CANYON



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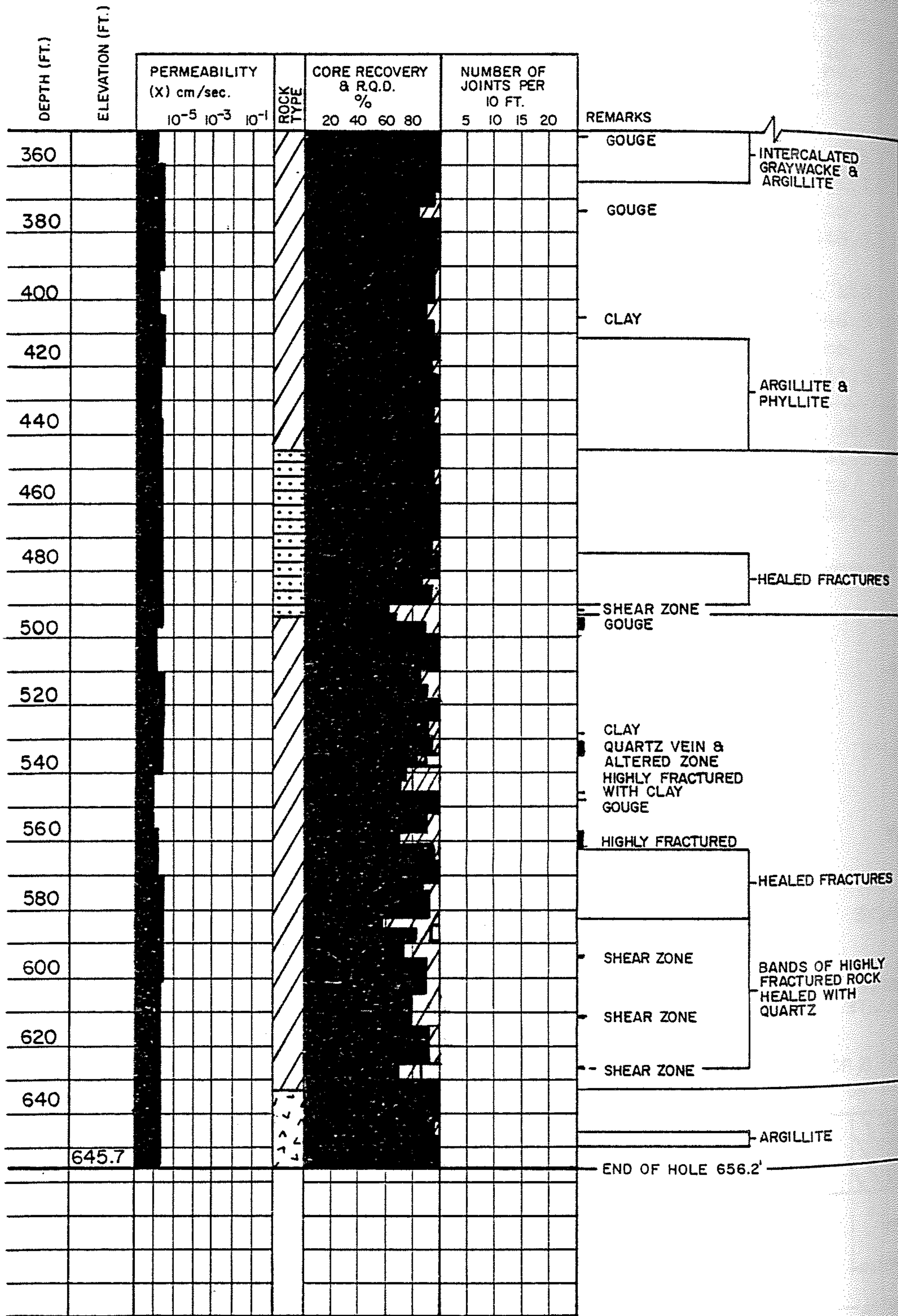
BEDROCK LOGS

HOLE NO. BH - 2 DATE SEPT 1980

LOCATION DEVIL CANYON



SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number BH-2

Location Devil Canyon

Ground Surface Elevation 1214

Static Water Level 4 feet (vertical)

Dip of Hole 60°

Depth Tested From (feet)	To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
13.9	30	7	12	10	.60 to .82	5.14×10^{-5} To 7.03×10^{-5}
28.9	45	2	18	10	1.1	7.89×10^{-5}
43.9	60	7	22	10	4.0	2.14×10^{-4}
58.9	75	2	25	10	1.15	6.15×10^{-5}
73.9	90	7	35	10	1.45	5.37×10^{-6}
88.9	105	2	42	12	.67	2.25×10^{-5}
103.9	120	7	50	10	.30	8.57×10^{-6}
118.9	135	2	55	10	.25	5.40×10^{-6}
133.9	150	7	65	10	2.90	6.01×10^{-5}
148.9	165	2	70	10	1.25	2.44×10^{-5}
163.9	180	7	82	10	.34	5.89×10^{-6}
178.9	195	2	85	10	.15	2.58×10^{-6}
193.9	210	7	100	10	.48	6.50×10^{-6}

Borehole BH-2 . Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficie[nt of] Permeab[ility] (cm/se[c])
208.9	225	2	105	10	.45	6.78 x
223.9	240	7	110	10	.38	4.32 x
238.9	255	2	115	10	.08	1.08 x
253.9	270	7	125	10	.20	2.51 x
268.9	285	2	130	32	.68 to 3.1	7.25 x To 3.31 x
283.9	300	7	100	10	.98	1.35 x
298.9	315	2	145	10	.21	1.92 x
313.9	330	7	155	10	.25	2.39 x
328.9	345	2	160	10	.38	3.31 x
343.9	360	7	170	10	.26	2.11 x
358.9	375	2	175	10	.68	4.78 x
373.9	390	7	185	10	.58	4.33 x
388.9	405	2	190	10	.38	2.79 x
403.9	420	7	200	10	.56	3.87 x
418.9	435	2	200	10	.36	2.51 x
433.9	450	7	200	10	.60	4.70 x
448.9	465	2	200	10	.60	4.33 x
463.9	480	7	200	10	.38	2.63 x
478.9	495	2	200	10	.56	4.05 x
493.9	510	7	200	10	.30	2.08 x
508.9	525	2	200	10	.58	3.91 x
523.9	540	7	200	10	.30	2.08 x
538.9	555	2	200	10	.25	1.82 x

Borehole BH-2, Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
[illegible]3.9	570	7	200	10	.36	2.63×10^{-6}
[illegible]8.9	585	2	200	10	.64	4.49×10^{-6}
[illegible]3.9	600	7	200	10	.56	4.15×10^{-6}
[illegible]8.9	615	2	200	10	.40	2.79×10^{-6}
[illegible]3.9	630	7	200	10	.40	2.77×10^{-6}
[illegible]8.9	645	2	200	10	.46	3.21×10^{-6}
[illegible]3.9	655	11	200	10	.38	2.75×10^{-6}

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DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-4
SHEET NO. 1 OF 13

SITE Devil Canyon South Abutment   JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR The Drilling Company   STARTED ____ M. AUG 14 19 80
FINISHED ____ M. AUG 19 19 80

DRILLING METHOD
SOIL Casing Advancer   CASING DIAM. NW (3.5" O.D.)
ROCK Diamond Core Drill   CORE DIAM. NQ (1.875)

LOCATION:
LATITUDE 624857.593
DEPARTURE 1491823.795
BEARING 195°
INITIAL DIP 60°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1353 ft
ROCK SURFACE 1346 ft
BOTTOM OF HOLE 912.1 ft
WATER TABLE 1322 ft

NOTE: All depths are along hole.

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD.)
0.0	Overburden			
7.0	Bedrock	0.0 - 12.0 No samples taken.		
12.0	Interbedded Graywacke & Argillite	Graywacke - medium to dark gray, clayey matrix containing fine to medium sand grains and sub-rounded clasts of quartz, argillite and other rock types. Interbedded with argillite - medium to dark gray, fine grained. Laminae oriented at approximately 20° to core axis. Rock is well indurated, moderatly hard to hard, and competent. Fresh to slightly weathered with limonite staining on joint surfaces. Minor sulfide mineralization. Joint spacing very close to moderately close. Occasional joints healed with quartz and carbonate.	Run 1 12.0 to 15.2	75 (17)
			Run 2 15.2 to 18.8	100 (67)
		12.0 - 15.2 Core loss 0.8'.	Run 3 18.8 to 20.4	101 (38)
		20.0, 23.4, 29.8 Slickensides and iron staining. Joints parallel texture at 20° to 30° to core axis. Some clay filling.	Run 4 20.4 to 25.4	101 (70)
25.4				

LOGGED BY
Hagen - Rahaim (R&M)
Summary by Acomb
Summary by Henschel (ACRES)

APPROVED ____ (R&M)
DATE ____
APPROVED ____ (ACRES)
DATE ____

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-4
SHEET NO. 2 OF 1[illegible]

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&[illegible]

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CO RE (R
25.4	Graywacke and Argillite (cont'd)	25.4 - 30.5 Core loss 0.2'.	R 5 25.4 to 30.5	[illegible] (7
30.7	Graywacke	Medium gray to dark gray, siliceous. Clayey matrix containing fine to coarse sand grains and elipsoid clasts approximately 2mm x 1mm in size. Well indurated moderately hard to hard, competent. Fresh to slightly weathered with some iron staining on joint surfaces. Minor sulfide mineralization throughtout. Joint spacing very close to moderately close. Numerous joints healed with calcite, oriented at approximately 15° to 30° to core axis. 30.7 - 45.0 Minor interbedded argillite. (30.7, 30.9, 38.8, 39.1) Slickensides and iron staining in joints. 45.0 - 46.2 Numerous joints at 15° to 20° to core axis. Open, highly weathered and clay filled. 62.7 Friable zone.	R 6 30.5 to 34.0 R 7 34.0 to 39.0 R 8 39.0 to 44.0 R 9 44.0 to 48.0 R 10 48.0 to 53.1 R 11 53.1 to 58.1 R 12 58.1 to 61.0 R 13 61.0 to 65.2	1[illegible] (1[illegible] (1[illegible] (1[illegible] (1[illegible] (1[illegible] (1[illegible] (1[illegible] (
65.2				

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SUSITNA HYDROELECTRIC PROJECT
for **ALASKA POWER AUTHORITY**

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
65.2	Graywacke (cont'd)	65.2 - 70.2 Core loss 0.1'.	R 14 65.2 to 70.2	98 (84)
			R 15 70.2 to 75.0	100 (98)
			R 16 75.0 to 80.2	100 (87)
		80.2 - 80.9 Core loss 0.1'.	R 17 80.2 to 80.9	89 (57)
			R 18 80.9 tl 84.1	100 (84)
		86.0 Quartz vein with sulfides 0.01' thick.	R 19 84.1 to 89.4	100 (100)
			R 20 89.4 to 93.2	100 (100)
			R 21 93.2 to 98.2	100 (68)
		102.0 - 103.0 Numerous quartz veins and stringers.	R 22 98.2 to 103.4	100 (83)
103.4				

DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-4
SHEET NO. 4 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CO RE (RQ
103.4	Graywacke	104.4 - 104.6 Joint with slickensides and clay filling.	R 23 103.4 to 108.4	10 (9
108.4	Graywacke w/ Interbedded Argillite	Graywacke (as described above) with some interbedded Argillite. Transitional to underlying phyllite. Argillite is medium to dark gray, fine grained. Laminae oriented approximately 20° to core axis. Moderately hard to very hard, fresh, generally competent. Numerous contorted quartz stringers throughout. Joint spacing close to moderately close.	R 24 108.4 to 113.3 R 25 113.3 to 117.7	10 (10 10 (9
114.9	Phyllite	Dark gray to black, very fine to fine grained. Foliation approximately 5° to 10° to core axis, with microfolds crosscutting foliation at approximately 30° (microfolds 20° to 30° to core axis). Hard to very hard, fresh. Minor sulfide mineralization throughout. Quartz and carbonate veins common. Joint spacing close to moderately close. Numerous healed joints throughout. 130.2 - 135.5 Core loss 0.2'.	R 26 117.7 to 120.0 R 27 120.0 to 125.0 R 28 125.0 to 130.2 R 29 130.2 to 135.5 R 30 135.5 to 140.5 R 31 140.5 to 145.6	10 (8 10 (10 10 (8 9 (9 10 (9 10 (
145.6				

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for ALASKA POWER AUTHORITY

HOLE NO. BH-4
SHEET NO. 5 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
145.6	Phyllite (cont'd)		R 32 145.6 to 150.8	100 (92)
151.5	Meta-Argillite	Dark gray to black, very fine grained, non-foliated to indistinct foliation. Hard to very hard, well indurated, fresh and competent. Very gradational contact with overlying phyllite. Joint spacing close to moderately close.	R 33 150.8 to 156.0	100 (100)
			R 34 156.0 to 161.0	100 (96)
			R 35 161.0 to 166.0	100 (100)
		166.0 - 171.0 Core loss 0.1'. 169.5 - 170.4 Quartz veins.	R 36 166.0 to 171.0	98 (84)
		171.3 - 172.3 Quartz veins and stringers, sulfide mineralization - core badly broken and ground by drilling; weak zone.	R 37 171.0 to 176.1	100 (84)
		178.1 - 181.6 Core badly broken and ground by drilling. Pieces 0.05' to 0.1' inches diameter. Joints have chlorite or talc coating.	R 38 176.1 to 179.6	100 (67)
		(179.6 - 184.0) Core loss 0.1'.	R 39 179.6 to 184.0	98 (45)
			R 40 184.0 to 189.1	100 (98)
189.1				

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HOLE NO. BH-4
SHEET NO. 6 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC (RQ
189.1	Meta-Argillite (cont'd)		R 41 189.1 to 194.3	10 (7
			R 42 194.3 to 199.6	10 (10
		199.6 - 201.6 Quartz vein 0.02' thick at approximately 10° to 20° to core axis. Sulfide mineralization.	R 43 199.6 to 204.6	10 (9
205.0	Phyllite	Gray brown to dark gray to black, very fine to fine grained, well developed foliation, with characteristic silvery luster (white-mica phyllite) on clearage surfaces. The rock contains highly contorted quartz veins and stringers throughout, which crosscut the foliation. Orientation of foliation is highly irregular in these zones. Rock is hard to very hard, fresh and competent. Joint spacing close to moderately close. Numerous healed joints.	R 44 204.6 to 209.6	10 (10
			R 45 209.6 to 214.9	1 (7
			R 46 214.9 to 220.0	1 (1
		222.3 - 250.0 Contorted quartz stringers and veins form 20% to 40% of rock. Foliation highly irregular.	R 47 220.0 to 225.3	1 (9
			R 48 225.3 to 230.1	1 (8
			R 49 230.1 to 235.5	1 (9
235.5				

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for ALASKA POWER AUTHORITY

HOLE NO. BH-4

SHEET NO. 7 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
235.5	Phyllite (cont'd)		R 50 235.5 to 240.3	100 (58)
			R 51 240.3 to 245.6	100 (96)
		246.3 - 246.8 Quartz vein, highly mineralized with sulfides.	R 52 245.6 to 247.8	100 (100)
			R 53 247.8 to 250.3	100 (98)
		252.0 - 267.0 Zone contains intermixed layers of spotted phyllite.	R 54 250.3 to 255.2	100 (98)
			R 55 255.2 to 260.3	100 (82)
		262.1 - 262.5, 263.9 - 264.5, 271.1 - 271.8 Quartz veins, highly mineralized with sulfides.	R 56 260.3 to 262.6	100 (69)
			R 57 262.6 to 267.6	100 (90)
			R 58 267.6 to 271.9	100 (84)
271.9				

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DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-4
SHEET NO. 8 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN
271.9	Phyllite (cont'd)	271.9 - 277.3 Core loss 0.3'.	R 59 271.9 to 277.3
		282.2 - 287.5 Massive quartz vein.	R 60 277.3 to 289.0
			R 61 281.0 to 286.0
			R 62 286.0 to 291.0
		292.9 - 295.6 Shear zone. Rock is highly brecciated with clay gouge. Very friable. Rock fragments range from 0.01' to 0.1'. Core loss 2.0'.	R 63 291.0 to 293.5
			R 64 293.5 to 297.9
			R 65 297.9 to 301.9
			R 66 301.9 to 307.0
		307.0 - 312.2 Core loss 0.1'. 308.1 - 311.5, 318.3 - 319.2 High angle joints with chlorite and calcite coatings.	R 67 307.0 to 312.2
312.2			

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for ALASKA POWER AUTHORITY

HOLE NO. BH-4

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
312.2	Phyllite (cont'd)		R 68 312.2 to 317.0	100 (81)
			R 69 317.0 to 322.0	100 (84)
			R 70 322.0 to 327.0	100 (100)
		330.4 - 331.1 Open joints at 20° to core axis.	R 71 327.2 to 332.2	100 (100)
			R 72 332.2 to 337.3	100 (94)
		343.9 - 345.0 Quartz vein.	R 73 337.3 to 347.0	100 (94)
			R 74 342.4 to 347.0	100 (89)
			R 75 347.0 to 350.0	100 (83)
		352.0 - 376.3 Zone contains intermixed layers of spotted phyllite.	R 76 350.0 to 353.3	100 (100)
353.3				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-4
SHEET NO. 10 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CO RE (RQ
353.3	Phyllite (cont'd)	353.3 - 356.5 Core loss 0.2'.	R 77 353.3 to 356.5	9 (8
			R 78 356.5 to 361.0	10 (9
		362.5 - 364.8 Massive quartz vein.	R 79 361.0 to 366.5	10 (9
		370.0 - 376.3 Quartz vein with some intermixed spotted phyllite.	R 80 366.5 to 371.0	10 (8
			R 81 371.0 to 376.3	1 (
		376.3 - 387.0 Dark gray to black, well developed foliation at 10° to 20° to core axis. Contains no quartz stringers. 376.3 - 379.4 Core loss 1.4'	R 82 376.3 to 379.4	(
		379.4 - 386.0 Mislatch of core barrel, section badly broken, core badly ground during drilling.	R 83 379.4 to 386.0	1 (N
		386.0 - 396.0 Core loss 0.5'. 387.1 - 399.0 Spotted phyllite.	R 84 386.0 to 390.8	(
			R 85 390.8 to 396.0	(
396.0				

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DRILLING REPORT
SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-4
SHEET NO. 11 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
396.0	Phyllite (cont'd)		R 86 396.0 to 401.1	100 (94)
			R 87 401.1 to 406.1	100 (100)
		406.5 - 461.7 Zone contains occasional layers of spotted phyllite.	R 88 406.1 to 411.1	100 (86)
			R 89 411.1 to 416.2	100 (100)
			R 90 416.2 to 420.0	100 (100)
			R 91 420.0 to 425.0	100 (100)
		(425.0 - 430.3) Core loss 0.1'.	R 92 425.0 to 430.3	98 (96)
			R 93 430.3 to 435.6	100 (81)
			R 94 435.6 to 440.6	100 (92)
440.6				

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SUSITNA HYDROELECTRIC PROJECT
for ALASKA POWER AUTHORITY

HOLE NO. BH-4
SHEET NO. 12 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	CORE RECOVERY (ROD)
440.6	Phyllite (cont'd)		R 95 440.6 to 445.7	[illegible]
			R 96 445.7 to 450.7	[illegible]
			R 97 450.7 to 454.3	[illegible]
			R 98 454.3 to 456.1	[illegible]
			R 99 456.1 to 456.7	[illegible]
			R 100 456.7 to 461.0	[illegible]
			R 101 461.0 to 466.0	[illegible]
			R 102 466.0 to 471.0	[illegible]
			R 103 471.0 to 476.0	[illegible]
476.0				

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HOLE NO. BH-4
SHEET NO. 13 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH (Ft)	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
476.0	Phyllite (cont'd)		R 104 476.0 to 481.0	100 (98)
			R 105 481.0 to 486.0	100 (100)
			R 106 486.0 to 491.0	100 (100)
			R 107 491.0 to 495.8	100 (94)
			R 108 495.8 to 501.0	100 (96)
501.0		End of Hole		

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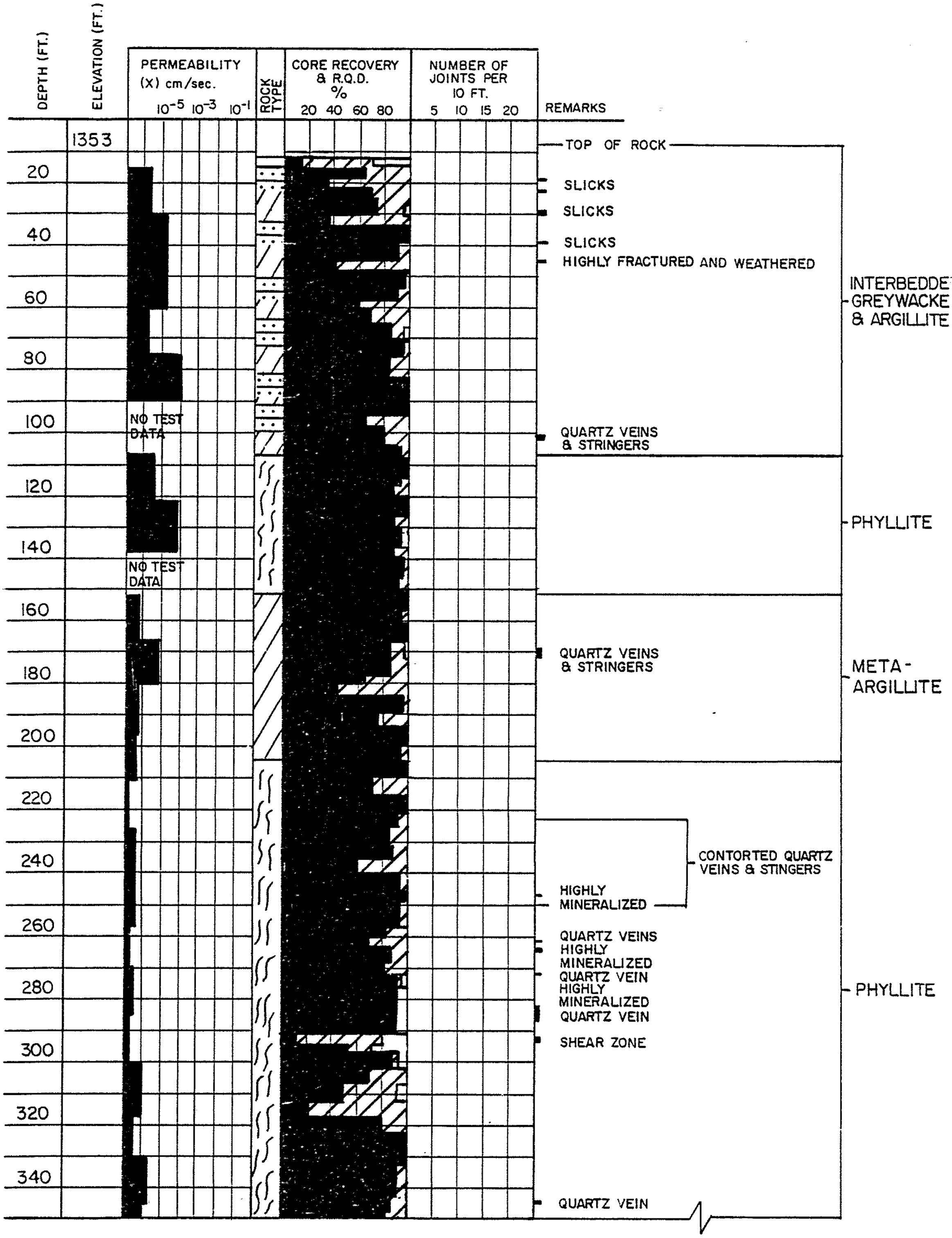
BEDROCK LOGS

HOLE NO. BH- 4 DATE JULY 1980

LOCATION DEVIL CANYON



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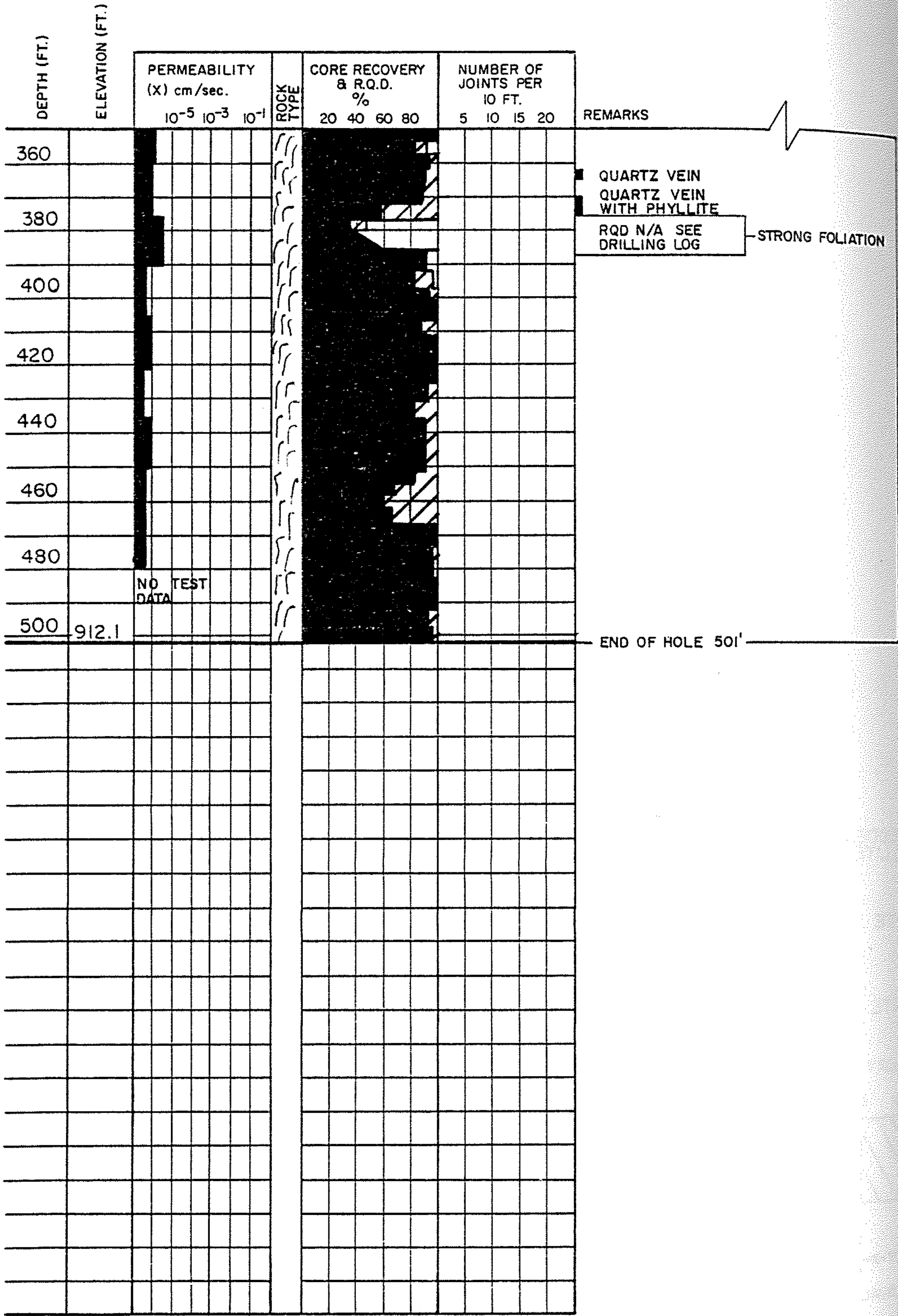
BEDROCK LOGS

HOLE NO. BH- 4 DATE JULY 1980

LOCATION DEVIL CANYON



SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number BH-4

Location Devil Canyon

Ground Surface Elevation 1353

Static Water Level 31 feet (Vertical)

Dip of Hole 60°

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
13.9	30	1	10	10	.045	2.67×10^{-6}
28.9	45	6	15	10	.24	1.20×10^{-5}
43.9	60	1	20	10	.25	1.05×10^{-5}
58.9	75	6	24	10	.04	1.43×10^{-6}
73.9	90	1	34	10	3.25	9.62×10^{-5}
88.9	110*	6				
108.9	125	14	50	10	.26	5.36×10^{-6}
118.9	135	1	55	10	3.65	7.31×10^{-5}
123.9	140	1	56	10	4.25	8.61×10^{-5}
138.9	155*	6				
148.9	165	6	70	10	.050	8.26×10^{-7}
153.9	170	1	50	10	1.03	2.35×10^{-5}

* Unable to test section - packer problems - high flow rate - water flow from top of borehole.

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
163.9	180	1	80	10	.64	9.84×10^{-6}
178.9	195	6	85	10	.04	5.75×10^{-7}
193.9	210	1	95	10	.04	5.22×10^{-7}
208.9	225	6	100	10	.02	2.49×10^{-7}
223.9	240	1	105	10	.03	3.58×10^{-7}
238.9	255	6	115	10	.05	5.51×10^{-7}
253.9	270	1	125	10	.035	3.58×10^{-7}
268.9	285	6	130	10	.035	4.28×10^{-7}
283.9	300	1	140	10	.025	2.76×10^{-7}
298.9	315	6	145	10	.105	9.69×10^{-7}
313.9	330	1	150	10	.035	3.02×10^{-7}
328.9	345	6	160	12	.45	3.62×10^{-6}
343.9	360	1	170	10	.20	1.54×10^{-6}
358.9	375	6	175	10	.11	8.53×10^{-7}
373.9	390	1	185	10	.90	6.40×10^{-6}
388.9	405	6	190	10	.09	6.19×10^{-7}
403.9	420	1	200	10	.14	9.93×10^{-7}
418.9	435	6	200	10	.12	7.87×10^{-7}
433.9	450	1	200	10	.12	7.94×10^{-7}
448.9	465	6	200	10	.10	6.56×10^{-7}
458.9	475	1	200	10	.105	6.95×10^{-7}

APPENDIX B-3

WATER PRESSURE TESTING DETAILS

Water Pressure Testing Details

This section expands on the mechanical details of Section 5.2b (ii) of the report by describing the actual procedures used.

Calculations

To calculate the maximum water pressure to be applied in a given test section, the following steps were undertaken. The vertical depth to the static water table in the hole and to the center of the test section was calculated. The maximum test pressure was equal to 1 psi per foot of vertical depth from the ground surface to the water table, plus 0.5 psi per foot of vertical depth from the water table down to the center of the test section to a maximum value of 200 psi.

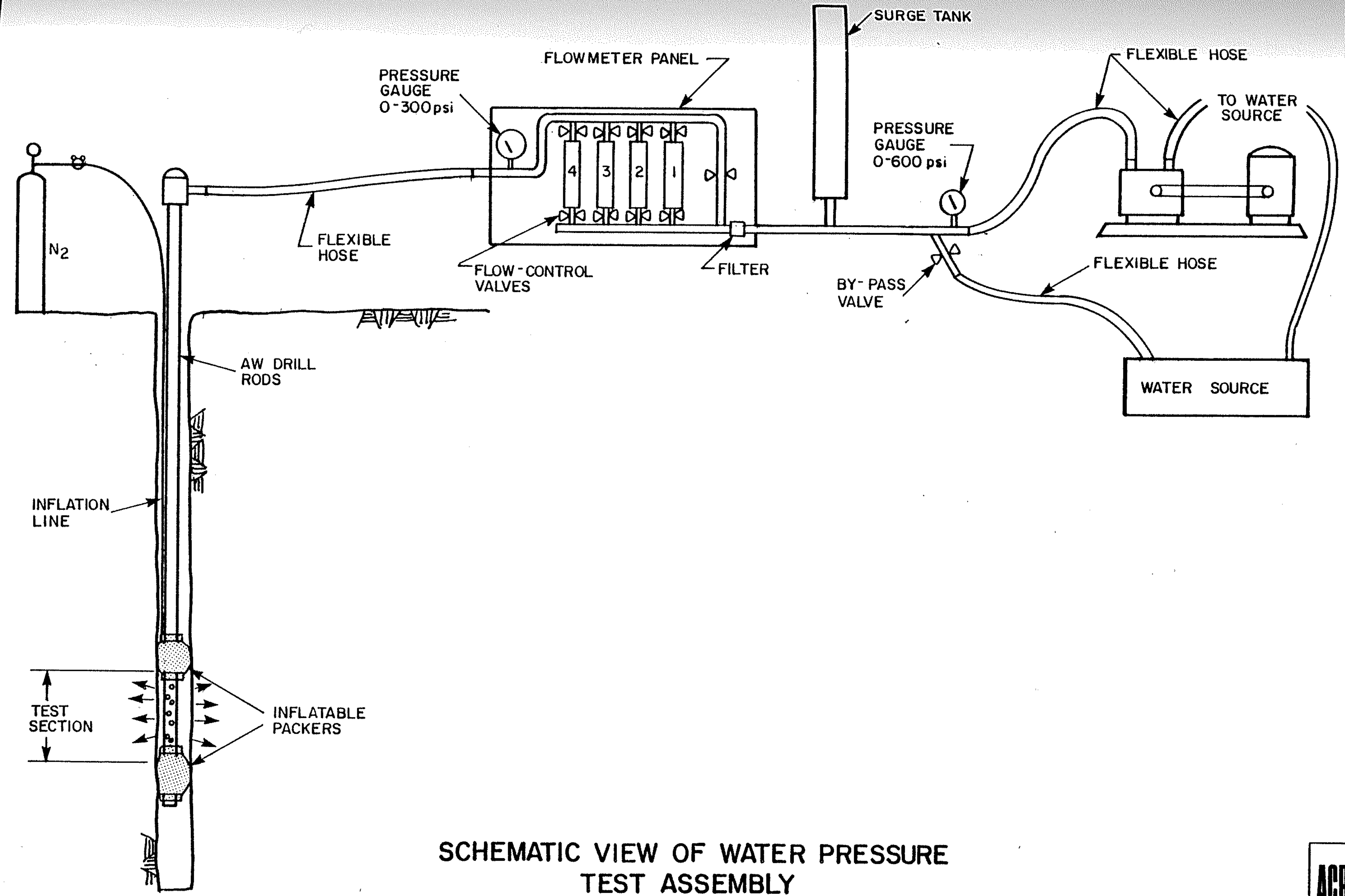
In calculating the actual gauge pressure to be applied at the surface, the hydrostatic pressure generated by the column of the water in the riser pipe from the water table to the top of the riser was subtracted from the calculated test pressure.

Accurate Measurements

In order to obtain accurate permeability values, it was necessary that the applied pressure and flow rates be measured accurately. A panel of four Fisher-Porter glass tube variable flow meters was set up as shown in Figure A.1. These meters have an accuracy of 1% over full scale and individual ranges of 0.021-0.267 gpm, 0.095-1.19 gpm, 0.34-4.25 gpm and 0.88-11.0 gpm. The panel was set up to use any of the four meters or to bypass them altogether.

Water pressure was supplied by a Bean fixed-displacement, piston pump. Test pressure was monitored using a liquid-filled Ashcroft model 1279 pressure gauge with a 0 to 300 psi range and 2 psi divisions. The accuracy of this gauge is ± 0.5% of full scale.

To eliminate pressure surging in the line, a surge tank was installed and pressure snubbers were used between the pressure gauge and the main line.



SCHEMATIC VIEW OF WATER PRESSURE TEST ASSEMBLY

FIGURE B.1

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APPENDIX C

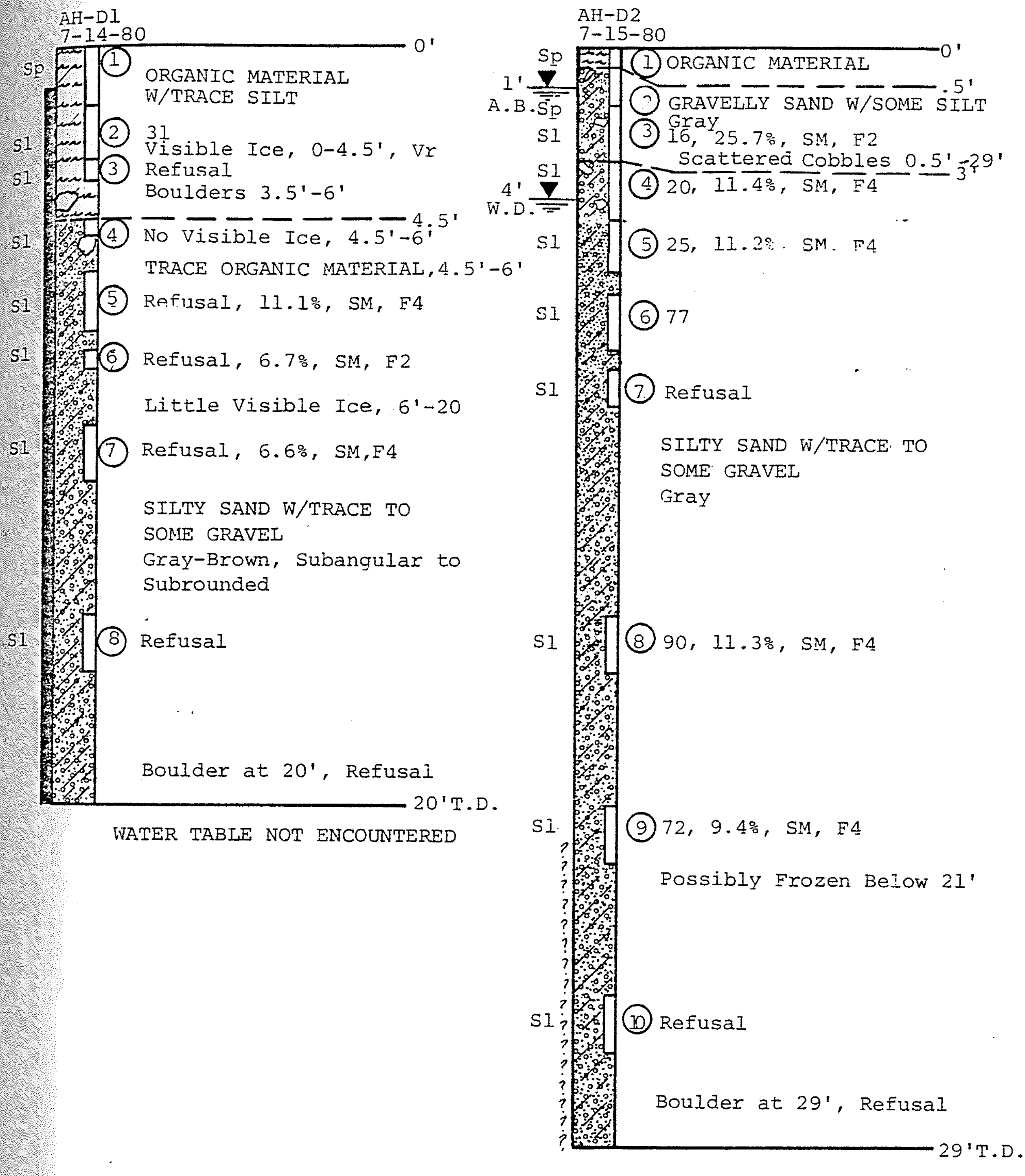
BORROW AREA INVESTIGATIONS

Prepared By: R&M Consultants, Inc.

APPENDIX C-1

AUGER DRILLING REPORTS

WATANA



DWN	KW
CKD	MH
DATE	Aug. 80
SCALE	1'=4'

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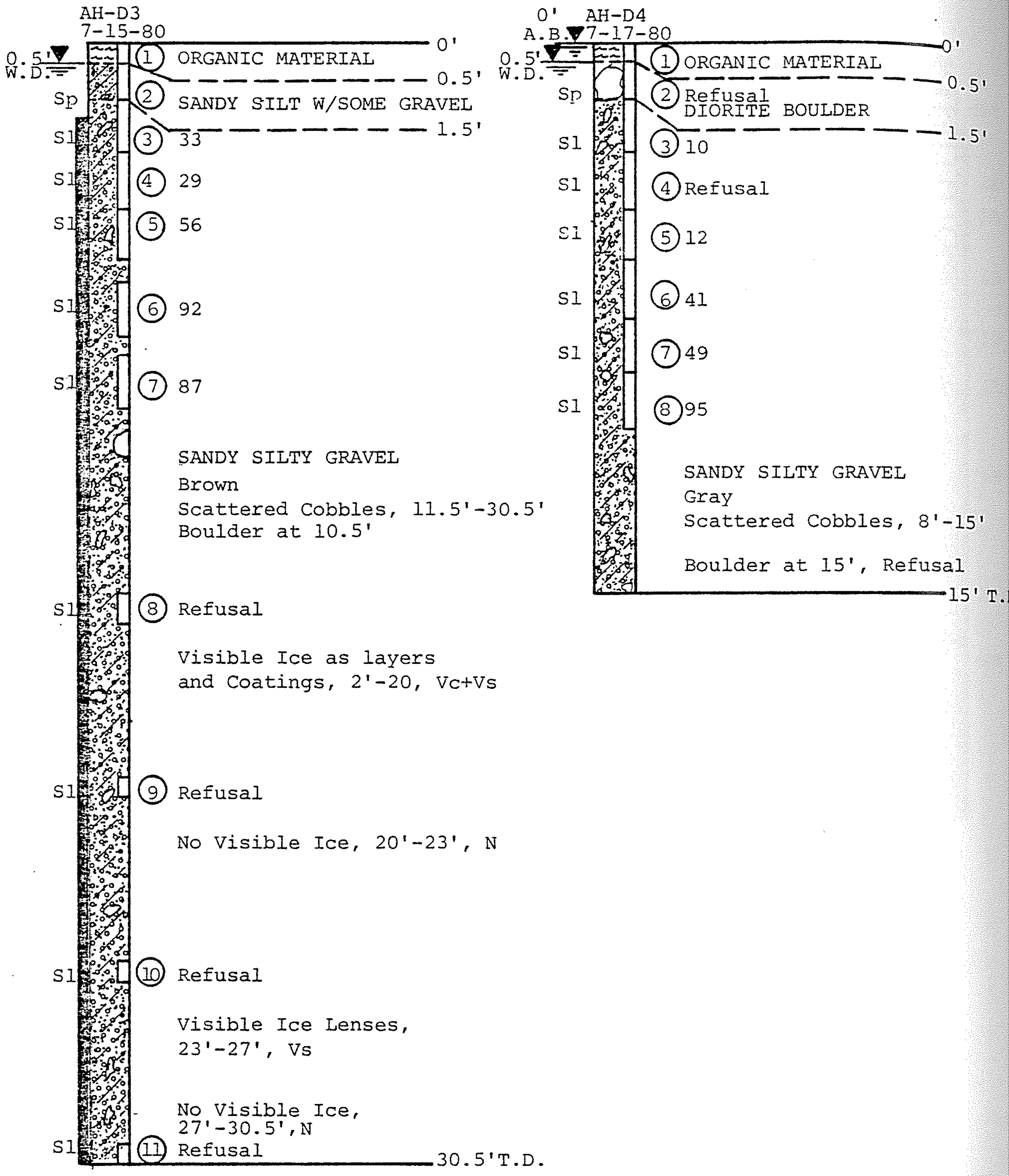
SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID.	
PROJ. NO.	052504
DWG. NO.	



DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE.	1'=4'

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GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID.	
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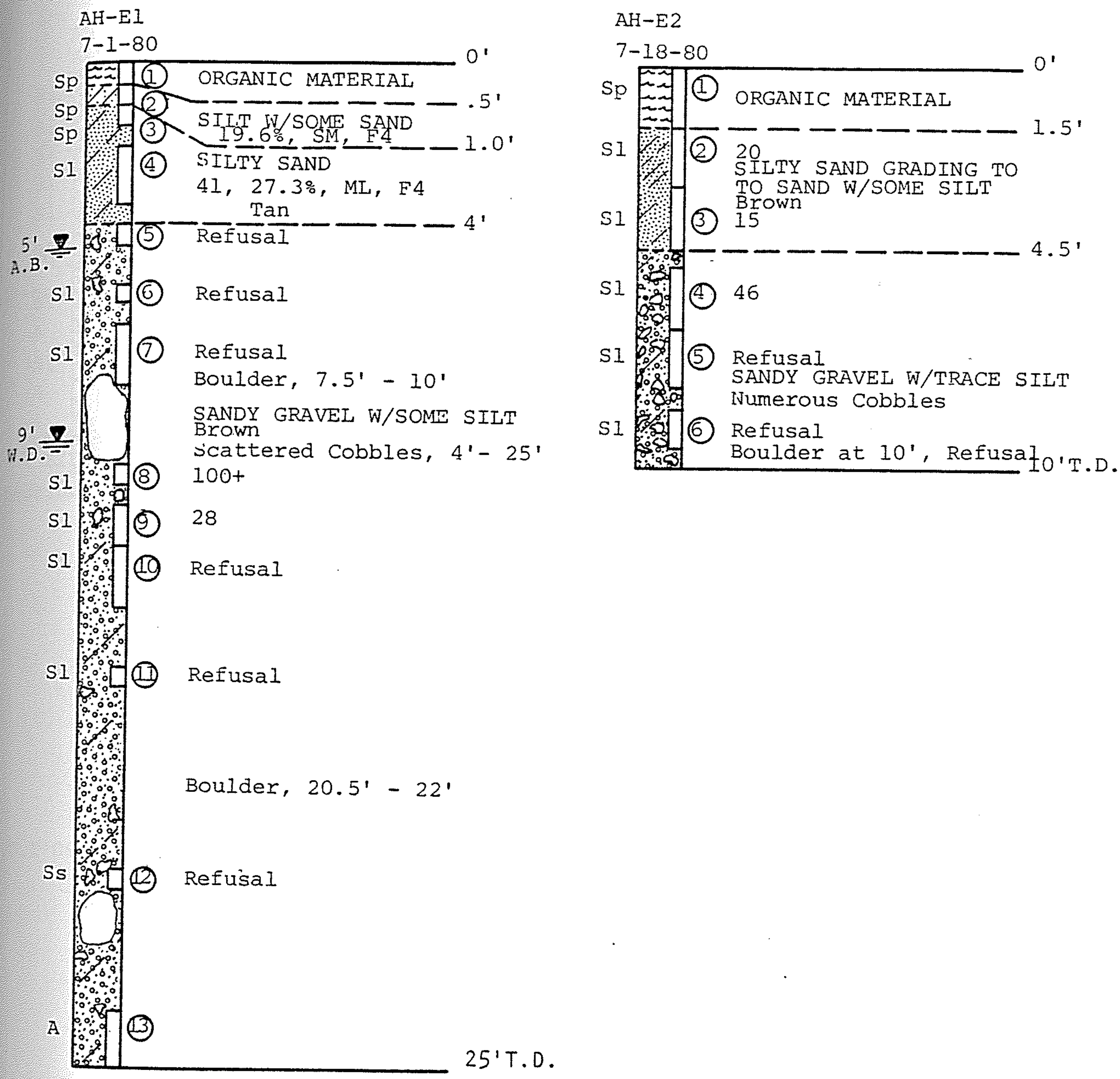
DWG. NO.	



DRAWN	KW
CHKD	MH
DATE	Aug.80
SCALE	1'=4'

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GEOTECHNICAL INVESTIGATIONS

F.B.	
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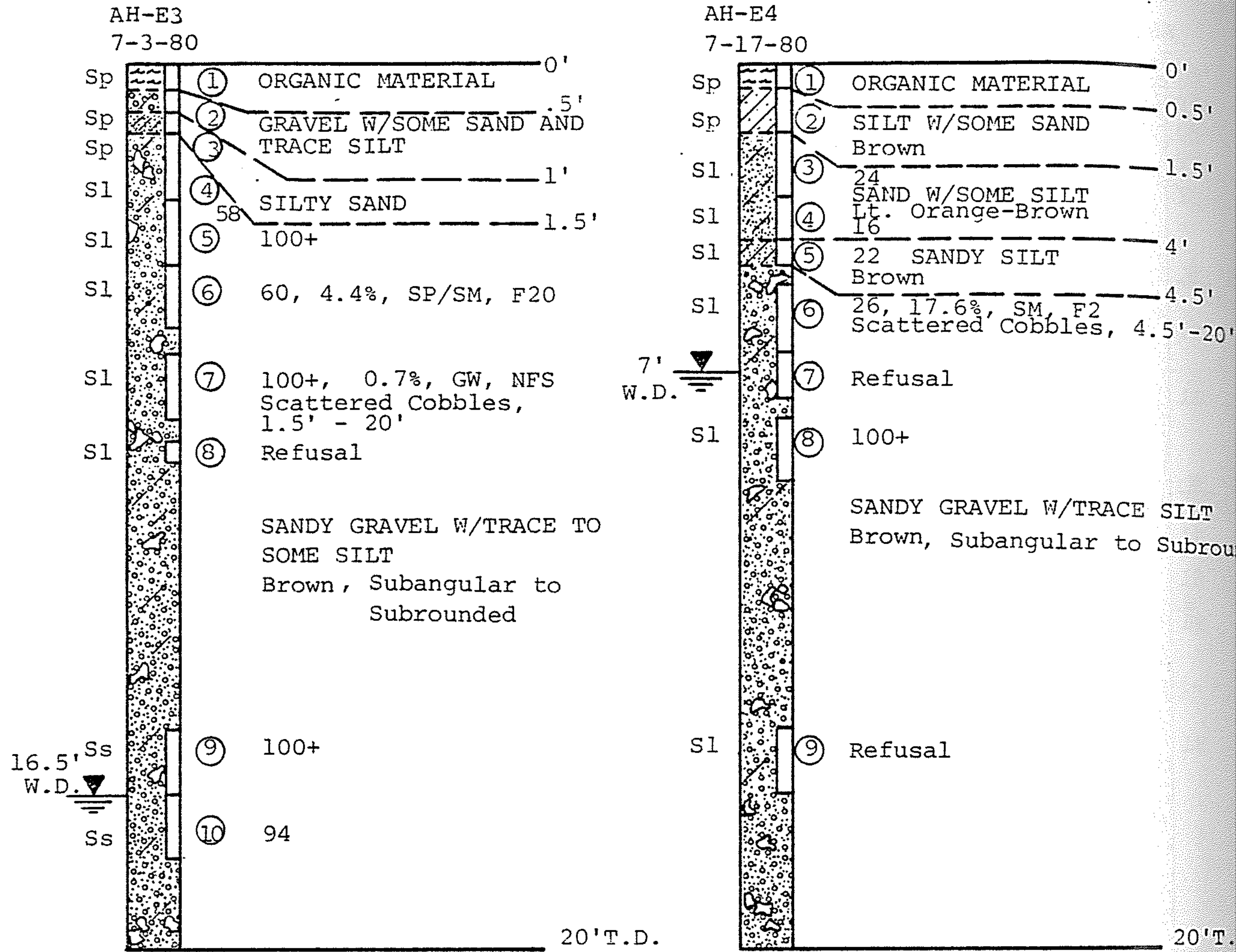
PROJ. NO.	052504
DWG. NO.	



DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE.	1'=4'

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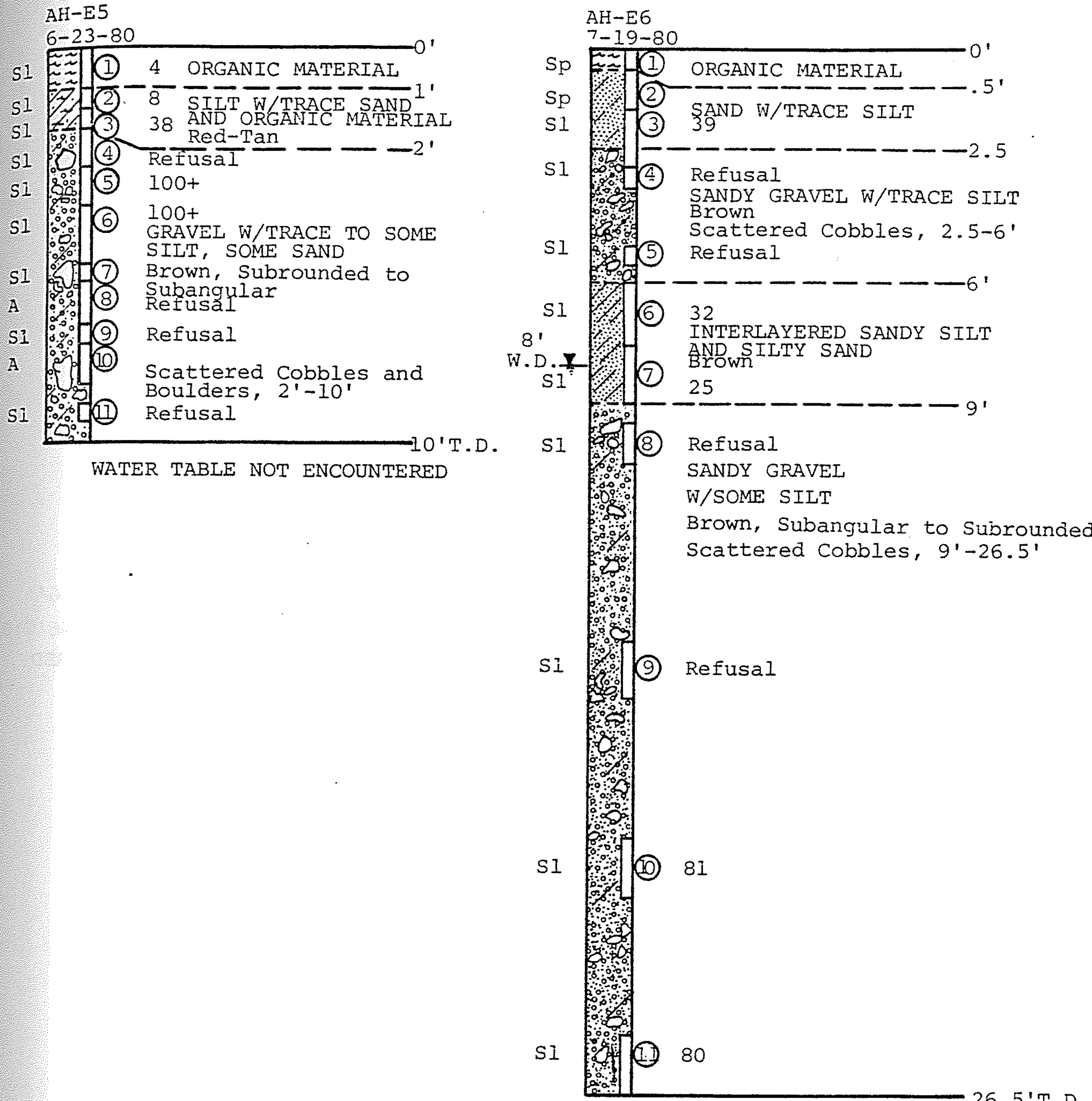
PROJ. NO. 052
DWG. NO.



DRAWN	KW
CHKD	MH
DATE	Aug. 80
SCALE	1'=4'

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F.B.	
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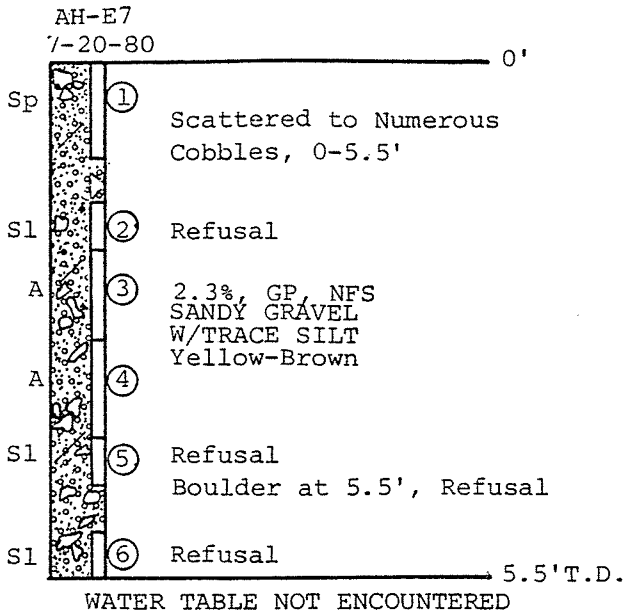
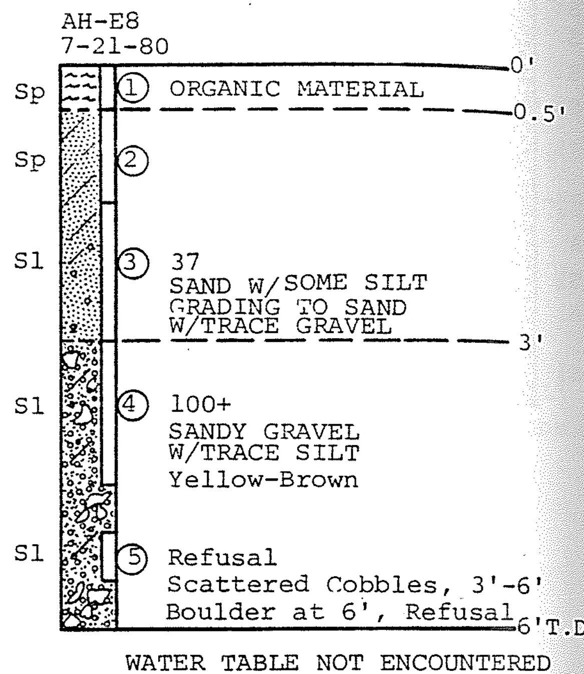
PROJ. NO.	052504
DWG. NO.	





DWN. KW
CKD. MH
DATE. Aug. 80
SCALE 1'=2'

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HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.
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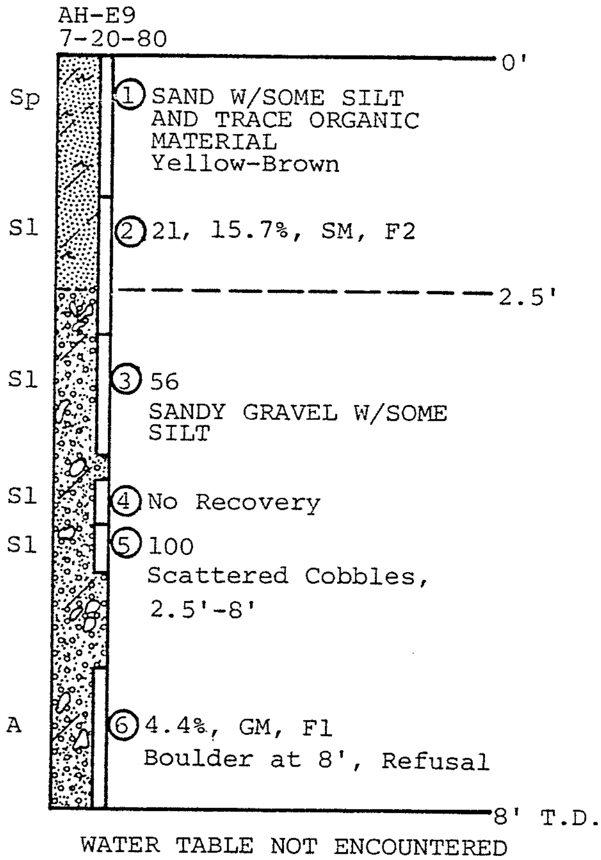
PROJ. NO. 05
DWG. NO.



DWN.	KW
CKD.	MH
DATE	Aug. 80
SCALE	1'=2'

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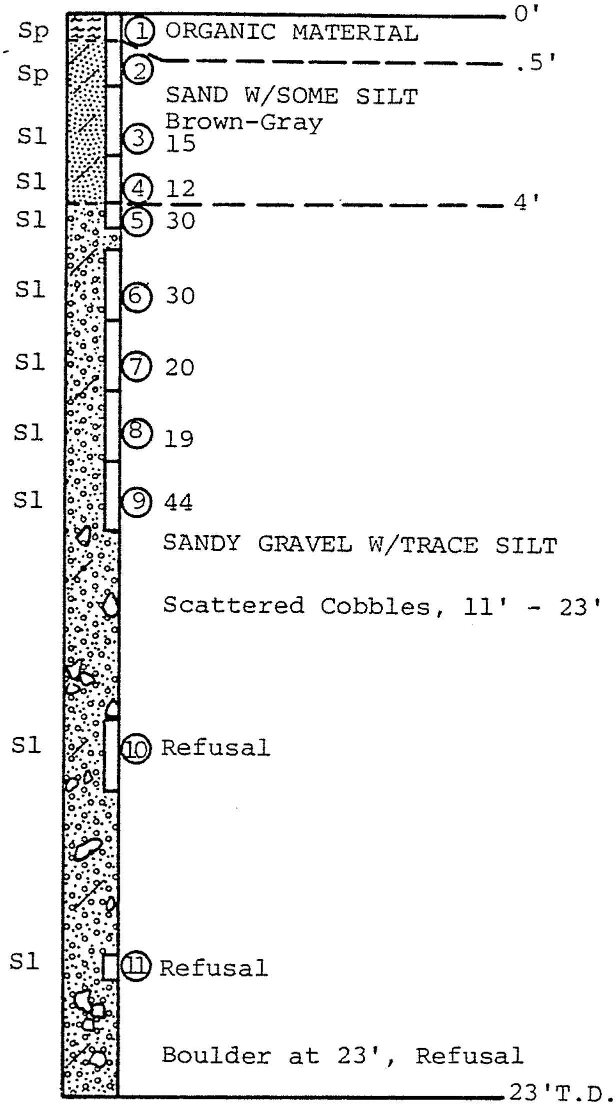
HYDROELECTRIC PROJECT
GEOTECHNICAL INVERSTIGATIONS

F.B.	
GRID.	
PROJ. NO.	052504
DWG. NO.	

DEVIL CANYON

AH-G1
7-22-80



WATER TABLE NOT ENCOUNTERED

	KW
	MH
E	Aug. 80
LE	1'=4'

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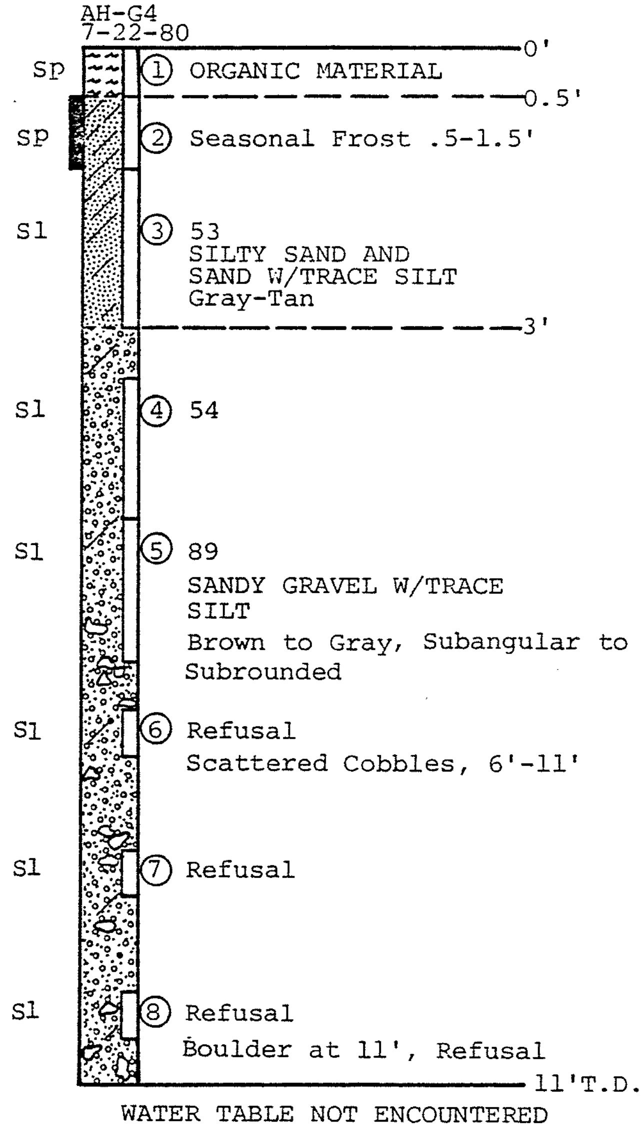
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID.	
PROJ. NO.	052504
DWG. NO.	



DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE	1'=2'

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SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID.	
PROJ.NO.	052
DWG.NO.	

APPENDIX C-2

LABORATORY TEST DATA

SUMMARY OF LABORATORY TEST DATA

PROJECT NO. 052504
CLIENT ·Acres
PROJECT NAME Susitna
(Watana Dam Site)

R & M CONSULTANTS, INC.

SUMMARY OF LABORATORY TEST DATA

DATE 10-17-80

PARTY NO. ______ PAGE NO. C-01

LAB NO.	BORING NO	SAMPLE NO	DEPTH	4"	3"	2"	1½"	1"	3/4"	1/2"	3/8"	#4	#10	#40	#200	.02	.005	.002	% Moist.	LL	PI	Unified Class.
BORROW		H	W-80-256			100	95	88	84	81	78	71	64	53	38.2	24.3	13.6	8.6	10.9	21.7	9.2	GC-SC
			(Grab sample)																			
BORROW		H	W-80-257			100	97	92	89	84	81	73	66	54	36.0	19.6	8.9	5.2	12.3	17.1	2.5	GM-SM
			(Grab sample)																			
DEADMAN			W-80-282											100	99.5	81.3	69.6	50.8	42.1	55.9	33.2	CL-CH
			(Grab sample)																			
DEADMAN			W-80-300			100	95	93	89	87	86	80	76	58	26.9	9.2	3.0	1.3	6.6	NV **	NP **	SM
			(Grab sample)																			
STREAM ALLUVIUM			W-80-302	100	92	90	82	69	58	45	38	27	23	14	2.6							GP
			(Grab sample)																			
BORROW		D	AH-D1 #5					100	99	95	94	90	84	69	42.3	19.0	6.1	2.6	11.1	NV	NP	SM
			(6.0 - 7.5')																			
BORROW		D	AH-D1 #6				100	87	87	83	80	76	69	54	28.3	14.4	6.1	3.3	6.7			SM*
			(8.0 - 8.5')																			
BORROW		D	AH-D1 #7						100	91	91	87	76	62	35.7	18.2	8.2	4.9	6.6			SM*
			(10.0 - 10.3')																			
BORROW		D	AH-D2 #3		100	80	80	80	77	73	72	67	61	47	28.5	12.0	3.2	2.9	25.7	NV	NP	SM
			(1.5 - 3.0')																			
BORROW		D	AH-D2 #4				100	94	92	90	89	86	79	62	35.0	21.2	4.1	2.4	11.4	13.9	NP	SM
			(3.0 - 4.5')																			

REMARKS: * Estimated Value
** NV = Non Viscous NP = Non Plastic

NOTE: SIEVE ANALYSIS = PERCENT PASSING

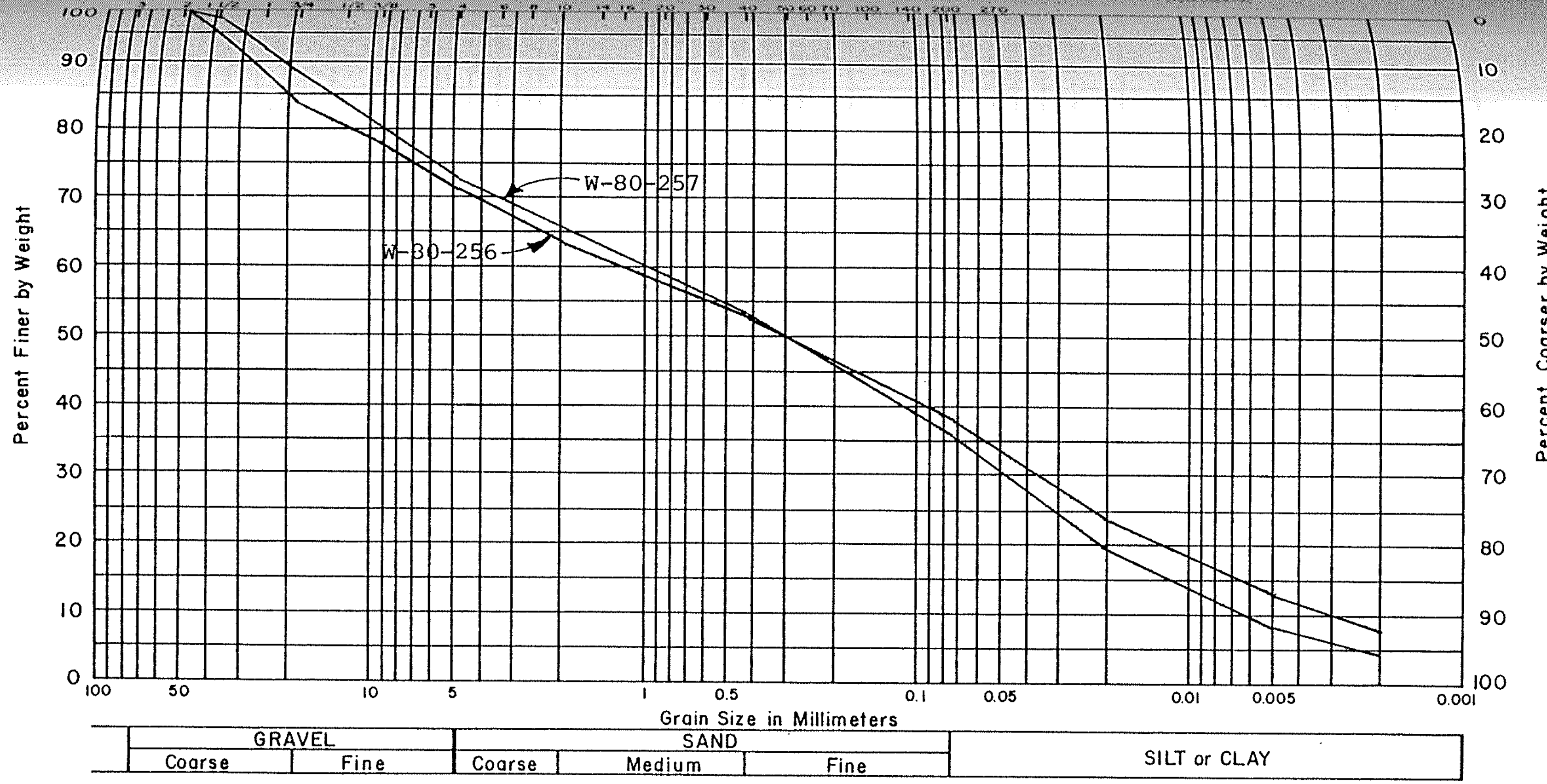
Janice Cleare
APPROVED

LAB NO.	BORING NO	SAMPLE NO	DEPTH	4"	3"	2"	1½"	1"	3/4"	1/2"	3/8"	#4	#10	#40	#200	.02	.005	.002	% Moist.	LL	PI	Unified Class.
BORROW		D	AH-D2 #5					100	98	96	92	87	80	59	30.7	13.8	3.9	1.6	11.2	NV	NP	SM
			(4.5 - 6.0')																			
BORROW		D	AH-D2 #8						100	99	97	93	87	70	44.0	22.5	8.9	4.0	11.3	15.5	2.2	SM
			(15.0 - 16.5')																			
BORROW		D	AH-D2 #9				100	96	94	93	91	85	78	61	38.6	21.3	10.3	4.2	9.4	17.5	4.2	SM
			(20.0 - 21.5')																			
BARROW		E	AH-E1 #3										100	99	48.0				19.6			SM
			(1.0 - 1.5')																			
BORROW		E	AH-E1 #4										100	98	59.5				27.3			ML*
			(2.0 - 3.5')																			
BORROW		E	AH-E3 #6		100	89	89	83	80	76	72	62	52	28	6.2				4.4			SP/SM
			(4.5 - 6.0')																			
BORROW		E	AH-E3 #7			**	100	90	76	62	57	40	31	16	3.7				0.7			GW
			(6.5 - 8.0')																			
BORROW		E	AH-E4 #6							100	99	98	92	66	22.2				17.6			SM
			(5.0 - 6.5')																			
BORROW		E	AH-E7 #3				100	85	73	56	49	39	31	12	2.1				2.3			GP
			(2.0 - 3.0')																			
BORROW		E	AH-E9 #2 (1.5 - 3.0')										100	99	28.6				15.7			SM
BORROW		E	AH-E9 #6 (6.5 - 8.0')					100	95	87	79	57	44	33	17.0				4.4			GM

REMARKS: ** 1-2" Rock Present in Sample
* Estimated Value

NOTE: SIEVE ANALYSIS = PERCENT PASSING

Janice Cleare
APPROVED



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI		CLASSIFICATION & DESCRIPTION
W-80-256						
W-80-257						

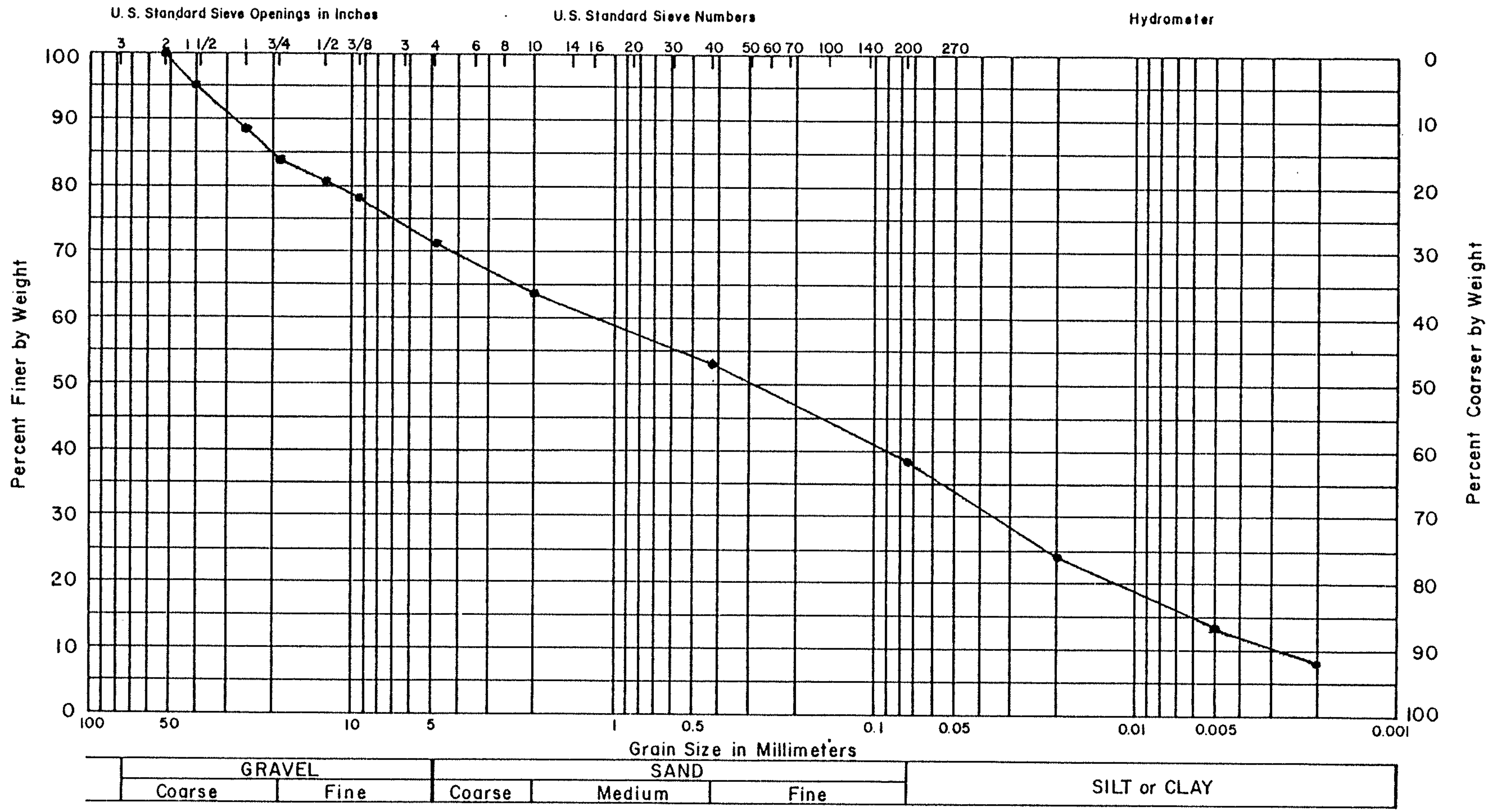
R & M CONSULTANTS, INC.

BORROW AREA H

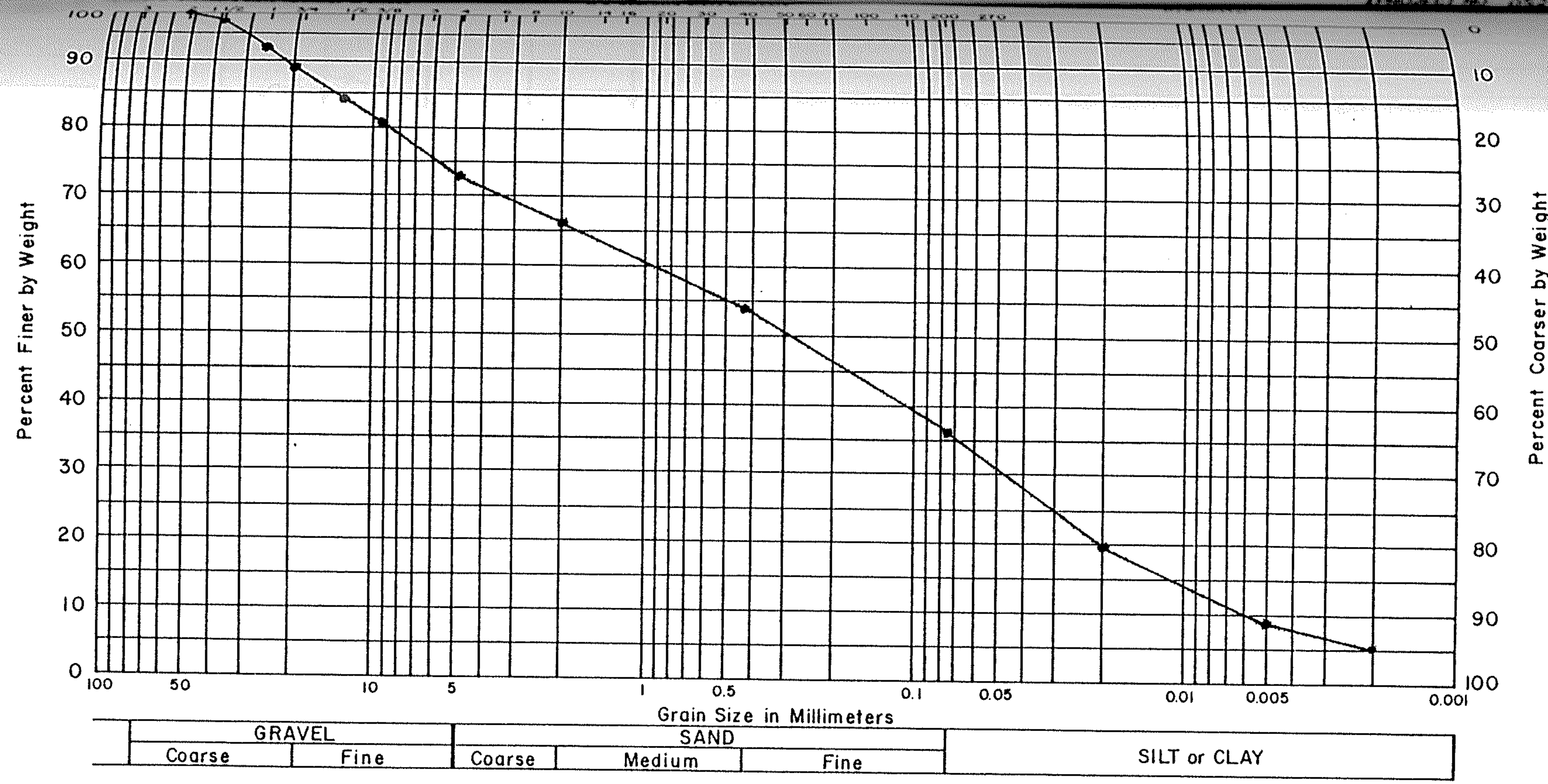
SUMMARY OF GRAIN SIZE DISTRIBUTION

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504

010272



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
W-80-256	10.9%		21.7	9.2	GC-SC	Poorly graded 'Till' with low Plasticity
(Grab Sample)						SILTY GRAVEL AND SAND WITH TRACE CLAY



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
W-80-257	12.3		17.1	2.5	GM-SM	Poorly graded 'Till' with Non-Plastic Fines
(Grab Sample)						SILTY GRAVEL AND SAND WITH TRACE CLAY

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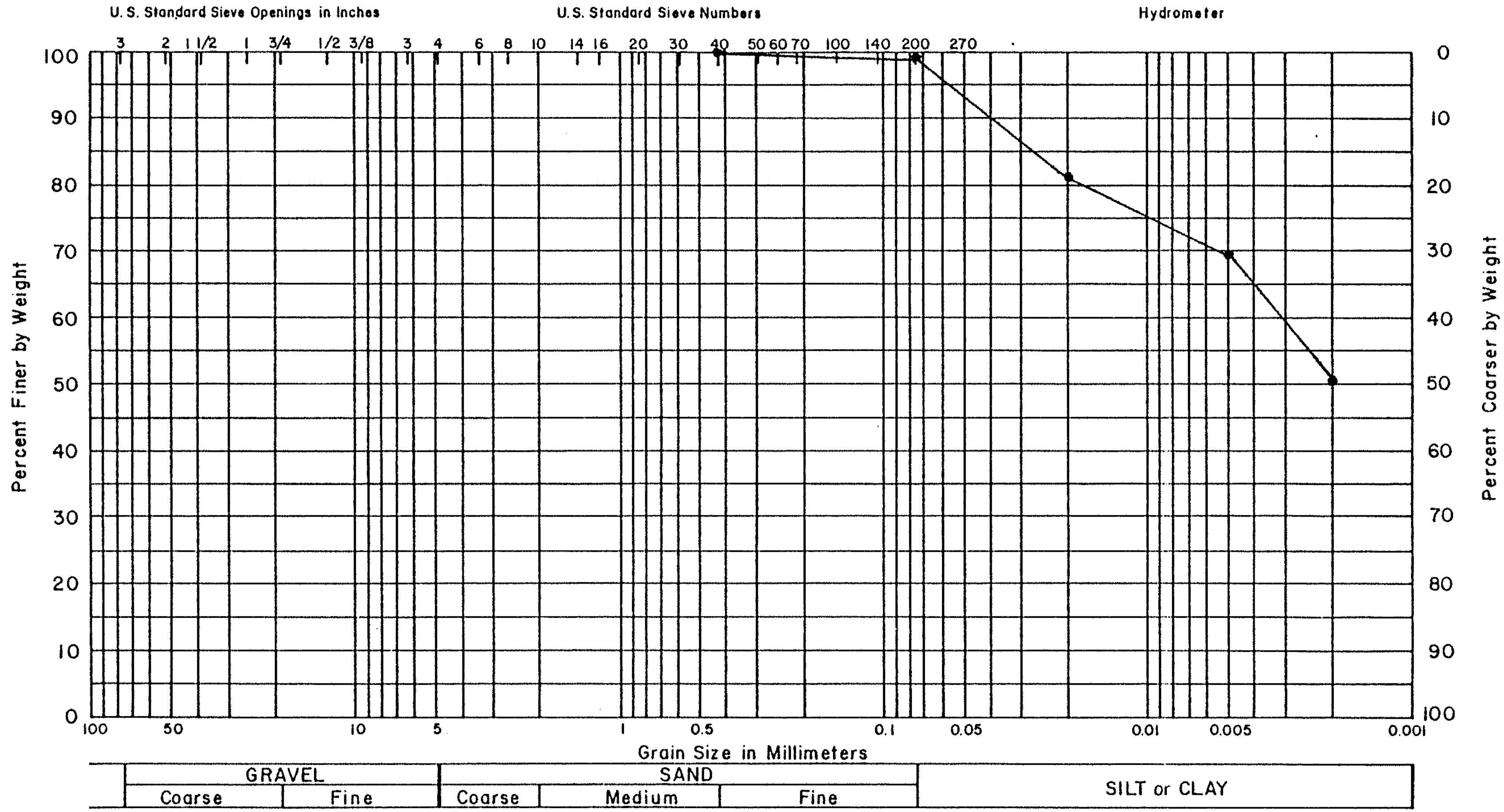
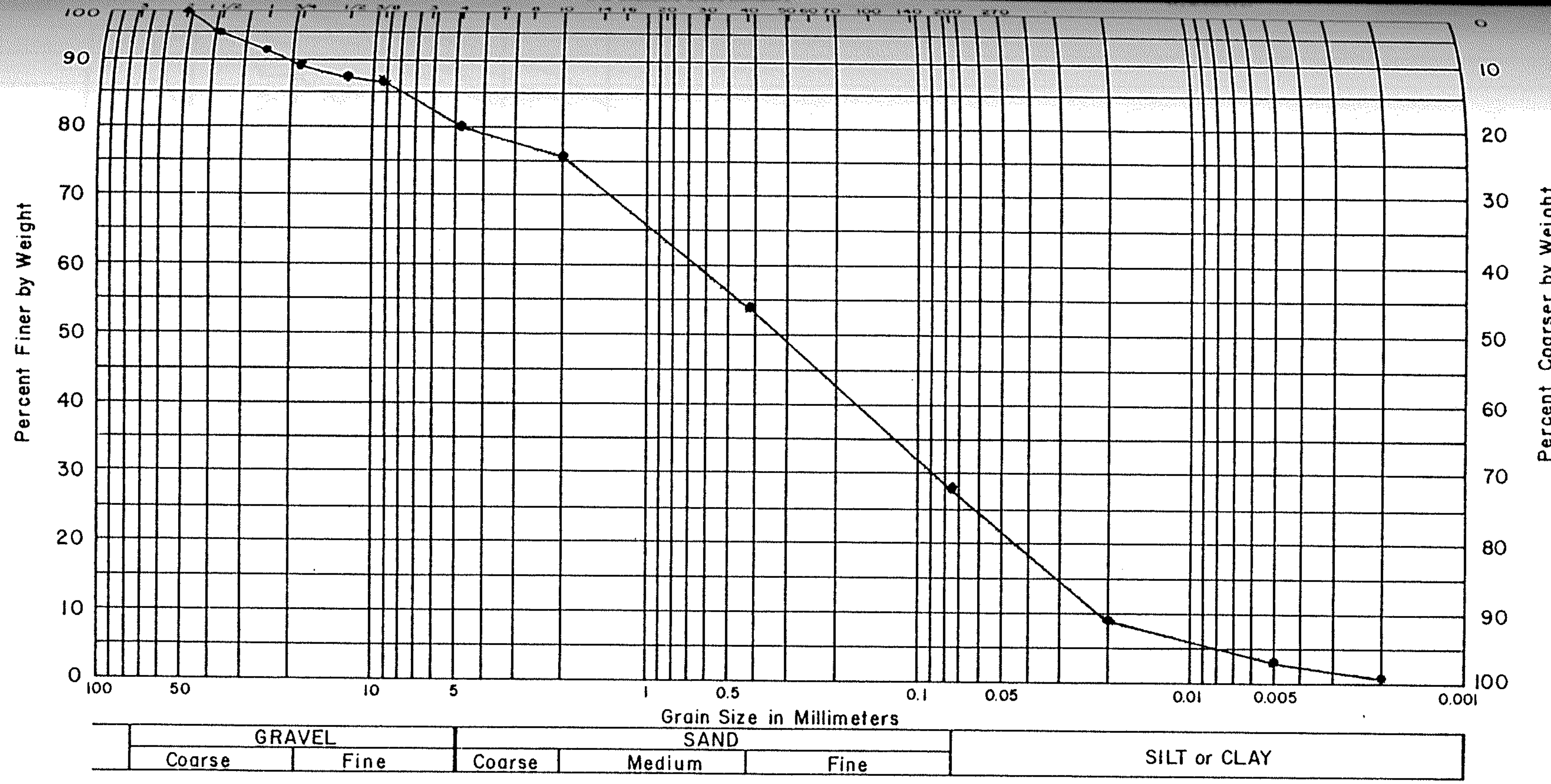
BORROW AREA H

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
W-80-282	42.1%		55.9	33.2	CL-CH	SILT AND CLAY Medium to High Plasticity
(Grab Sample)						



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI		CLASSIFICATION & DESCRIPTION
W-80-300	6.6%		NV	NP	SM	Sandy 'Till' with non plastic fines
(Grab Sample)						GRAVELLY SILTY SAND WITH TRACE CLAY
						Well graded

