SUSITNA HYDROELECTRIC PROJECT

FY 83 PROPOSED GEOTECHNICAL EXPLORATION PROGRAM

FINAL

JULY, 1982

Prepared by:

ACRES

ALASKA POWER AUTHORITY

DCNO 63

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1 - INTRODUCTON

This report details the proposed fiscal year 1983 (FY83) (July 1, 1982 through June 30, 1983) Task 5 Geotechnical program for the Susitna project. The scope of work has been directed to build upon the Task 5 Geotechnical Explorations completed in 1981, with objectives of reinforcing the feasibility recommendations and of addressing the areas of concern identified by the Acres and APA consultant boards and review panels. The level of effort for FY83 has been mandated by scheduling and logistic constraints and available budget. Because the Watana site is scheduled to be the first site developed, all FY83 activities will be directed toward that site.

The FY83 field program will be performed in three phases. Phase I field work will commence on July 1 and continue through September 30; Phase II will begin in December - January and continue through March - April; and Phase III will commence in April - May and continue through the end of fiscal year. Subsequent phases of study would be a continuation of Phase III activities.

This report is intended to provide a detailed explanation of the scope, objective, methodology of approach, and schedule for the FY83 activities. It is the intent of this report to set forth a general exploration program to be followed, not to "lock-in" the proposed field activities. To expedite the project, field data will be primarily reduced and interpreted in the field. This will assist the field personnel in guiding and revising the field studies as required to meet the objectives of the project. Activities in the Buffalo office will provide backup statistical analysis, review and comment on the field interpretation, and final report and drawing preparation. Contract preparation and administration functions will also be supported by the Buffalo personnel.

Work performed during Phase I will be used in detailed planning of the subsequent phases of work. The four principal areas that will be investigated during FY83 are:

- Relict Channels;
- Borrow Site D;
- Borrow Sites E and I; and
- Damsite.

The FY83 program will involve a multidisciplinary approach to include geologic mapping, geophysical explorations, subsurface investigation, and laboratory testing. The following sections detail the scope, methods, and schedule for Phase I and II activities. The scope of Phase III will be dependent on information obtained in Phases I and II, as well as budgetary constraints for the fiscal year, and therefore are not detailed in this document.

2 - DAMSITE INVESTIGATION

2.1 - General

The FY83 damsite investigation will be a continuation of the previous investigation performed during 1980-81 programs (1980-1981 Geotechnical Report). The principal objectives are to:

- Extend geologic mapping and confirm interpretations previously performed onsite;
- Determine depth of river alluvium beneath the proposed main dam and cofferdam;
- Detail overburden depth and general rock quality in the proposed major structure arch; and
- Determine rock condition in areas of proposed major civil structures.

The damsite investigations will consist of geologic mapping during Phase I; seismic profiling during Phases I and II; and drilling during Phases II and III. Details of the damsite exploration plans are shown in Figure 2.1 and are described in Tables 2.1 through 2.3. A schedule of field activities is contained in Section 8.

2.2 - Civil Structures

(a) Main Dam and Cofferdam Riverbed Foundations

(i) Objectives

The objectives of this investigation will be to conduct explorations for riverbed foundation conditions for the cofferdams and main dam. Explorations will examine both alluvial and bedrock conditions beneath the river and on the immediate adjacent abutments. Data from this task will be used in developing the general arrangement

and design of the cofferdams, and represents a significant and critical factor in determination of design parameters and criteria for cofferdam diversion and main dam planning.

(ii) Approach

The alluvial deposits of the Susitna River, as determined to date, consist of gravel, cobbles, and boulders with a sand matrix. The thickness and type of material, as well as bedrock conditions, are known at only a few locations. Development of the general arrangement and design of cofferdams and the main dam will require detailed data on the following: thickness and types of alluvial material, frozen layers (if any), top of bedrock surface, bedrock lithology and structure, and depth to sound rock. The FY83 investigations to obtain this information will consist of geologic mapping, geophysical explorations, and drilling. Geologic mapping, which will be performed during Phase I, will consist of two parts: first, examination of the geology in the immediate area of the proposed cofferdam locations; and, second, mapping of geologic structures on the abutments which may affect dam and cofferdam locations and design. The latter work will be discussed in a subsequent section. Geologic mapping of the cofferdam sites will consist of examining alluvial and bedrock conditions in the immediate area of the planned locations and extrapolation of this information to tie in with information from the damsite geologic mapping and previous explorations.

During the winter a seismic refraction survey will be performed on the frozen river surface. The surveys will run from "The Fins" to downstream of the "Fingerbuster" (upstream to downstream damsite limits) to define the top of bedrock surface and alluvial thickness. The seismic lines will be arranged in a grid pattern both perpendicular to the dam axis and along the center of the river (Figure 2.1 and Table 2.2). The results of this survey will be the basis for selecting river borehole locations and for refinement of the

top-of-rock maps. Boreholes will be drilled during the winter from the surface of the frozen river to confirm the seismic line data and to sample alluvium and bedrock. A "Becker" type hammer drilling, capable of drilling 400-600 feet deep in alluvial material will be used for the drilling and sampling. Drilling will consist of both plug holes and sampled holes (Table 2.3). Plug holes (holes without systematic, deliberate sampling or coring, although sampling of the disturbed material will be conducted for hole-logging purposes) will be drilled to confirm fluvial thickness and depth to sound bedrock as a calibration check on the seismic lines. Sampled holes will continuously sample the alluvium and bedrock. Rock drilling, for both plug and sampled holes, will continue until a minimum of 10 feet of sound bedrock is encountered to ensure that large boulders are not mistaken as bedrock. A minimum of two of the holes beneath the core of the proposed dam will be core-drilled to a depth of 50-100 feet and pressure-tested to determine rock permeability and to assess the quality of rock at various depths.

(iii) Schedule

Geologic mapping for the cofferdam locations will be done by the team of two geologists who conducted mapping in the damsite in 1981. Because of the priority, this mapping will be done at the onset of the field season in Phase I. During the winter when ice conditions on the river are suitable, approximately 11,000 feet of seismic lines will be run along the axis of the river and an additional 4,100 linear feet in the cofferdam areas (Table 2.2). Drilling of the river alluvium will commence after completion of at least the initial seismic lines. A total of four drill holes are planned for each cofferdam site: two sample holes and two plug holes. Total drill footage for the cofferdam sites is estimated to be 800 feet. An additional seven drill holes will be drilled beneath the proposed main dam, and two holes are planned to verify the seismic refraction data in the plunge pool area. While Table 2.3 details the assigned priority of these holes, the actual order of drilling and number of

holes will be controlled by the effectiveness of the seismic refraction surveys and drilling rate. Since the river drilling program requires a thick, stable ice cover, the drilling in the damsite area will be performed according to available climatic and snow and ice cover conditions rather than a fixed number of holes.

(b) Portals

Portals include the upstream diversion tunnel portals and downstream diversion and outlet facilities, access, and tailrace tunnel portals.