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DEADMAN BORROW AREA

DRAWN BY	DL
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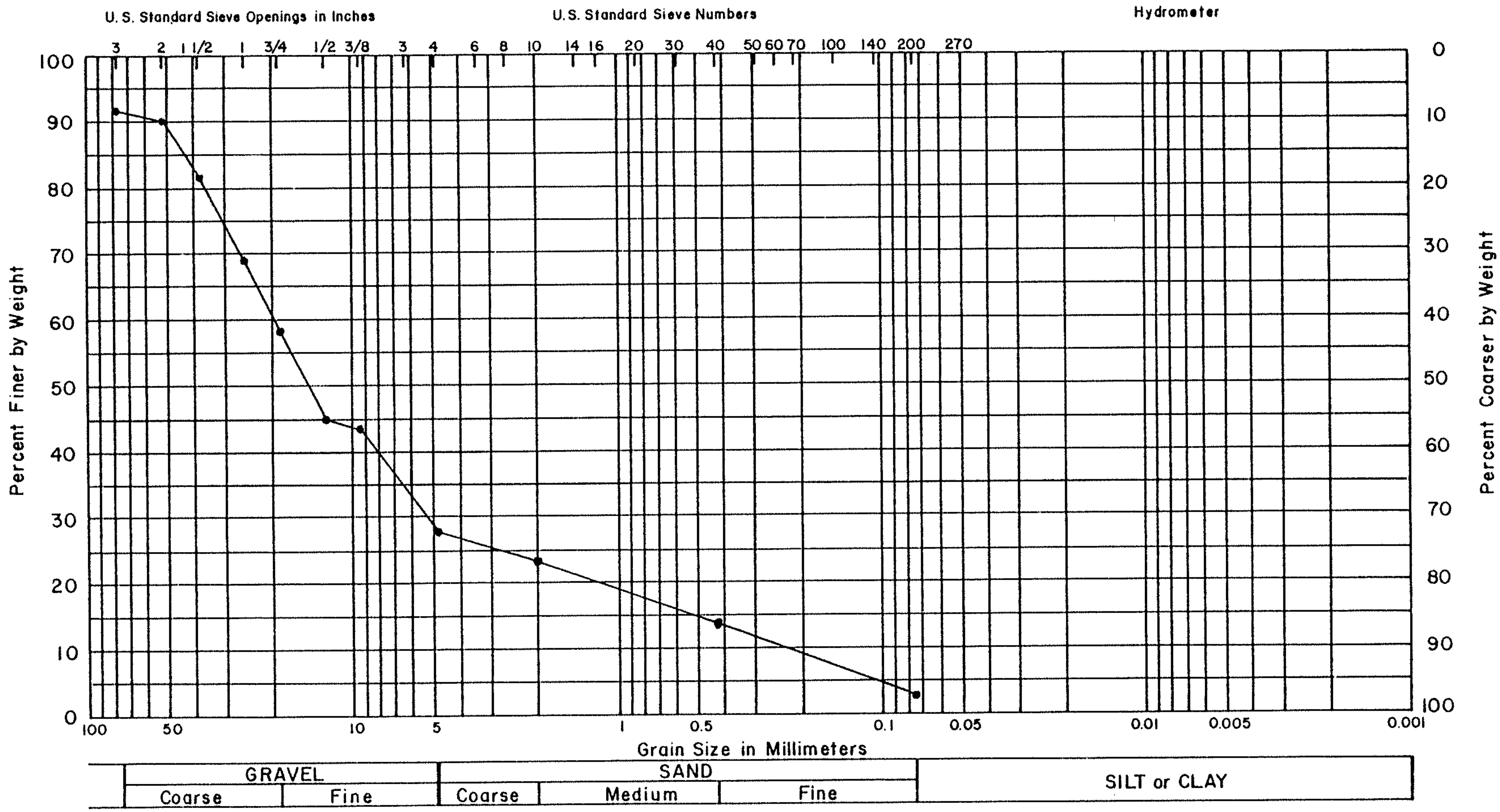
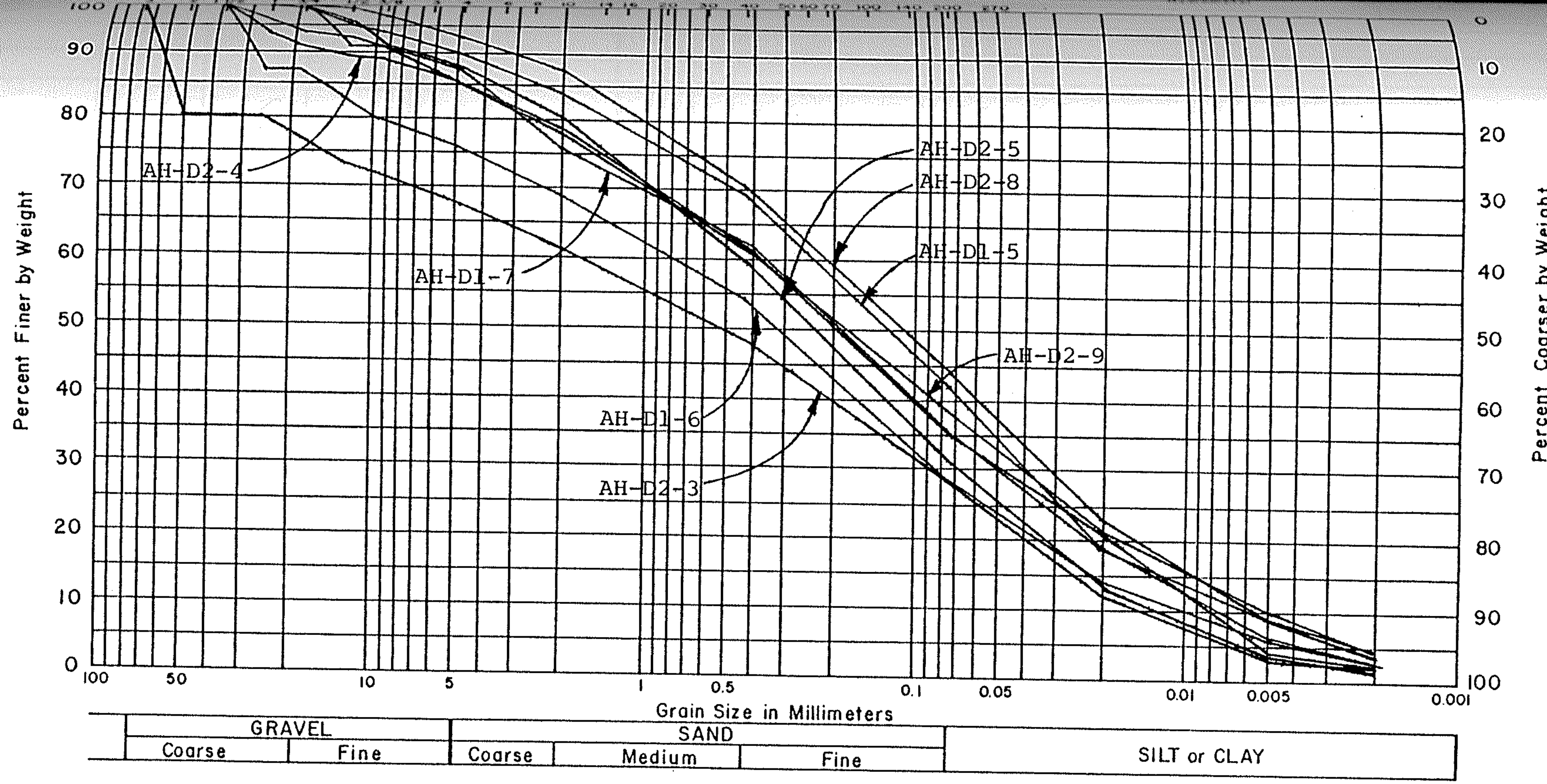


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
W-80-302					GP	SANDY GRAVEL W/TRACE SILT
(Grab Sample)						Poorly Graded



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D1-5					SM	
AH-D1-6					SM	
AH-D1-7					SM	
AH-D2-3					SM	
AH-D2-4					SM	
AH-D2-5					SM	
AH-D2-8					SM	
AH-D2-9					SM	

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BORROW AREA D

SUMMARY OF GRAIN SIZE DISTRIBUTIONS

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504

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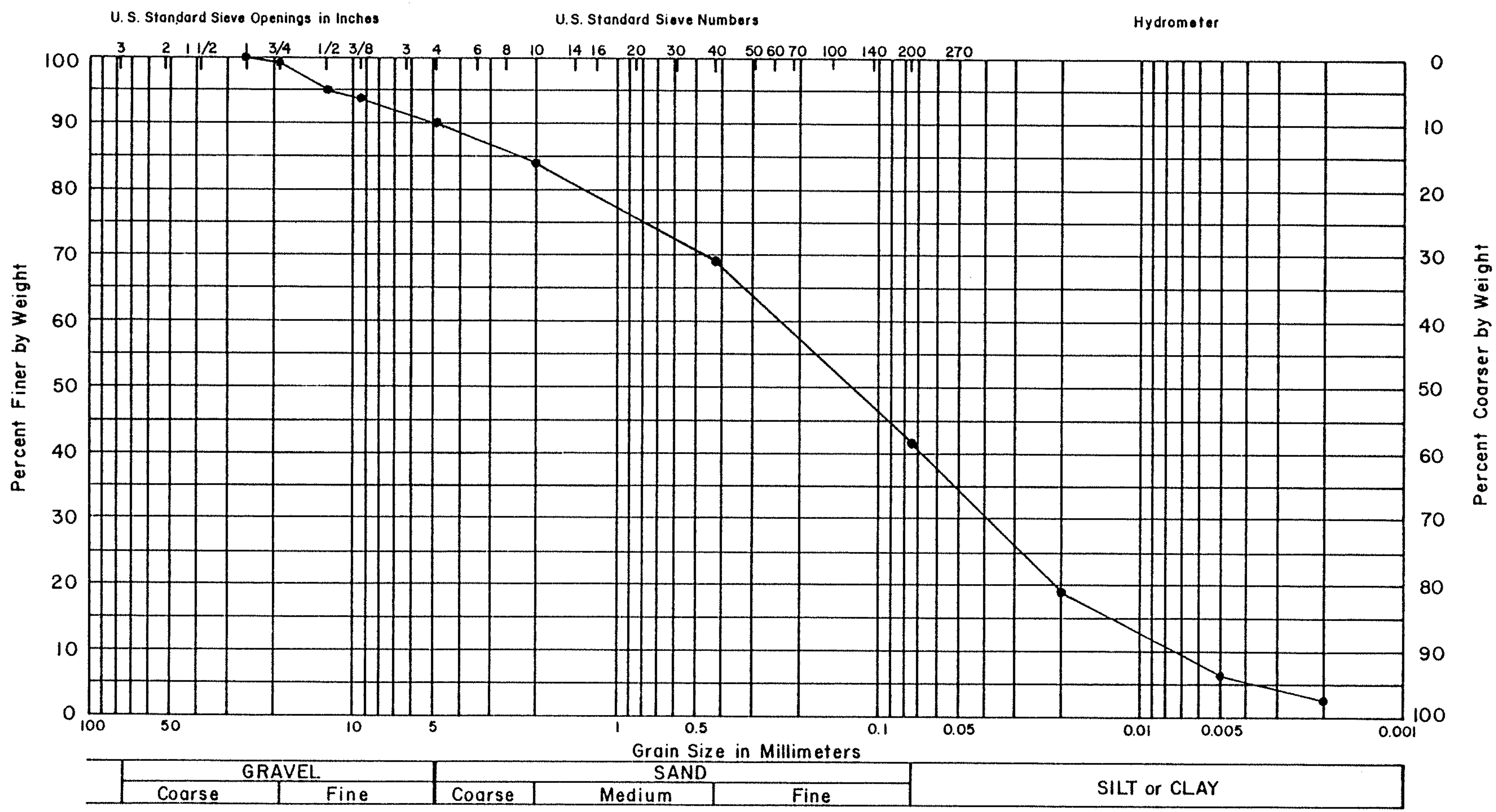
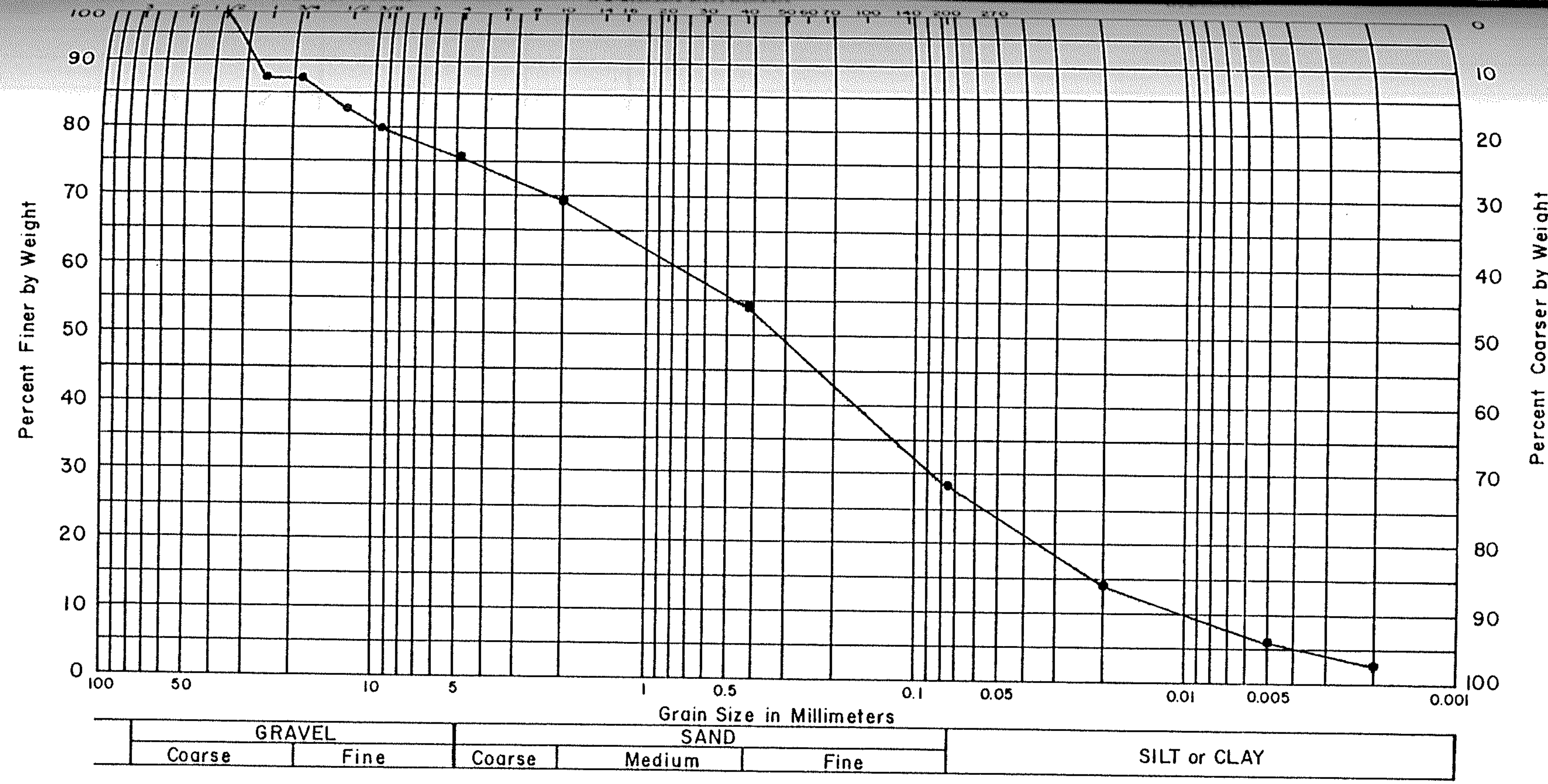


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH- D1-5	11.1%		NV	NP	SM	SILT AND SAND WITH TRACE GRAVEL AND TRACE CLAY
(6.0-7.5')						Non Viscous, Non Plastic



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH- D1-6 (8.0-8.5')	6.7%				SM	GRAVELLY SILTY SAND WITH TRACE CLAY

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BORROW AREA D

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DATE DEC. 1980
PROJECT NO. 052504

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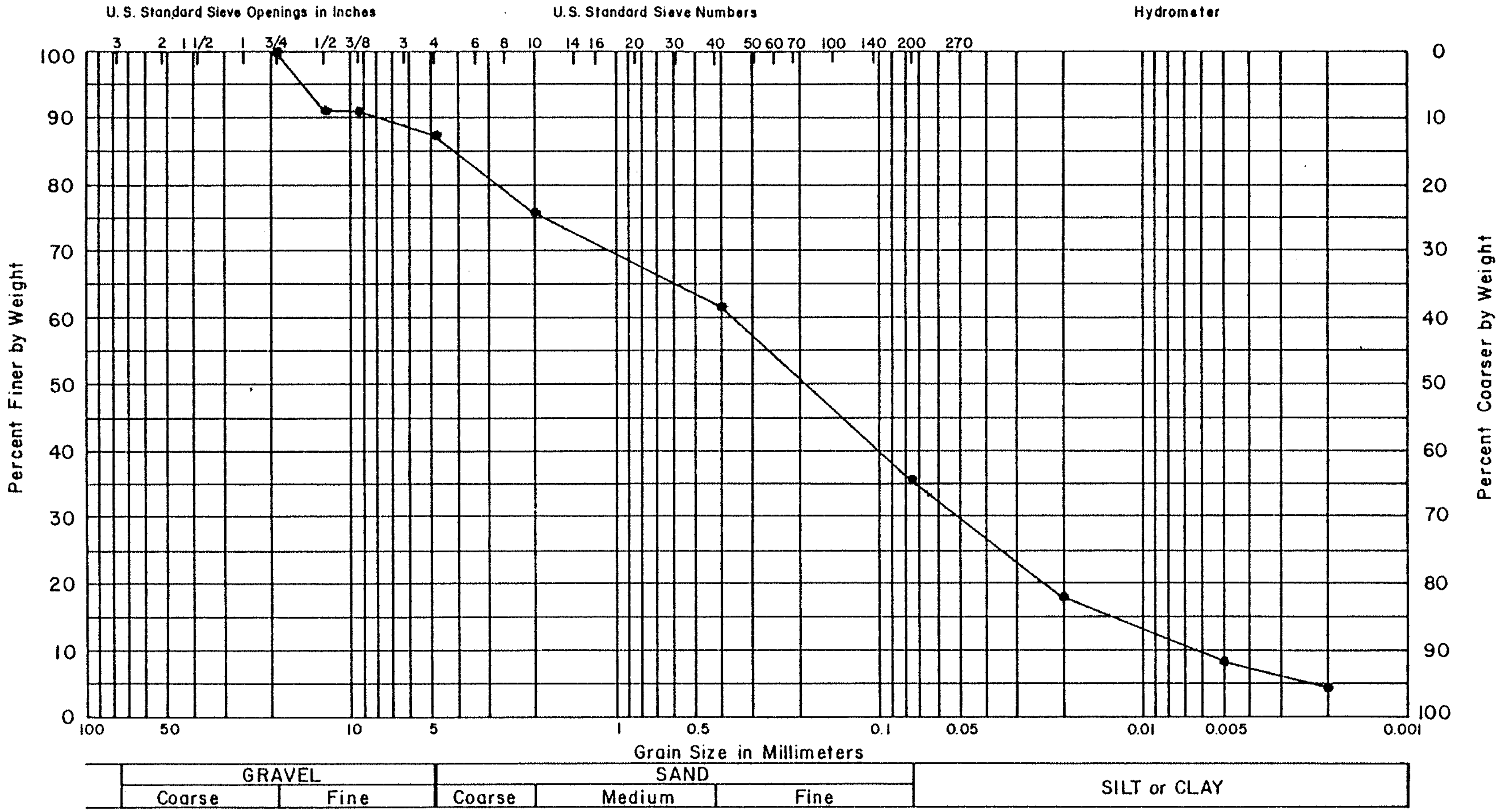
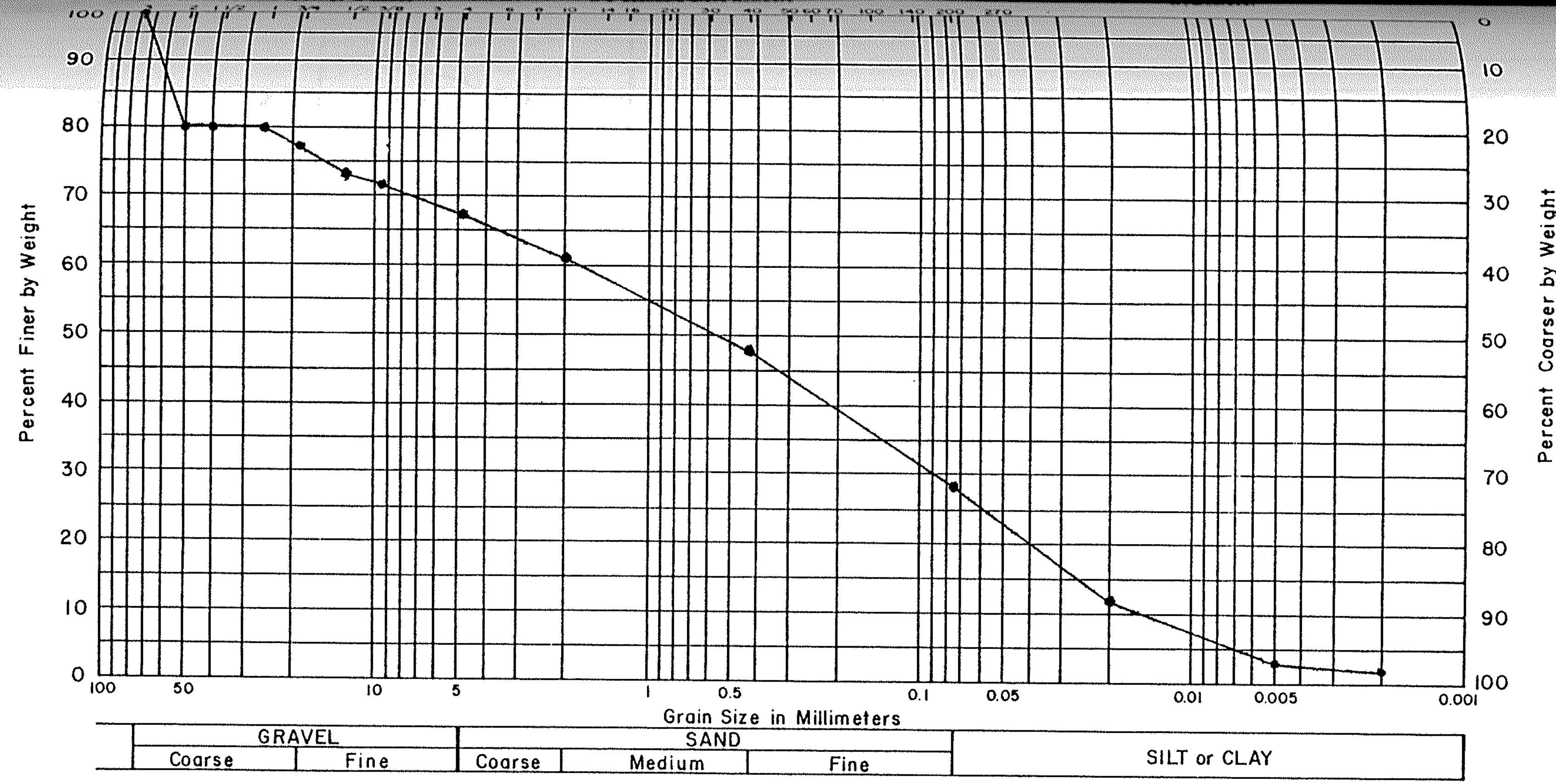


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D1-7	6.6%				SM	SILTY SAND WITH SOME GRAVEL, TRACE CLAY
(10.0-10.3')						



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D2-3	25.7%		NV	NP	SM	SILTY GRAVELLY SAND W/TRACE CLAY
(1.5-3.0')						

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BORROW AREA D

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APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

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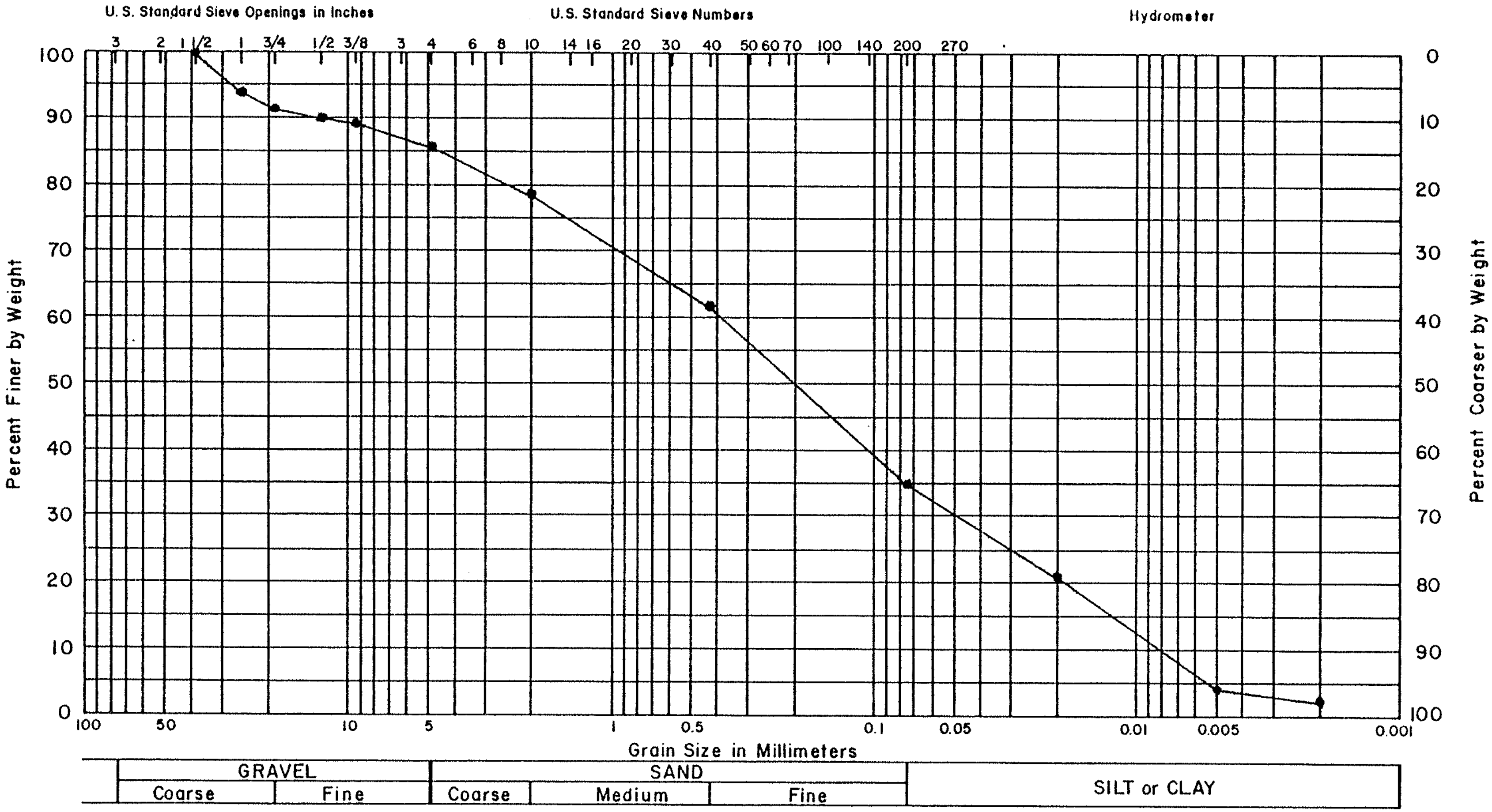
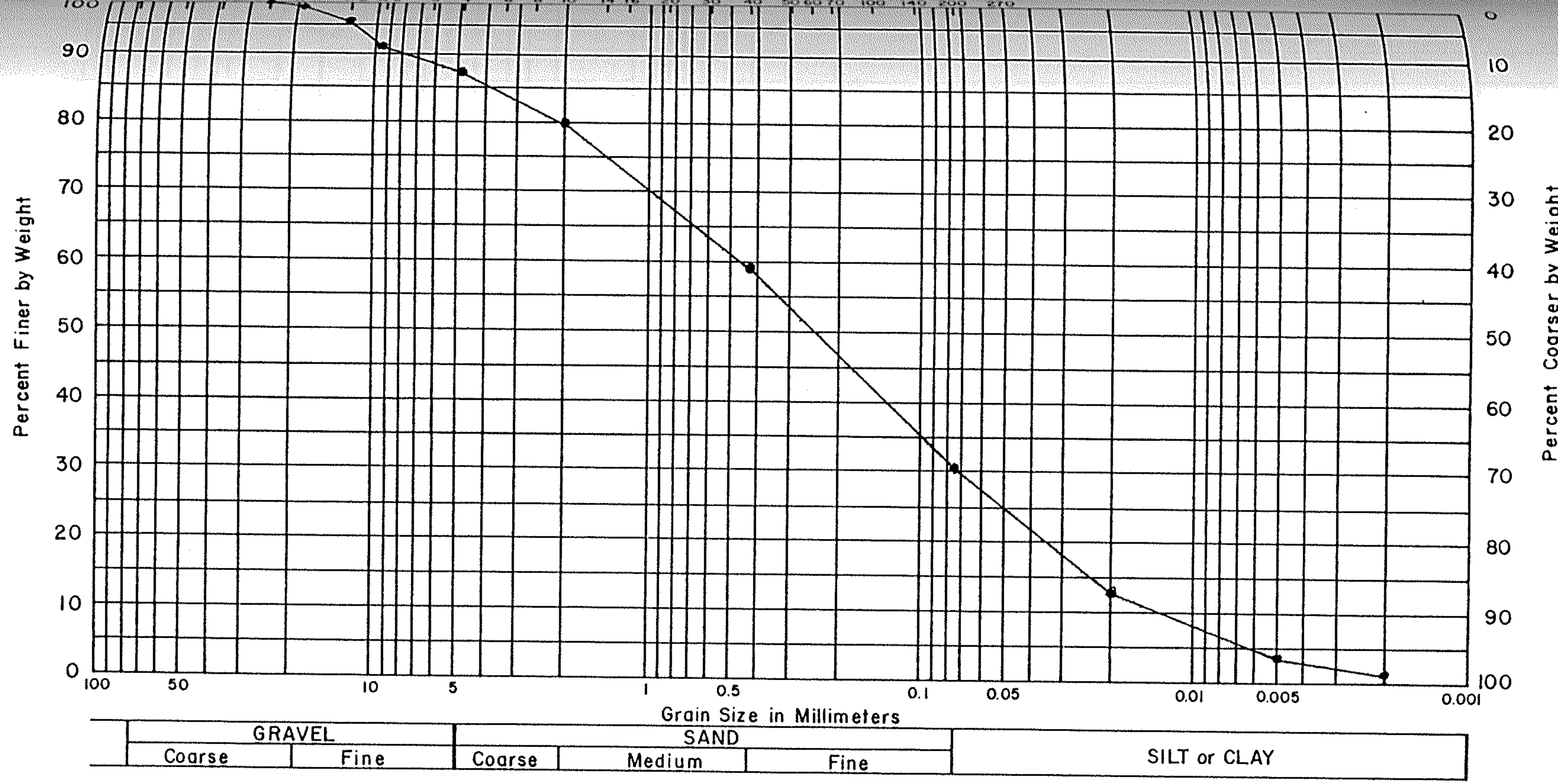


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D2-4	11.4%		13.9	NP	SM	SILTY SAND WITH SOME GRAVEL, TRACE CLAY
(3.0-4.5')						Non Plastic



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D2-5	11.2%		NV	NP	SM	SILTY SAND WITH SOME GRAVEL, TRACE CLAY
(4.5-6.0')						Non Viscous, Non Plastic

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BORROW AREA D

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504

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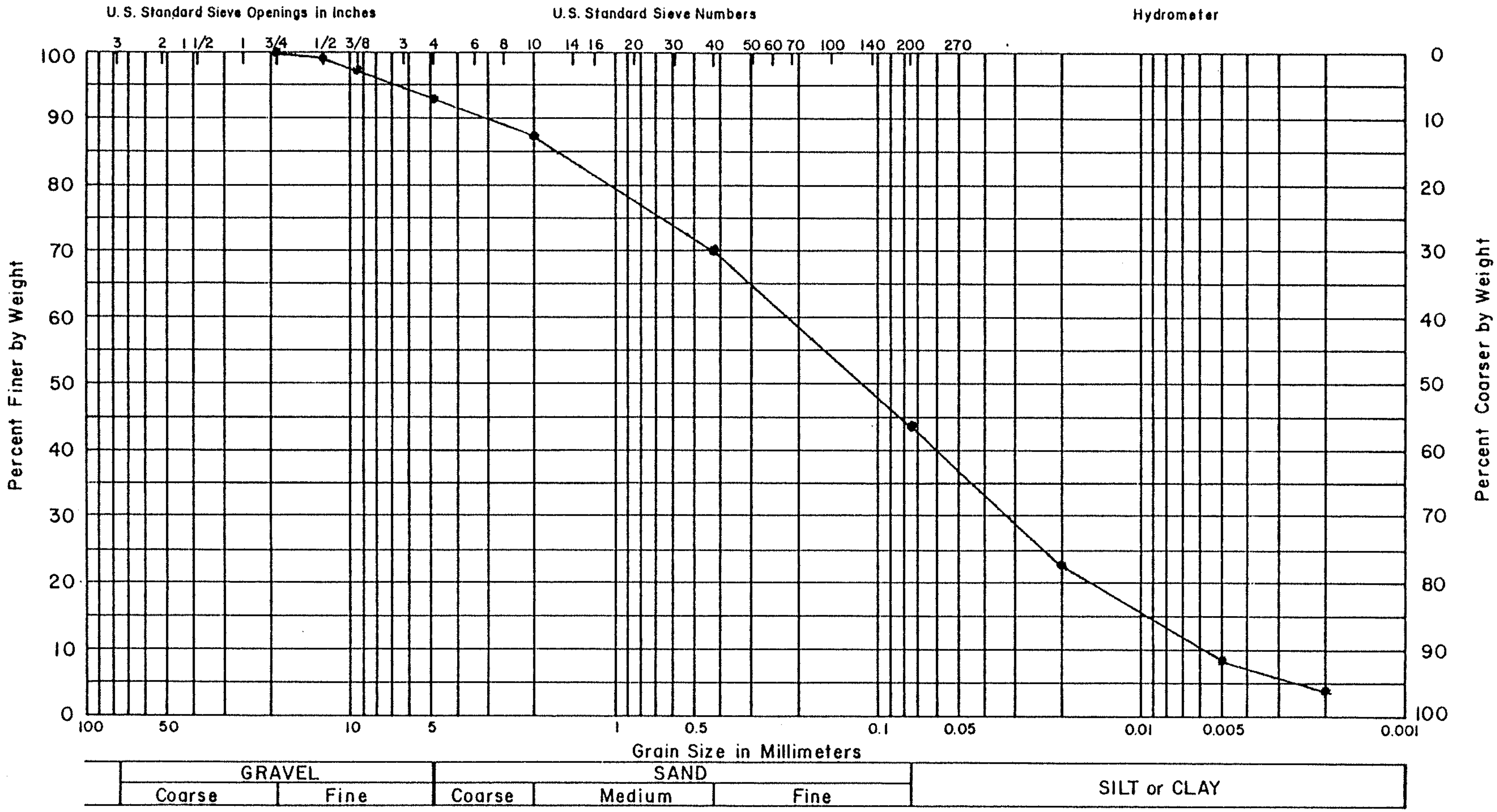
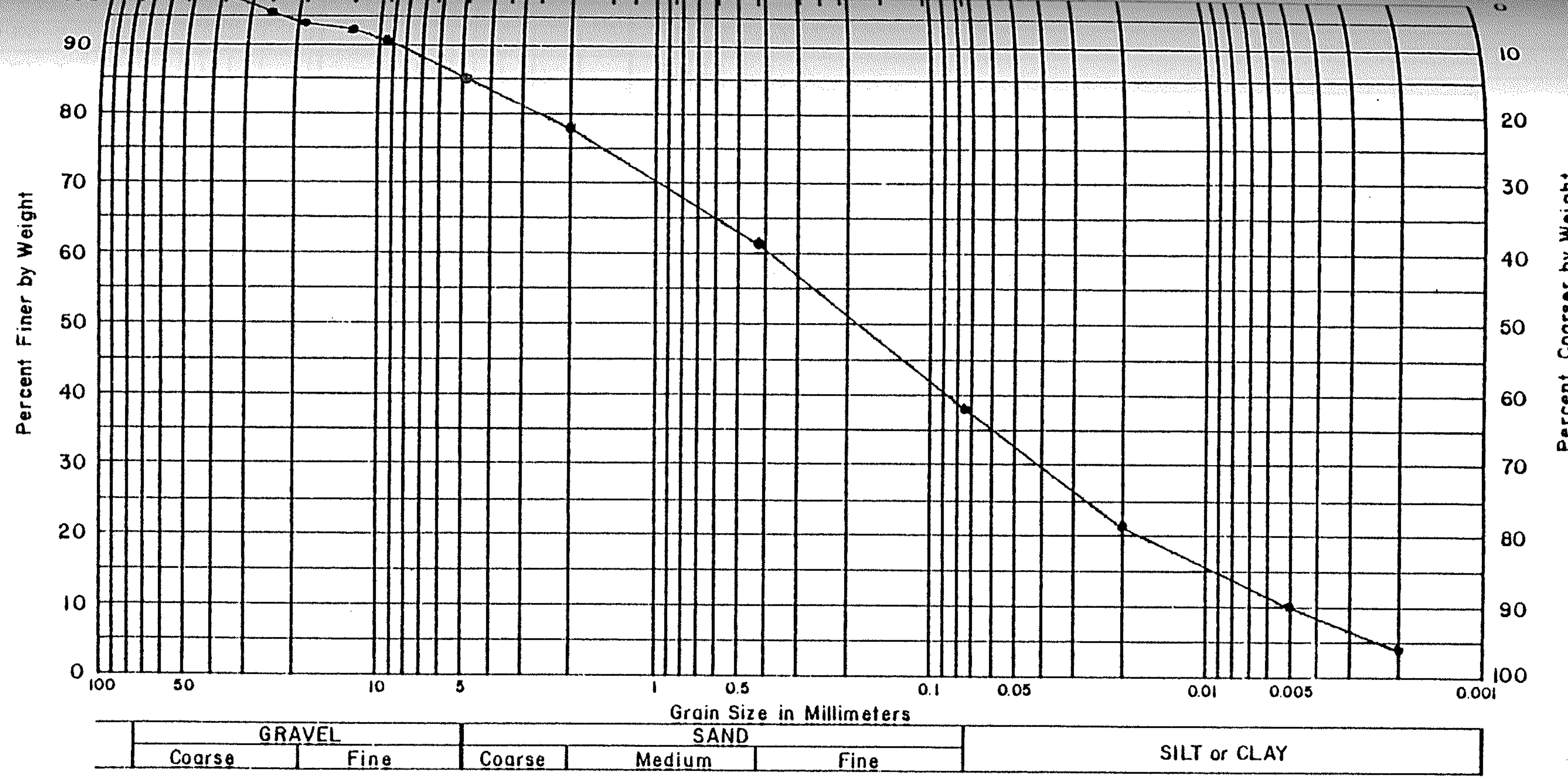


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D2-8	11.3%		15.5	2.2	SM	SILTY SAND WITH TRACE GRAVEL, TRACE CLAY
(15.0-16.5')						

DRAWN BY DL



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D2-9 (20.0-21.5')	9.4%	—	17.5	4.2	SM	Silty sand with some gravel, clay.

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BORROW AREA D

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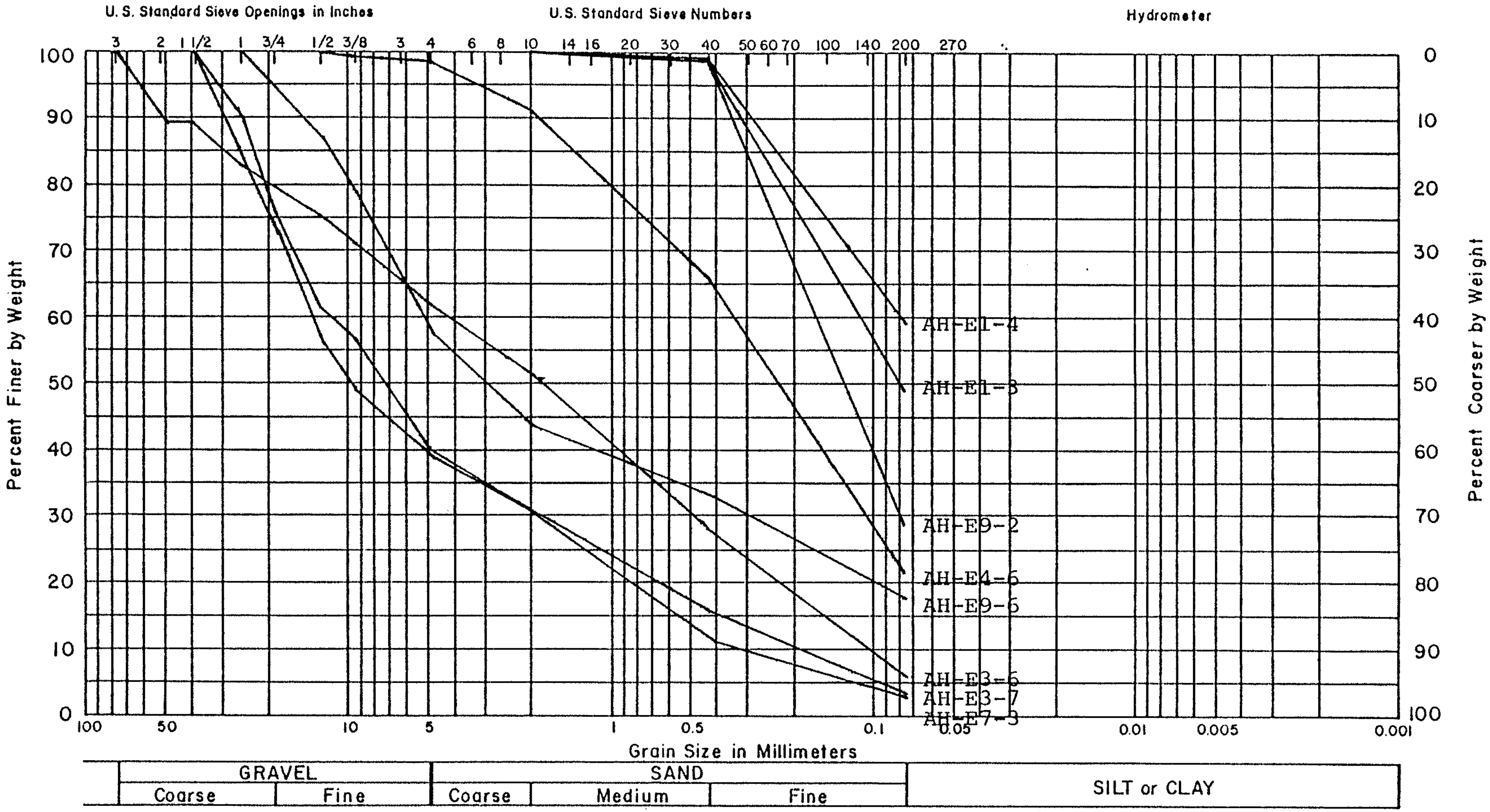
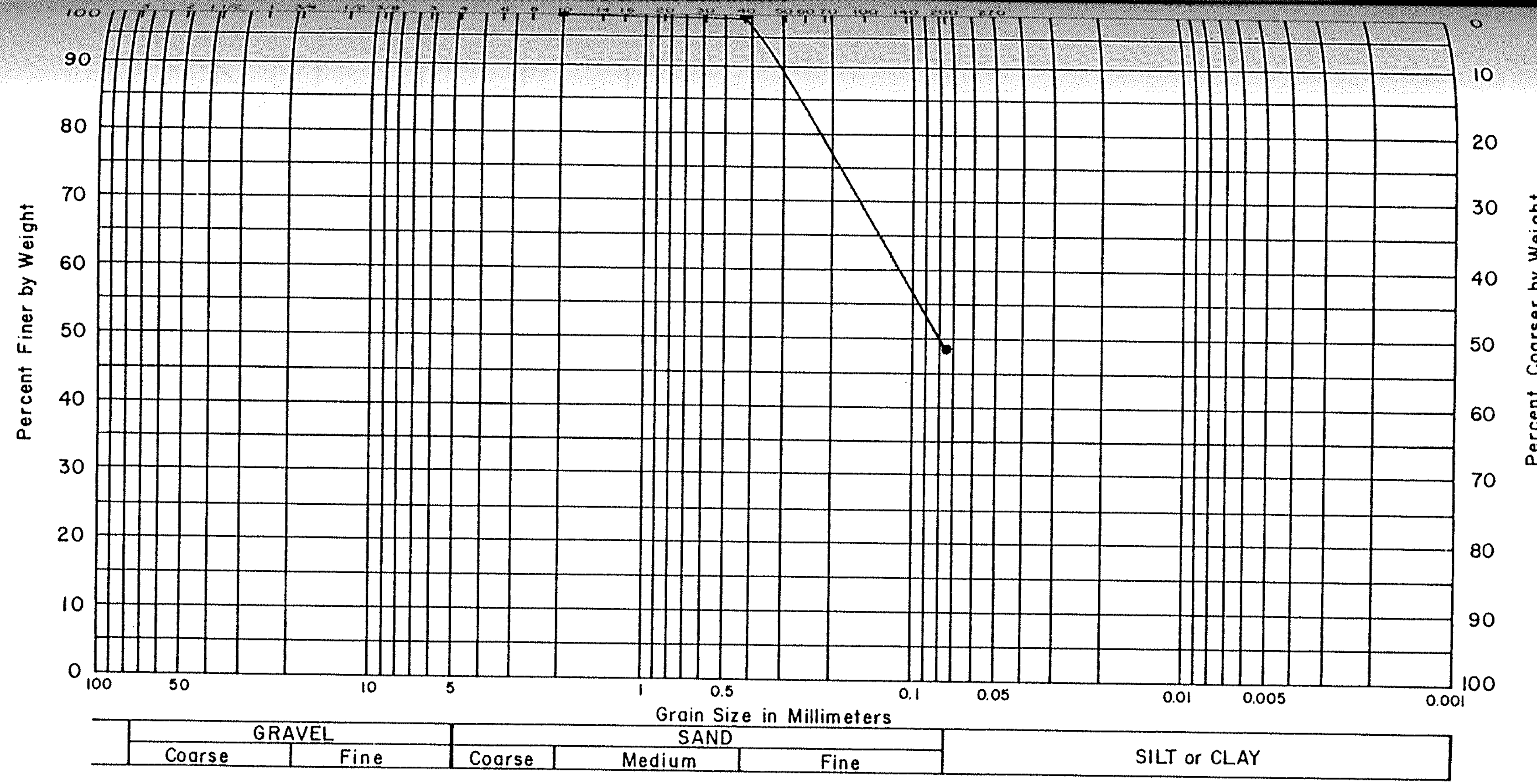
DATE DEC. 1980
PROJECT NO. 052504



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION
AH-E1-3					
AH-E1-4					
AH-E3-6					
AH-E3-7					
AH-E4-6					
AH-E7-3					
AH-E9-2					



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E1-3	19.6%				SM	SILTY SAND
(1.0-1.5')						

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BORROW AREA E

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PROJECT NO.	052504

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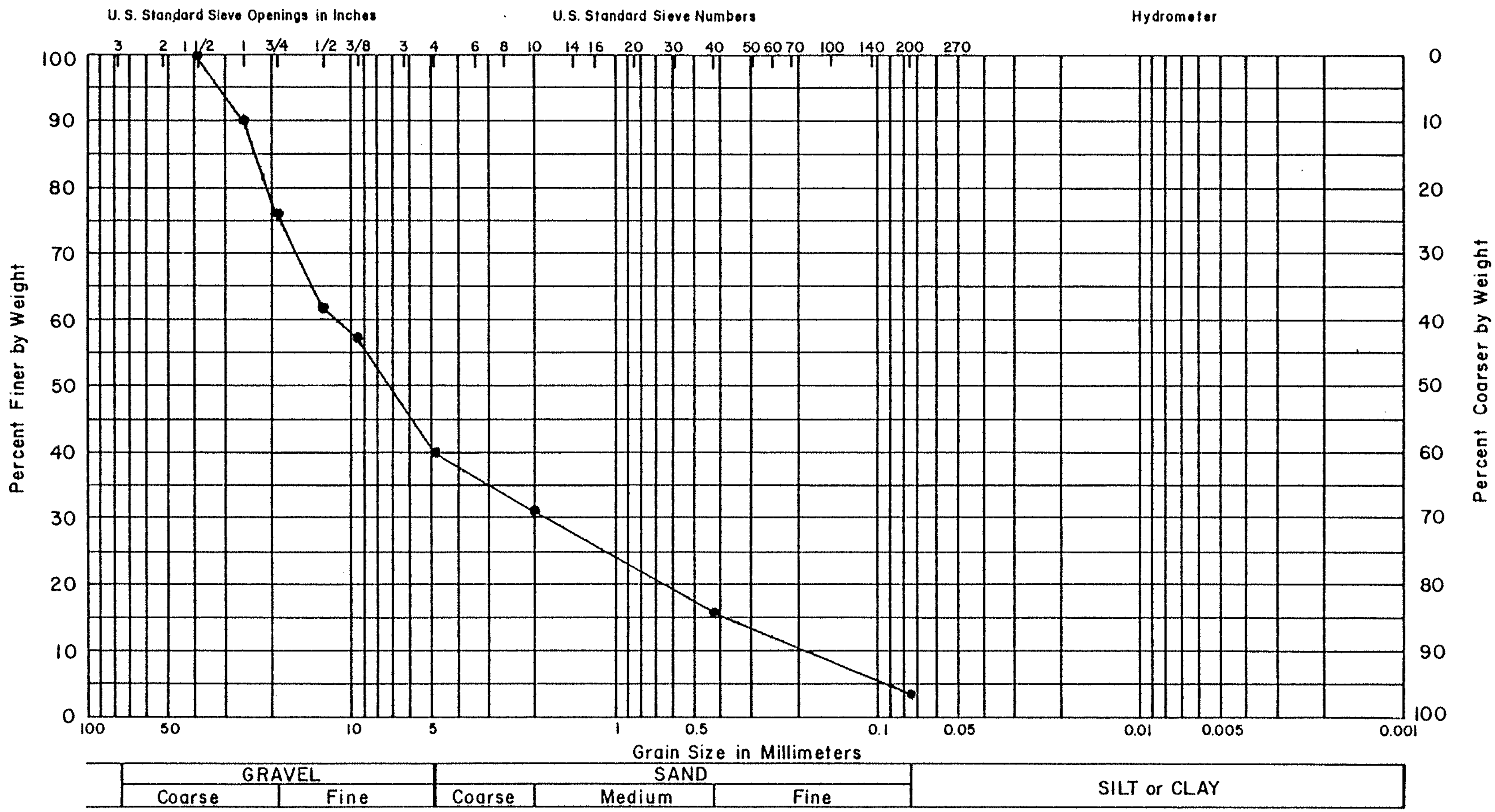
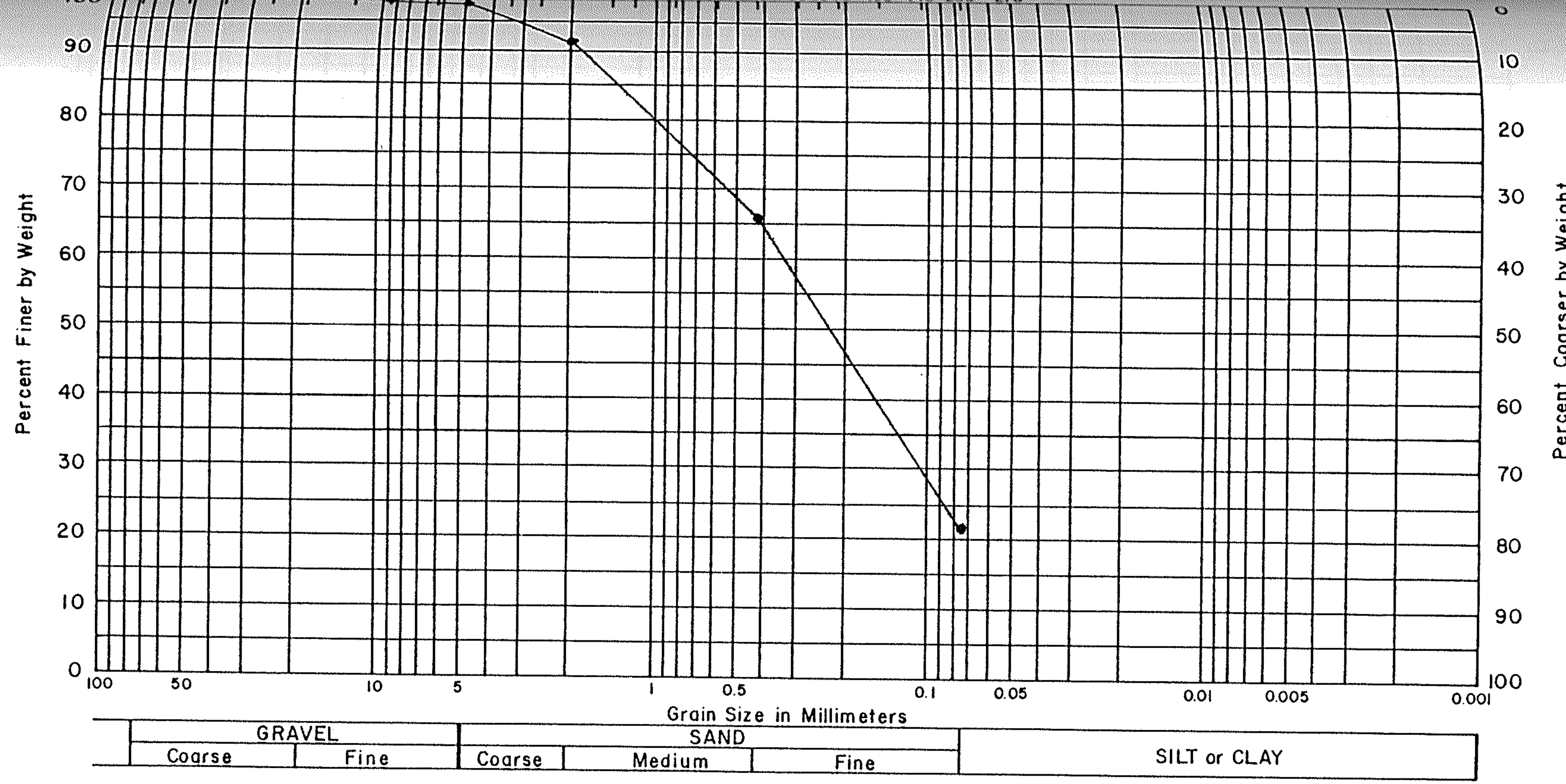


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E3-7	0.7%				GW	SANDY GRAVEL
(6.5-8.0')						Well Graded

DRAWN BY DL



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E4-6	17.6%				SM	SILTY SAND WITH TRACE GRAVEL
(5.0-6.5')						

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BORROW AREA E

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APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

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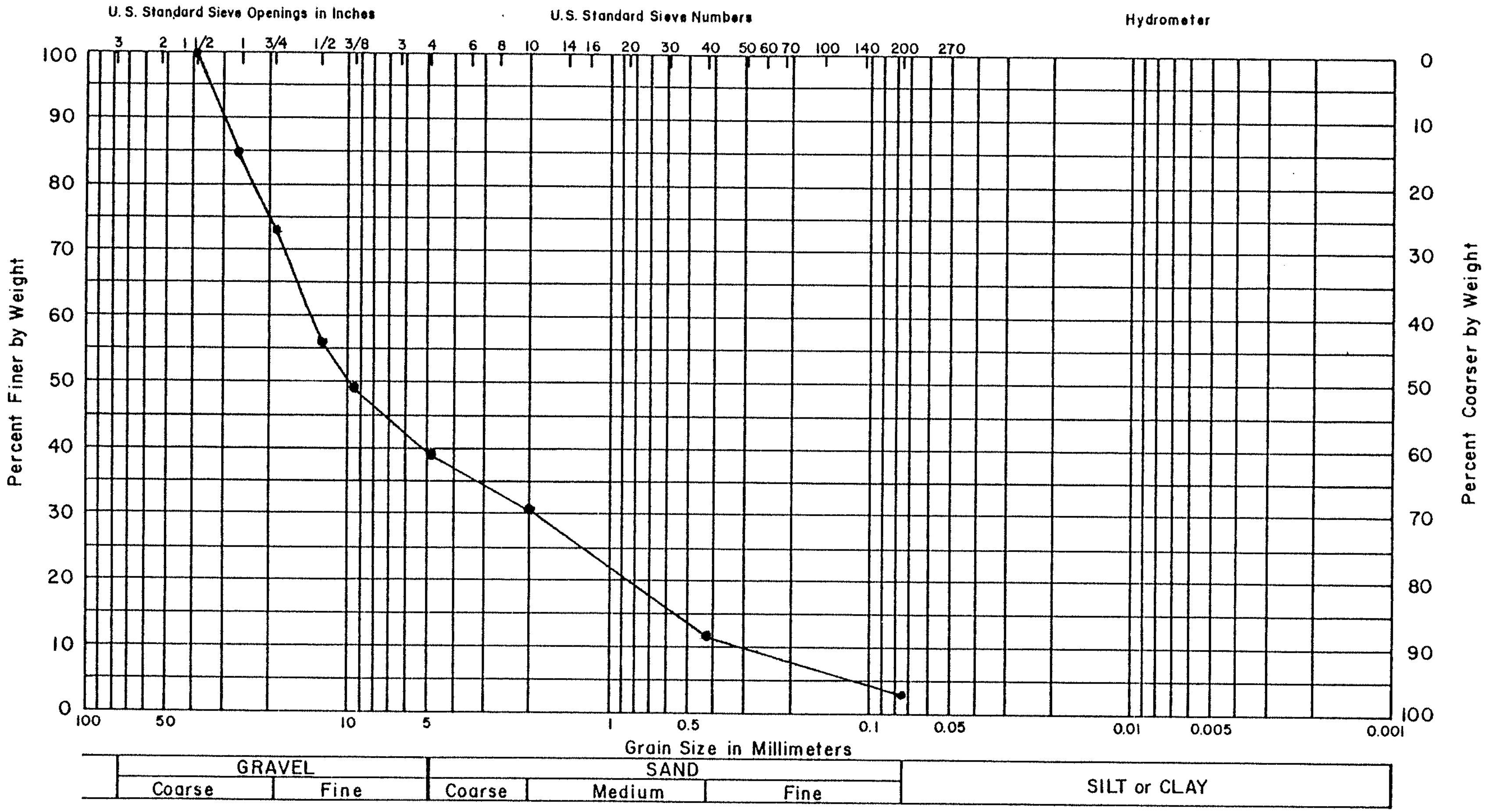
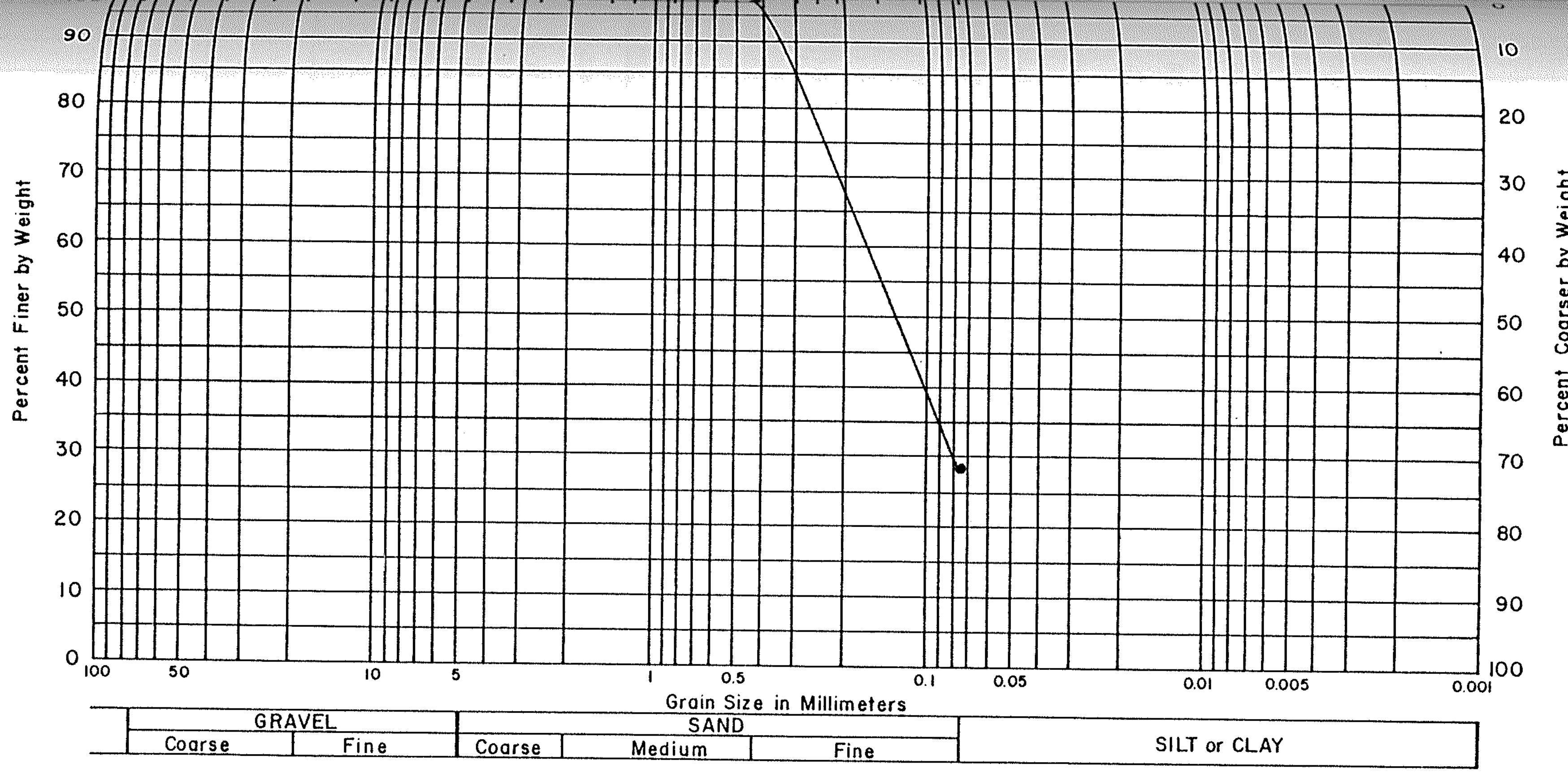


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E7-3	2.3%				GP	SANDY GRAVEL WITH TRACE SILT
(2.0-3.0')						



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E9-2	15.7%				SM	SILTY SAND
(1.5-3.0')						Poorly Graded

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BORROW AREA E

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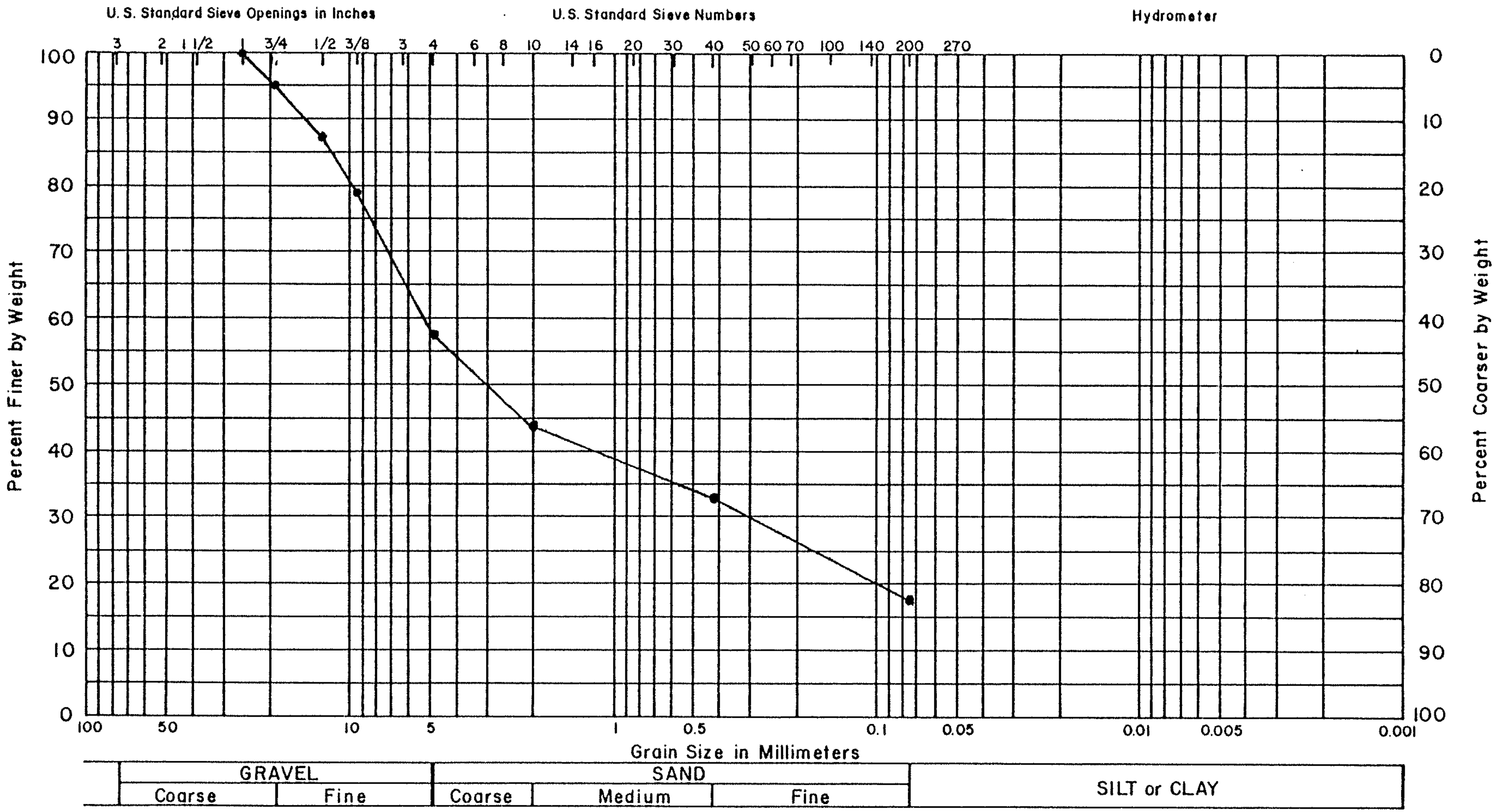
PROJECT NO.	052504



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E9-6	4.4%				GM	SANDY GRAVEL WITH SOME SILT
(6.5-8.0')						

Project No. 052504
Date 11-20-80

R&M Consultant Inc.

LABORATORY COMPACTION CONTROL REPORT

Job Name and Location: Susitna (Watana Dam Site)

Architect or Engineer: Acres American Inc.

Contractor:

A. Description of Soil: SILT AND CLAY

Material Mark: A   Unified Classification: CL-CH   AASHO Classification:

Source of Material: Deadman Creek Sample No. W-80-282

Natural Water Content 42.1% % Natural Dry Density ______ PCF Specific Gravity ______

Liquid Limit 55.9 % Plastic Limit ______ % Plasticity Index 33.2

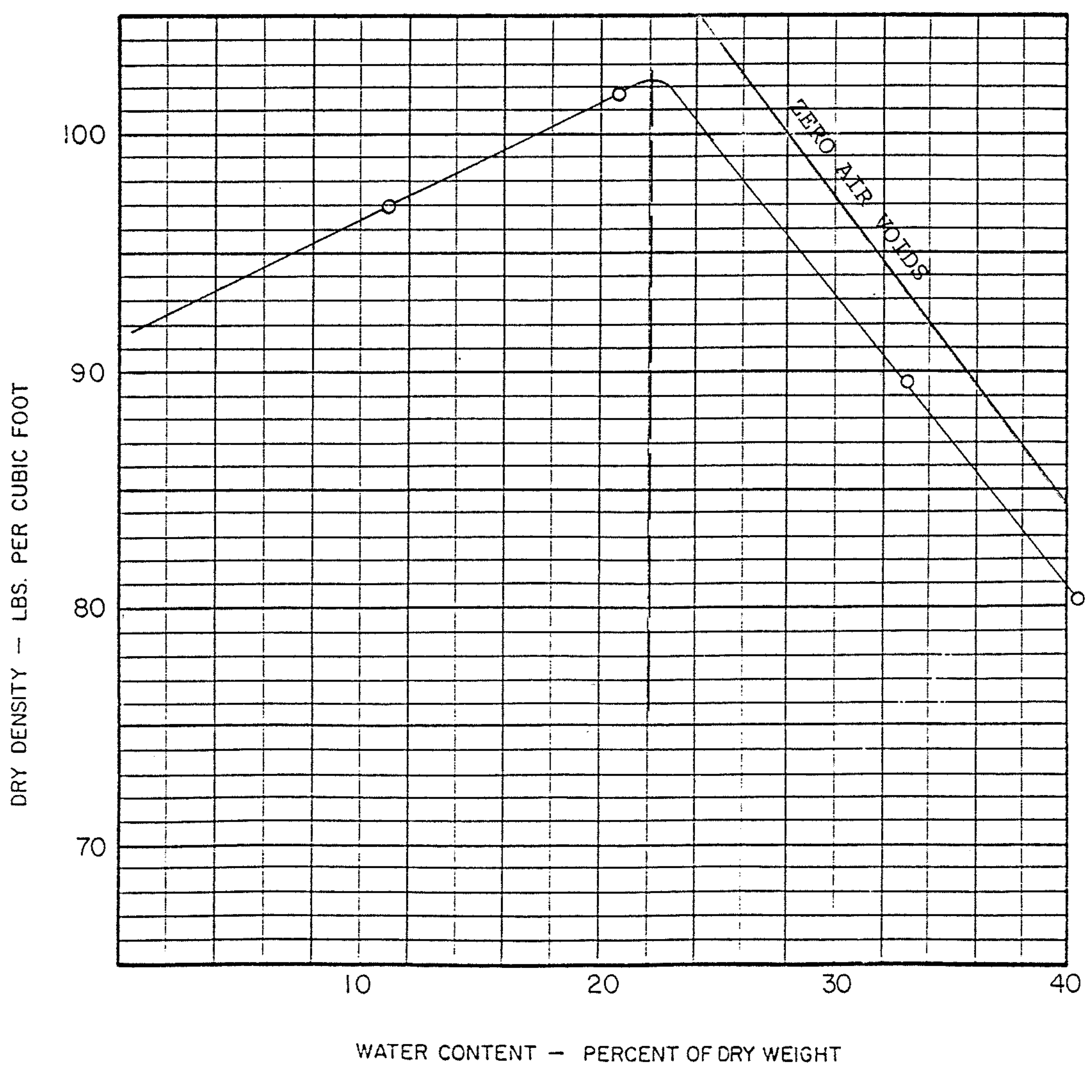
B. Test Procedure Used: T-180 Method "A" - AASHTO

C. Test Results: Maximum Dry Density 102.5 PCF Optimum Water Content 22.0%

ysis

assing

100
99.5
81.3
69.6
50.8



Project No. 052504
Date 11-20-

R&M Consultant Inc.

LABORATORY COMPACTION CONTROL REPORT

Job Name and Location Susitna (Watana Dam Site)

Architect or Engineer Acres American Inc.

Contractor

A. Description of Soil: Well Graded 'Till'- GRAVELLY, SILTY SAND W/TRACE CLAY

Material Mark B Unified Classification SM AASHO Classification

Source of Material Deadman Creek Sample No. W-80-300

Natural Water Content 6.6% % Natural Dry Density PCF Specific Gravity

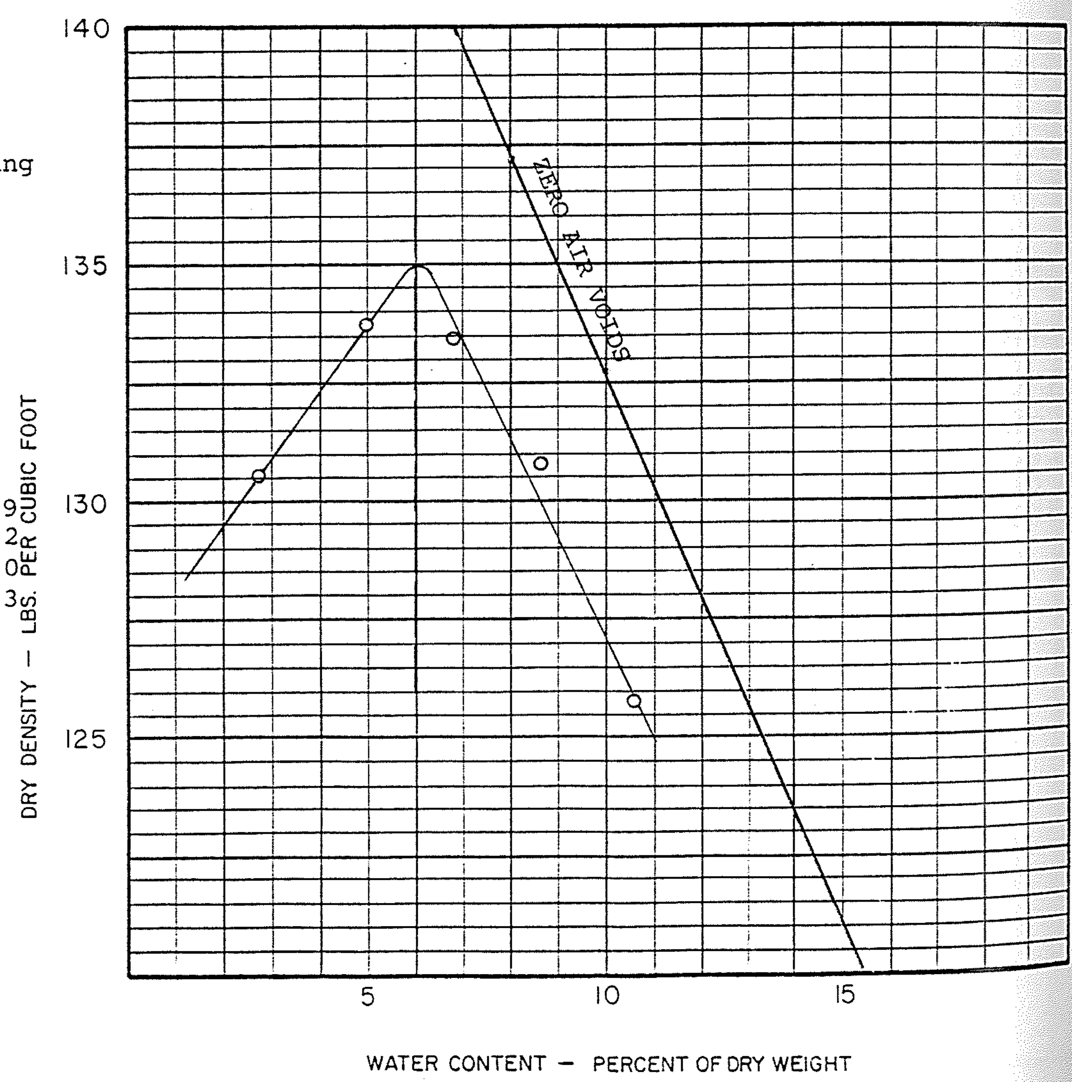
Liquid Limit Non Viscous % Plastic Limit % Plasticity Index Non Plastic

B. Test Procedure Used T-180 "D" - AASHTO

C. Test Results: Maximum Dry Density 135.0 PCF Optimum Water Content 6.

Sieve Analysis

Size	% Passing
2 "	100
1½ "	95
1 "	93
3/4"	89
1/2"	87
3/8"	86
# 4	80
# 10	76
# 40	58
#200	26.9
.02mm	9.2
.005	3.0
.002	1.3



Project No. 052504
Date 11-20-80

R&M Consultant Inc.

LABORATORY COMPACTION CONTROL REPORT

Job Name and Location Susitna (Watana Dam Site)

Architect or Engineer Acres American Inc.

Contractor

A. Description of Soil: Poorly Graded 'Till', SILTY GRAVEL AND SAND W/TRACE CLAY

Material Mark C   Unified Classification GC-SC   AASHO Classification

Source of Material Borrow Area H Sample No. W-80-256

Natural Water Content 10.9 % Natural Dry Density ____ PCF Specific Gravity ____

Liquid Limit 21.7 % Plastic Limit ____ % Plasticity Index 9.2

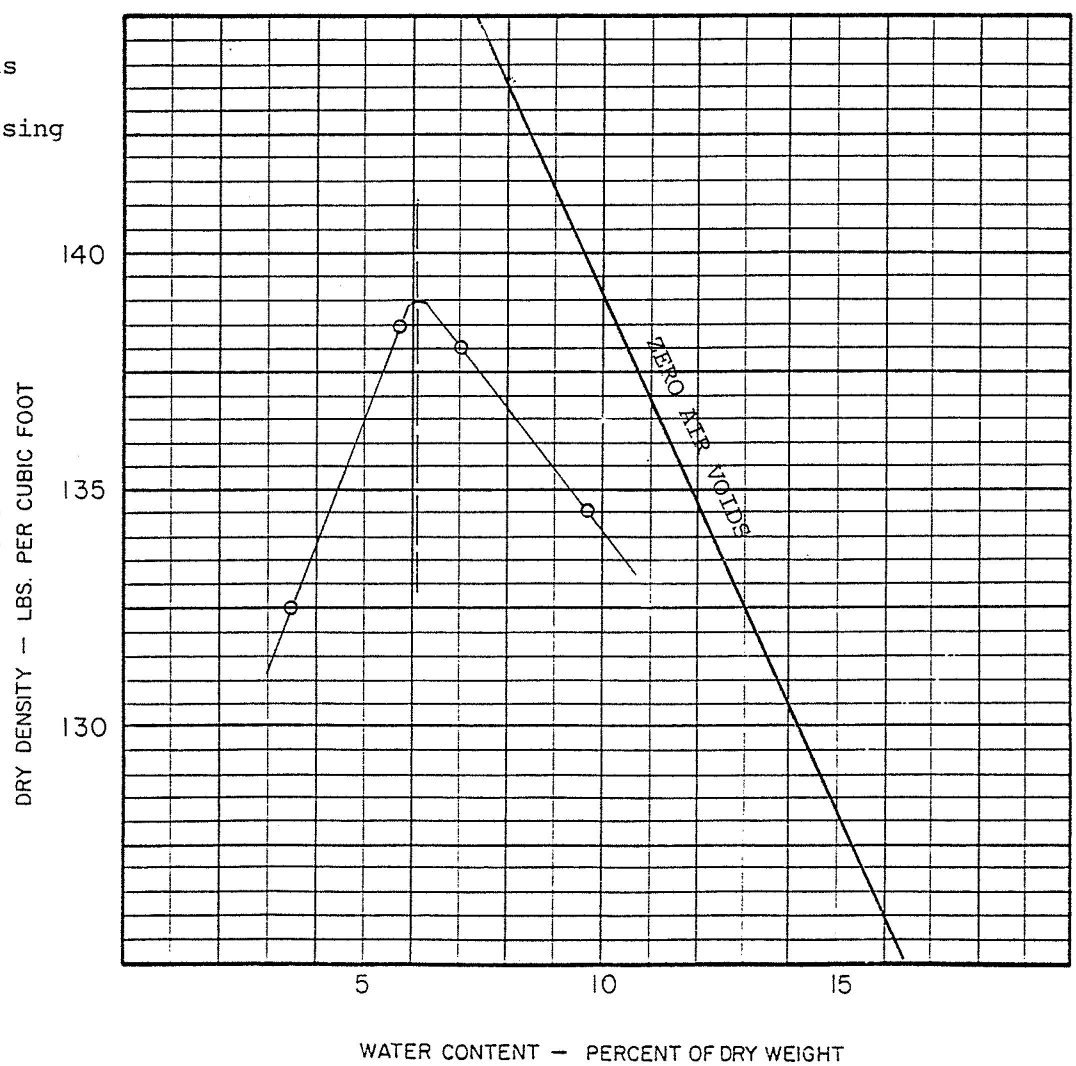
B. Test Procedure Used T-180 Method "D" - AASHTO

C. Test Results: Maximum Dry Density 139.0 PCF Optimum Water Content 6.2 %

e Analysis

% Passing

100
95
88
84
81
78
71
64
53
38.2
24.3
13.6
8.6



APPENDIX D

SEISMIC REFRACTION SURVEY

Prepared By: Woodward-Clyde Consultants

Woodward-Clyde Consultants

FINAL REPORT
SUSITNA HYDROELECTRIC PROJECT
SEISMIC REFRACTION SURVEY
SUMMER, 1980

Submitted To

R & M Consultants
5024 Cordova
Anchorage, Alaska 99502

4000 West Chapman Avenue
Post Office Box 1149
Orange, California 92668
(714) 634-4440
Telex 68-3420

Woodward-Clyde Consultants

19 December 1980
Project No. 41306I

R & M Consultants
5024 Cordova
Anchorage, Alaska 99502

Attention: Mr. Gary Smith

Gentlemen:

SUBJECT: FINAL REPORT - SUSITNA HYDROELECTRIC PROJECT
SEISMIC REFRACTION SURVEY, SUMMER, 1980

Enclosed are 10 copies of our Final Report from the geophysical survey conducted under our agreement of July 23, 1980. This report reflects your comments and those of Acres American to our draft report dated October 23, 1980.

As requested by Mr. Robert Henschel of Acres American in our meeting earlier this month, we are preparing a set of recommended additional surveys to investigate areas where uncertainties still exist. These recommendations will be forwarded under separate cover. Mr. Henschel also requested revision of the profile figures in this report to reflect true elevations rather than relative elevations. We will make the appropriate changes and forward revised drafts when datum elevations become available.

We have enjoyed working with you on this project. Please call us if you have any questions or comments.

Very truly yours,

Jan D. Rietman

Jan D. Rietman, Ph.D.
Deputy Director of Geophysics

Dennis E. Jensen

Dennis E. Jensen
Project Geophysicist

JDR:DEJ/ab

Enclosures

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

This report presents the results of a seismic refraction survey performed during June and July, 1980, on the Upper Susitna River, Alaska, approximately 125 miles north of Anchorage. The survey was performed under contract with R & M Consultants as part of their subcontract with Acres American Incorporated.

Most of the survey was performed on the abutments and in borrow areas for the proposed earth and rockfill dam near the confluence of Watana Creek and the Susitna River. The locations of lines run at the Watana site are shown on Figures 1, 2, and 3.

The remainder of the survey was performed across a possible saddle dam location adjacent to a proposed concrete dam at Devil Canyon, approximately 27 miles west of the Watana site. The locations of lines at the Devil Canyon site are shown on Figure 4.

1.1 Purpose

The purpose of this survey is to provide additional data for the continuing feasibility studies for the Susitna Hydroelectric Project proposed by the Alaska Power Authority. This survey is to supplement borings, geologic mapping, and previous geophysical surveys accomplished over the past several years.

Line locations were selected by Acres American based on previous studies. Line lengths, geophone spacing and field procedures were designed to investigate the nature and distribution of bedrock and overburden materials.

1.2 Scope of Work

A total of 27,800 feet of seismic line was run as separate traverses. Thirty-six geophone spreads we tested at 122 shot points. The scope of the field work w limited by several factors including planned duration the program, weather, and logistics. Several lines we deleted or altered with the concurrence of Acres and R & field representatives. A few additional lines were adde In particular, lines planned across the river at both d sites were not considered feasible because of the high ra of flow at that time. Deleted line locations are shown Figures 1, 3, and 4.

R&M personnel laid out and brushed all seismic lines a provided a survey of relative elevations and spacing geophone and shot locations which had been flagged duri seismic testing.

The accumulated data were reduced and interpreted the Orange, California office of Woodward-Clyde Consu tants. Previous seismic studies by Dames & Moore, 197 and by Shannon and Wilson, 1978, were used as backgrou for the present interpretation. Field observations and t judgment of a Woodward-Clyde Consultants' geologist, w was part of the survey crew, were included in the interpre tation.

2.0 DATA ACQUISITION

The majority of geophone spreads for this survey were 1,100 feet long with 100 feet spacing between geophones. Shorter spacing of 10, 20, 25, 40, and 50 feet were used where terrain limited the length of a particular spread or where greater detail was desired. For traverses of more than one spread, end geophones on adjustment spreads were located at the same point.

For most spreads, shots were placed at half-geophone spacing beyond the end geophones and at the middle of the line. Explosive charges of one pound provided sufficient seismic energy for lines as long as 1100 feet. For about half of the spreads, greater depths to bedrock required shots at greater offsets from the ends to achieve refraction from deeper interfaces. The largest offsets were 1,000 feet from the end geophone, resulting in a shot to furthest geophone distance of 2,100 feet. Usually, an explosive charge of two pounds was required for these longer shots. For short lines explosives were not necessary and a hammer and plate were used as the energy source.

The signature of seismic waves arriving at geophones from each shot was recorded on a geoMetrics/Nimbus model ES-1210F 12-channel stacking seismograph. Recording gains were selected by trial and error and filters were used when background noise levels were high such as during heavy rain or near the river.

The stacking feature of the seismograph employs an analog/digital converter and an internal memory which stores wave traces from each geophone separately. A digital/analog converter is then used to display the stored traces on an oscilloscope. The input from multiple shots can be summed into the memory and the summed or "stacked" traces displayed on the oscilloscope. Stacking of multiple shots tends to enhance coherent seismic signals while the influence of random background noise is reduced by destructive interference. Stacking was used on this survey for shorter lines where multiple hammer blows provided seismic energy instead of explosives. The overall amplitude of the single or stacked wave traces can be amplified or reduced by the seismograph before a hard copy of the record is produced by an electrostatic printer.

For each shot, a field plot was made of distance to each geophone versus the time of arrival of the compressional seismic wave picked from the recorded wave trace. This was done to assure that sufficient information had been obtained for later interpretation. At the same time, notes were made as to terrain and exposed geologic features.

3.0 DATA REDUCTION PROCEDURES

Methods of reducing raw data to values suitable for interpretation were generally those described by Redpath (1973). These general techniques have been augmented to some degree through our experience on past projects.

First, field records were reviewed and picks of arrival times tabulated. Final time-distance plots were constructed to reflect changes in arrival times from those used for field plots. These plots are shown in Appendix A, Figures A1 through A10. Apparent layering, apparent seismic velocities, and variations in arrival times from those expected from a particular layer, were used to direct subsequent data reduction.

Representative "true" velocities were calculated from differences in arrival times at each geophone from shots at opposite ends of the line. Where sufficient data were available, delay times were calculated beneath each geophone for each layer. Layer thicknesses were then calculated using the representative velocity. If sufficient information was not available for rigorous delay-time determination, approximation methods were used to estimate depths.

In many cases, a layer which was well expressed on one spread, or believed to be present from previous investigations, would not be apparent on an adjacent spread. In these cases, a judgment was made as to the continuation of the layer, as a hidden layer or blind zone, beneath the spread in question to produce the most geologically reasonable interpretation. This often required adjustment of other layer thicknesses to account for the total delay time.

4.0 DISCUSSION OF RESULTS

The locations of the seismic lines are shown on Figures 1 through 4. Profiles along each seismic line illustrating subsurface conditions interpreted from the survey are presented as Figures 5 through 14. On these profiles, layer thicknesses and surface topography are shown at a twofold vertical exaggeration. This distortion is required to illustrate the interpreted thickness of thin, shallow layers.

Lines of contact between layers of differing velocities vary on the profiles according to the confidence placed on the interpretation. Solid lines represent a well controlled contact with depths shown probably within 15 percent of the true total depth. Dots on the line represent points of control where the depth is well constrained by the data. Dashed lines are less well controlled. Short dashed lines with no control-point dots represent assumed contacts based on information other than that resulting directly from data reduction.

The following paragraphs discuss the setting of each traverse, the results of our interpretation, and anomalous or ambiguous conditions which became apparent during data reduction and subsequent review of data from borings, test trenches, and surficial geologic mapping.

4.1 Traverse 80-1

This traverse consists of six 1,100 foot geophone spreads and three 225 foot detail spreads. As shown on Figure 1, the line extends northward about 3300 feet from the right abutment downstream from the proposed Watana Dam, and then northeastward an additional 3300 feet across the proposed spillway alignment. Topography is relatively steep at both ends of the line and relatively gentle elsewhere.

The interpreted profile for traverse 80-1 is shown o Figure 5. Bedrock velocities along the line appear t be relatively uniform, ranging from 14,500 fps (feet pe second) to 16,000 fps. Intermediate layer velocities rang from 5,250 fps to 13,000 fps and shallow layer velocitie from 1,300 fps to 3,600 fps. The lower velocities repre sent loose surficial materials and possibly, in part fine-grained lake deposits such as encountered in borin DR-6 (the location of borings designated DR are shown i U. S. Army Corps of Engineers [1979]).