(i) Objectives

The objectives of the portal investigation will be to conduct explorations for portal locations, orientations, and support requirements for upstream and downstream portals. Explorations will examine and define overburden materials and bedrock conditions and provide more definitive information on specific conditions at the proposed portal areas. While very detailed drilling and possibly test adits will be necessary for deliberate portal design, the FY83 program is expected to produce adequate information to allow preliminary siting design for these structures.

(ii) Approach

The primary geologic structures which may have an effect on the upstream and downstream portal design are the geologic structures referred to as "The Fins" and the "Fingerbuster," respectively (Figure 2.2). These features will be the main focus of data gathering. Both areas are characterized by northwest and north trending shear, fracture, and alteration zones. Bedrock is well exposed in "The Fins" in a series of cliff faces. Outcrops are not as common in the "Fingerbuster" where talus covers much of the area.

The investigation will examine and describe the type and thickness of overburden material, bedrock lithology and structure, depth to

sound bedrock, rock permeability, permafrost (if present), ground water table, and areas of potential slope instability. Explorations for the portals will consist of geologic mapping, seismic refraction surveys, and drilling. Explorations will be more detailed and concentrated than during previous investigations. Geologic mapping will precede other forms of exploration in the summer of FY83 (Phase I), and will form the basis for locating seismic lines and drill holes. Geologic mapping will consist of identifying and describing the following: overburden material and extent, bedrock outcrop extent, bedrock lithology, joints and joint spacings, shear, fracture and alteration zones, and areas of potential slope instability. For the upstream portal, mapping will be done in an area approximately 500 feet upstream and downstream from the proposed portal locations and between river level and elevation 1,800 feet. Mapping for the downstream portals will cover an area from the toe of the proposed dam to the "Fingerbuster" shear zone, approximately 1,500 feet, and between river level and elevation 2,000 feet (Figure 2.2). Data from the mapping will be plotted on maps and sections at enlarged scales and on joint stereo plots. These data will be interpreted and used for further explorations and design requirements.

A seismic refraction survey will be run in the downstream portal area to define overburden thickness structures and depth to sound bedrock. Seismic lines will be run in a grid pattern based on the results of geologic mapping (Figure 2.1). An estimated 6,600 feet of seismic lines will be run. A 550-foot seismic line is planned at this time for the upstream portal. This line will be run on the frozen river surface immediately offshore of "The Fins" structure (Phase II).

Boreholes are planned to be drilled in both portal areas to determine type and thickness of overburden material, subsurface geologic conditions, rock permeability and ground water conditions. Drilling will consist of approximately 6 to 10 predominantly angled boreholes to various depths during Phase III. Total drill footage is estimated at 2,000 linear feet. Bedrock will be continuously cored, and

core samples will be logged for lithology and structure. Selected samples will be tested for unconfined compressive strength using a point load tester. Following completion of the drilling, joint and fracture orientations at depth will be determined using a borehole camera. Water pressure testing will be done over the length of the borehole to determine rock permeability. At least one borehole in the upstream portal area and two boreholes in the downstream portal area will be instrumented with piezometers for ground water monitoring.

(iii) Schedule

Geologic mapping will begin following completion of cofferdam site mapping. One two-man team of geologists will be used for mapping the portal areas. Seismic surveys will be run following geologic mapping in Phase I. Diamond core drilling would be done during Phase III.

(c) Spillway and Intake Area

This area includes the entire main spillway, control structure, and powerhouse surface areas, including the emergency spillway intake channel area.

(i) Objectives

The objective of investigating the spillway and intake areas is to locate any geologic features which pass through the area and might present adverse foundation or underground support problems.

(ii) Approach

The geologic features which are identified in the shear, fracture, and alteration zone studies (Section 2.3a) will be traced where possible into the proposed civil structure sites. Particular emphasis will be placed on the potential work slope stability problems in the intake and spillway channel cuts.

The investigation will commence in Phase I with geologic mapping by the same team that is performing the other damsite geologic mapping, and will be followed by seismic refraction lines down the proposed spillway centerline, flip bucket area, and general intake area. The specific seismic refraction lines scheduled for this area of the north abutment total 6,600 feet.

Borings in the intake facility and powerhouse area, which would be conducted in Phase II, would be planned to explore the structure location and simultaneously intercept any significant inferred geologic features in the vicinity. These borings would be the same ones discussed in Section 2.3(a)(ii).

(iii) Schedule

The geologic mapping will be conducted late in the Phase I program, after the potential geologic features have been identified elsewhere in the damsite. Seismic lines will be run before the detailed mapping to serve as a guide for mapping. Boreholes in this area would be drilled in Phase III.

2.3 - Geologic Structures

(a) Shear, Fracture, and Alteration Zones

The shear, fracture, and alteration zones are the northwest and north trending geologic features identified during the 1980-81 explorations. This aspect of the exploration does not include "The Fins," "Fingerbuster," and geologic features GF7 and GF8 which will be investigated during subsequent detailed exploration (Figure 2.2, Section 2.3c).

(i) Objectives

The objectives of the geologic structure investigation are to provide adequate geological and geotechnical information for developing the general arrangements. Explorations will be directed to determining the nature and extent of these geologic features on the surface and representative conditions at depth.

(ii) Approach

Northwest and north trending geologic structures, which include shear, fracture, and alteration zones, were identified during previous investigations. These features were tentatively correlated across the site on the surface and to depth in boreholes. The FY83 investigation will attempt to confirm these geologic interpretation and further delineate the trace, continuity, and attitudes of the less significant structures.

Principal attention will be directed to the right abutment where the majority of civil structures are tentatively proposed.

Specific areas requiring further investigation are geologic features GF2, GF3, and GF4, which were defined in the 1980-81 program as potentially projecting into the proposed powerhouse intake area (Figure 2.2).

Explorations for the northwest and north trending geologic structures will consist initially of geologic mapping and seismic refraction surveys (Phase I) followed by diamond core drilling (Phase III). Geologic mapping will precede other forms of exploration and will be the basis for locating the seismic lines and boreholes. Geologic mapping will consist of identifying and describing the following: type of geologic structure, orientation and extent, degree of weathering or alteration and joint sets, and spacing. Geologic data will be plotted on maps and sections at a suitable scale. These data will be interpreted in the field and used as the basis for planning future explorations. Mapping will consist primarily of traversing the extent of the structures and accurately locating their positions. Cross traverses will be run across the abutments as necessary. Most of the traverses will be done on the north abutment between "The Fins" and "Fingerbuster" shear zones from river level to elevation 2,300 feet. On the south abutment, mapping will extend from geologic feature GF1B to GF6B and from river level to elevation 2,000 feet (Figure 2.2).

Seismic refraction lines will be run on both abutments to define the location of low velocity zones related to shear, fracture, and alteration zones, as well as thickness of overburden materials and depth to sound bedrock (Figure 2.1). On the north abutment, one seismic line will be run from "The Fins" area parallel to the slope at about elevation 1,500-1,700 feet downstream to the "Fingerbuster" shear zone. This line will cross the entire abutment and all major geologic structures. An additional seismic line at approximately elevation 2,050 feet will connect seismic lines SL81-15 and SW-2 to complete coverage at this elevation. An estimated 4,600 linear feet of seismic lines will be run on this abutment. On the south bank, one seismic line will be run eastward from the end of SL81-20 between elevation 2,000 and 2,050 feet. This line will help define the extent of the geologic features GF3 and GF4. Line length is approximately 2,200 linear feet. Seismic velocities will be plotted on maps and sections at the same scale as geologic data. Correlations will be made where possible between low seismic velocity zones and mapped surface expressions of geologic structures.

Based on the interpretation of geologic and seismic data, boreholes will be drilled (in Phase III) across various geologic structures to verify their presence and define their subsurface characteristics. Data will include joint spacing and, where possible, orientation, rock permeability and strength, and ground water and permafrost conditions. Drilling will consist of approximately 10 angled boreholes to an average depth of 500 feet. Locations of these borings will be based on Phase I and II activities. Boreholes may be drilled on both abutments and crossing beneath the river. Bedrock will be continuously cored, and core samples will be logged for lithology and structure. Selected samples will be tested for unconfined compressive strength using a point load tester. Following completion, fracture and joint orientation at depth may be determined using a borehole camera and borehole geophysical logging. Water pressure testing will be done over the length of the borehole to determine rock permeability. Selected boreholes will be instrumented with piezometers and thermistors for ground water and temperature monitoring.

(iii) Schedule

Geologic mapping will begin following portal area mapping. One two-man team of geologists will be used for mapping on the abutments Diamond core drilling will be done during Plase III following completion of portal area drilling.

(b) Pluton Structure

(i) Objectives

The objective of this investigation is to establish the geologic model for the damsite area and potential quarry sources for general site arrangements. Explorations will examine the extent of the diorite pluton, the nature of its contacts with adjacent rock types, and its structural relationships.

(ii) Approach

The Watana damsite is underlain by a diorite pluton which has intruded into surrounding metasedimentary. West of the damsite, the pluton is overlain by andesite porphyry which, in turn, appears to be overlain by volcaniclastic rocks. The andesite porphyry has intruded the diorite pluton. The contact between the diorite and andesite porphyry is locally fractured with minor, local shearing. The andesite porphyry immediately above the contact is generally highly fractured, however, the underlying diorite is generally unfractured. The eastern boundary of the pluton has been projected to cross through the reservoir area east of the damsite; however, this contact has not been adequately defined. The pluton is cross-cut by shear, fracture, and alteration zones. The origin of these zones, whether due to regional tectonic forces, local pluton related forces, or a combination of the two, has not been determined.

Understanding of the lithology, structure, and contacts of the pluton and surrounding rocks requires the preparation of a geologic model of the development of the diorite pluton and surrounding rocks in the damsite area. The geologic model can be used to predict the nature and extent of various lithologies and structures where there is a scarcity of data.

Explorations for the development of a geologic model for pluton structure will consist of geologic mapping based on previous investigations. Mapping will consist of describing and defining the limits of diorite pluton, nature of lithologic contacts, nature of geologic structures at the contacts, and extent of geologic structures away from the main damsite. Geologic mapping will be done upstream and downstream from the damsite along the Susitna River, on Tsusena and Deadman Creeks, in Quarry Site A, and any other suitable locations as determined by aerial reconnaissance. Geologic mapping for this investigation will not require the level of detail or control as that done for the portals, cofferdams or shear, fracture, and alteration zones. Detail airphoto interpretation will be done prior to mapping to identify locations to be mapped.

In addition, detailed petrographic studies and age dating may be performed on various rock types collected during the mapping program to determine mineralogy, lithology, and the sequence of geologic events.

(iii) Schedule

Geologic mapping for pluton structures will require a team of two geologists during Phase I.

(c) "The Fins" and "Fingerbuster"

(i) Objectives

The objective of this investigation is to complete explorations of these geologic features for general arrangements and design of un-

derground civil structures. Explorations will examine and define the surface and subsurface nature and extent of these features.

(ii) Approach

"The Fins" and "Fingerbuster" bound the damsite on the upstream and downstream sides, respectively (Figure 2.2). Both features contain major northwest and north trending shears, fractures, and alteration zones which would have a significant impact on costs for any civil structures located within them. At present, these structures have been identified on the north abutment and tentatively projected to the south bank based on correlation with boreholes, seismic data, and topography. This investigation will attempt to confirm these correlations and define and describe, in detail, the surface and subsurface characteristics of these features. Explorations will consist initially of geologic mapping, followed by seismic refraction surveys (Phase I and II) and diamond core drilling (Phase III). Geologic mapping will be the basis for locating seismic lines and boreholes. Mapping will consist of identifying and describing the following: type of geologic structure, orientation and extent, degree of weathering or alteration, and joint sets, continuity, and spacing. Geologic data will be plotted on maps and sections at suitable scales. This data will be interpreted in the field for use in planning further explorations. Geologic mapping will consist of tracing the extent of these features by ground traverses and aerial reconnaissance. Mapping on the north bank will extend from the Susitna River to Tsusena Creek. On the south bank, limited outcrops restrict mapping to within about one mile of the river.

Seismic refraction lines will be run in both "The Fins" and "Fingerbuster" areas to define the extent of low seismic velocity zones related to these features, thickness of overburden, and depth to sound bedrock. The amount and location of seismic lines is dependent on the results of geologic mapping. An estimated 3,300 linear feet are planned for "The Fins" and 3,300 linear feet for the "Fingerbuster" (Figure 2.1).

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Seismic refraction lines will be run in both "The Fins" and "Fingerbuster" areas to define the extent of low seismic velocity zones related to these features, thickness of overburden, and depth to sound bedrock. The amount and location of seismic lines is dependent on the results of geologic mapping. An estimated 3,300 linear feet are planned for "The Fins" and 3,300 linear feet for the "Fingerbuster" (Figure 2.1).

(iii) Schedule

Geologic mapping of "The Fins" and "Fingerbuster" is planned during Phase I with two geologists forming a team.

2.4 - Miscellaneous Investigations

(a) Instrumentation of Existing Boreholes

(i) Objectives

The objective of these explorations is to gain additional data on ground water and permafrost conditions in the bedrock at the main damsite for design and construction activities.

(ii) Approach

To complete the 1980-1981 instrumentation program at the damsite requires installation of additional piezometers and thermistors. At present, thermistors are located on the north abutment in BH-3 and BH-6. It is proposed that a thermistor string be installed in BH-8 (drilled in 1981) to evaluate permafrost conditions on the south abutment. Thermistor construction would be the same as the existing units with 16 thermistor points along a 250 foot cable.

Two piezometer installations are proposed for special conditions in Boreholes BH-4 and BH-12. A pneumatic piezometer tip will be installed at the elevation of the powerhouse in BH-4 to determine water pressure conditions at this depth. In BH-12, a pneumatic piezometer tip will be installed below the artesian aquifier at about 400 feet.