At the southern end of the line, a 50-foot-thick layer o 10,000 fps material probably represents weathered bedrock Near the northern end of spread 80-1E, this layer thicken to over 100 feet and may represent an anomaly similar t that shown on Shannon and Wilson (1978), line 2 (SW2) t the southeast. We understand that a prominent gouge zon is exposed on the steep slopes near the anomaly shown o SW2. The anomaly on line 80-1E may represent a continu ation of that zone in which case, its trend would b approximately N40W.

A thick 13,000 fps layer is present near the center of th traverse. It probably represents weathered diorite bedroc but may be a different lithology such as volcanic roc which has been mapped in the vicinity. Another possibilit is that the 13,000 fps material is part of a vertica tabular fractured or altered zone which extends from th intersection of traverses 80-2 and SW2 where material o the same velocity has been detected. Although the 13,00 fps zone is shown to be underlain by higher velocity mater ial on Figure 5, the higher velocity material may instea be to the side. Additional refraction lines or boring will be required to resolve this possibility.

The thin irregular edges of the relict channel discussed in previous reports are apparent on spreads 80-1A and 80-1B. Channel fill beneath these lines, which is probably bouldery glacial detritus, ranges from 7000 to 9000 fps. The configuration of the channel beneath line 80-1B is probably much more complicated than shown on Figure 5. The profile shows depths which are based on approximation reduction methods because of the complexity of the time-distance plot (Figure A-1, Appendix A) for which no reasonable mathematical solution could be found. Depth to bedrock is shown to be more than 150 feet but is probably highly irregular and much shallower especially near the center of the line. Boring DR-6 just southeast of the center of the line encountered bedrock at a depth of 65 feet.

The channel appears to be the same as that documented by the 1975 Dames and Moore survey and on line SW3. It is also well expressed on lines 80-2 and 80-6 which are discussed in later paragraphs. The southwestern edge of the channel and the apparent thalweg are shown by dashed lines on Figure 1. The eastern edge of the channel appears to be immediately north of line 80-7 and appears to be expressed at the northern end of 80-8.

4.2 Traverse 80-2

Traverse 80-2 consists of five 1100 foot spreads on the right abutment extending from near the toe of the proposed Watana Dam, northward across the proposed spillway. It roughly parallels Traverse 80-1 between 1,800 and 2,200 feet to the east and southeast (Figure 1). The topography is relatively steep at the southern end and moderate to gentle elsewhere. The interpreted profile for traverse 80-2 is shown on Figure 6.

Bedrock velocities are similar to those of 80-1 rangi from 14,000 to 17,000 fps. Intermediate layers consist thick 13,000 fps layers beneath the southern slopes a channel fill at the northern end of the line ranging fr 6,000 to 8,000 fps. Near surface velocity layers ran from 1250 to 2800 fps.

The lowest bedrock velocity encountered on the traverse beneath spread 80-2D and underlies an anomalously de portion of the relict channel. Borings DR-18 and DR-1 northwest and southeast of the spread respectively, confi the depth to bedrock shown on the profile and indicate th the rock in that area is highly fractured diorite wi apparent clay gouge zones. This low velocity zone m represent a continuation of a shear zone known as "T Fins" exposed adjacent to the river to the southeast. T trend of this possible continuation projects toward t northeastern end of spread 80-1B which, as previous discussed, produced a highly irregular seismic recor

The 13,000 fps layer at the southern end of the traver appears to be weathered bedrock based on the shape a location of the layer. Line SW2 which crosses the traver near its southern end (see Figure 1), also shows the 13,0 fps layer and the same depth to bedrock at the inte section. A 6,000 fps layer shown on SW2 was not detect on 80-2. The 13,000 fps layer is shown on SW2 as conti uous for about 2400 feet parallel to the river. The sha of the material shown on the profile of 80-2 (Figure 6) not inconsistent with the suggestion by Shannon and Wils (1978) that it may be involved in landsliding.

The channel fill at the northeastern end of the line consists of two distinct velocity zones similar to those detected on traverse 80-1. The southern portion of the fill ranges from 6,500 to 8,000 fps. Boring DR-20 appears to have encountered this material southeast of the line where it consists of saturated sandy gravels with finer grained interlayers. Boring DR-18, northwest of the line, appears to have penetrated lower velocity material detected at the northeasternmost end of the traverse. This material, ranging from 5,400 to 6,000 fps, appears to be mostly silty sands and sandy silts with some clay and scattered gravels and boulders.

Surficial materials near borings DR-18 and DR-20 appear to be sandy silts. Seismic velocities of the surface layer near the borings are generally less than 2,000 fps. Velocities to the south along the traverse range are up to 2,800 fps and interpreted as representing more gravelly or better compacted sediments than those near the borings.

4.3 Traverse 80-3

Traverse 80-3 was run on the rugged steep slopes of the abutments across the proposed upstream portion of the dam. The profile, shown as Figure 7, is based on one 1,000 foot spread on the left abutment and three spreads, 1,000 feet, 265 feet, and 300 feet respectively, on the right abutment. A proposed segment of the traverse across the river was not considered feasible at the time of the survey due to high water levels, and was therefore not performed.

Bedrock is shallow on both abutments. On the south side, bedrock appears to be of a uniform 15,000 fps velocity. The top of the southern slope is underlain by 5,200 fps material which may reflect frozen soil exposed in a shallow trench in that area. Farther down the slope, surficial velocities drop to about 2,200 fps. This appears to b very loose talus on the slope, at least at the center sho point. The base of the slope is underlain by 7,000 fp material which appears to be highly weathered bedrock

Representative bedrock velocities on the north side rang from about 15,000 fps near the top to as high as 22,000 fp lower on the slope. Surficial material on the north sid is generally about 15-foot-thick and between 1,500 ar 2,200 fps on the upper slope. Surficial material i thinner and lower in velocity near the bottom. Most of th upper slope is covered with loose talus.

Geophone spread 80-3D was run parallel to the river alon the north bank. This line detected a 7,000 fps laye 50-foot-thick which probably projects beneath the river This layer was not apparent on spread 80-3C near the bas of the north slope. It appears as if 80-3C was run above resistant bedrock spur and that the 7,000 fps material i present to each side of the spur near the base of th slope.

Lines 80-4 and 80-5 which were planned across the river a the proposed dam axis and beneath the upstream toe, re spectively, were not run due to high water conditions. I may be possible to complete these lines after the river ha frozen.

4.4 <u>Traverse 80-6</u>

This traverse consisted of one 1,100 foot spread and coincident shorter 600 foot detail spread across an appar ently anomalous topographic depression approximately 4,0 feet upstream from the proposed dam axis on the north sid of the river. The profile presented as Figure 8, shows th edge of the relict channel discussed in conjunction wit Traverses 80-1 and 80-2.

Bedrock velocity ranges from 11,500 fps near the western end of the line to 20,000 fps beneath the channel. The channel appears to be filled with 7,000 fps material which also is thinly distributed beneath the western portion of the line. Overlying this is a layer of 2,300 fps material and, in part, a thin surface layer of 1,100 fps material.

The increase in bedrock velocity across the traverse from west to east may be related to effects of "The Fins" shear zone which is exposed about 700 feet southwest of the end of spread 80-6A. This increase in bedrock velocity east of the shear zone is also expressed on the 1975 seismic line and on SW-3 which are both to the northwest of 80-06. Progressively higher velocity zones on those three traverses are roughly correlatible and appear to form bands generally parallel to the shear zone.

The nearest borings to traverse 80-6 are more than 1,000 feet away. The channel fill material is therefore interpreted to be similar to that interpreted for line SW-3 and for traverses 80-1 and 80-2 as previously discussed. The 7,000 fps velocity of the fill is more uniform than seen elsewhere and probably represents an averaging of both higher and lower velocity materials such as saturated alluvium and glacial detritus.

The Shannon and Wilson, 1978, interpretation of nearby line SW-3 shows a shallower channel containing 4,500 fps material within the larger relict channel feature. This layer can also be interpreted to underlie 80-6 based on the time-distance plot (see Appendix A, Figure A-5). However, the present interpretation of a slight thickening of the 2,300 fps layer is also reasonably consistent with the data.

Surficial materials are probably similar to those at dep but less saturated. The 2,300 fps layer may also be fin grained. The low velocity of the 1,100 fps layer sugges it is very loose and probably dry.

4.5 Traverse 80-7

Traverse 80-7 consists of two 1,100 foot spreads orient north-south across the western end of Borrow Area D. Th line is shown on both Figures 1 and 2. Ground surfa rises gently to the north along the line.

Velocity analysis indicated that bedrock was uniform 15,500 fps even though the time-distance plots show higher values. The differences are attributed to geomet of the bedrock surface and not to lateral changes. Th interpreted profile for traverse 80-7 is shown on Figu 9.

The line appears to be located over the northeastern si of the relict channel. Channel fill material ranges fr 7,400 to 9,000 fps. It is generally about 200-feet-de but is shallower near the north end. At the south end, i may deepen to as much as 400 feet. Line SW3, which cross spread 80-7A near its northern end, shows a similar dept and velocity for bedrock at that point. The velocity o the channel fill is given as 7,000 fps on SW3.

Boring DR-26, which is located west of the north end o line 80-7B, encountered silty sand, clayey silt, gravels and sandy silt with boulders at depths equivalent to th channel fill material interpreted from seismic data

The velocity of surface materials along the line appears t be uniformly 1,850 fps. Several exposures along the lin indicate that the upper portion of this unit consists o boulder accumulations with little or no matrix. Borings and trenches in the vicinity have encountered gravelly sands below the immediate surface.

4.6 Traverse 80-8

The two 1,000 foot lines that comprise Traverse 80-8 extend southward from the end of line SW5 at the edge of Borrow Area D near Deadman Creek across proposed Quarry Source B as shown on Figure 2. The line crosses moderate and then very steep topography southward.

Four continuous layers are interpreted on the profile presented as Figure 10. These include a shallow 1,350 to 1,600 fps layer and intermediate velocity layers of 5,000 to 7,000 fps and 8,400 to 9,000 fps. Bedrock appears to change laterally from 12,500 fps near the north end to 23,500 fps at the center, and to 16,500 fps near the south end.

The highest bedrock velocity is at the middle of the traverse where the rock apparently forms a buried resistant ridge. The bedrock surface may be as deep as 500 feet at a point below the middle of spread 80-8A. At the north end of the line bedrock does not appear to be as deep as shown in Shannon and Wilson, 1978, line SW5. However, this location is near the end of both lines and additional control is lacking.

It does not appear likely that hard rock is near enough to the surface to provide an adequate quarry source along the line of the profile. We have no information as to possible outcrops elsewhere within the designated area. The intermediate velocity layers appear to be similar to those filling the relict channel to the west as previously discussed. The 5,000 to 7,000 fps layer probably represents a younger episode of channeling and filling similar to th shown on traverses 80-1 and 80-2. Both intermediate uni probably consist of saturated alluvial deposits and bou dery glacial detritus.

A number of test pits in the vicinity of the traver indicate that the shallow materials 1,350 to 1,600 f surface layers are highly variable. Most pits encounter loose, unsaturated silty gravely sands.

4.7 Traverse 80-9

Traverse 80-9 was a single 1,100-foot-line at the weste end of Borrow Area E extending upslope from previous li SW14. The present interpretation, shown on Figure 11, in good agreement with that line.

A relatively uniform mantle of low velocity material (1,1 to 1,800 fps) appears to cover the slope 30 to 50 fe deep. Shallow exposures suggest that the 1,100 fps m terial at the base of the hill is a loose gravel. High on the hill, the surface is mantled by organic soi

A higher velocity layer (6,000 to 7,250 fps) underlies t surficial deposits and thickens northward. These vel ocities are similar to those of saturated alluvium a glacial detritus found elsewhere. Bedrock with an approx mate velocity of 15,000 fps, is about 100 feet below t surface at the base of the hill and may be as deep as 3 feet at the north end of the line.

4.8 Traverse 80-11

This traverse was run north and west of Tsusena Creek ne the eastern end of Borrow Area E. The alignment w changed from east of the creek when surface reconnaissan showed that area to be underlain primarily with boulde glacial deposits.

Spread 80-11A was run from the bank of Tsusena Creek northward 1,100 feet across gentle topography to the base of a hill (Figure 3). A second 1,100 foot spread, 80-11B, was run from the center of the first in a northeasterly direction. This line hd not been previously staked or brushed and when surveyed later, was found to bend to the north as shown on Figure 3. Two shorter detail spreads (80-11C and 80-11D) were also run near the middle of spread 80-11A.

On the southern end of the traverse 80-11A, a 2,800 fps layer of loose surficial deposits appears to be about 30 feet thick and thins to the north. This appears to be underlain by a 11,000 fps weathered bedrock layer about 100 feet thick which also thins to the north. Bedrock velocity beneath the area is between 16,000 and 17,000 fps.

In the northern part of the area the 11,000 fps layer wedges out beneath an apparent relict channel filled with 5,000 fps material which may be loose saturated sands and gravels. A 7,000 fps intermediate zone at the north end of spread 80-11A is not apparent on 80-11B. Instead, the northern part of 80-11B shows shallow bedrock beneath about 20 feet of 1,400 fps surficial deposits. The 7,000 fps material may be similar to the relict channel fill detected on lines previously discussed.

4.9 Traverses 80-12, 80-13, and 80-15

These three traverses were run across a small lake and on the adjacent slopes above the left abutment of the proposed Devil Canyon Dam as shown on Figure 4. Traverse 80-12 consisted of a 250 foot hydrophone spread across the western part of the lake and two 500 foot geophone spreads up steep adjacent slopes to the north and south. Traver 80-13 consisted of a similar combination across the easte part of the lake. Traverse 15 was a single hydropho line, 500 foot long, extending northwest to southea across the lake.

The profiles shown on Figures 13 and 14 indicate simil bedrock velocities of between 16,800 and 18,800 fp Profile 80-12 shows a distinct intermediate layer benea the slopes of between 7,000 and 10,000 fps. This may highly weathered bedrock or glacial deposits. A 5,000 f intermediate layer beneath the relatively flat north end 80-13, probably indicates water table in otherwise l velocity sediments. Surficial deposits on the slopes a generally between 1,400 and 2,200 fps. The 4,000 f indicated beneath the north-facing slope on line 80- probably represents partically frozen ground.

A layer of approximately 5,000 fps underlies the lake all three profiles. This is probably saturated so sediments which may be as deep as 50 feet near the cent of the lake as shown on profile 80-15. Time-distance plo from all three spreads run across the lake are very i regular and subject to alternative interpretations. Da from spread 80-15 appear to indicate that high-veloci bedrock directly underlies the saturated sediments benea most of the lake. The other two profiles, however, ind cate that only weathered rock is present beneath part the area.

The possibility of a shear zone trending approximate east-west beneath the lake was suggested by Shannon a Wilson (1978) based on results of line SW-17, which pa allels 80-12, 400 feet to the west. On that line, bedro velocities underlying 7,000 fps channel fill near the center of the line were interpreted to be lower than beneath the slopes to either side. Three of 5 borings drilled along that line encountered highly fractured or sheared phylltic bedrock.

The results of the present survey can neither confirm nor deny the presence of a shear zone. Although the time-distance plots appear to be anomalously irregular, reasonable mathematical interpretations were obtained from the data. Lower velocities were obtained for bedrock beneath the lake than on the adjacent slopes (as on SW-17) but the reason for these lower velocities is not clear from the data. They may indicate sheared material or, alternatively, dense fill material or weathered, surficially fractured bedrock.

5.0 GENERAL OBSERVATIONS AND CONCLUSIONS

Materials represented by velocity layers interpreted for this report have been assigned, at least in general terms, where boring and test pit data have been available. In areas where this control has not been available, similarities in layering and velocities with better controlled areas have allowed assignment of material types with a reasonable degree of confidence.

In general, bedrock velocities near the Watana site vary between 14,000 and 23,000 fps. Velocities of 18,000 to 23,000 fps are representative of hard, unfractured diorite as exposed in the immediate site vicinity. Lower velocities indicate increasing degrees of fracturing and weathering if the rock is indeed diorite. These lower velocities may also represent other lithologies such as metamorphic zones or volcanics such as have been mapped on the right abutment downstream from the dam.

Velocities as low as 10,000 fps in intermediate layers overlying higher velocity bedrock may represent highly weathered diorite. Apparent layers of 13,000 fps material found near the middle of traverse 80-1 and at the south end of 80-2 have been interpreted as weathered bedrock but may represent a different lithology.

Lateral changes in bedrock velocity have been noted on several lines for this and previous surveys near the Watana site. These changes appear to form bands of increasing velocity eastward from "The Fins" shear zone as presently interpreted, and may also form northwest trending bands farther to the west. Present data, however, is insufficient to verify this pattern.

Portions of the relict channel at the Watana site have bee defined by the present interpretation. The channel i apparent on traverses 80-1, 80-2, 80-6, 80-7, and 80-8 Channel fill material ranges from 5,000 to 9,000 fps ar has been shown by borings to be highly variable but pre dominantly alluvial sands and gravels, bouldery glacia silts and sands, and to a lesser extent lacustrine silt and clays. Two episodes of channeling are apparent o traverses 80-1, 80-2, and 80-8. Materials on traverse 80-9, and 80-10 with similar velocities appear to b lithologically similar to those in the relict channel

At the Devil Canyon site, the highest bedrock velocit detected was nearly 18,000 fps. This is the velocit reported for fresh phyllite in the area by Shannon an Wilson (1978). Lower velocity bedrock interpreted from th present survey may reflect weathering or lateral lithologi changes.

Intermediate layer velocities at the Devil Canyon sit range from 5,000 to 10,000 fps. Velocities as low as 7,00 fps could represent weathered bedrock in the metamorphi terrain. The 5,000 fps layers interpreted from this surve appear to be equivalent to the 7,000 fps layer on SW-17 t the west of the lake. Borings in that area showed th material to be predominantly sand with some gravel an boulders.

Surficial deposits are highly variable in the area of th survey and are therefore difficult to discuss in genera terms. Surficial materials are best investigated wit short lines and small geophone spacing. Since most of th lines for this survey used wide geophone spacing, th information obtained about surficial layers is highl generalized. Most of the surficial velocities reported herein are probably averages of several smaller distinct layers and are more related to the distance from shot point to the first geophone than to the velocity of any particular material.

With regard to structure, two possible shear zones have been interpreted from this survey. These are northwest trending zones extending from the right abutment at the Watana site and are discussed with respect to traverses 80-1, and 80-2 in earlier sections. Information regarding a possible shear zone beneath the saddle dam site at Devil Canyon was indeterminate.

The data from the present survey were sufficient to make fairly definite interpretations. However, specific depths and material types should be confirmed by borings in critical areas. We suggest that when sufficient boring control becomes available, that all three refraction surveys be re-evaluated to more accurately portray conditions between borings.

The interpretation resulting from the present survey are considered the most reasonable based on available information. They are not the only interpretations possible. The limitations of the seismic method and the present data are discussed further in Appendix A and the references.

REFERENCES

Dames and Moore, 1975, Subsurface exploration, proposed Watana Dam site on the Susitna River, Alaska: Report for Department of the Army, Alaska District, Corps of Engineers, Contract DACW85-C-0004.

Redpath, B. B., 1973, Seismic refraction exploration for engineering site investigations: U. S. Army Engineer Waterways Experiment Station, Explosive Excavation Research Laboratory, Livermore, California, Technical Report E-73-4, 55 p.

Shannon and Wilson, Inc., 1978, Seismic refraction survey, Susitna Hydroelectric Project, Watana Dam site: Report for Department of the Army, Alaska District, Corps of Engineers, Contract DACW85-78-C-0027.

U. S. Army Corps of Engineers - Alaska District, 1979, Southcentral Railbelt Area, Alaska Upper Susitna River Basin - Supplemental Feasibility Report: Appendix Part I.

NOTES:
1. TOPOGRAPHIC CONTOURS ARE BASED ON AERIAL PHOTOGRAPHY DATED 10 JUNE 1978 VERTICAL DATUM IS MEAN SEA LEVEL (MSL)

-N-

SEISMIC REFRACTION LINES

1A

Current Survey

Previous Reports

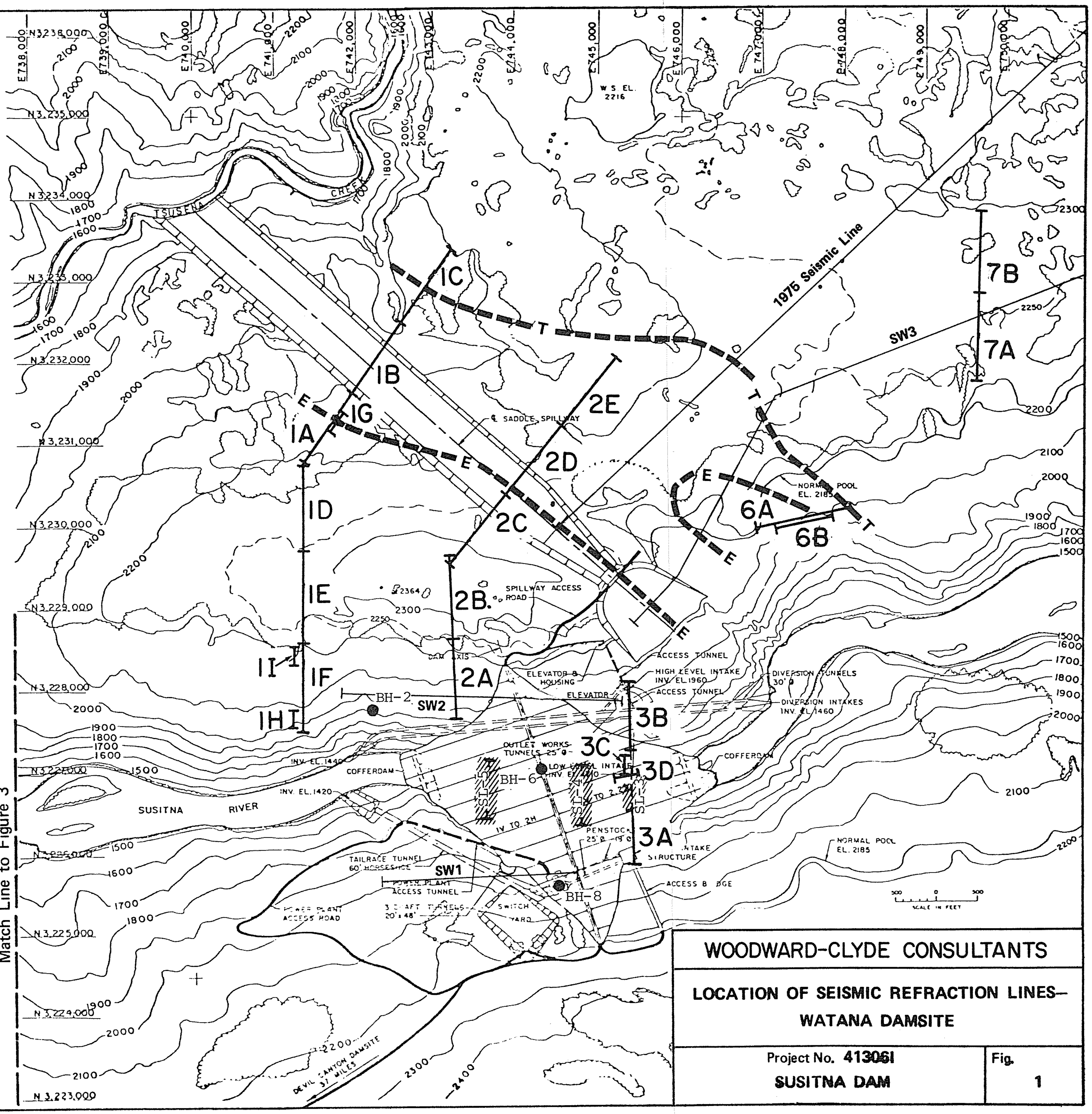
Proposed for current survey but altered or deleted

Note: 1975 Seismic Line is from Dames and Moore, 1975; all other previous lines are from Shannon and Wilson, 1978. Line designations (1A) are abbreviated from those in the text (8- (80–1A).

RELICT CHANNEL

E — E — Edge

— T — Thalweg



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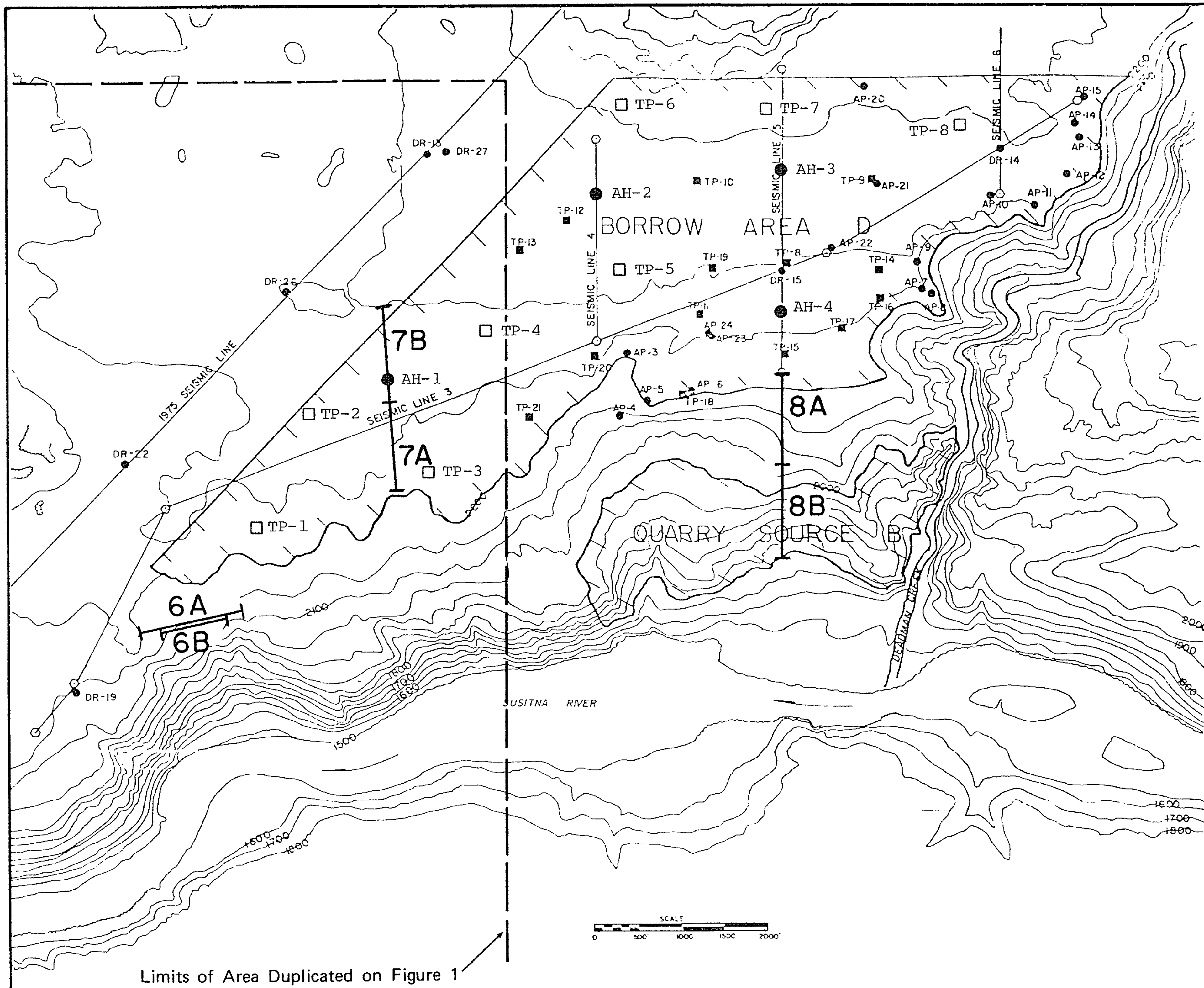
LOCATION OF SEISMIC REFRACTION LINES– WATANA DAMSITE

Project No. 41306I

SUSITNA DAM

Fig. 1



SEISMIC REFRACTION LINES

7A — Current Survey

— Previous Reports

Note: 1975 Seismic Line is from Dames and Moore, 1975; all others are from Shannon and Wilson, 1978. Line designations (1A) are abbreviated from those in the text (80–1A).

N

LEGEND

- TP TEST PITS
- DR DRILL HOLE
- AP AUGER HOLE
- SW SEISMIC LINE

NOTES

1. SEISMIC LINE PROFILES MAY BE FOUND IN EXHIBIT D-1.
2. AUGER HOLES 16-19 LIE NORTH OF BORROW AREA D, ZERO TO ½ MILE NORTH OF AND BETWEEN AP-15 AND AP-20. SEE PLATE D-2
3. AP-1 AND AP-2 ARE NEAR DR-20 IN SPILLWAY AREA. SEE PLATE D-2.
4. FOR LOCATION OF TP 6-7 AND TP 22-26, SEE PLATE D-2.

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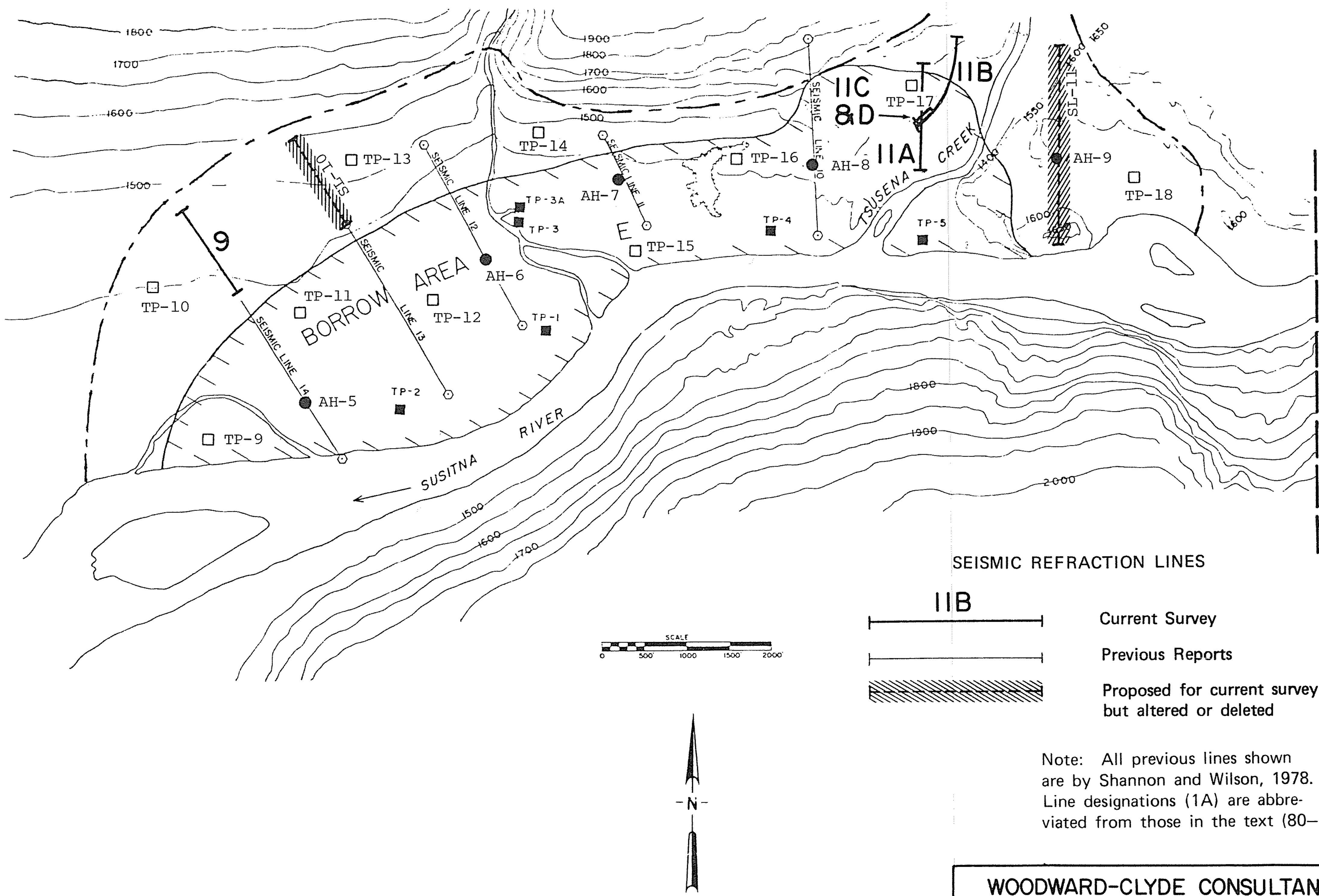
LOCATION OF SEISMIC REFRACTION LINES– WATANA BORROW AREAS B AND D

Project No. 413061 SUSITNA DAM	Fig. 2



SEISMIC REFRACTION LINES

11B

Current Survey

Previous Reports

Proposed for current survey but altered or deleted

Note: All previous lines shown are by Shannon and Wilson, 1978. Line designations (1A) are abbreviated from those in the text (80–1A).

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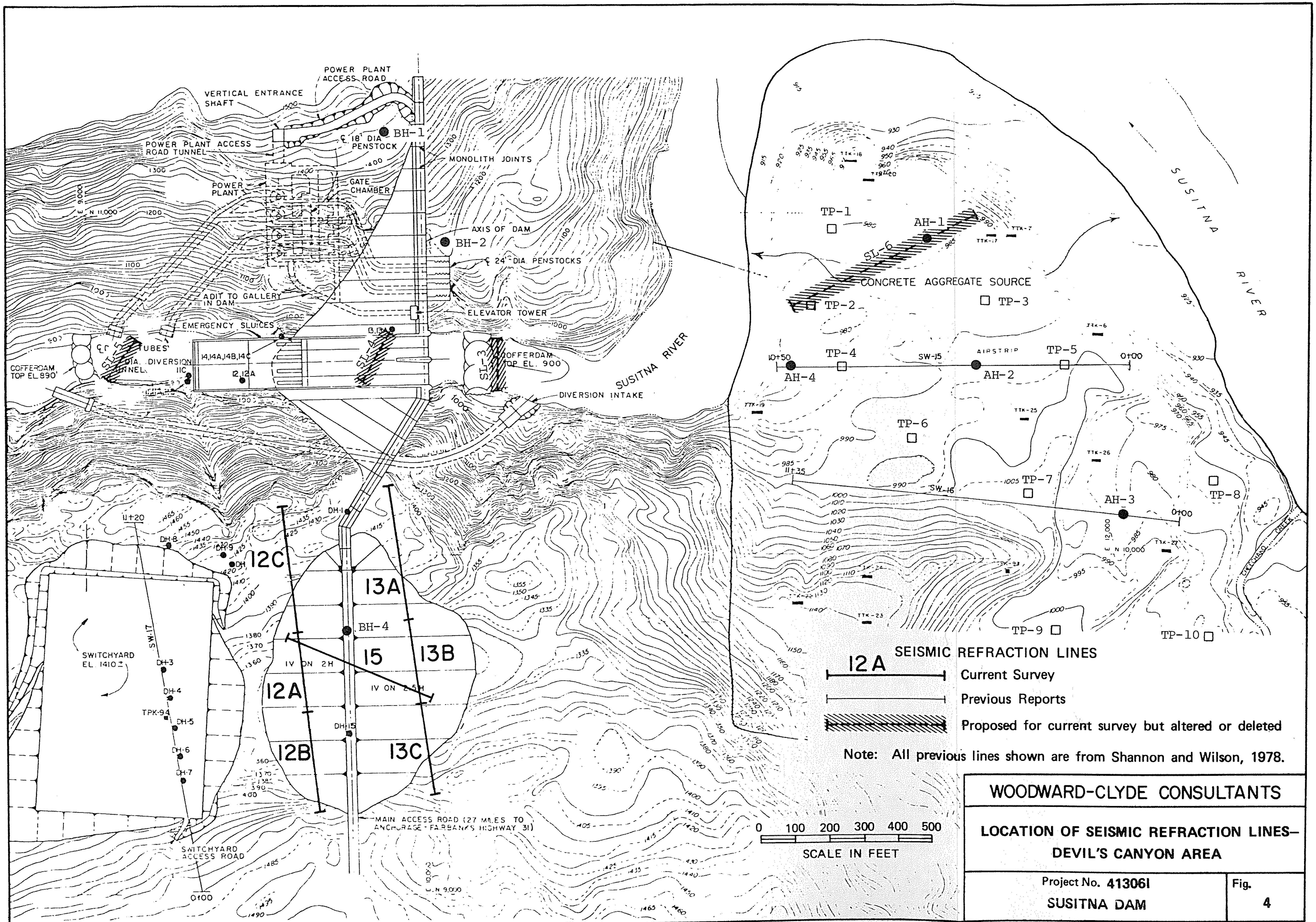
LOCATION OF SEISMIC REFRACTION LINES– WATANA BORROW AREA E	
Project No. 41306I SUSITNA DAM	Fig. 3



12A SEISMIC REFRACTION LINES

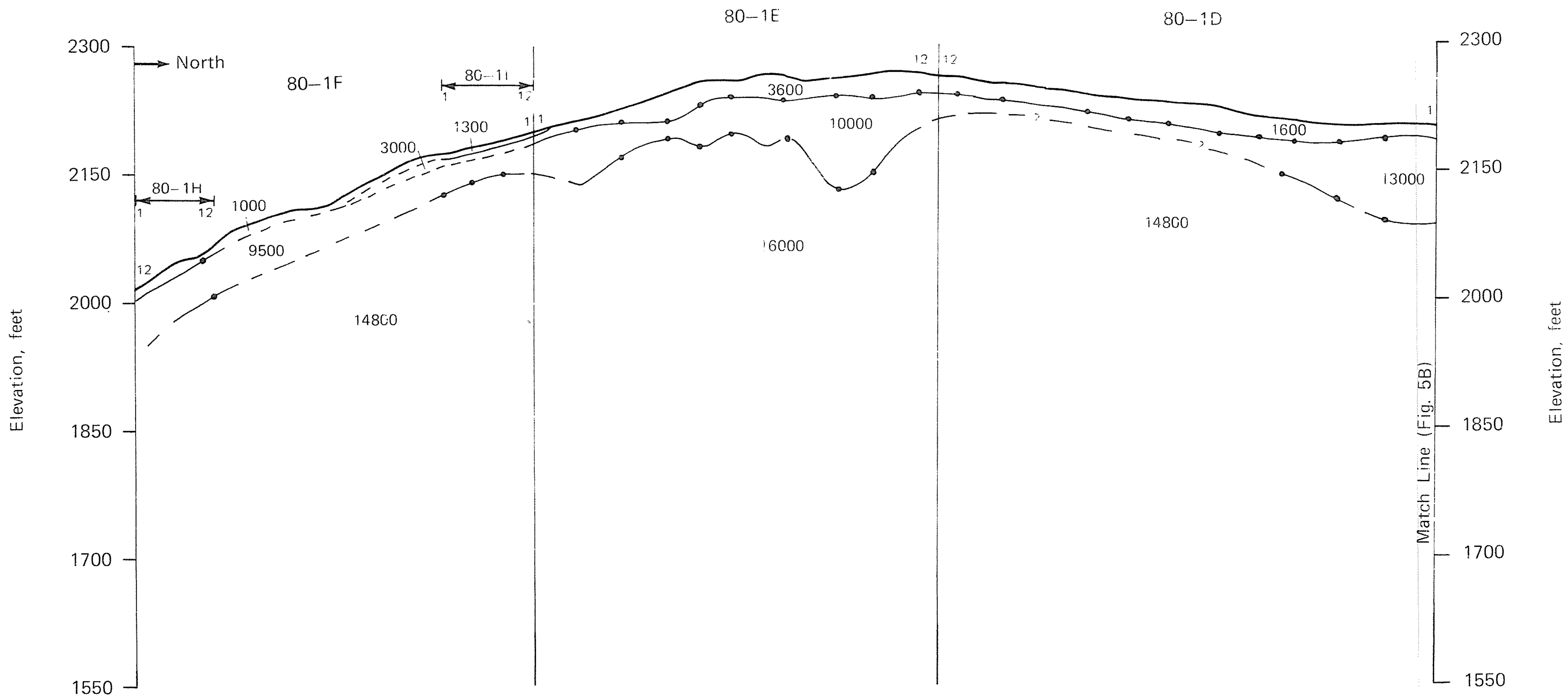
- Current Survey
- Previous Reports
- Proposed for current survey but altered or deleted

Note: All previous lines shown are from Shannon and Wilson, 1978.