To install the piezometers and thermistors, boreholes BH-4, BH-8, and BH-12 will have to be reamed out to the required depths to allow placement. Approximately 1,600 feet of reaming will be required.

(iii) Schedule

This work will be undertaken during Phase III.

(b) Survey Control

(i) Objective

The objective of establishing survey control is to establish adequate ground control for use in damsite investigations and to control the field mapping activities.

(ii) Approach

Upon commencing work in July, a survey grid will be established on both abutments and along the river for ground control. The grid will be on an average of 500-foot spacing with permanent markers established at designed locations. The grid will be tied into the state of Alaska grid system, which is the system established at the site in 1980-81.

All field exploration performed on the damsite will be controlled by the surveyed grid.

(iii) Schedule

Work on establishing the grid will be undertaken in the early part of Phase I.

TABLE 2.1: FY83 EXPLORATORY PROGRAM - PHASE I
WATANA DAMSITE GEOPHYSICAL SURVEYS

Seismic Refraction Line No.*	Location**	Approximate Length (ft)	Purpose
SL82-D***	Downstream Portals, BH-6 towards BH-2	2,200	Depth to bedrock, overburden thickness.
SL82-E	Downstream Portals, DM-C to SW2	1,100	Overburden thickness, bedrock conditions.
SL82-F	Downstream Portals, SW-2 to river	1,100	Overburden thickness, bedrock conditions.
SL82-G	Flip Bucket, Spillway Area Rock Stability	1,100	Overburden thickness, bedrock conditions in "Fingerbuster".
SL82-H	Downstream Portals, mid slope	2,200	Overburden thickness, bedrock conditions, NW and N shears.
SL82-I	DH-9 to SL80-2	1,100	Overburden thickness, bedrock conditions, NW and N shears, overall slope stability.
SL82-J	Spillway	4,400	Overburden thickness, bedrock conditions, NW and N shears.
SL82-Ka	North Abutment	2,200	Overburden thickness, bedrock conditions, NW and N shears.
SL82-Kb	Upstream North Abutment	1,100	"The Fins," NW and N shears.
SL82-L	Powerhouse Area	2,200	"The Fins," NW and N shears.
SL82-M	Upstream South Abutment	2,200	NW and N shears.
SL82-N	North Abutment, SL81-15 to SW-2	1,300	NW and N shears.
SL82-O	North Abutment	1,100	"The Fins," and possible east-trending structures.
SL82-P	Upstream South Abutment	1,100	"The Fins".
SL82-Q	Downstream Portal Area, Right Bank	1,100	"Fingerbuster".
SL82-R	Downstream Portal Area, Right Bank		
	TOTAL	26,600	

*Seismic lines listed in order of priority, seismic lines SL82-A through C are listed on Table 4.2.
**See Figure 2.1.
***Upon execution of work, temporary line letters will be replaced with a permanent chronologically sequential line number.

TABLE 2.2: FY83 EXPLORATORY PROGRAM - PHASE II
WATANA DAMSITE GEOPHYSICAL SURVEY

Seismic Refraction Line No.	Location	Approximate Length (ft)	Purpose
SL83-AA*	Upstream Cofferdam Centerline	800	Depth of overburden and bedrock conditions.
SL83-BB	Upstream Cofferdam, River Centerline	1,100	Depth of overburden, bedrock conditions, and "The Fins".
SL83-CC	Main Dam Centerline	500	Depth of overburden and bedrock conditions.
SL83-DD	Downstream Cofferdam, River Centerline	1,100	Depth of overburden, bedrock conditions, and "Fingerbuster".
SL83-EE	Downstream Cofferdam	550	Depth of overburden, bedrock conditions,
SL83-FF	Downstream Cofferdam Centerline	550	Depth of overburden, bedrock conditions, and "Fingerbuster".
SL83-GG	Upstream Portal	550	Depth of overburden, bedrock conditions, and "The Fins".
SL83-HH	Main Dam River Centerline	3,850	Depth of overburden, bedrock conditions, and NW and N shears.
SL82-II	Main Dam Upstream Toe	550	Depth of overburden and bedrock conditions.
SL83-JJ	Main Dam Upstream of Centerline	550	Depth of overburden and bedrock conditions.
SL83-KK	Main Dam Downstream of Centerline	400	Depth of overburden and bedrock conditions.
SL83-LL	Main Dam Downstream Toe	550	Depth of overburden, bedrock conditions, and "Fingerbuster".
SL83-MM	Plunge Pool	500	Depth of overburden, bedrock conditions, and "Fingerbuster".
SL83-NN	Plunge Pool	1,100	Depth of overburden, bedrock conditions, and "Fingerbuster".
SL83-OO	Plunge Pool	2,200	Depth of overburden, bedrock conditions, and "Fingerbuster".
	TOTAL	14,850	

*Upon execution of work, temporary line letter designation will be replced with a permanent chronologically sequential line number.

TABLE 2.3: FY83 EXPLORATORY PROGRAM
WATANA DAMSITE HAMMER DRILLING PROGRAM

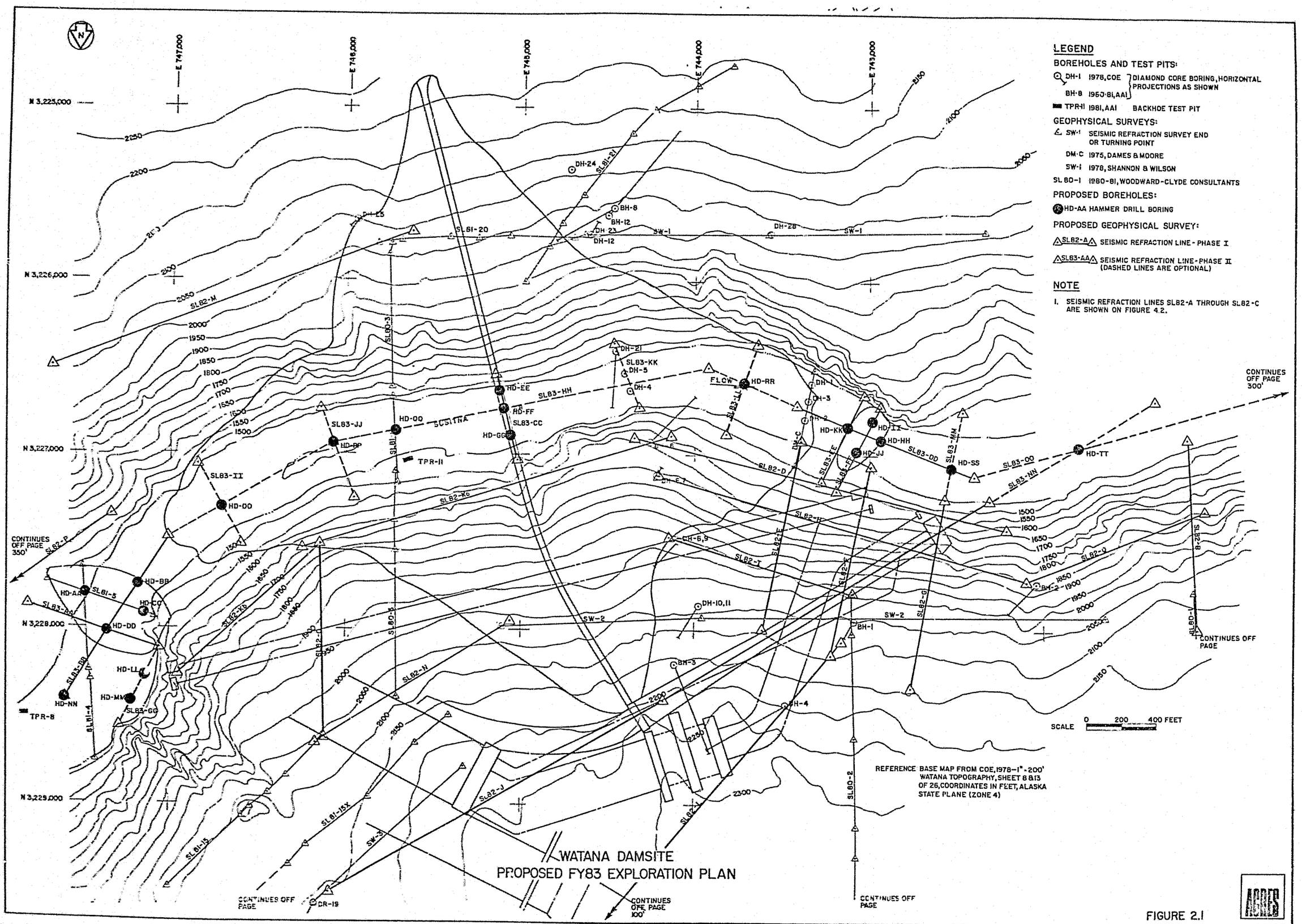
Drill Hole* Number	Location**	Approximate Depth (ft)***	Sampling	Purpose
Upstream Cofferdam				
HD-AA****	SL81-4, SLB1-5	110	Alluvium and rock	Overburden material and thickness, bedrock surface, lithology and structure.
HD-BB	SL83-BB	120	Alluvium and rock	Same as above.
HD-CC	SL81-5	90	Alluvium	Overburden material and thickness.
HD-DD	SL83-AA and SL83-BB	100	Alluvium	Same as above.
Main Dam				
HD-EE	Centerline SL83-CC	85	Alluvium	Same as above.
HD-FF	Centerline SL83-CC and SL83-HH	130	Alluvium and rock	Overburden material and thickness; bedrock surface, lithology and structure.
HD-GG	Centerline SL83-CC	95	Alluvium	Overburden material and thickness.
Downstream Cofferdam				
HD-HH	SL83-DD	110	Alluvium and rock	Overburden material and thickness; bedrock surface, lithology, and structure.
HD-II	SL83-FF	95	Alluvium	Overburden material and thickness.
HD-JJ	SL83-FF	75	Alluvium and rock	Overburden material and thickness; bedrock surface, lithology, and structure.
HD-KK	SL83-EE and SL83-DD	80	Alluvium	Overburden material and thickness.
Upstream Portals				
HD-LL	SL83-GG	70	Alluvium	Same as above.
HD-MM	SL83-GG	70	Alluvium	Same as above.
HD-NN	SL83-BB	100	Alluvium	Same as above.
Main Dam				
HD-OO	Upstream Toe, SL83-HH and SL83-II	100	Alluvium	Same as above.
HD-PP	SL83-JJ and SL83-HH	130	Alluvium and rock	Overburden material and thickness; bedrock surface, lithology and structure.
HD-QQ	SL81-16	100	Alluvium	Overburden material and thickness.
HD-RR	Downstream Toe, SL83-HH and SL83-II	130	Alluvium and rock	Overburden material and thickness; bedrock surface, lithology and structure.

TABLE 2.3 (Cont'd)

Drill Hole* Number	Location**	Approximate Depth (ft)***	Sampling	Purpose
Plunge Pool				
HD-SS	SL83-MM	90	Alluvium	Overburden material and thickness.
HD-TT	SL83-MM and SL83-00	90	Alluvium and rock	Overburden material and thickness; bedrock surface, lithology and structure.
	TOTAL	1,970		

*Borings listed by priority.
**See Figure 2.1
***Assume 10 feet of rock drilling except 40 feet where rock will be sampled.
****Upon execution of work, temporary boring letter designation will be replaced with a permanent chronologically sequential hole number.

Note: While this table lists priority sequence, holes will not necessarily be drilled in this order, depending on ice conditions, weather, and drilling progress.



LEGEND

BOREHOLES AND TEST PITS:

- DH-1 1978, COE } DIAMOND CORE BORING, HORIZONTAL PROJECTIONS AS SHOWN
- BH-8 1950-81, AAI }
- TPR-11 1981, AAI BACKHOE TEST PIT

GEOPHYSICAL SURVEYS:

- SW-1 SEISMIC REFRACTION SURVEY END OR TURNING POINT
- DM-C 1975, DAMES & MOORE
- SW-1 1978, SHANNON & WILSON
- SL 80-1 1980-81, WOODWARD-CLYDE CONSULTANTS

PROPOSED BOREHOLES:

- HD-AA HAMMER DRILL BORING

PROPOSED GEOPHYSICAL SURVEY:

- SL82-AA SEISMIC REFRACTION LINE - PHASE I
- SL83-AA SEISMIC REFRACTION LINE - PHASE II (DASHED LINES ARE OPTIONAL)