WOODWARD-CLYDE CONSULTANTS

LOCATION OF SEISMIC REFRACTION LINES– DEVIL'S CANYON AREA

Project No. 41306I SUSITNA DAM	Fig. 4



Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 300 feet
Vertical Scale: 1 inch = 150 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

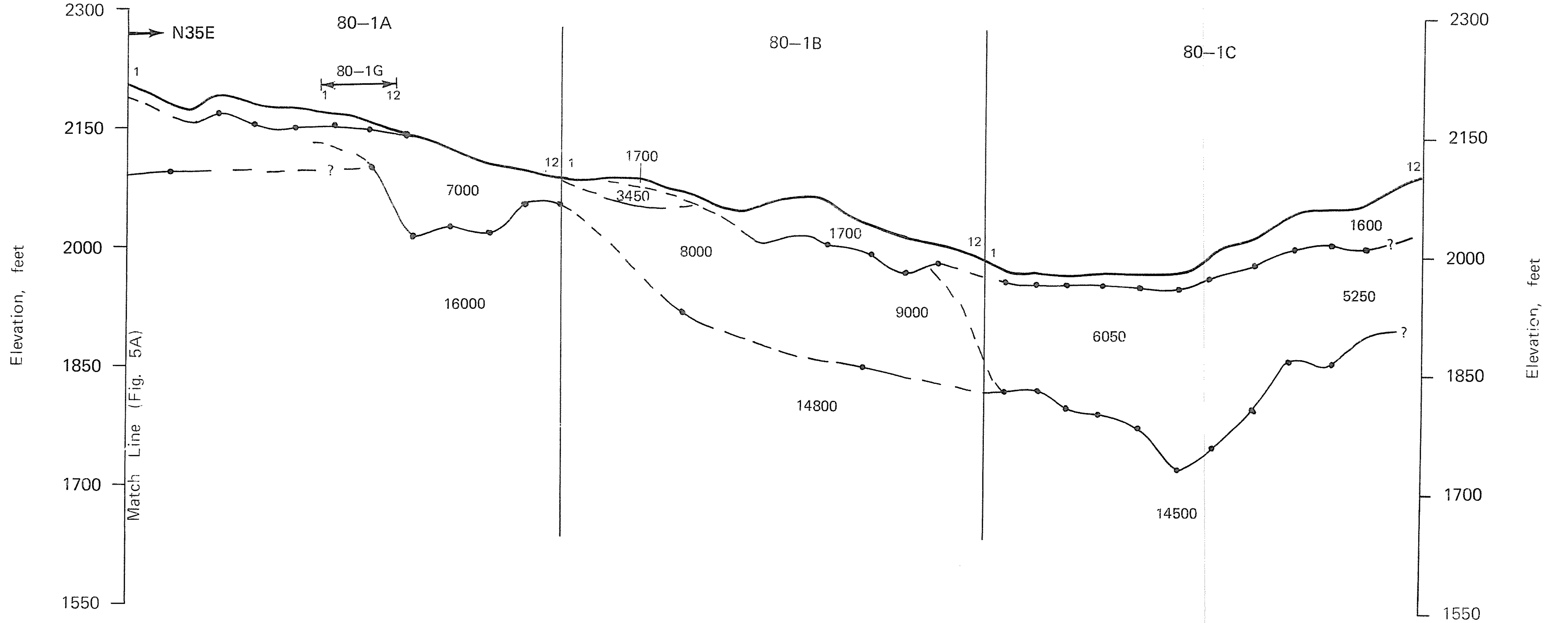
WOODWARD-CLYDE CONSULTANTS

SEISMIC REFRACTION PROFILE 80-1 (Sheet 1 of 2)

Project No. 41306I

SUSITNA DAM

Fig. 5A



Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 300 feet
Vertical Scale: 1 inch = 150 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3-19/81

WOODWARD-CLYDE CONSULTANTS

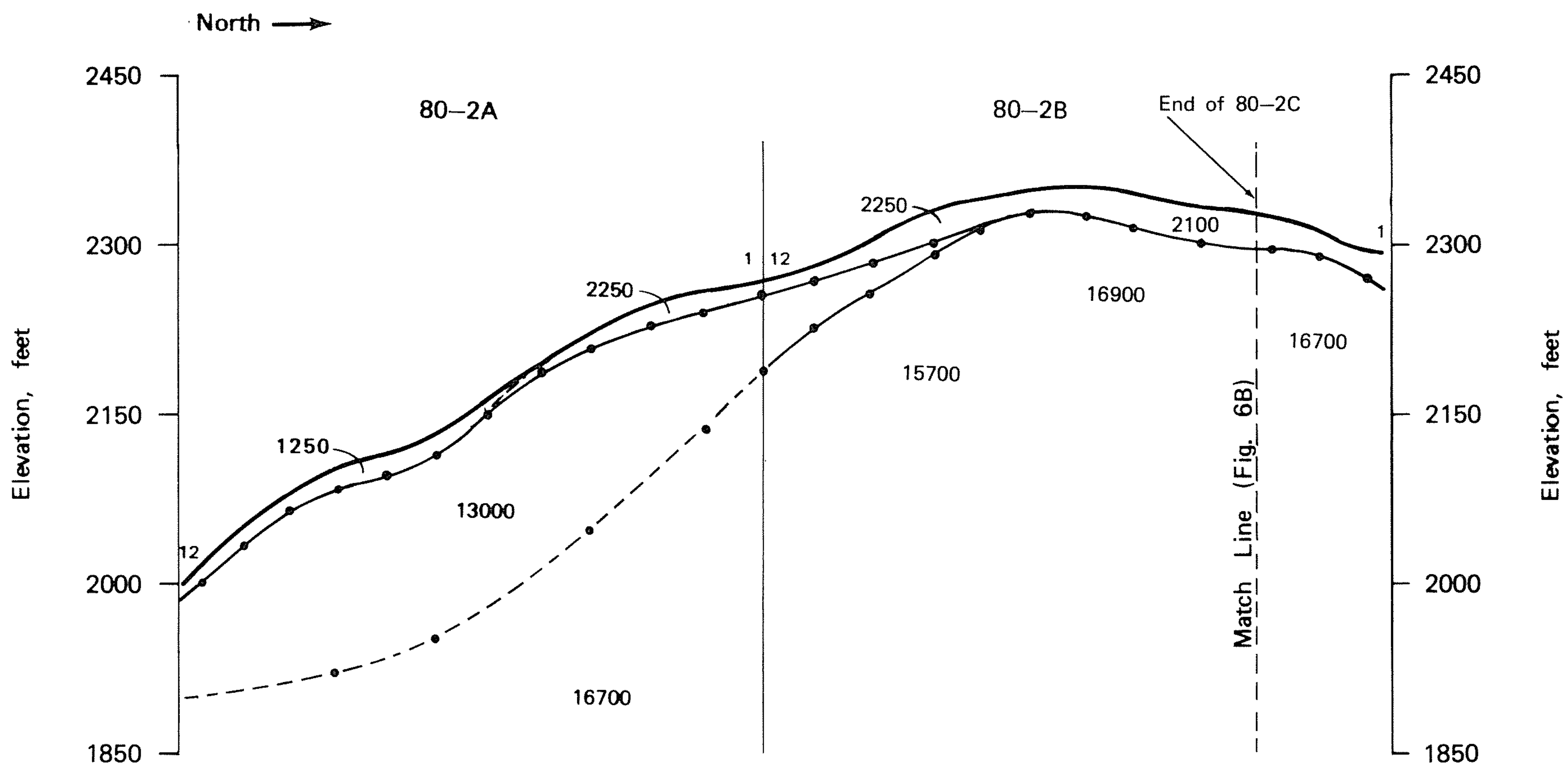
SEISMIC REFRACTION PROFILE 80–1

(Sheet 2 of 2)

Project No. 41306I

SUSITNA DAM

Fig. 5B

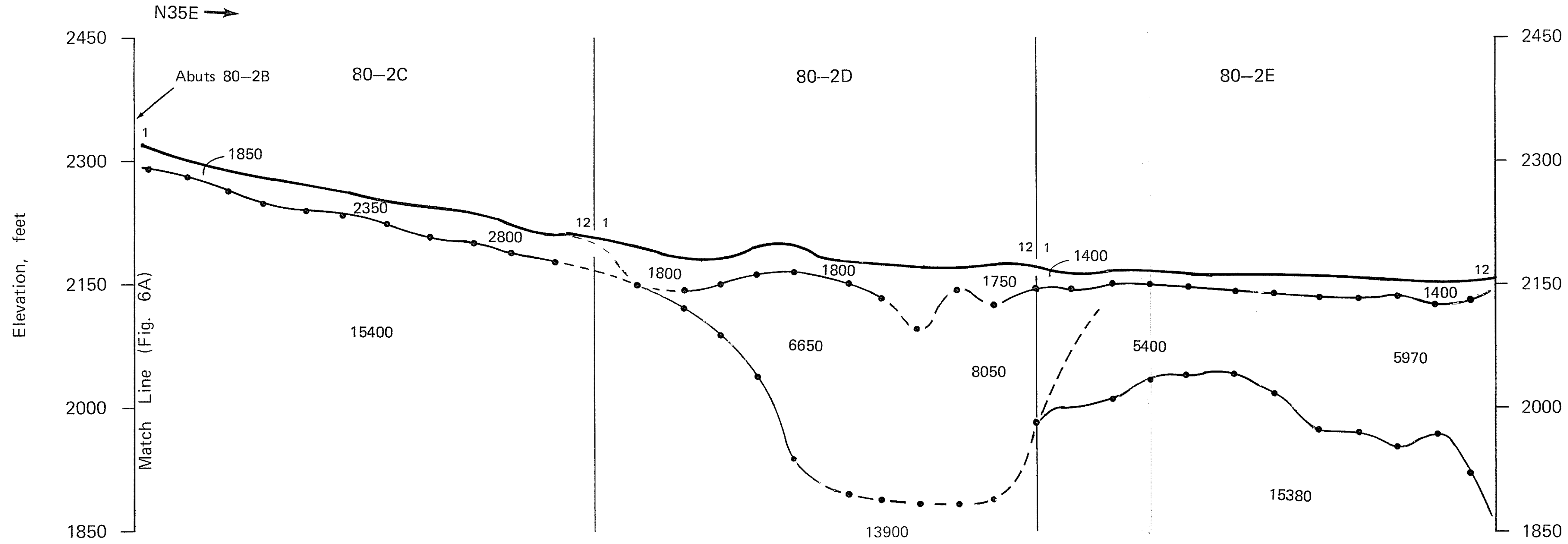


Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 300 feet
Vertical Scale: 1 inch = 150 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

WOODWARD-CLYDE CONSULTANTS	
SEISMIC REFRACTION PROFILE 80–2 (Sheet 1 of 2)	
Project No. **41306I** **SUSITNA DAM**	Fig. **6A**



Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 300 feet
Vertical Scale: 1 inch = 150 feet

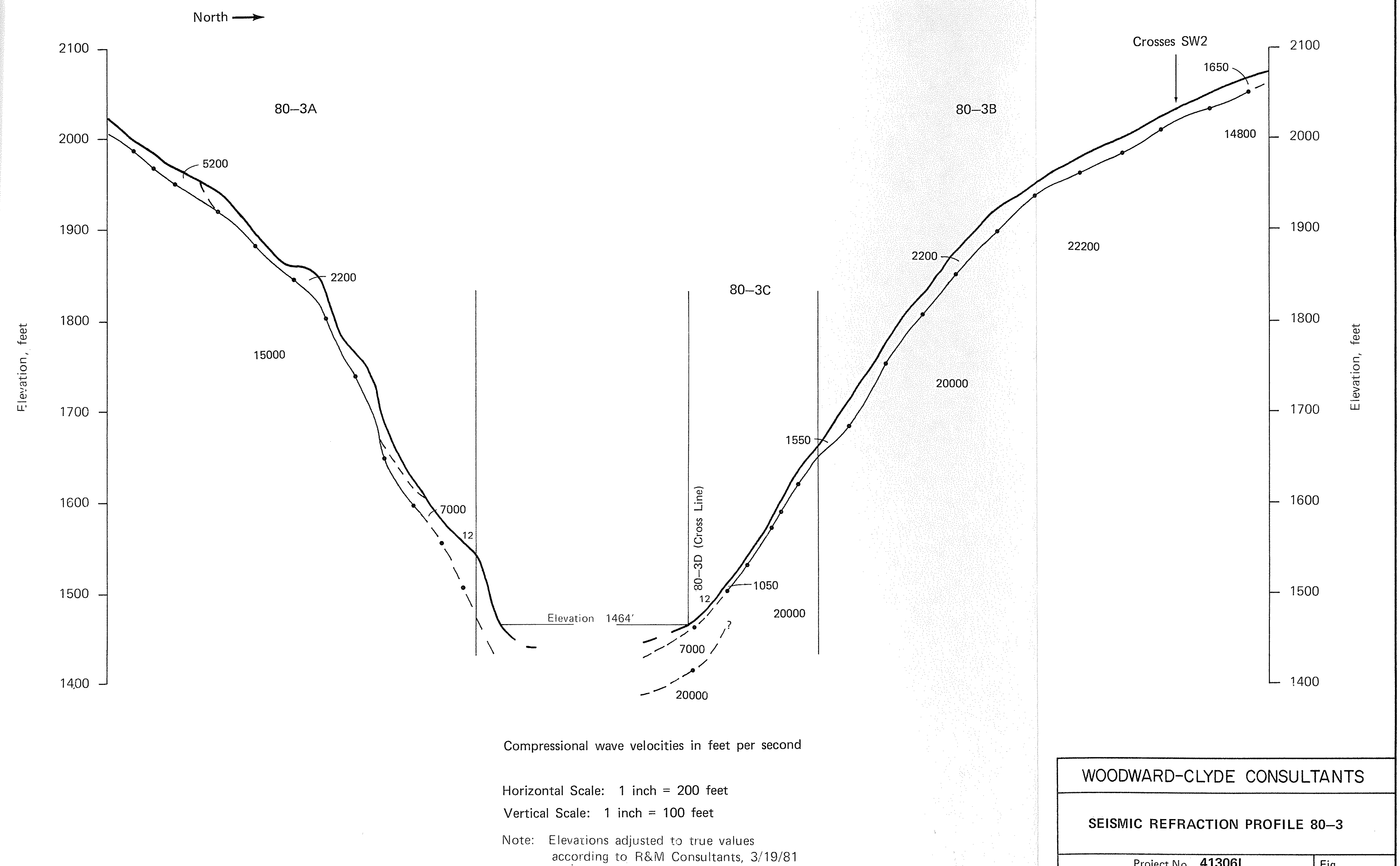
Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

WOODWARD-CLYDE CONSULTANTS

SEISMIC REFRACTION PROFILE 80–2
(Sheet 2 of 2)

Project No. 41306;
SUSITNA DAM

Fig. 6B



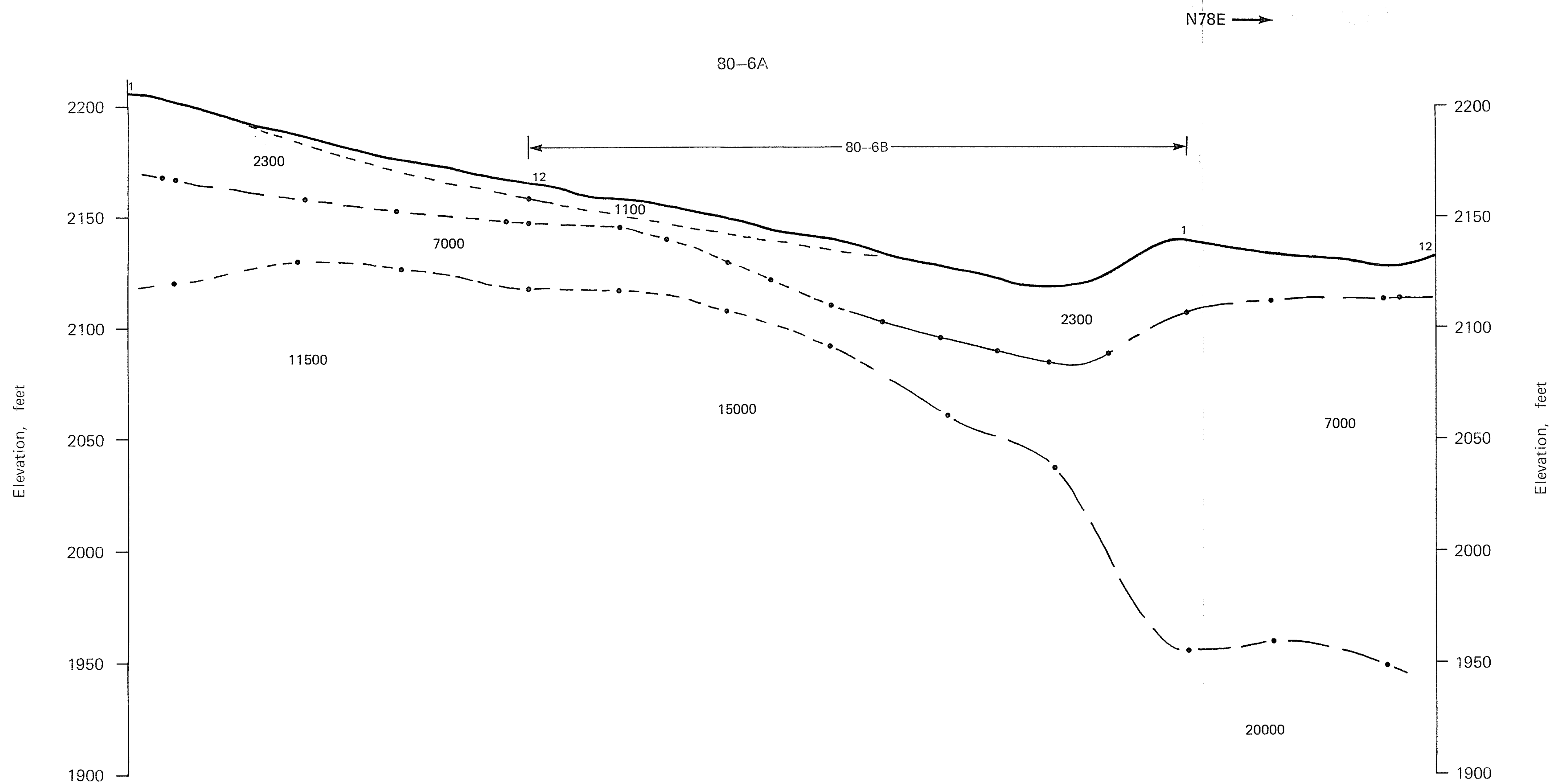
WOODWARD-CLYDE CONSULTANTS

SEISMIC REFRACTION PROFILE 80–3

Project No. 41306I

SUSITNA DAM

Fig. 7



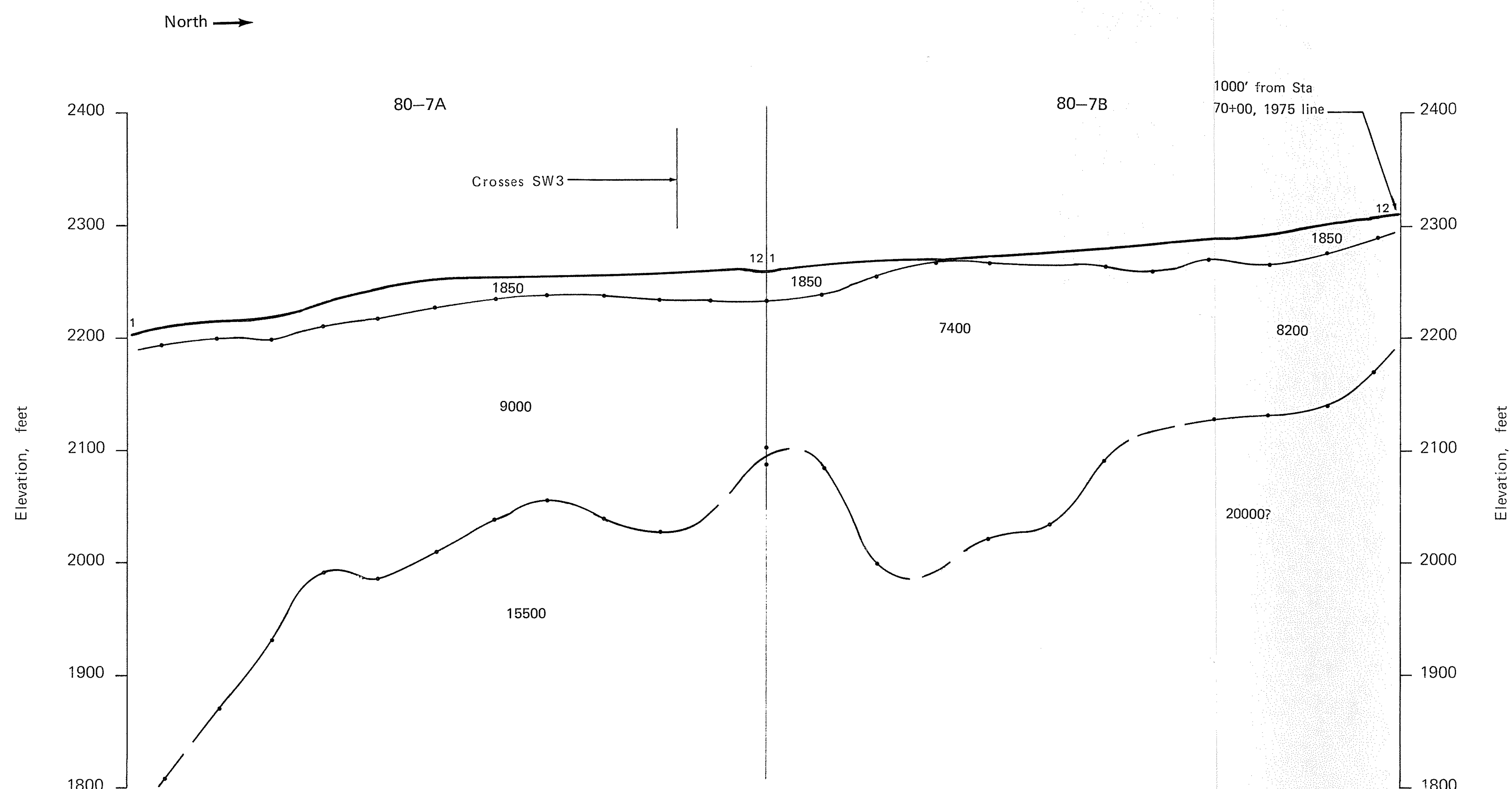
Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 100 feet

Vertical Scale: 1 inch = 50 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

WOODWARD–CLYDE CONSULTANTS	
SEISMIC REFRACTION PROFILE 80–6	
Project No. 41306I SUSITNA DAM	Fig. 8

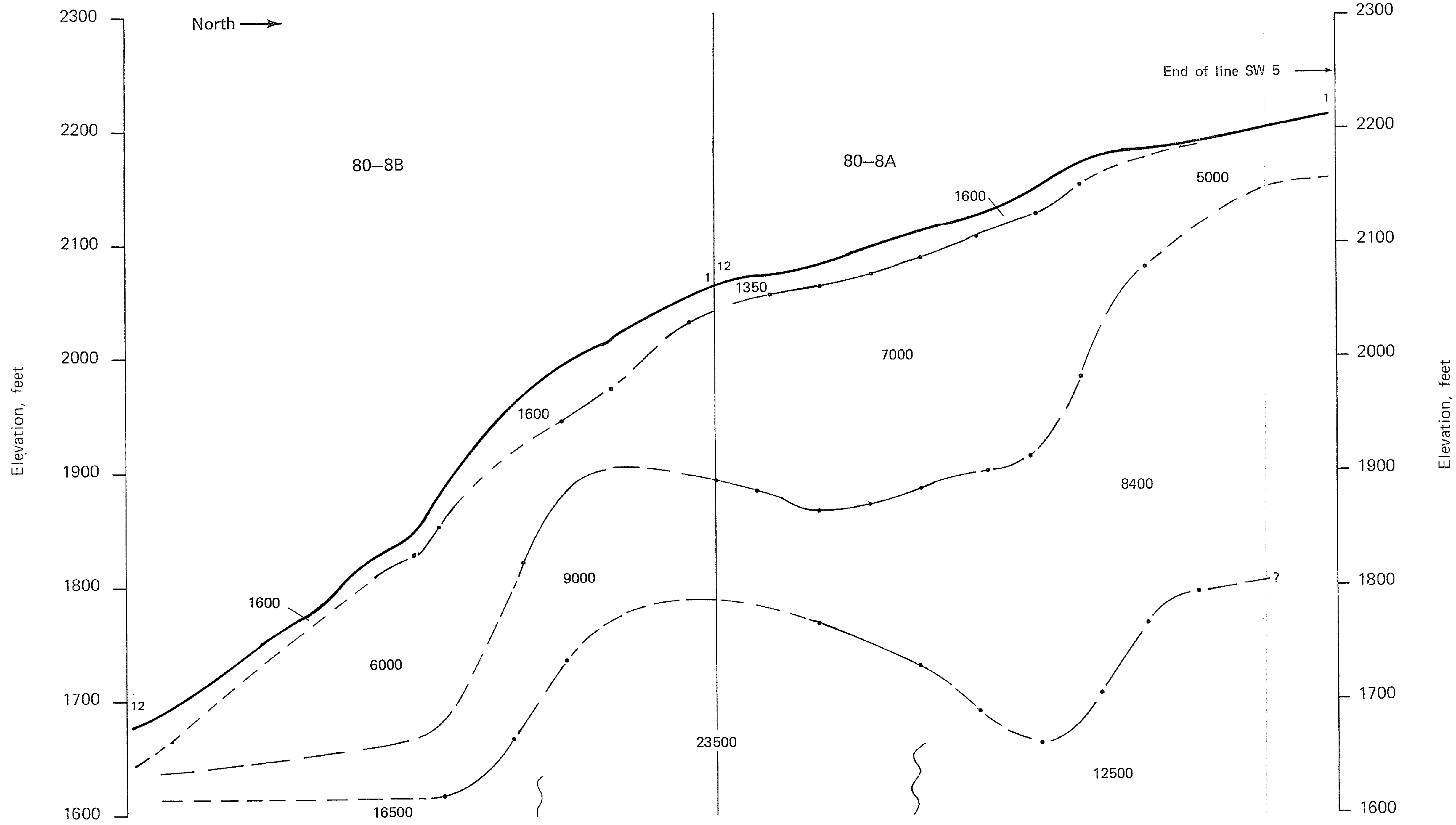


Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 200 feet
Vertical Scale: 1 inch = 100 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

WOODWARD-CLYDE CONSULTANTS	
SEISMIC REFRACTION PROFILE 80–7	
Project No. 41306I SUSITNA DAM	Fig. 9



Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 200 feet

Vertical Scale: 1 inch = 100 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

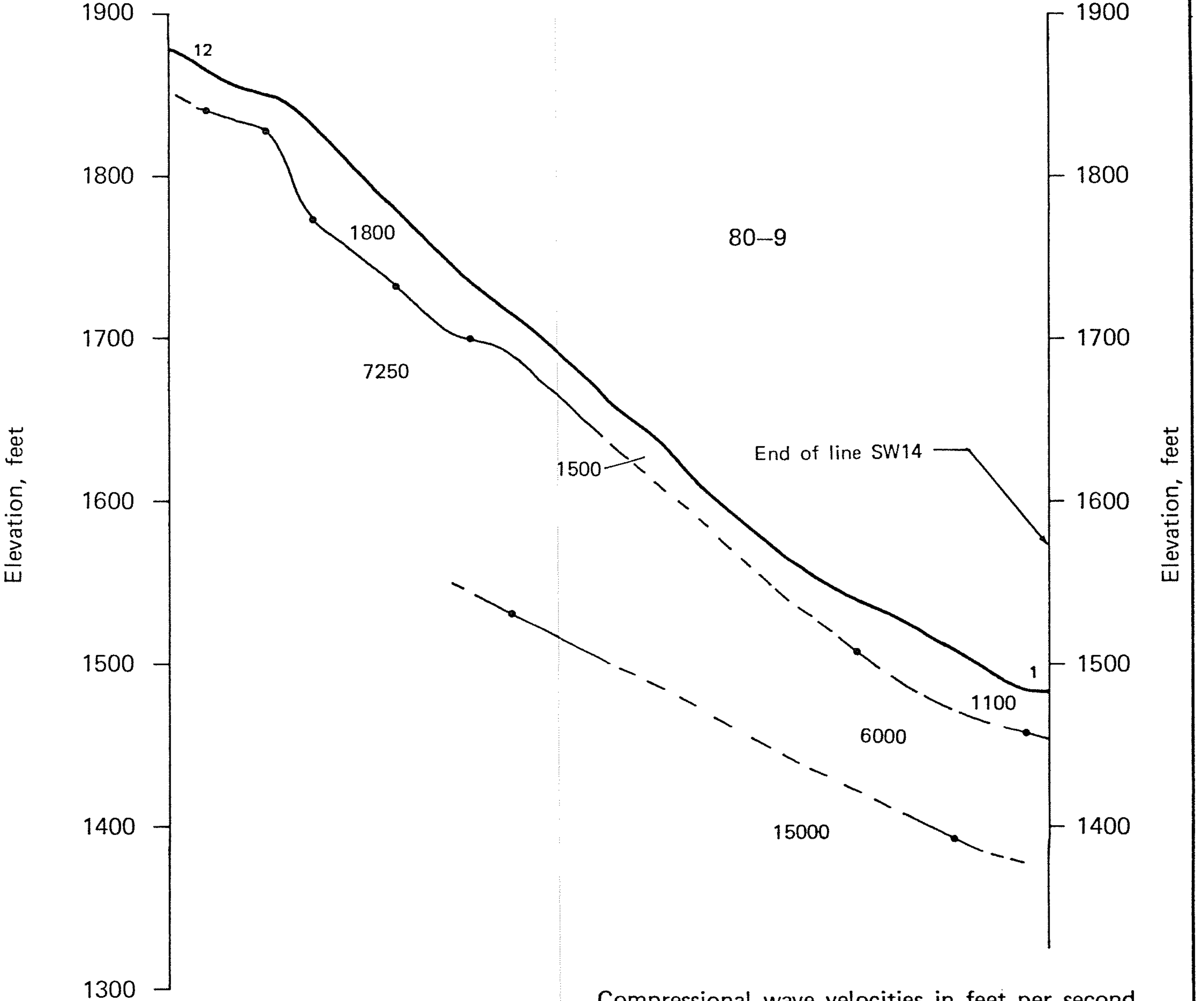
WOODWARD-CLYDE CONSULTANTS

SEISMIC REFRACTION PROFILE 80–8

Project No. **41306I**

SUSITNA DAM

Fig. **10**



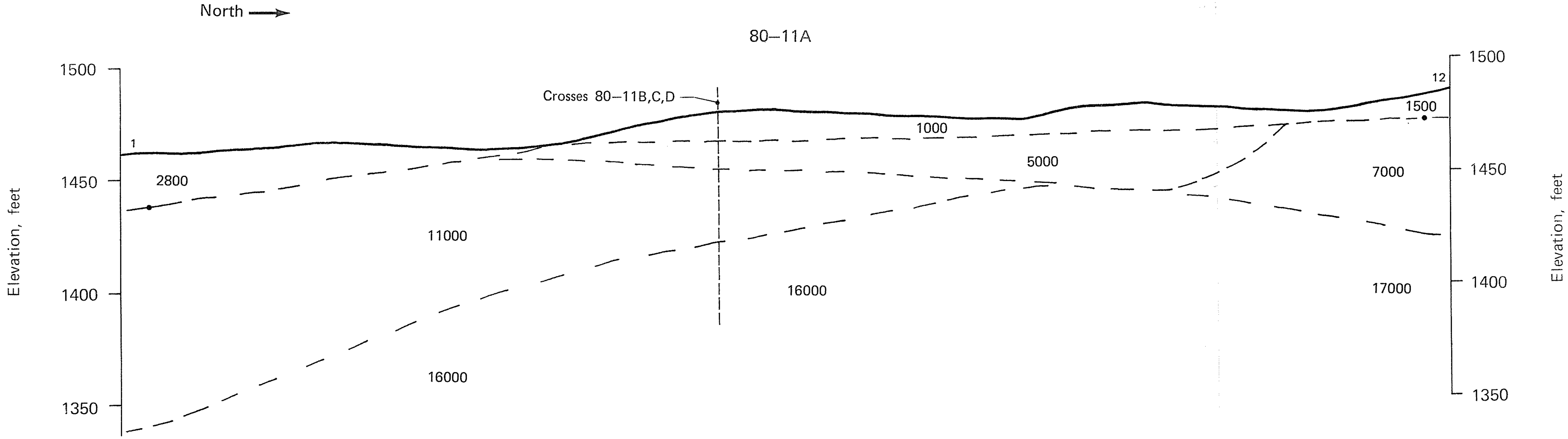
Compressional wave velocities in feet per second

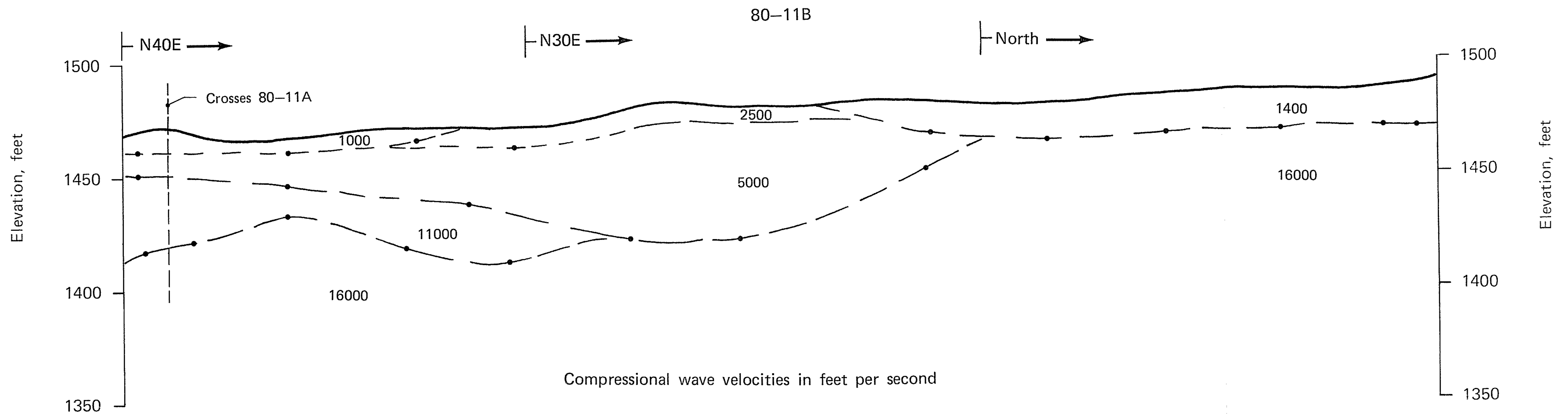
Horizontal Scale: 1 inch = 200 feet
Vertical Scale: 1 inch = 100 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

Project: SUSITNA DAM Project No. 41306I	SEISMIC REFRACTION PROFILE 80–9	Fig. 11

WOODWARD–CLYDE CONSULTANTS





Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 100 feet

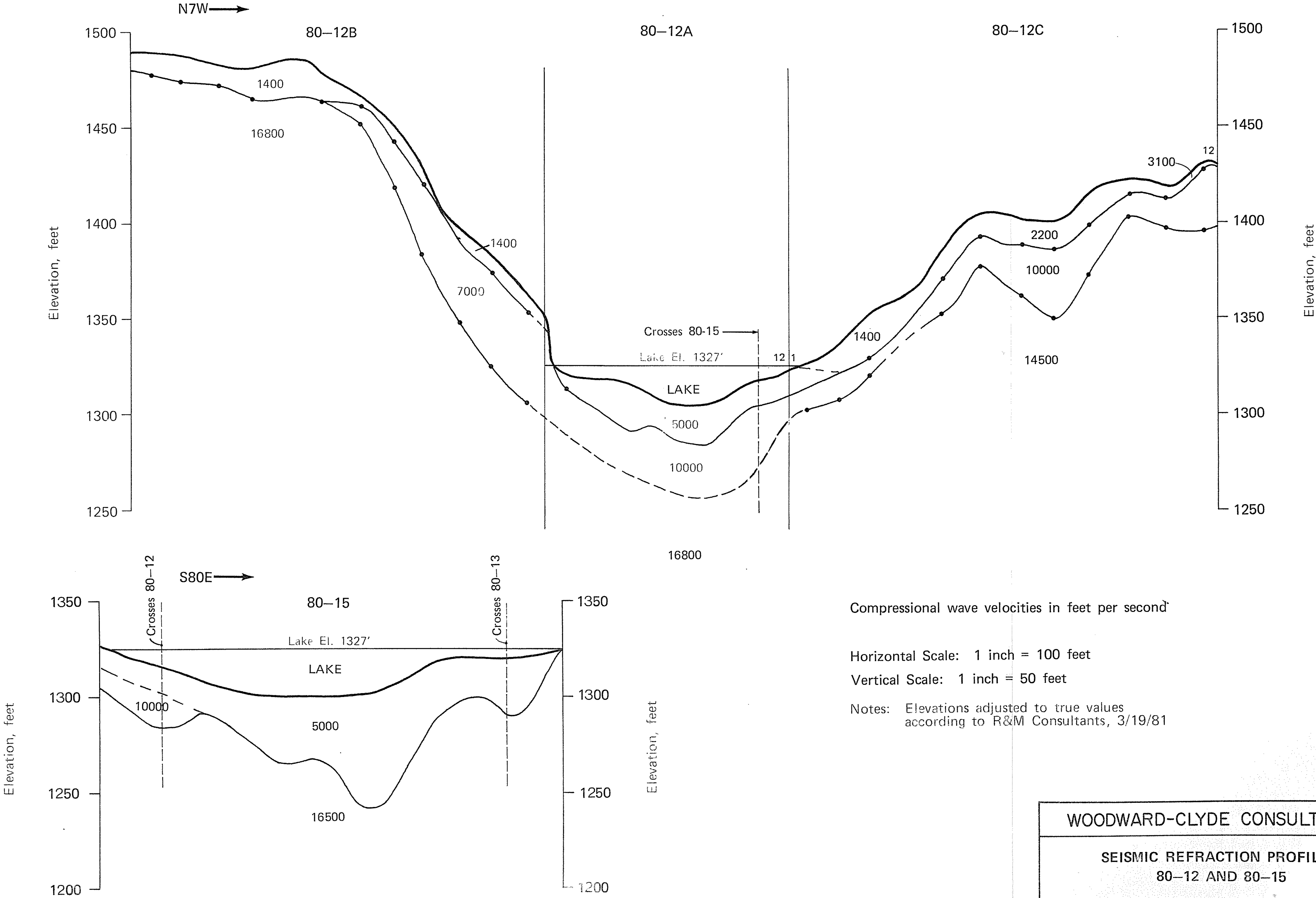
Vertical Scale: 1 inch = 50 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

WOODWARD-CLYDE CONSULTANTS

SEISMIC REFRACTION PROFILE 80–11

Project No. **41306I**	Fig.
SUSITNA DAM	12



Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 100 feet

Vertical Scale: 1 inch = 50 feet

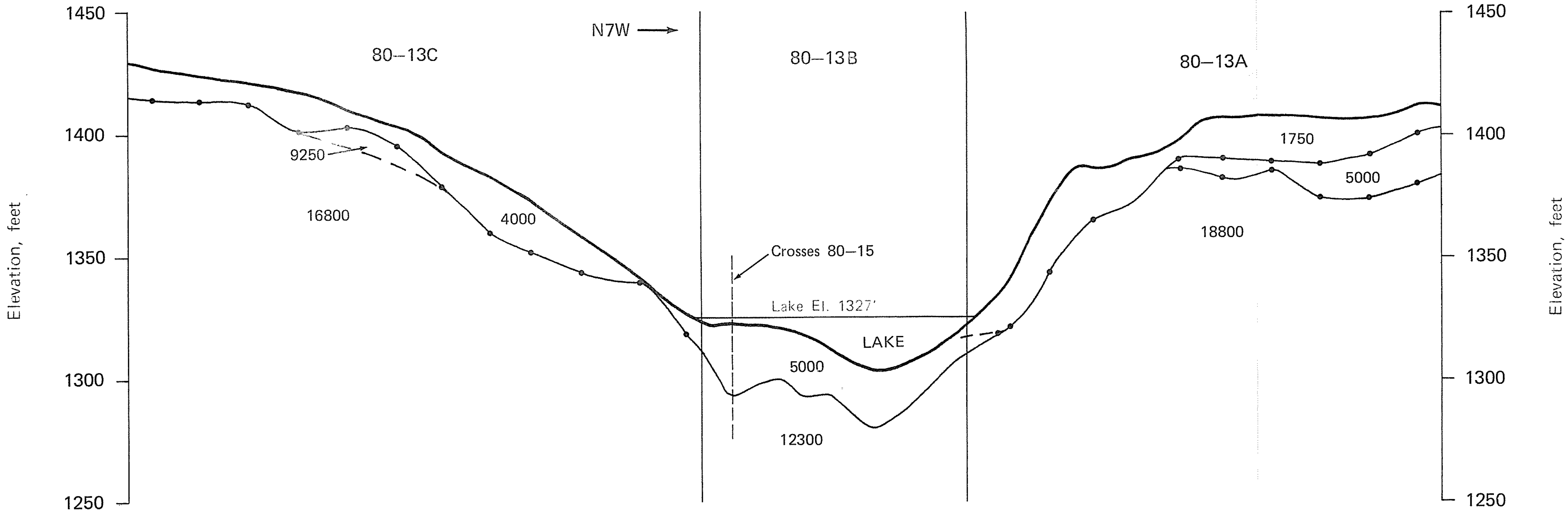
Notes: Elevations adjusted to true values according to R&M Consultants, 3/19/81

WOODWARD-CLYDE CONSULTANTS

SEISMIC REFRACTION PROFILES
80–12 AND 80–15

Project No. 41306I
SUSITNA DAM

Fig. 13



Compressional wave velocities in feet per second

Horizontal Scale: 1 inch = 100 feet
Vertical Scale: 1 inch = 50 feet

Note: Elevations adjusted to true values according to R&M Consultants, 3/19/81

WOODWARD-CLYDE CONSULTANTS

SEISMIC REFRACTION PROFILES 80–13

Project No. 41306I
SUSITNA DAM

Fig. 14

APPENDIX A

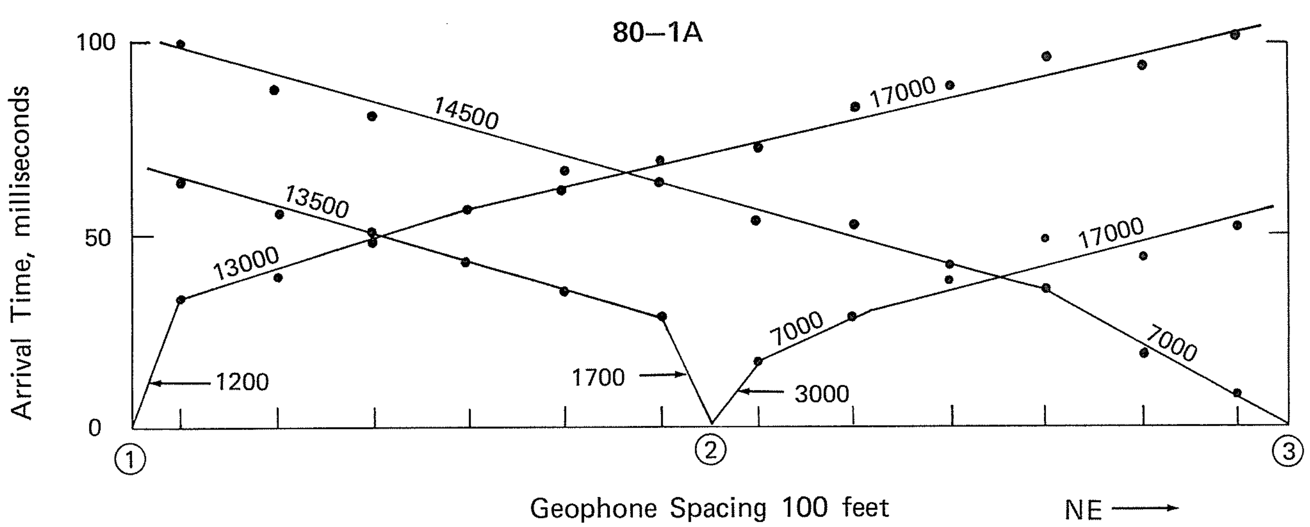
TIME-DISTANCE RELATIONSHIPS AND LIMITATIONS OF THE DATA

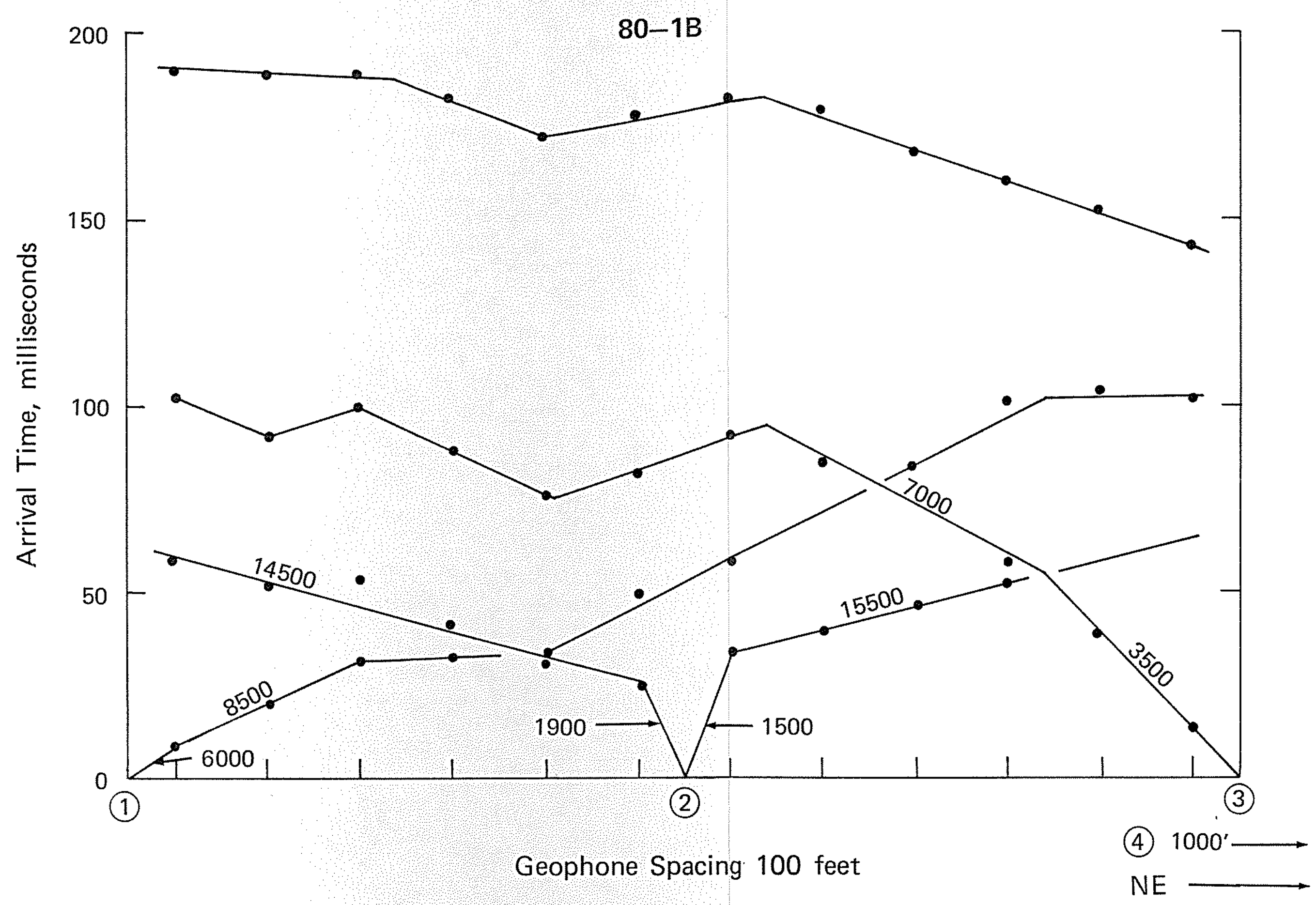
Plots of seismic wave arrival time versus shot and geophone spacing for all lines which comprise this survey are shown on Figures A1 through A10. These plots are the first step in reduction of the data and illustrate the variations in the raw data which were interpreted by methods explained in the text.