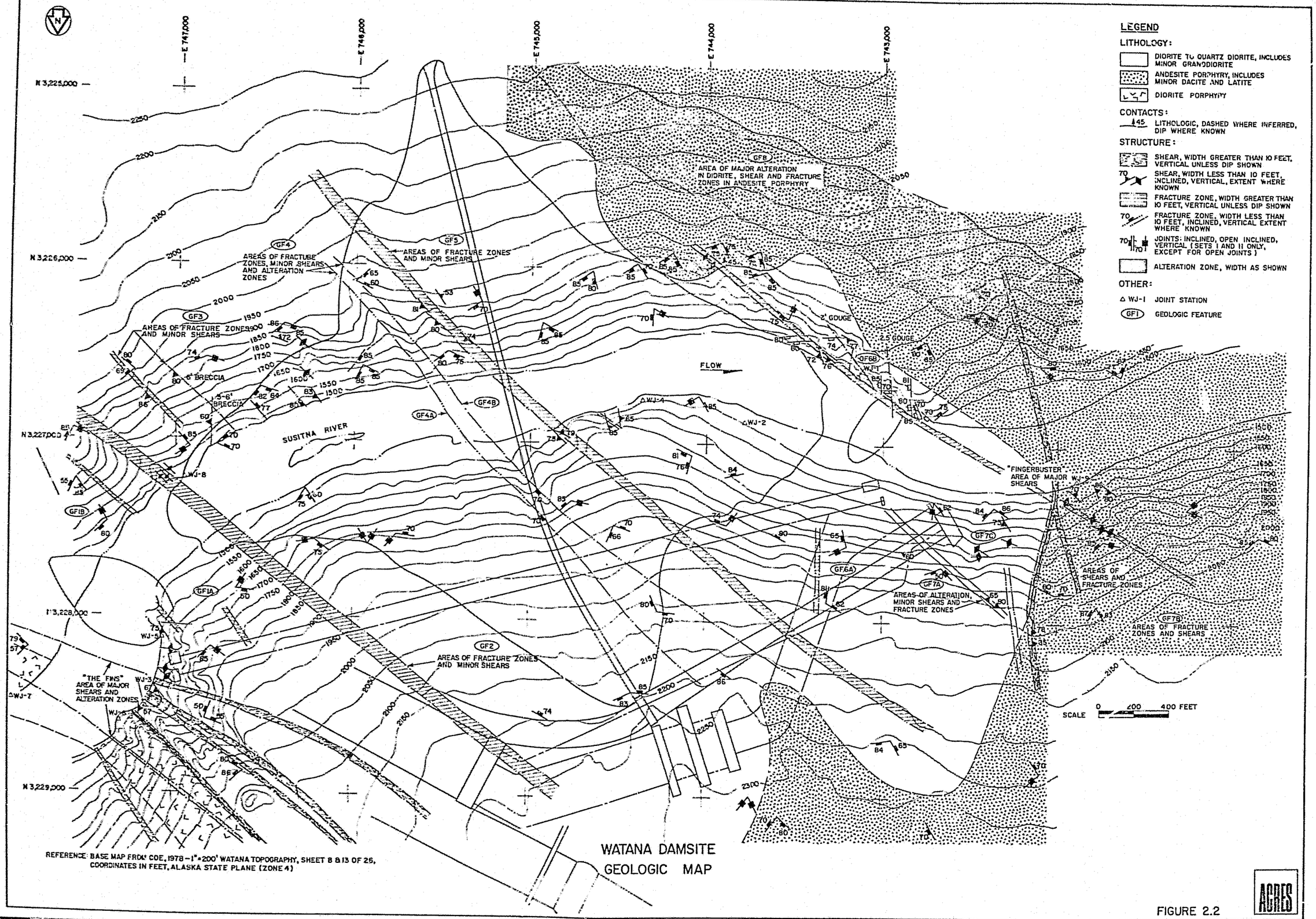
NOTE

1. SEISMIC REFRACTION LINES SL82-A THROUGH SL82-C ARE SHOWN ON FIGURE 4.2.

REFERENCE BASE MAP FROM COE, 1978 - 1" = 200' WATANA TOPOGRAPHY, SHEET 8 813 OF 26, COORDINATES IN FEET, ALASKA STATE PLANE (ZONE 4)

WATANA DAMSITE
PROPOSED FY83 EXPLORATION PLAN

FIGURE 2.1



REFERENCE: BASE MAP FROM COE, 1978 – 1"=200' WATANA TOPOGRAPHY, SHEET 8 &13 OF 26, COORDINATES IN FEET, ALASKA STATE PLANE (ZONE 4)

WATANA DAMSITE
GEOLOGIC MAP

FIGURE 2.2

ACRES

3 - BORROW SITE D

3.1 - General

Borrow Site D has been identified as a zone ranging from 2,000-6,000 feet in north-south dimension, stretching over 12,000 feet from a point on Deadman Creek to the approximate thalweg of the relict channel, including approximately 7,000 feet of exposure as bluffs overlooking the Susitna River, for a total area of about 1,075 acres (Figures 3.1 and 3.2). The area has been identified as the most favorable source for impervious core material for a total estimated site requirement of approximately 8.25 mcy. The information to date on the borrow site comprises seismic refraction surveys, auger holes, several deep rotary drill holes, and shallow test pits.

3.2 - Objectives

The objectives of the FY83 program are to obtain sufficient details to confirm the stratigraphy developed during feasibility, and to develop a clear understanding of material properties, ground water, and permafrost conditions. Results of the FY83 will form the basis for the subsequent detailed design level investigations. The long-range objective of the Borrow Site D investigations will be to determine:

(a) Borrow site stratigraphy and extent of each of the various identified units of interest to a level adequate to develop volume-distance relationships, stripping parameters, and producible volumes.

(b) Define site and adjoining areas, ground water, and permafrost conditions in order to allow optimization of production methodology, mining method, and water/frost handling.

(c) Limits of desired excavation based on geologic conditions and desired material properties and determination of mining methods.

(d) Continuity of material properties and their influence on production, processing, and placement requirements.

(e) Engineering properties of the material as required for placement in the fill, including placement water content, gradation, plasticity, and compaction characteristics. Explorations will place emphasis on detailing volumes of reserve with various properties to allow for selectivity in production, if necessary.

3.3 - Approach

Since Borrow Site D lies within the relict channel area, the exploration for borrow materials will also provide desired information on the relict channel stratigraphy.

The Phase I summer explorations on Borrow Site D will be limited to: surficial outcrop mapping during early summer to delineate exposed borrow materials and bedrock; a seismic refraction survey in both the borrow area and relict channel; and an auger/rotary drilling program which is intended to provide high quality split spoon and "undisturbed" core samples to a depth of approximately 200 feet (Figure 3.2 and Table 3.1). The drilling will be performed with helicopter-transportable rigs equipped with a variety of drill tools enabling it to utilize rotary drilling with casing, hollow stem auger, and conventional wireline coring methods of advance. It is planned that each boring will commence with large diameter casing capable of obtaining 3-inch samples to an approximate depth of 75 feet. It is anticipated that from 100 to 200 feet the auger system will not be effective; therefore, a wireline drill rod will be used with a "casing advancer" rotary tricone bit. Depending on drilling difficulty and sample recovery, it is likely that this method will, in a large portion, replace the augering method of advance. Normal advance procedure will involve taking of frequent samples, as described in a subsequent paragraph, with rotary drilling to overcome boulders and cobble zones and to advance between samples. Proposed borehole and seismic line locations are shown in Figure 3.2. The information collected during the summer program will be used to locate the drill sites for the larger diameter hammer drill boring to be conducted in the winter when over-land access is possible.

The winter Phase II program will be conducted as part of the relict channel exploration program and will involve use of a large hammer drill with large

inside diameter (6-inch) drill pipe (Figure 3.2 and Table 3.2). Continuous sampling of the blown out cuttings will provide large samples of the various stratigraphic units for use in geologic interpretation of the stratigraphy and in materials laboratory testing. In addition, drive and core type samples will be taken at selected intervals.

The drilling program in Borrow Site D will be directed to:

- Obtaining information on the stratigraphy in relict channel and borrow site; and;

- Obtaining bulk samples of the potential borrow materials for subsequent testing.