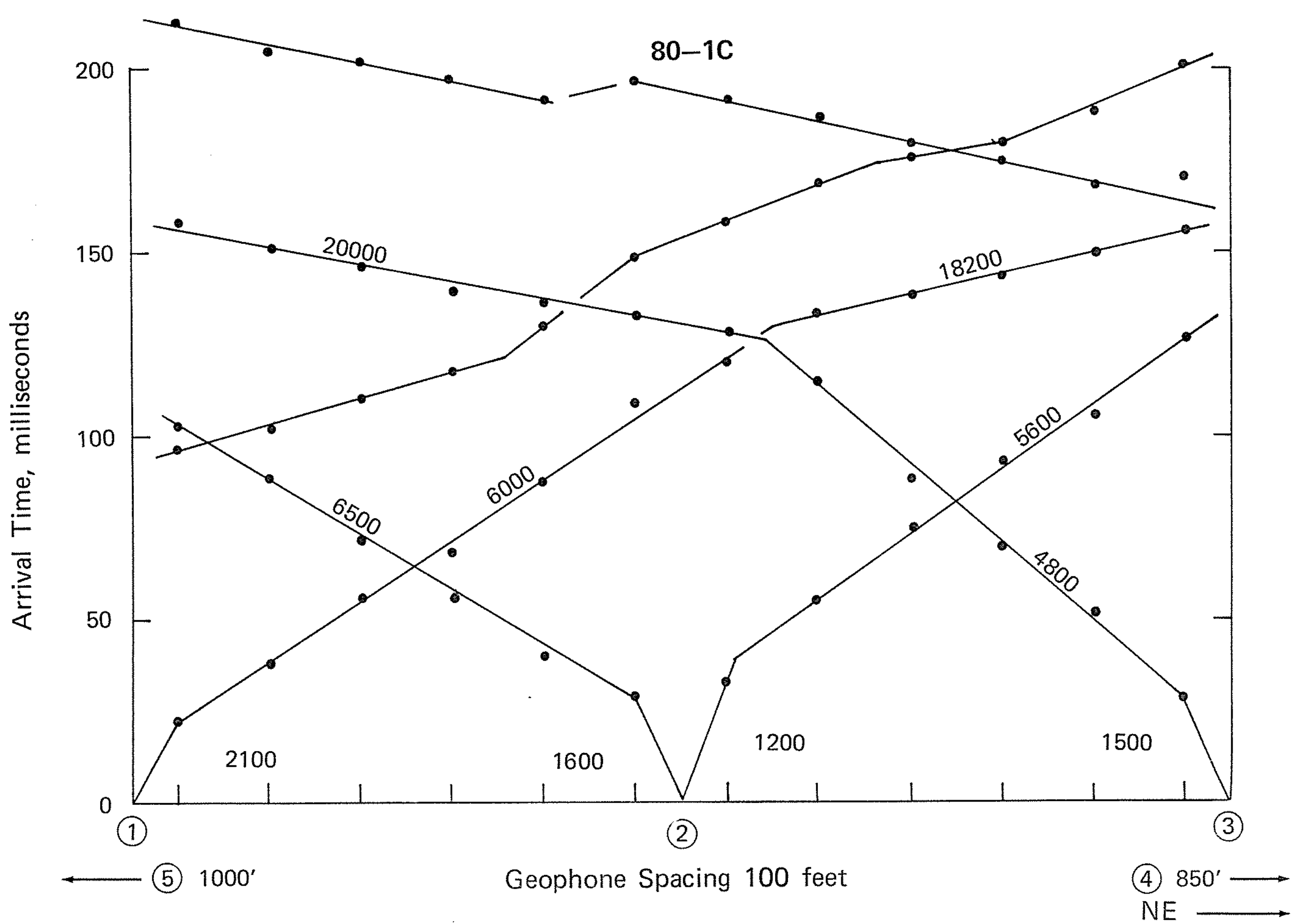
The time-distance plots are essentially the same as those made in the field to evaluate the quality of the data as it was aquired. A thorough review of the records was made during data reduction and some changes were made in the plots.

The number of layers and the velocities shown on the plots are only apparent and often reflect irregularities in terrain or subsurface geometry rather than discrete layers. Interpretation based on these apparent values can be misleading. More realistic interpretations are made by techniques described in the text. Often several mathematically correct interpretations can result from a particular data set. Selection of a particular interpretation depends to a large extent on available control, such as from borings, surface mapping, and adjacent seismic lines, and on the judgment of the interpreter.

A further discussion of the general limitations of the seismic method can be found in Redpath (1973).







EXPLANATION

7000 Apparent compressional wave velocity in feet per second

Tick marks on base of plots refer to geophone locations

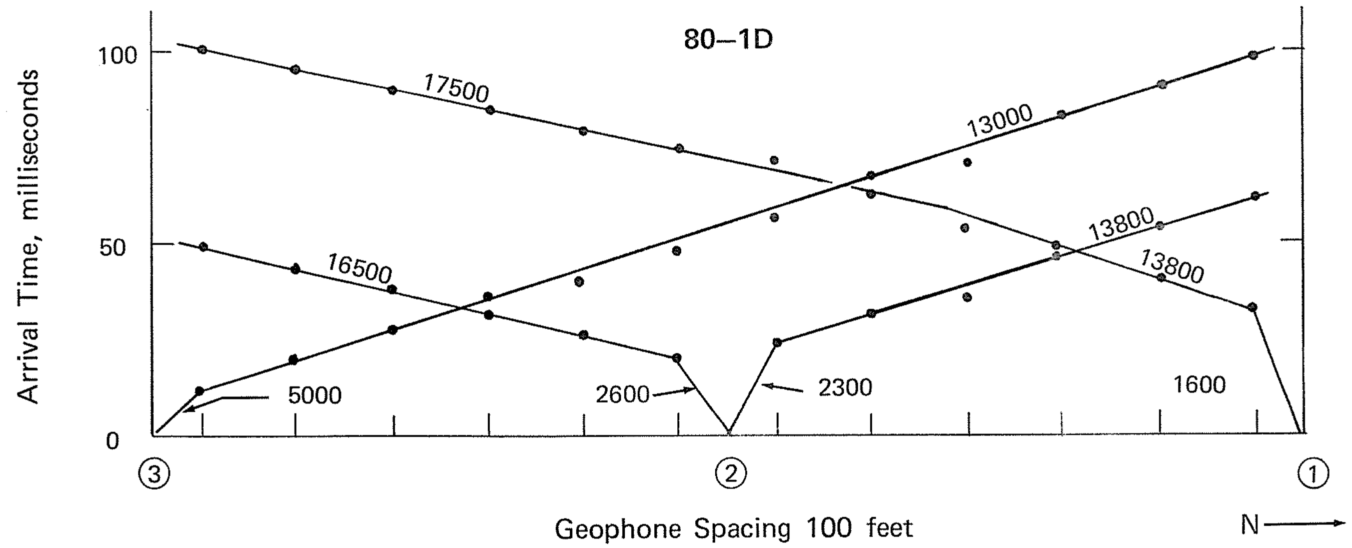
Dots indicate arrival times in relation to "best fit" line

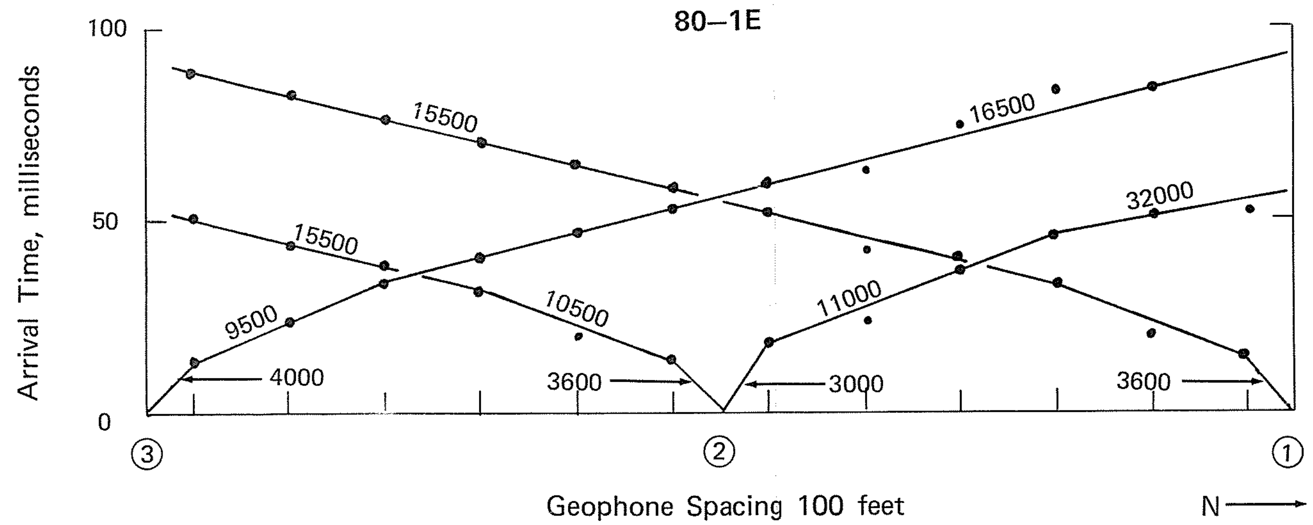
③ Shot point location

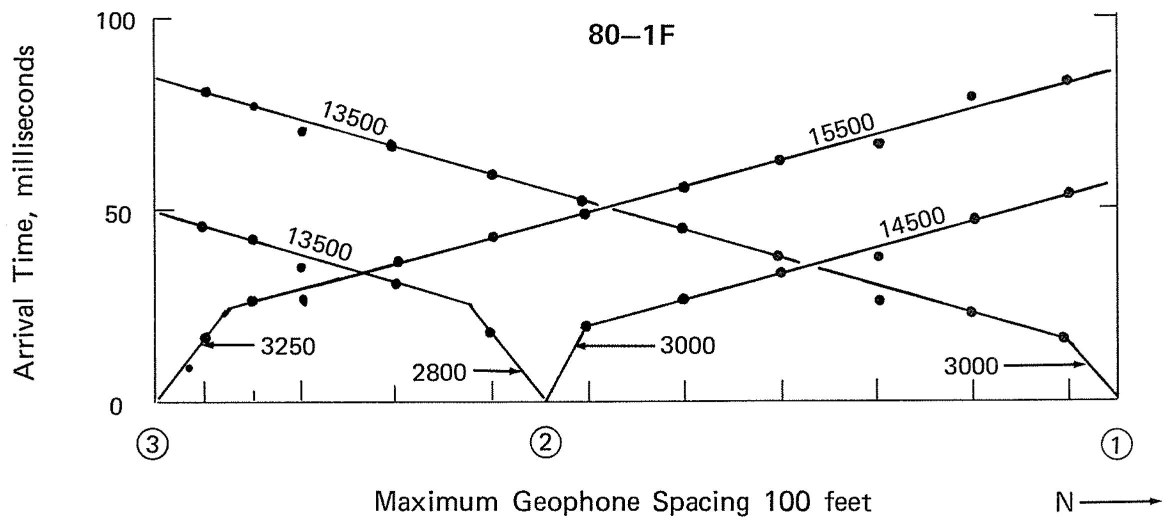
④ 1000′ → Direction and distance of offset shot from end geophone

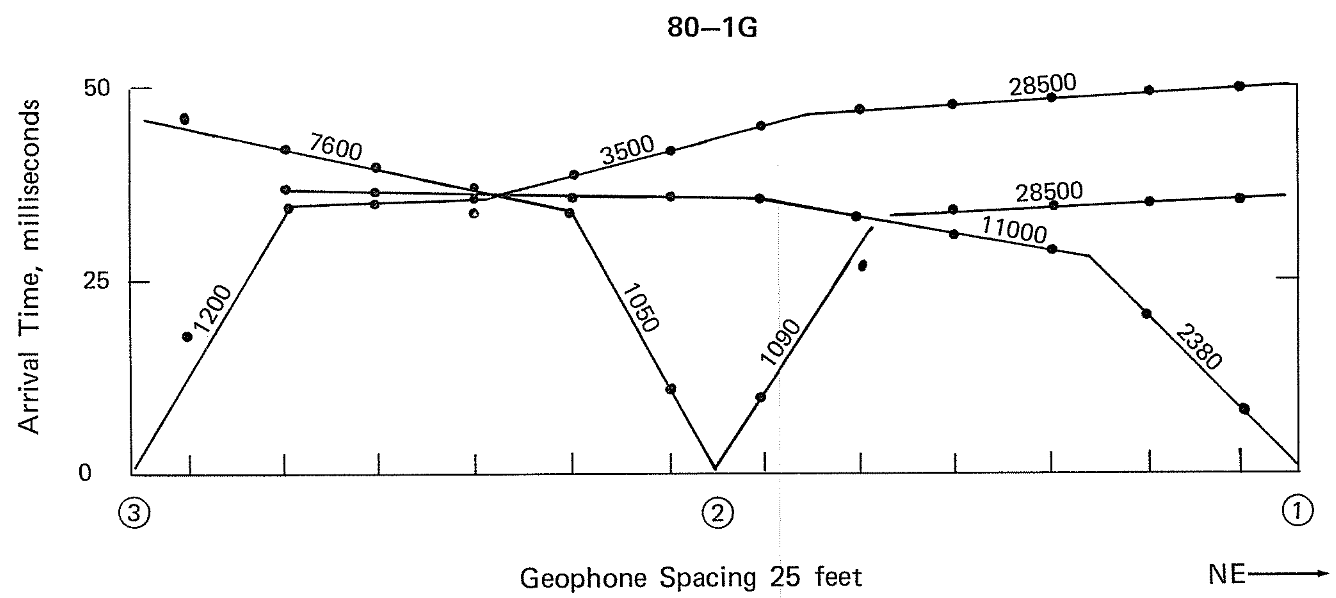
(-50 ms) Arrival times along entire line plotted at 50 milliseconds less than recorded

WOODWARD-CLYDE CONSULTANTS	
TIME–DISTANCE PLOTS Sheet 1 of 10	
Project No. 41306I SUSITNA DAM	Fig. A-1









See Sheet 1 for Explanation.

WOODWARD-CLYDE CONSULTANTS

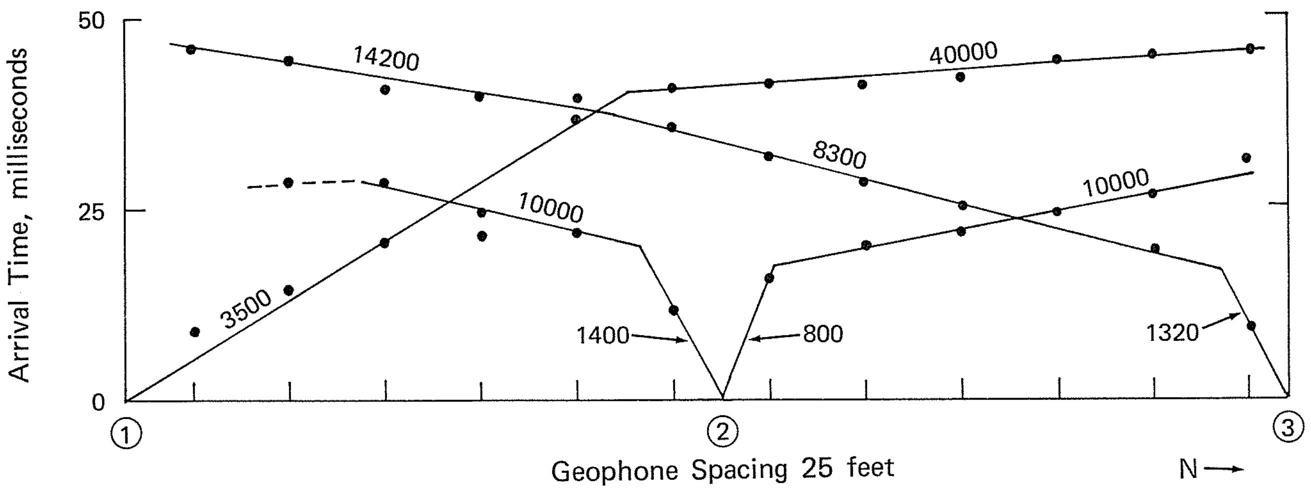
TIME DISTANCE PLOTS

Sheet 2 of 10

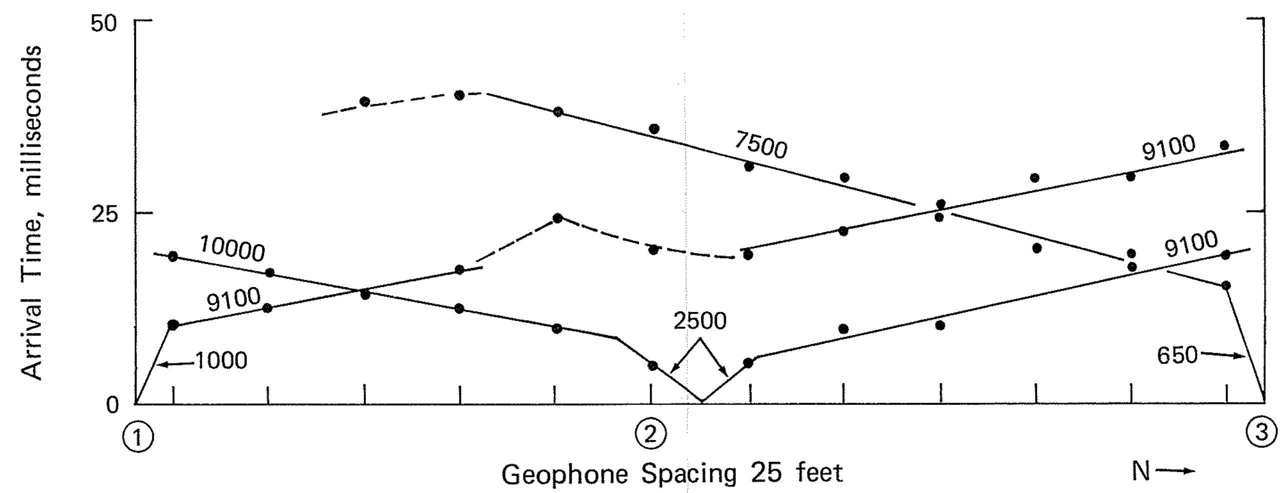
Project No. **41306I**
SUSITNA DAM

Fig. A-2

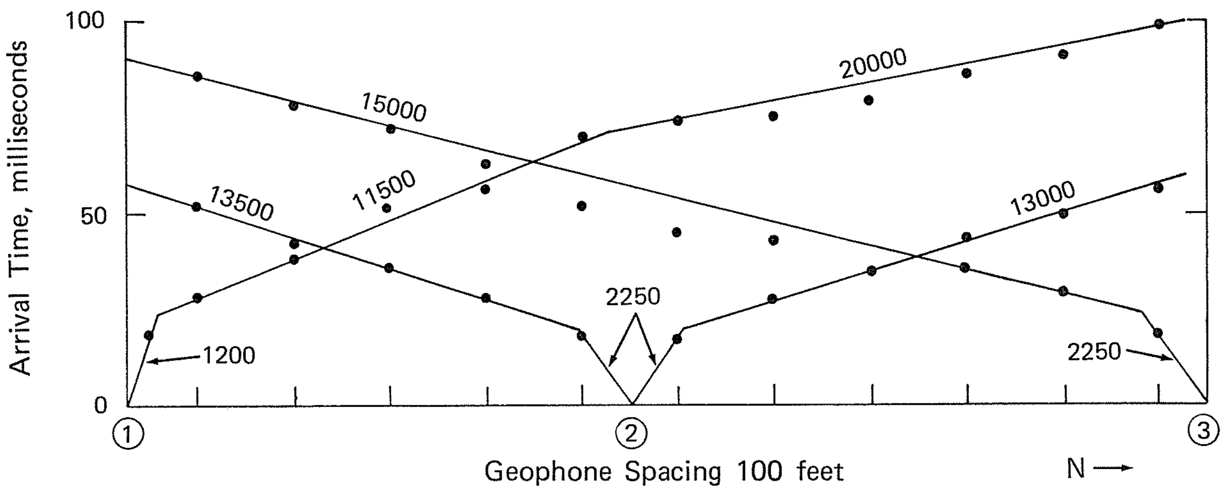
80–1H



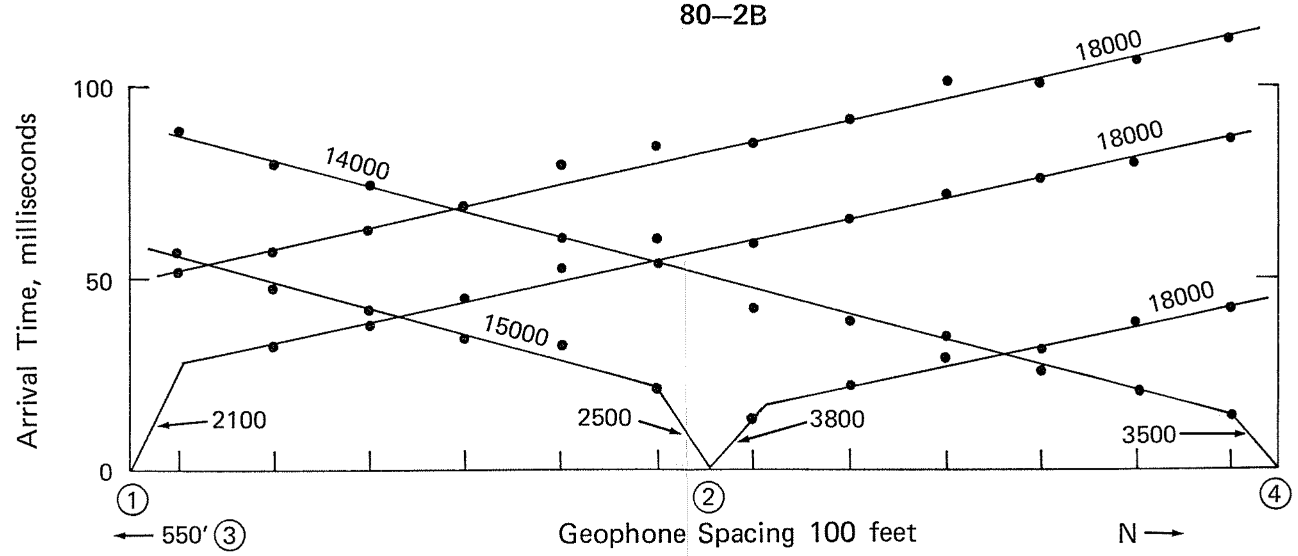
80–1I



80–2A



80–2B

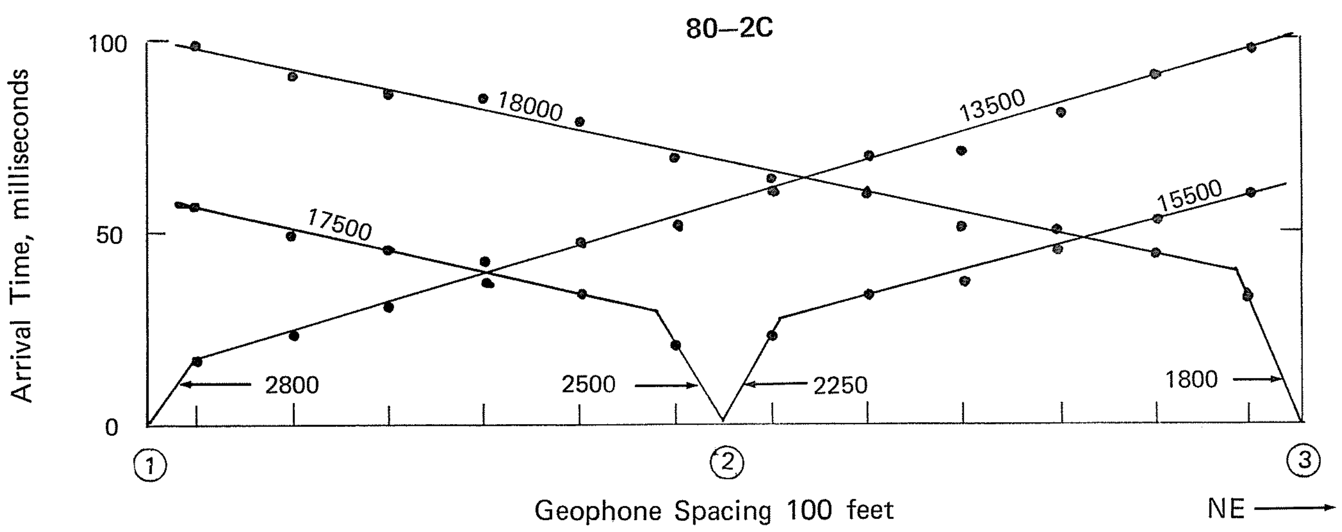


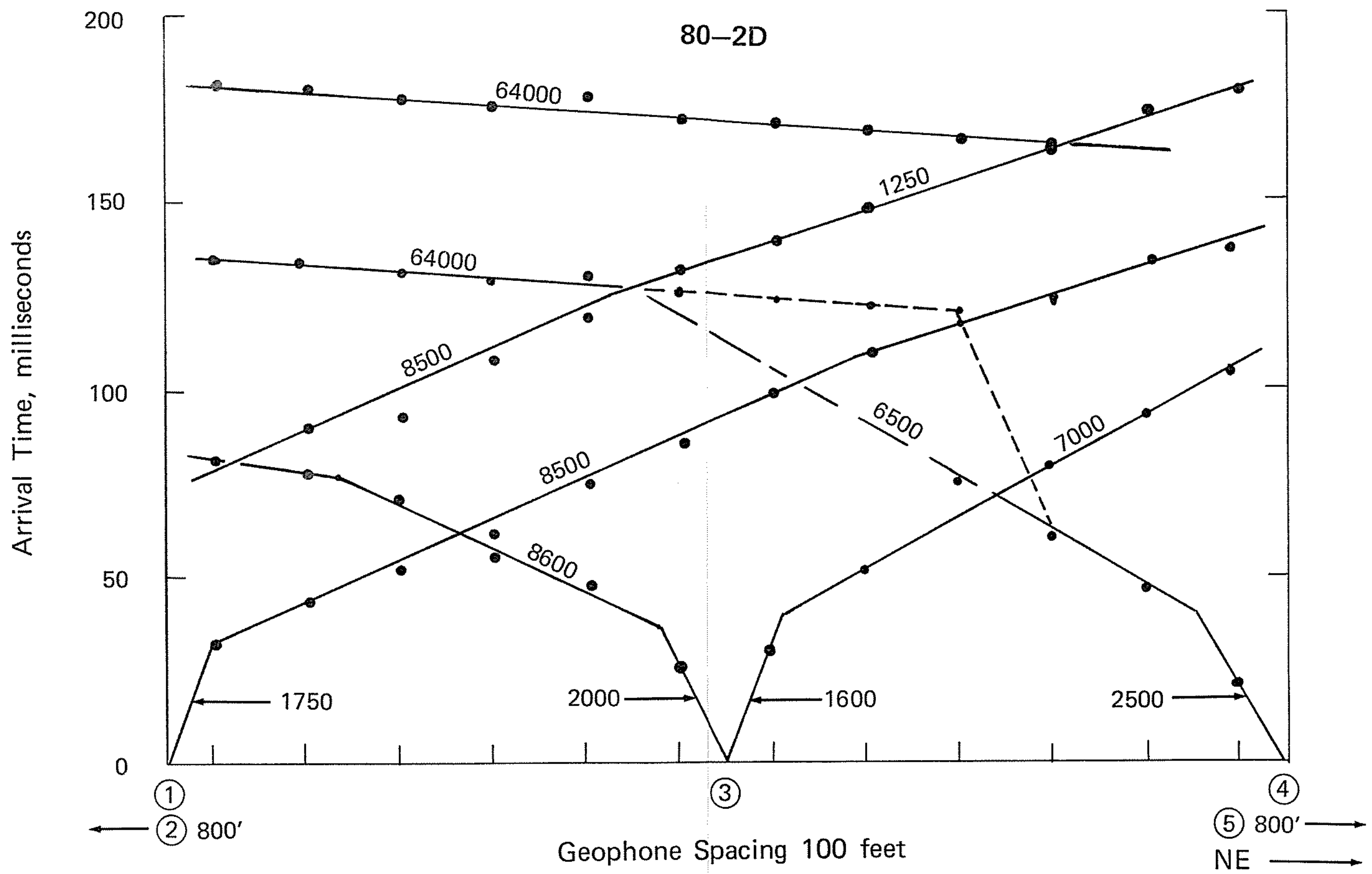
See Sheet 1 for Explanation.

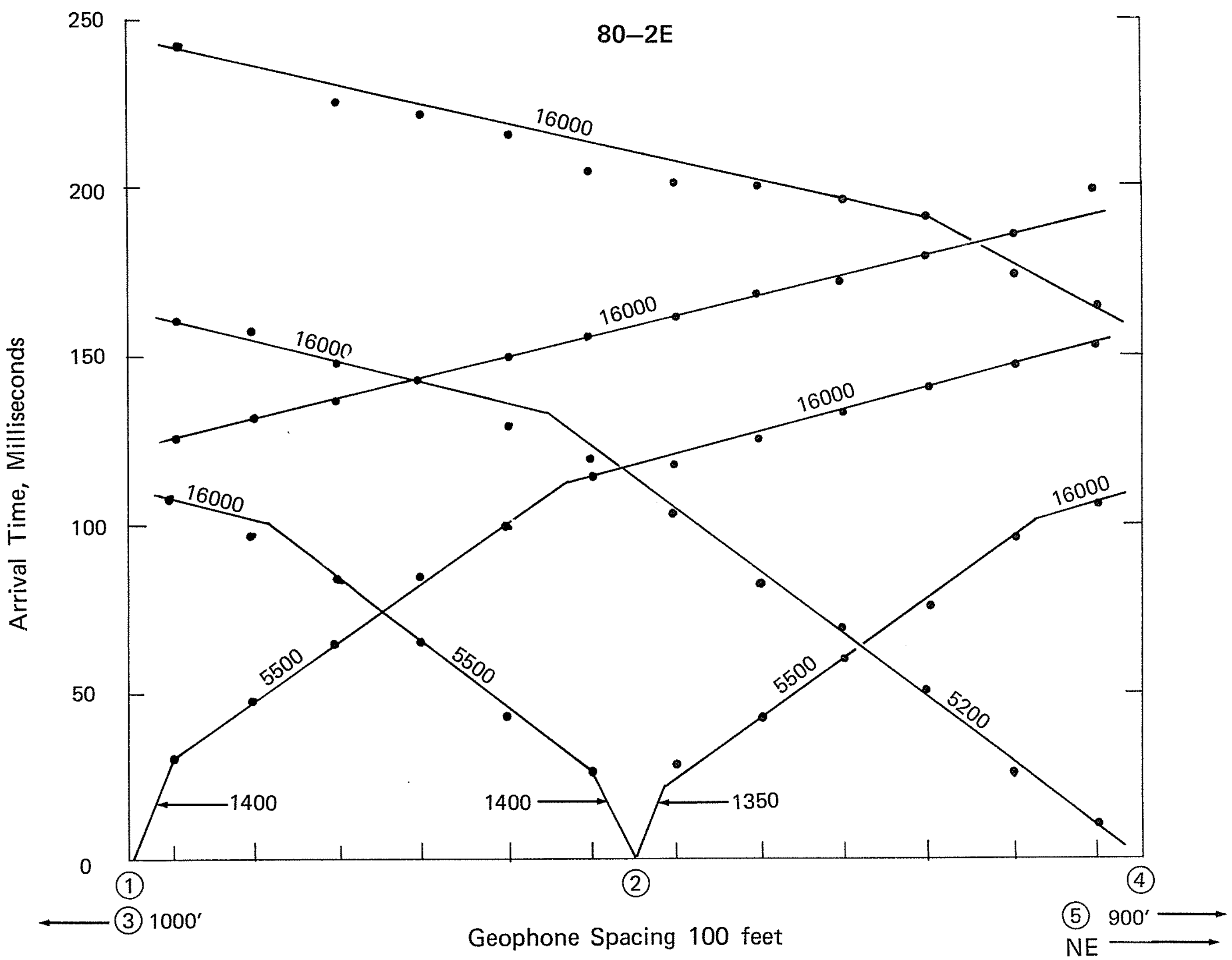
WOODWARD-CLYDE CONSULTANTS

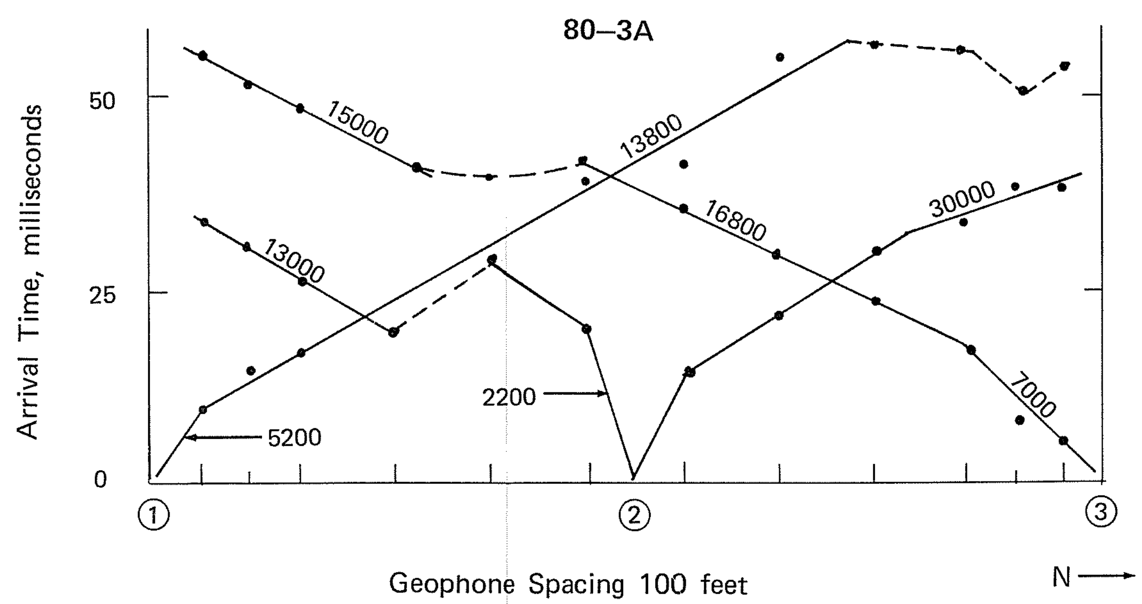
TIME–DISTANCE PLOTS
Sheet 3 of 10

Project No. **41306I** **SUSITNA DAM**	Fig. **A-3**





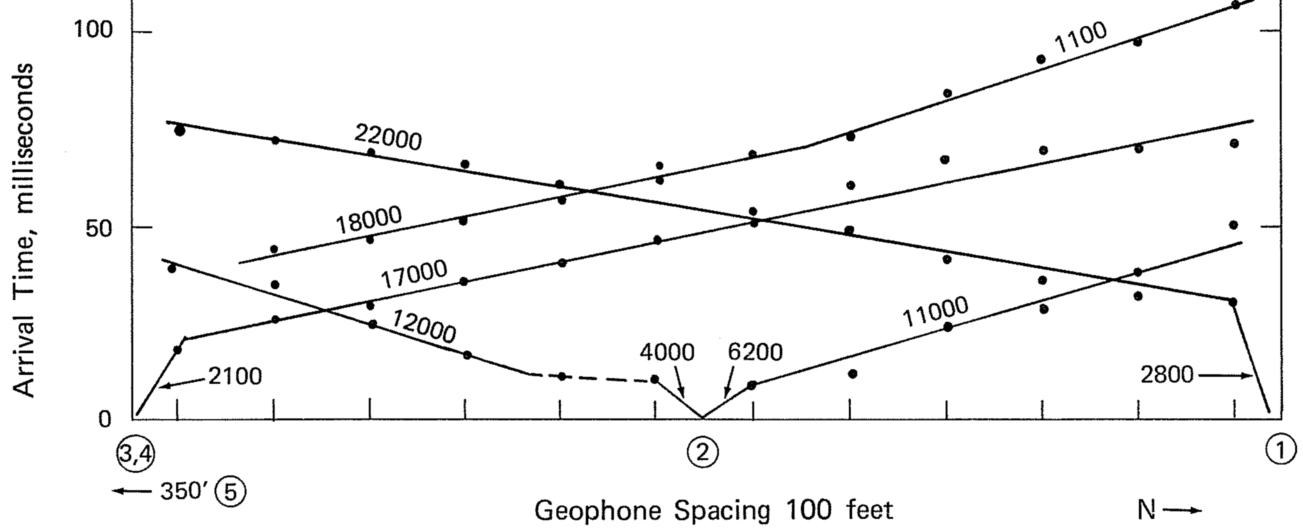




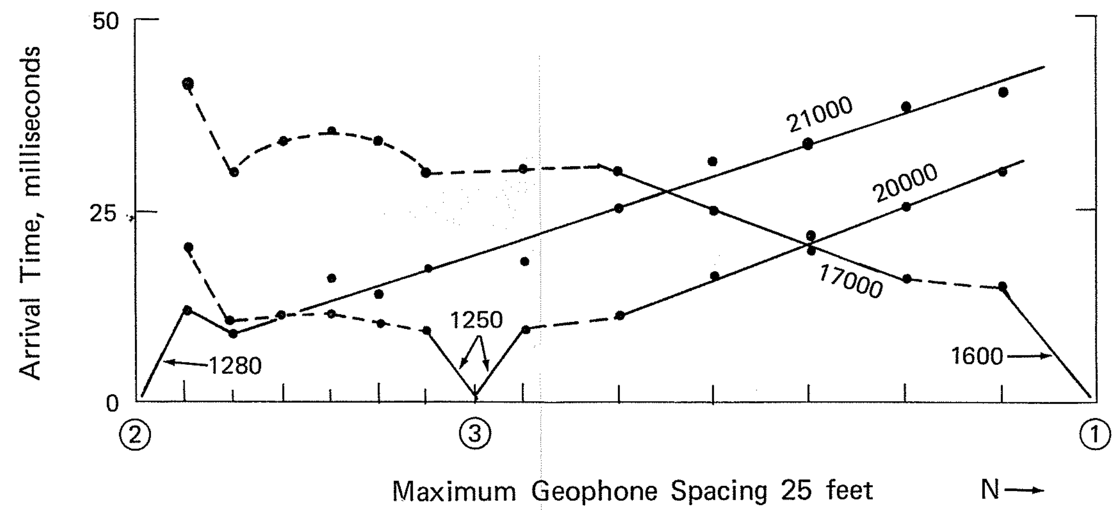
See Sheet 1 for Explanation.

WOODWARD-CLYDE CONSULTANTS	
TIME DISTANCE PLOTS Sheet 4 of 10	
Project No. 41306I SUSITNA DAM	Fig. A-4

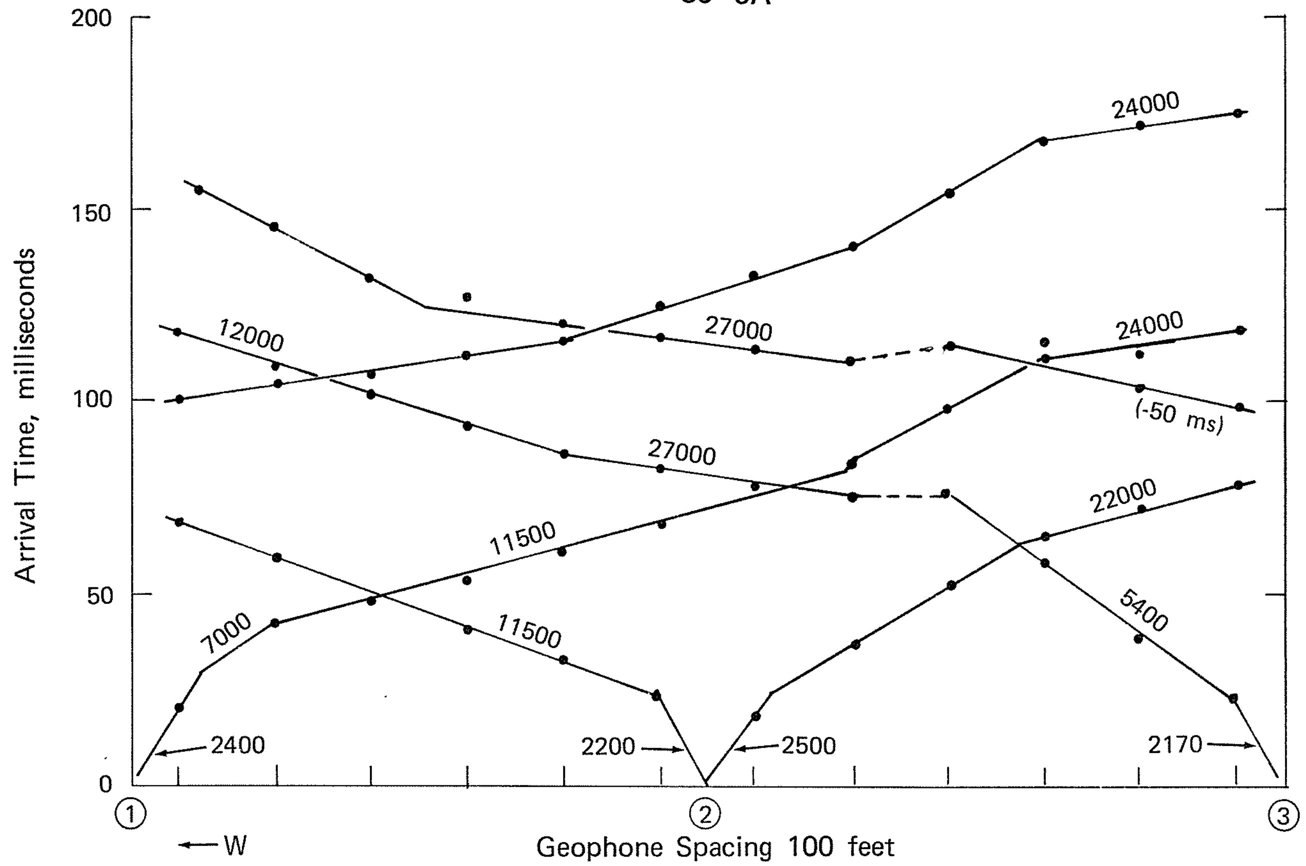
80–3B



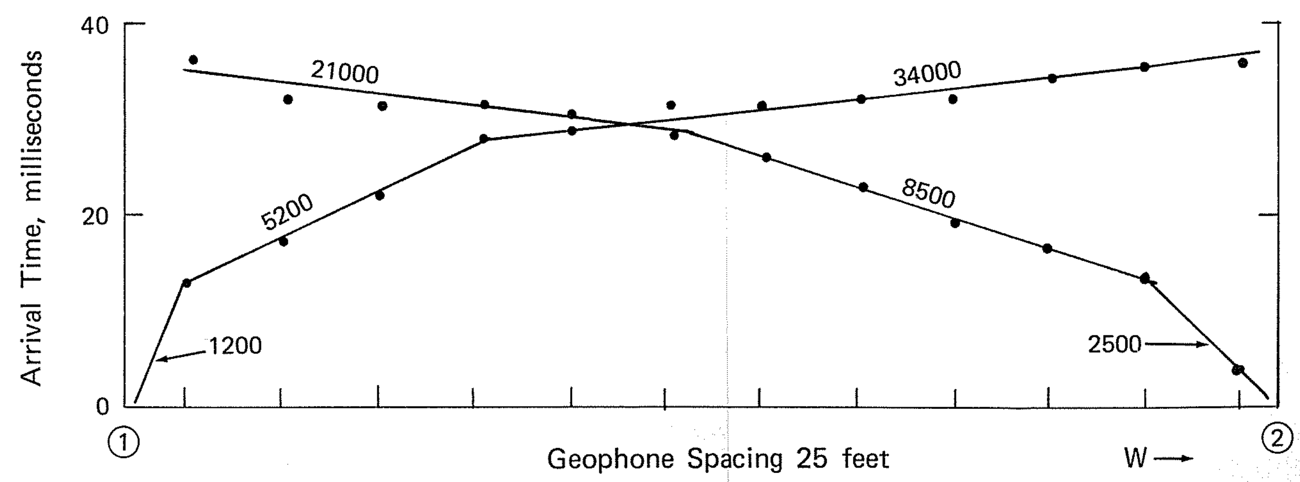
80–3C



80–6A



80–3D



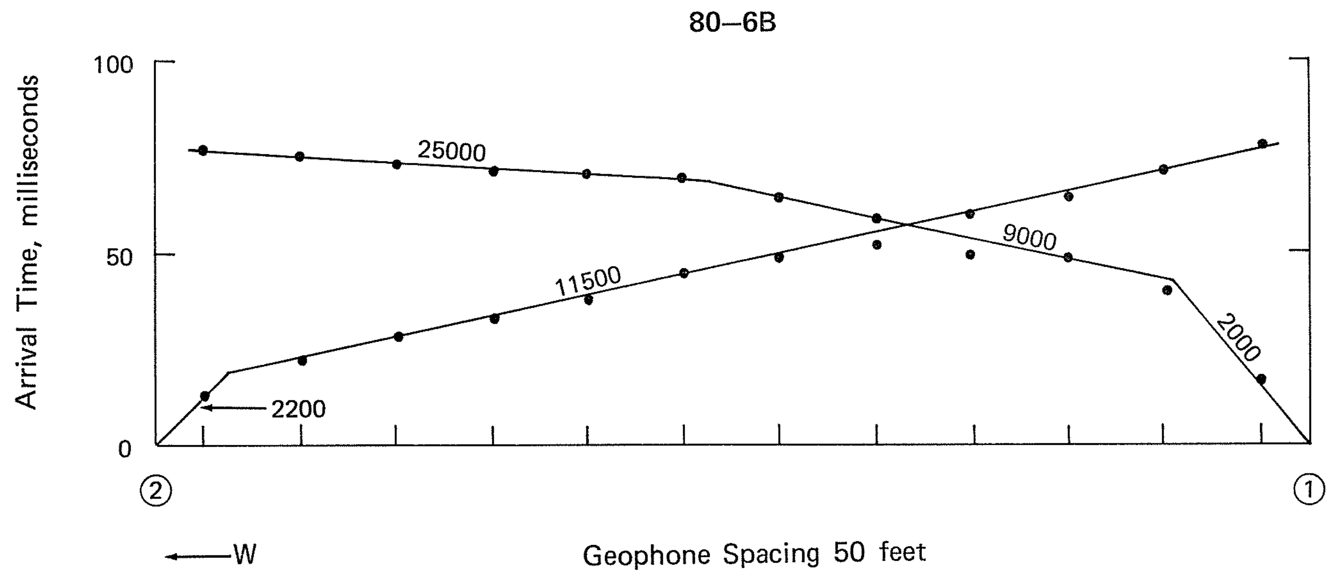
See Sheet 1 for Explanation.