Due to the primary need for stratigraphic information and the fact that systematic pattern explorations of the borrow reserves will be conducted in the subsequent stage of design investigations, the emphasis of the FY83 program will be put on stratigraphic data collection. The sampling and instrumentation activities carried out in this program will be directed at maximizing the level of information obtained from each boring. Instrumentation will be installed to provide baseline thermal and geohydrologic data. The various methods that will be utilized are described individually below:

(a) Full depth sampling to provide material for geologic examination of the larger particle sizes and for laboratory testing.

(b) Drive and core type sampling as is appropriate using 2- and 3-inch standard split spoon with standard penetration blow counts. Denison sampling, and dry-blocked and conventional fluid circulation core barrel sampling will be conducted.

(c) Casing drive tests (open casing drive tests) for general correlation of stratigraphy and density.

(d) "Undisturbed" samples, using such samplers as fixed piston, "Osterberg," "Shelby," and other special split and tube type barrel samples.

(e) Water level detection and monitoring both during and after drilling to detect various aquifers, perched water zones, and "dry" zones. Due to the preliminary indications that the area has a complex system of ground water levels, most borings will have a minimum of a standpipe type piezometer, and those which penetrate a definite zone of interest may have pneumatic or electric piezometers installed. This system of observation points will be correlated with the relict channel installations.

(f) Limited aquifer permeability testing such as falling head and/or constant head tests will be performed where possible to obtain order-of-magnitude information on the ranges of permeabilities of the materials in the borrow site.

(g) Permafrost detection will be limited to observation of both seasonal and permanent frost during drilling and installation of thermistors in most of the holes. The probes will enable detection of permafrost in the following year after the frost has stabilized, and of the depth of annual frost penetration during the winter. This information will be utilized to evaluate the frost conditions likely to be encountered in excavation and, at a later stage of design, will be used with the results of all thermal investigations data to develop the borrow site production method to minimize the adverse effects of the frost in excavation and fill placement.

(h) Depending on the variability of the stratigraphic units and material properties across the area, and the confidence in the geologic interpretation from recoverd samples, downhole geophysical logging may be conducted. PVC plastic pipe will be installed in the boreholes to allow logging at the end of Phase I or Phase II, if it is deemed appropriate at that time.

(i) Depending on the nature of the materials encountered, special vane, core, or downhole insite density measurement testing may be performed in the boreholes. Standard penetration and tube sample density will be performed as a routine form of testing.

TABLE 3.1: FY83 EXPLORATORY PROGRAM - PHASE I
WATANA RELICT CHANNEL/BORROW SITE D
AUGER DRILLING PROGRAM

Boring* Number	Approximate Location***	Depth (ft)	Instrumentation	Purpose
AH-A	D/RC on SW-3 (Borrow Site D, Relict Channel)	Assume all drill holes to 150 feet	SP	Expand stratigraphic correlations across D/RC.
AH-B	D/RC on DM-A	Same as above	P = 3 T	Same as above.
AH-C	D/RC at Intersection of DM-A and DM-B	Same as above	P = 3 T	Same as above.
AH-D	D/RC, 100 feet E of SW - 5	Same as above	P = 3 T	Same as above.
AH-E	D/RC at intersection of SW-3 and SL80-7	Same as above	SP	Same as above.
AH-F	RC on SL81-14	Same as above	P = 2	Same as above.
AH-G	RC on SL80-2	Same as above	P = 3	Same as above.
AH-H**	RC on SL80-1	Same as above	SP	Same as above.
AH-I**	RC on SL82-A	Same as above	SP	Same as above.
AH-J	RC on SL80-1	Same as above	P = 3	Same as above.
AH-K**	RC on SL82-B	Same as above	SP	Same as above.
AH-L	RC on SW-3	Same as above	SP	Same as above.
AH-M	D/RC on SL80-7	Same as above	P = 3 T	Same as above.
AH-N**	D/RC near TP-21	Same as above	SP	Same as above.
AH-O**	RC	Same as above	SP	Add detail to stratigraphy and material properties.
AH-P**	D	Same as above	SP	Same as above.
AH-Q	D	Same as above	P = 3 T	Same as above.
AH-R	D Near DR-14 on SW-3	Same as above	SP	Same as above.
AH-S**	D on SL80-8	Same as above	SP	Same as above.
AH-T**	RC at intersection of SL81-14 and SL82-C	Same as above	SP	Same as above.
AH-U	RC on SL81-15X	Same as above	P = 3	Same as above.
AH-V	RC on SL82-A	Same as above	SP	Same as above.
AH-W	RC on SL80-2	Same as above	SP	Same as above.
AH-X	RC between DR-19 and DR-20	Same as above	T, SP	Same as above.

TABLE 3.1 (Cont'd)

Boring* Number	Approximate Location***	Depth (ft)	Instrumentation	Purpose
AH-Y**	D/RC on SL81-6	Assume all drill holes to 150 feet	SP	Add detail to stratigraphy and material properties.
AH-Z	D on SW-3	Same as above	SP	Same as above.
AH-AA	RC between DR-26 and DR-22	Same as above	P = 2, SP	Same as above.
AH-BB	RC on SL81-13	Same as above	P = 2, SP	Same as above.
AH-CC	RC on SL80-1	Same as above.	SP	Same as above.
AH-DD**	RC on SL82-B	Same as above.	SP	Same as above.
AH-EE	RC on DM-A	Same as above.	P = 1	Same as above.
AH-FF	D/RC near AH-D-8	Same as above.	P = 3	Same as above.
AH-GG	D on DM-A	Same as above.	SP	Same as above.
AH-HH	D near AN-D-10 and AN-D-11	Same as above.	SP	Same as above.
AH-II	D near AP-18	Same as above.	P = 1	Same as above.
AH-JJ	D between AP-10 and AP-11	Same as above.	SP	Same as above.
AH-KK	D near TP-14	Same as above.	P = 1	Same as above.
AH-LL	D near TP-10	Same as above.	SP	Same as above.
AH-MM	RC on SL81-14	Same as above.	P=1	Same as above.
AH-NN**	D/RC on DM-A	Same as above.	SP	Same as above.
AH-OO	D on DM-A	Same as above.	SP	Same as above.
AH-PP**	RC near DR-20	Same as above.	SP	Same as above.
AH-QQ	RC near SL81-15	Same as above.	SP	Same as above.
AH-RR	D near SL81-19	Same as above.	SP	Same as above.
AH-SS	D, SW of RR	Same as above.	SP	Same as above.
AH-TT	D, near TP-13	Same as above.	SP	Same as above.
AH-UU AH-VV AH-WW AH-XX	Miscellaneous, locations to be determined in field, also for more detailed investigation of freeboard dike.			

*Borings listed by priority.
**Auger borings adjacent to hammer drill holes.
***See Figures 3.2 and 4.2.

D = Borrow Site D
P = Piezometer tips (pneumatic)

RC = Watana Relict Channel
SP = Standpipe Piezometer
T = Thermistors

Note: Standpipe piezometers may be largely replaced in the pneumatic piezometers depending on installation depth and cost. Quantities shown are maximum possible requirement.