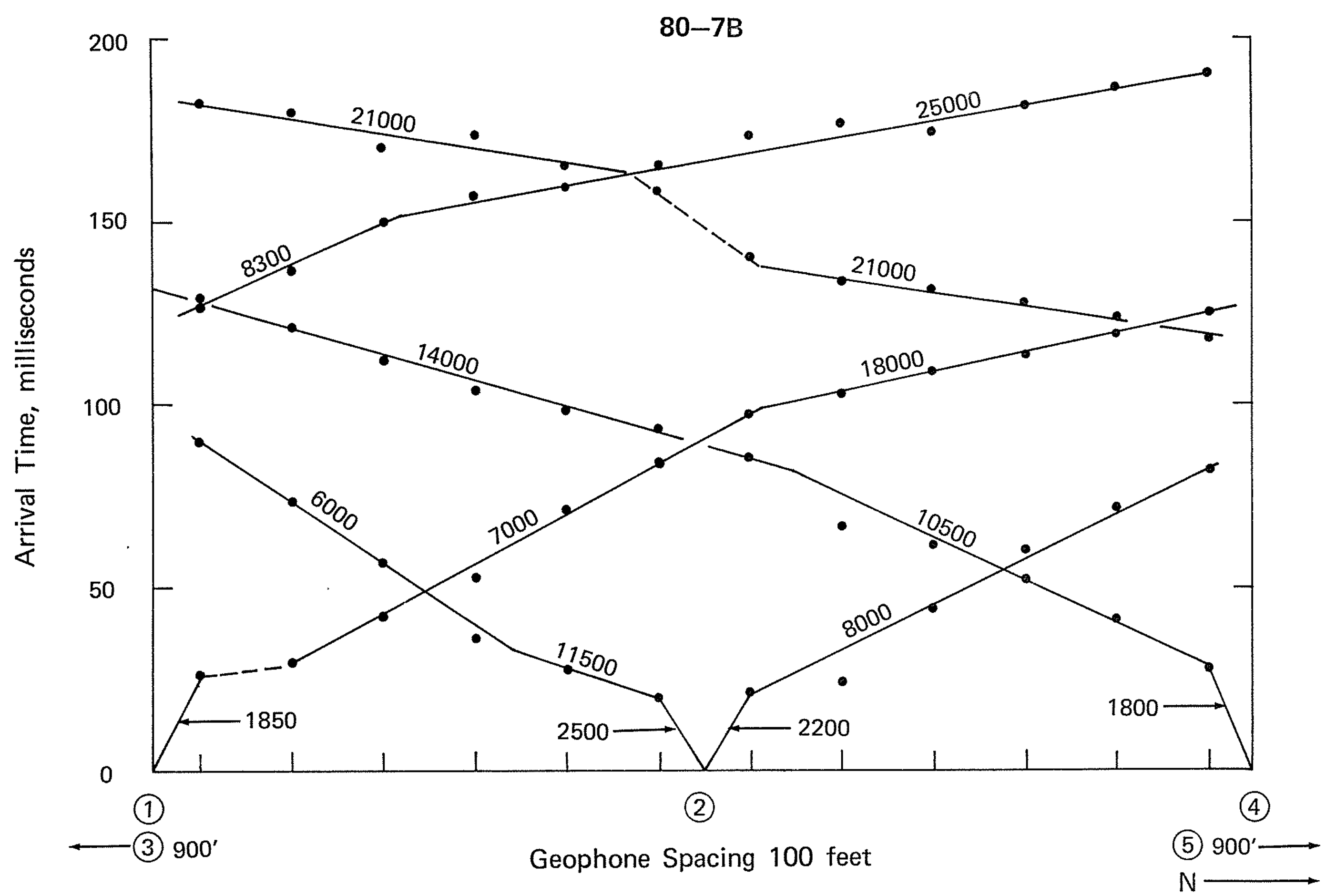
WOODWARD-CLYDE CONSULTANTS

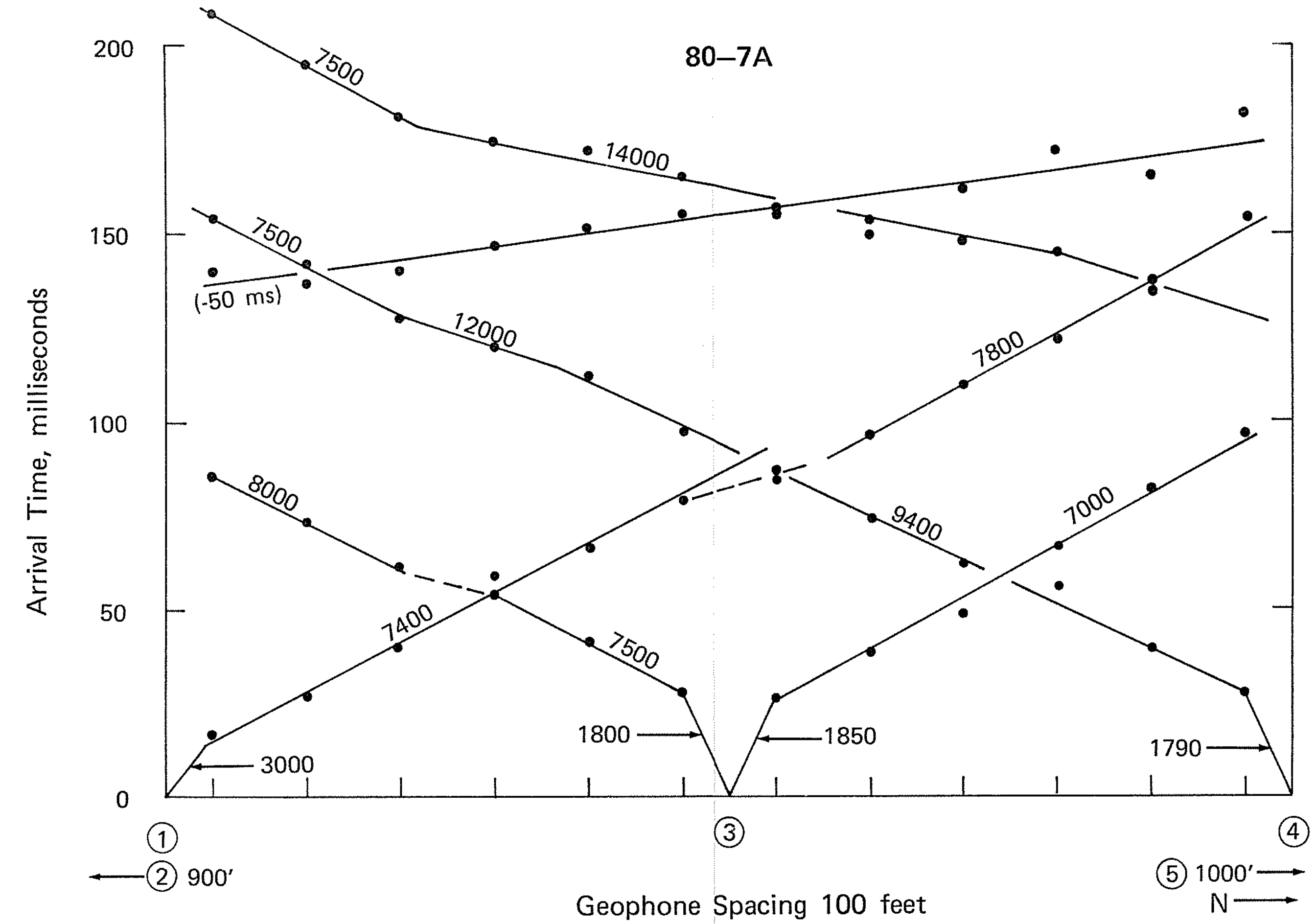
TIME–DISTANCE PLOTS
Sheet 5 of 10

Project No. 41306I
SUSITNA DAM

Fig. A-5

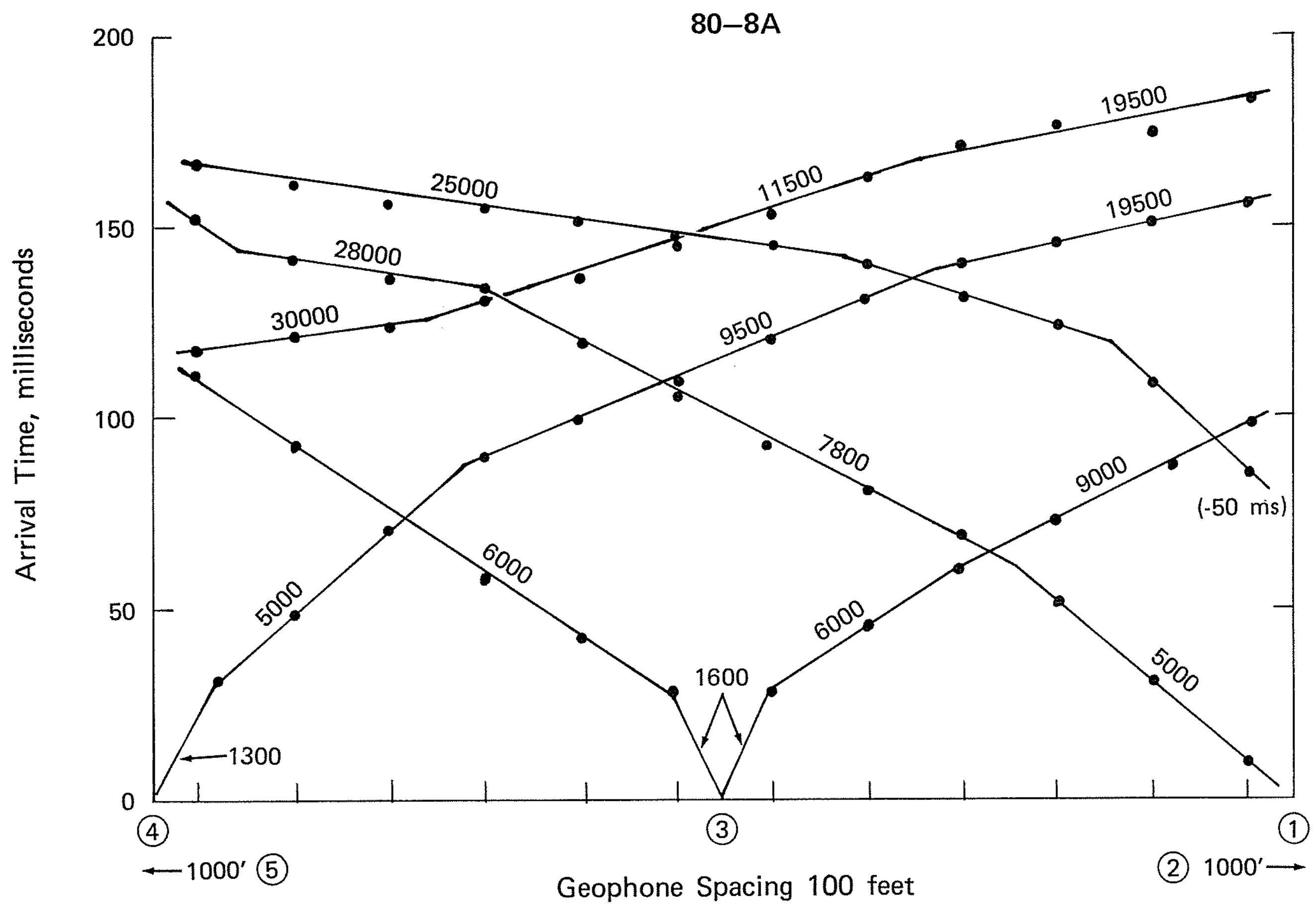


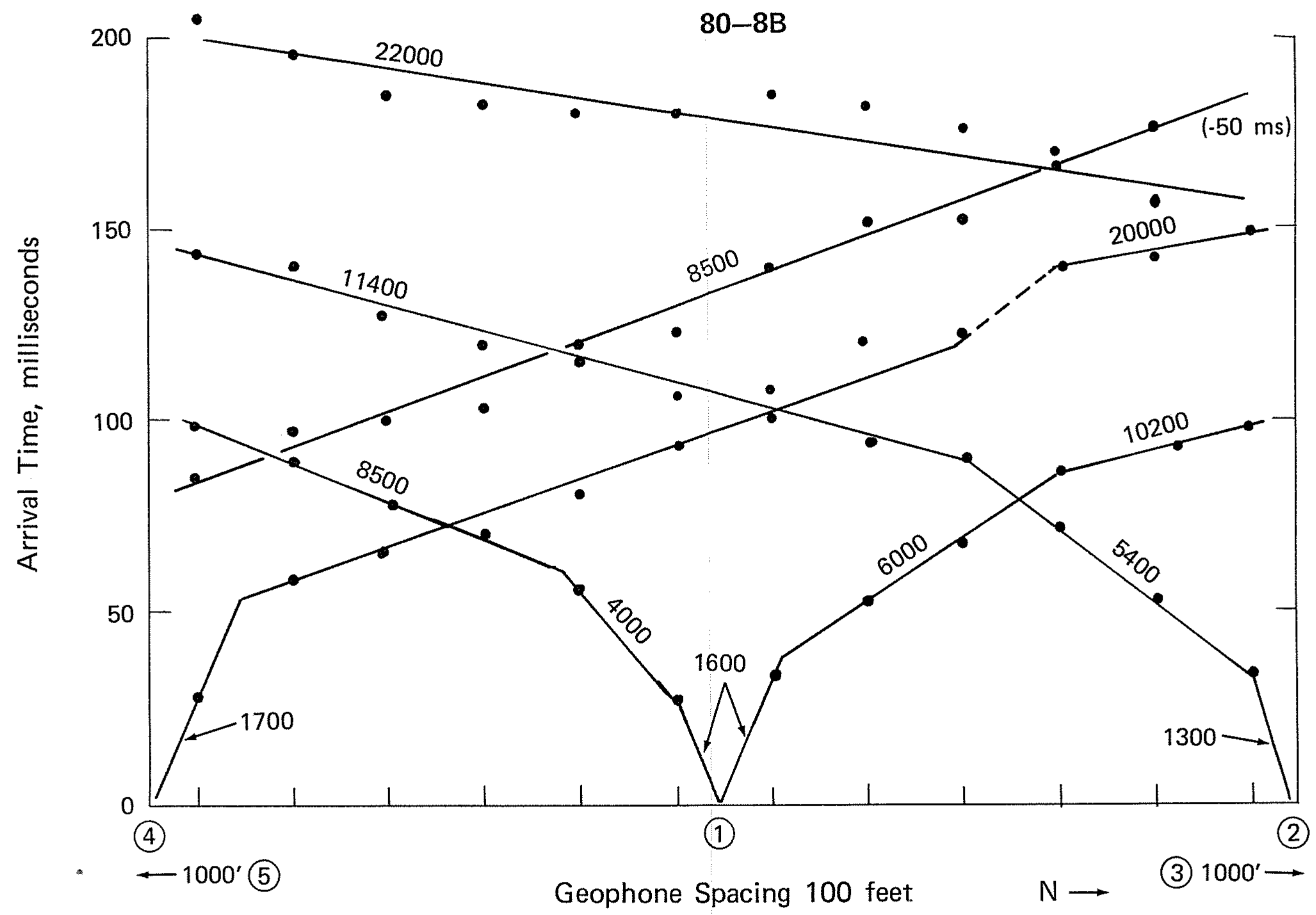


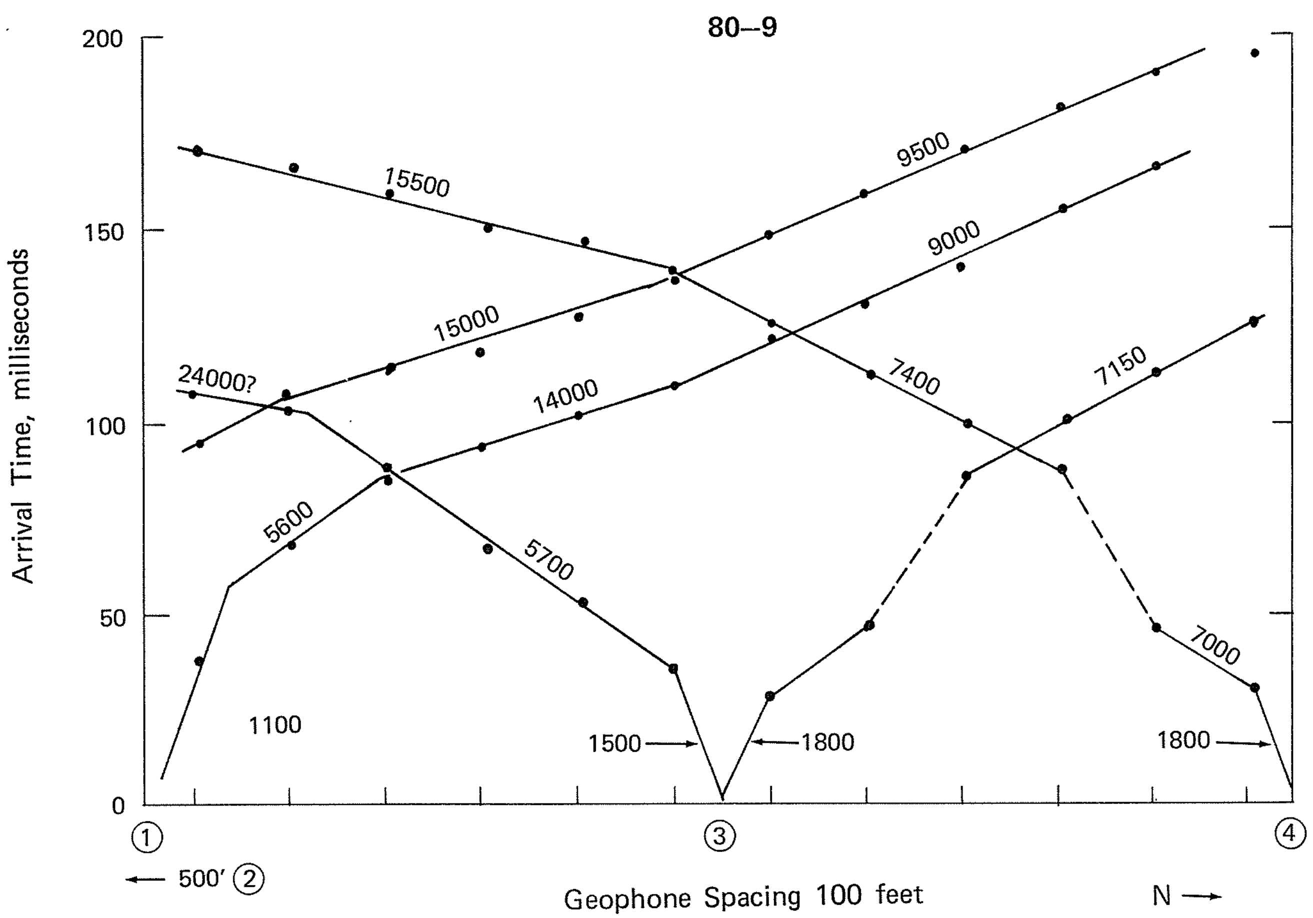


See Sheet 1 for Explanation.

WOODWARD-CLYDE CONSULTANTS	
TIME–DISTANCE PLOTS Sheet 6 of 10	
Project No. 41306I SUSITNA DAM	Fig. A-6

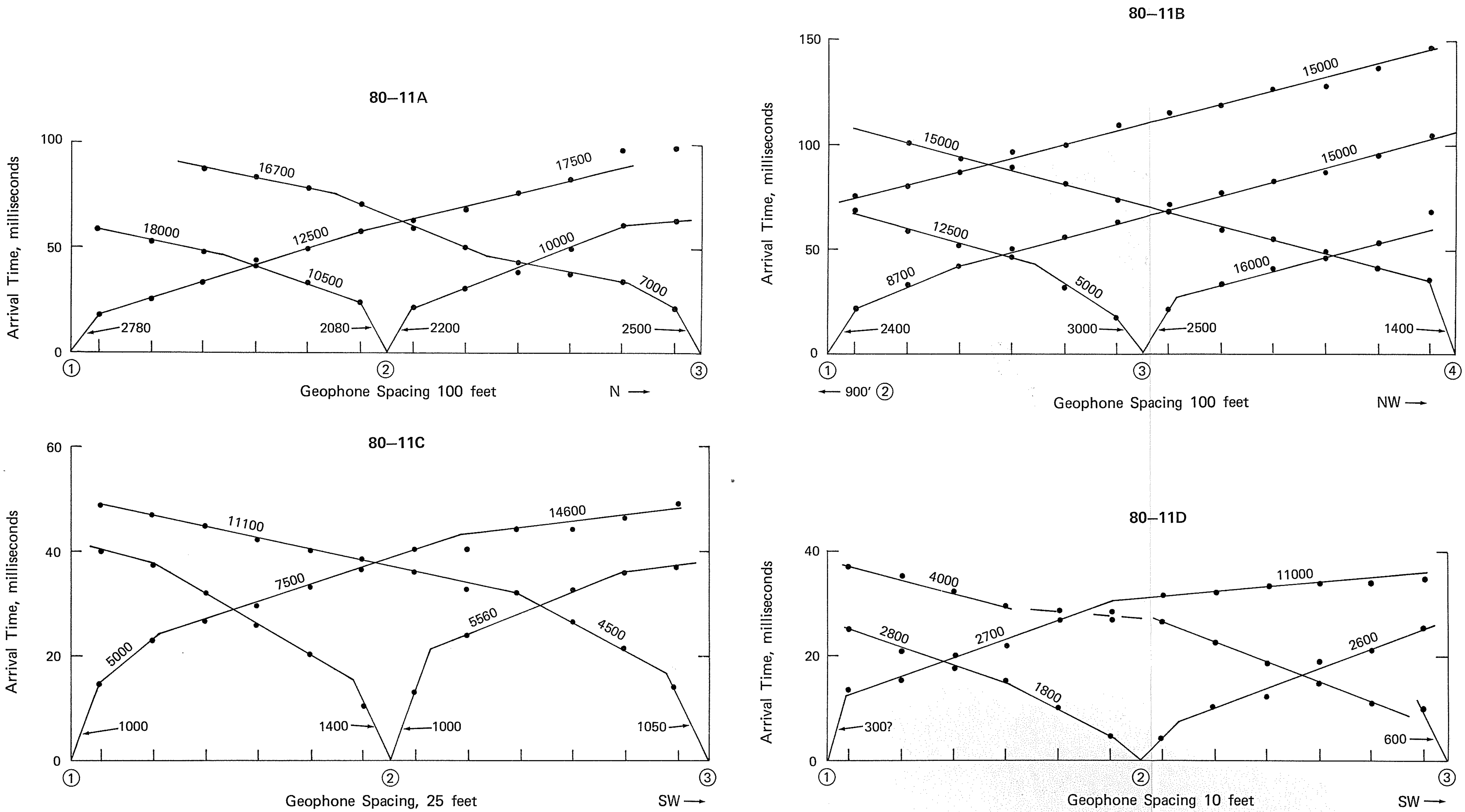






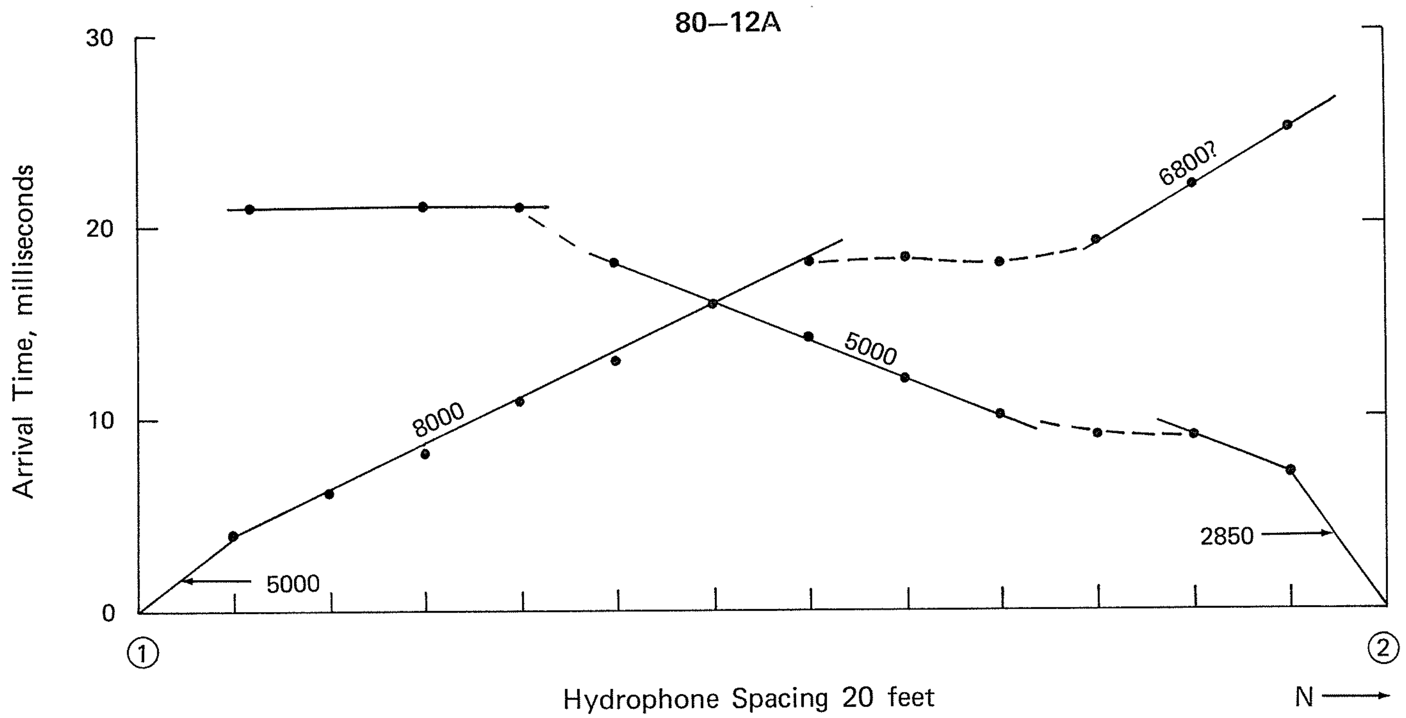
See Sheet 1 for Explanation.

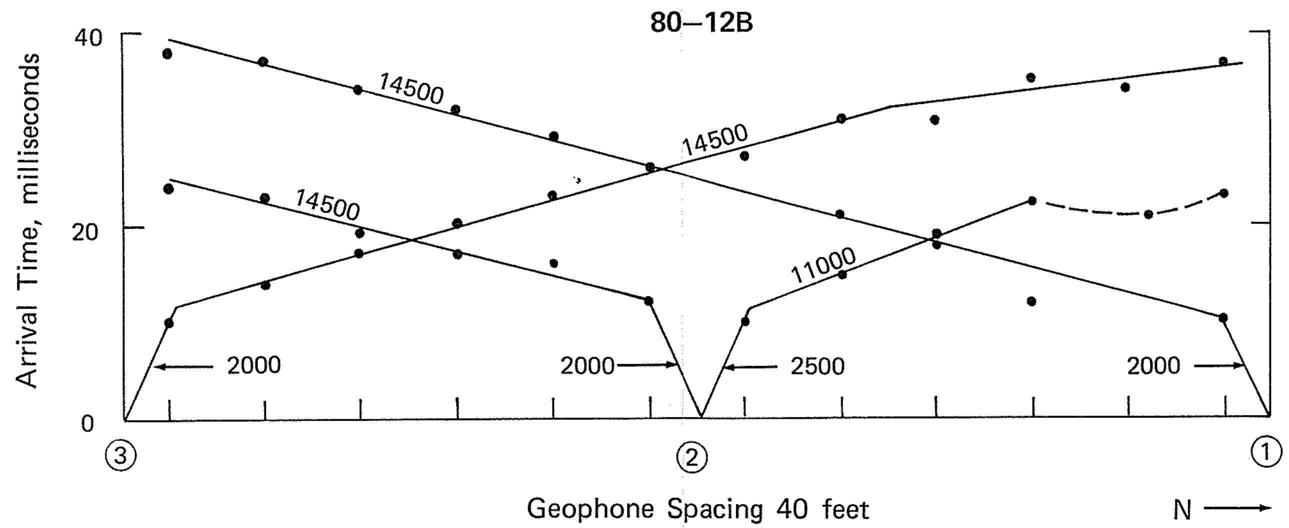
WOODWARD-CLYDE CONSULTANTS	
TIME–DISTANCE PLOTS Sheet 7 of 10	
Project No. **41306I** **SUSITNA DAM**	Fig. A-7

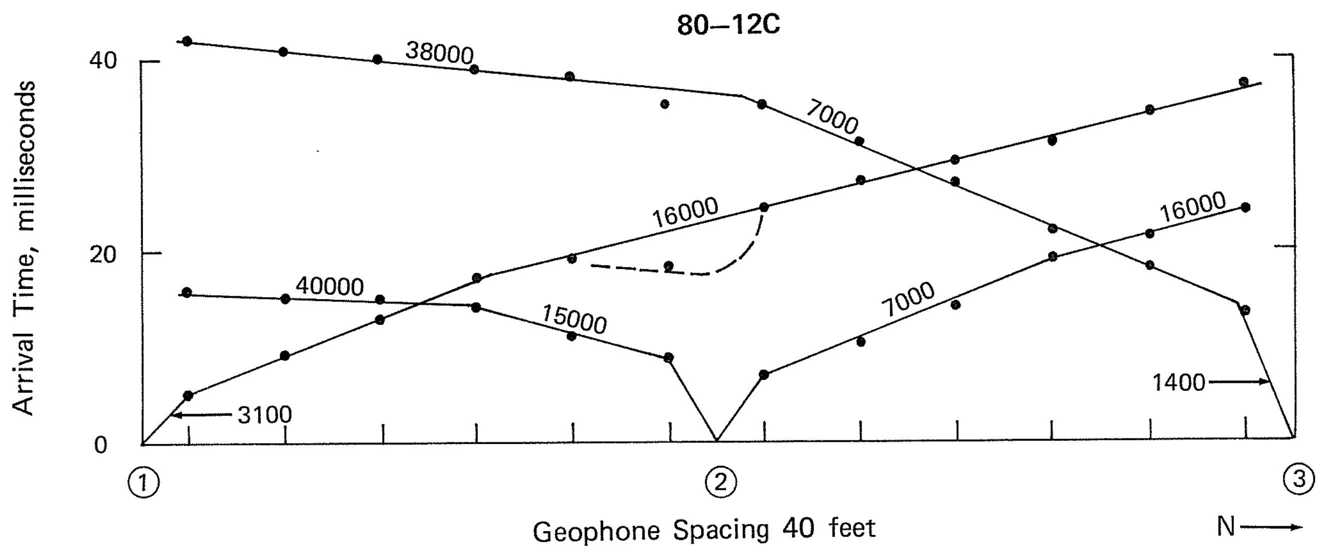


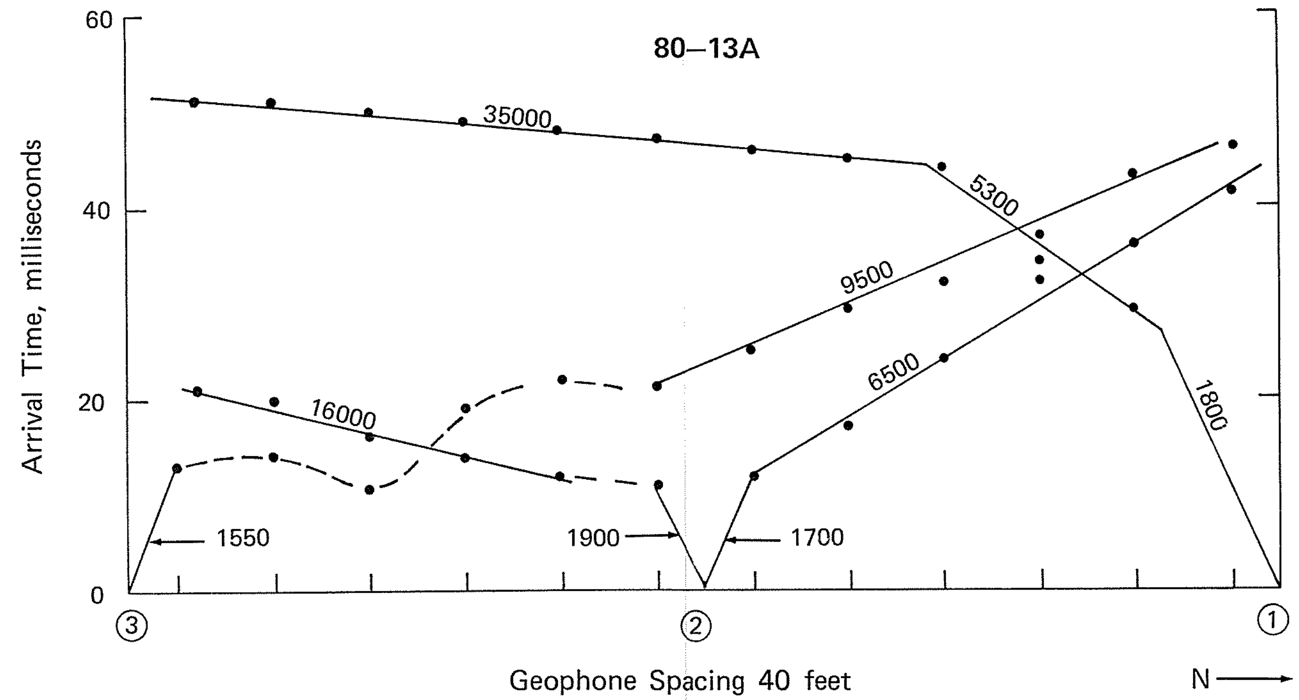
See Sheet 1 for Explanation.

WOODWARD-CLYDE CONSULTANTS	
TIME DISTANCE PLOTS Sheet 8 of 10	
Project No. **41306I** **SUSITNA DAM**	Fig. A-8



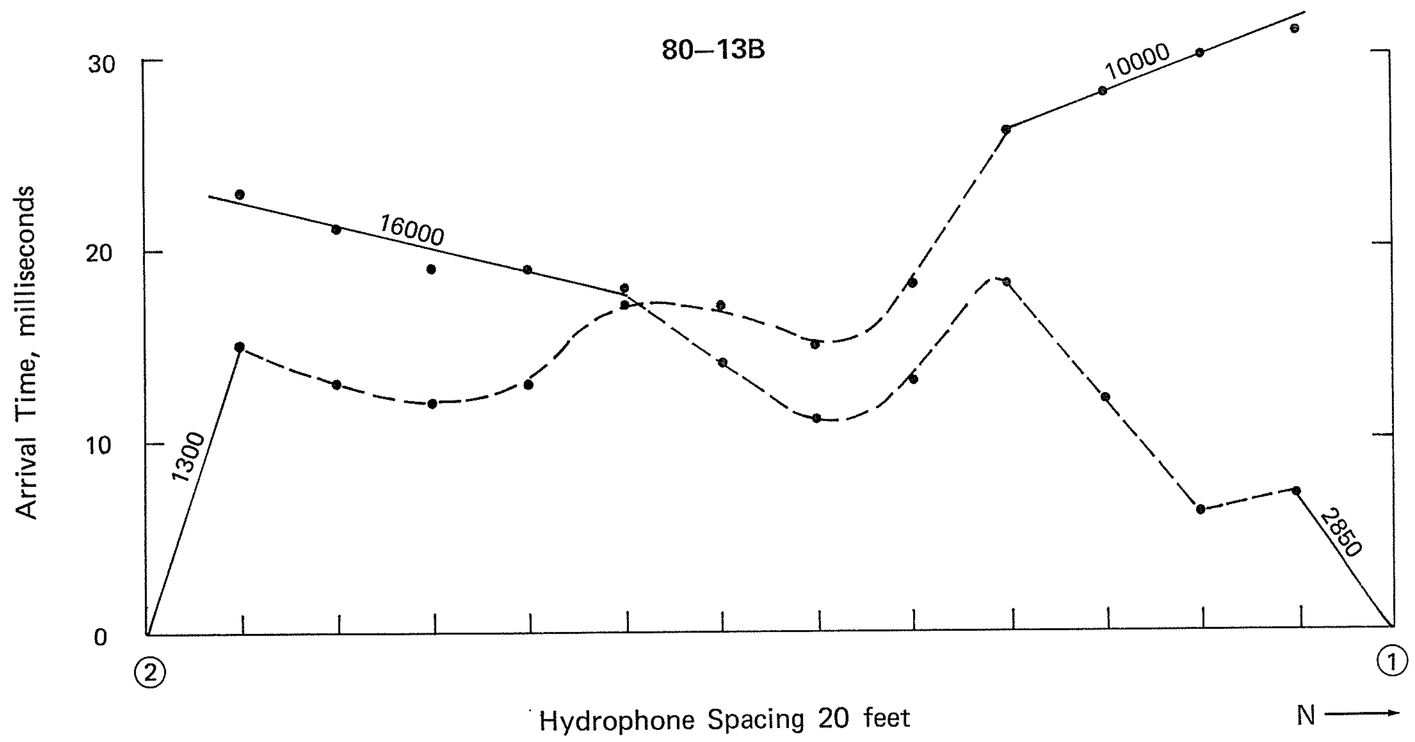


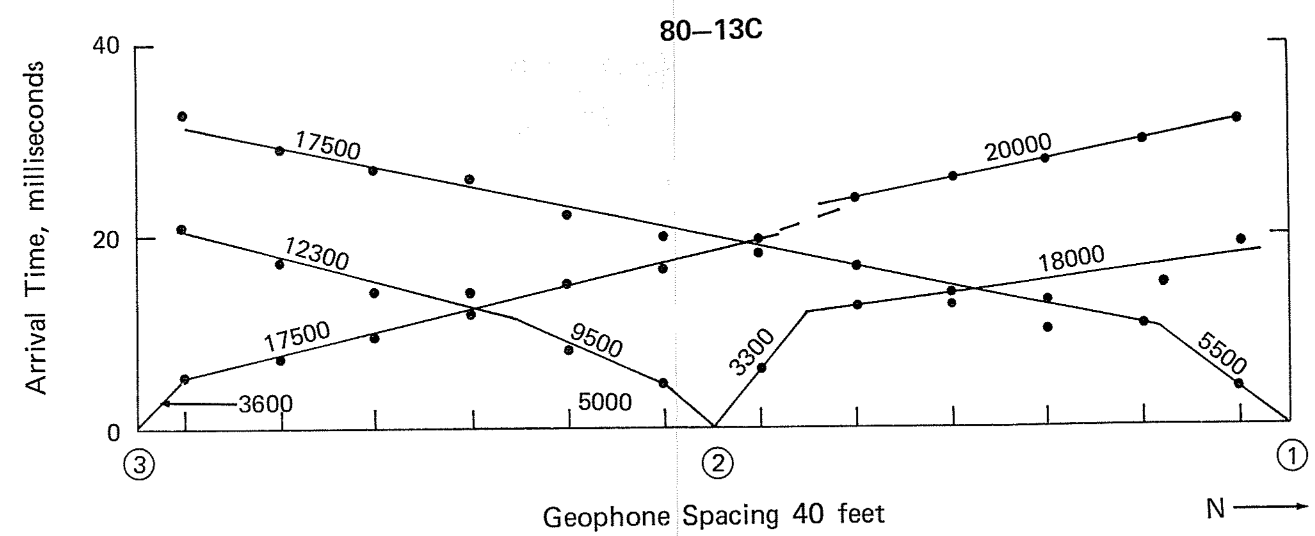


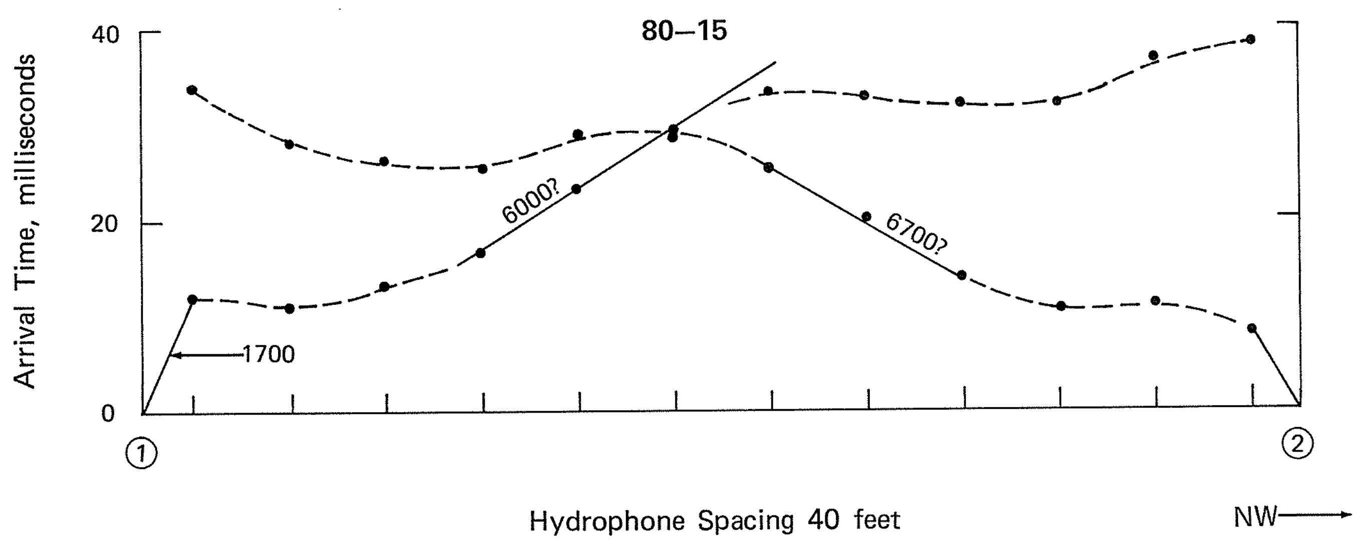


See Sheet 1 for Explanation.

WOODWARD-CLYDE CONSULTANTS	
TIME–DISTANCE PLOTS **Sheet 9 of 10**	
Project No. **41306I** **SUSITNA DAM**	Fig. **A-9**







See Sheet 1 for Explanation.

WOODWARD–CLYDE CONSULTANTS	
TIME–DISTANCE PLOTS Sheet 10 of 10	
Project No. 41306I SUSITNA DAM	Fig. A-10

APPENDIX E

GEOPHYSICAL LOGGING

Prepared By: Exploration Data Consultants, Inc.
(To be provided separately when available)

APPENDIX F

AIR PHOTOINTERPRETATION

Prepared By: R&M Consultants, Inc.
(To be provided separately when available)