TABLE 3.2: FY83 EXPLORATORY PROGRAM - PHASE II
WATANA RELICT CHANNEL/BORROW SITE D
HAMMER DRILLING PROGRAM

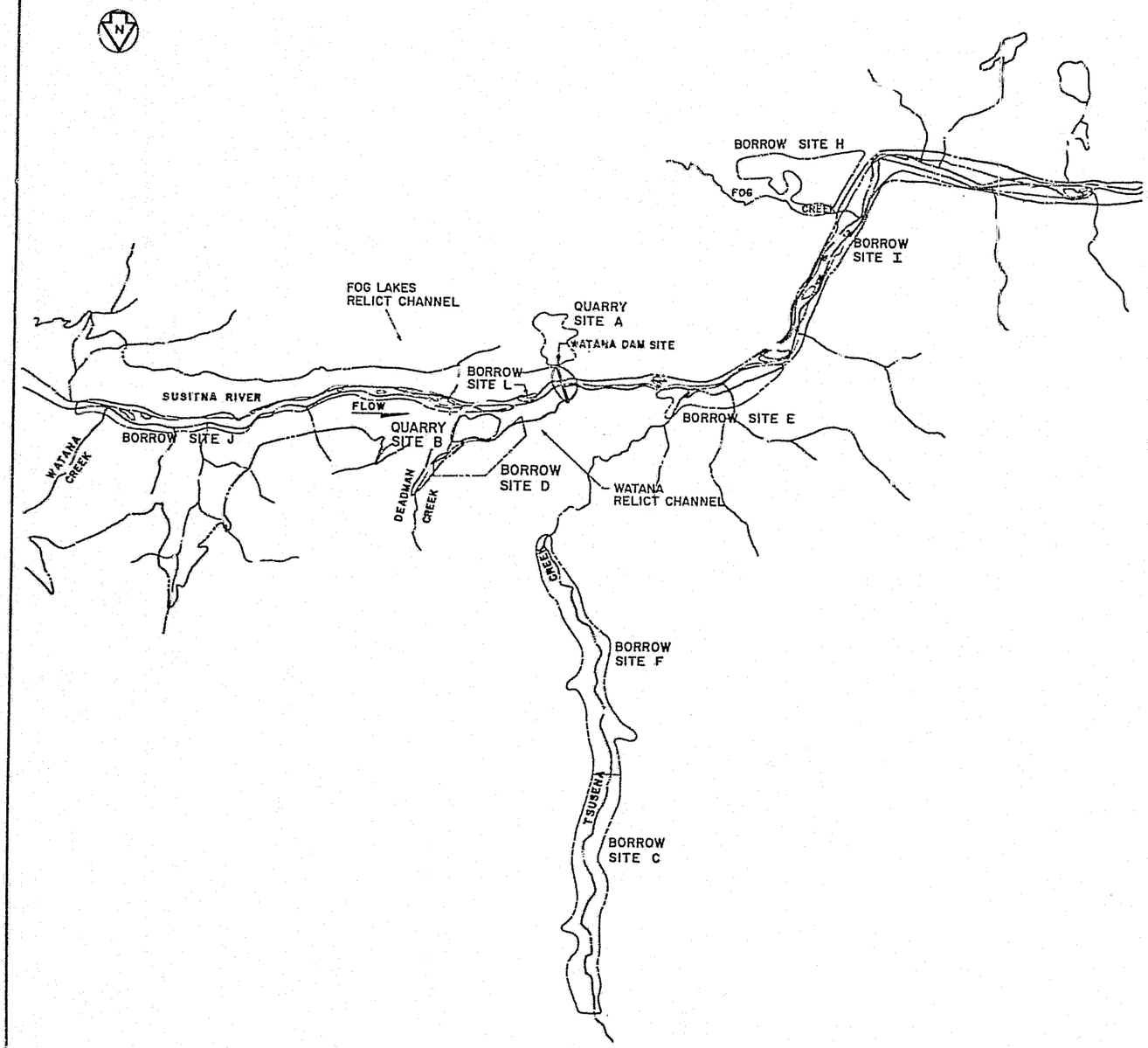
Boring* Number	Approximate Location***	Approximate Depth (ft)	Instrumentation***	Purpose
HD-A	RC on SL80-1 near AH-H	200	P = 3 T	Stratigraphy material, properties, ground water, and permeability.
HD-B	RC on SL82-A near AH-I	100	P = 2 T	Same as above. On main thalweg.
HD-C	RC on SL82-B near AH-K	450	P = 5	Same as above.
HD-D	RC on SL82-B near AH-DD	300	P = 3	Same as above.
HD-E	RC near DR-20, and AH-PP	225	P = 3 T	Same as above.
HD-F	RC on SL80-2	50	P = 3	Same as above.
HD-G	RC on SW-3	150	P = 2	Same as above.
HD-H	D/RC on SL81-6 near AH-Y	425	P = 5	Same as above.
HD-I	RC near AH-O	425	P = 5 T	Same as above.
HD-J	RC on SL81-14 and SL82-C, near AH-T	525	P = 5 T	Same as above.
HD-K	D/RC on DM-A, near AH-NN	225	P = 3	Same as above.
HD-L	D/RC near TP-21 and AH-N	400	P = 5 T	Same as above.
HD-M	D on SL80-8, near AH-S	600	P = 3 T	Same as above.
HD-N	D on SW-4	250	P = 3	Same as above.
	TOTAL	4,325		

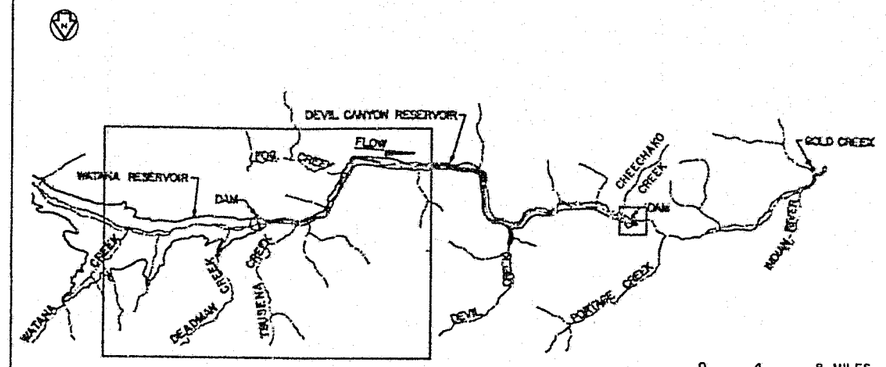
P = 50 tips, allow 20 additional tips for miscellaneous locations.

T = 7 strings, allow 3 additional strings for miscellaneous locations.

*Borings listed by priority.
**Auger borings adjacent to hammer drill holes.
***See Figures 3.2 and 4.2.

D = Borrow Site D
P = Piezometer tips (pneumatic)
RC = Relict Channel
SP = Standpipe Piezometer
T = Thermistors





LEGEND

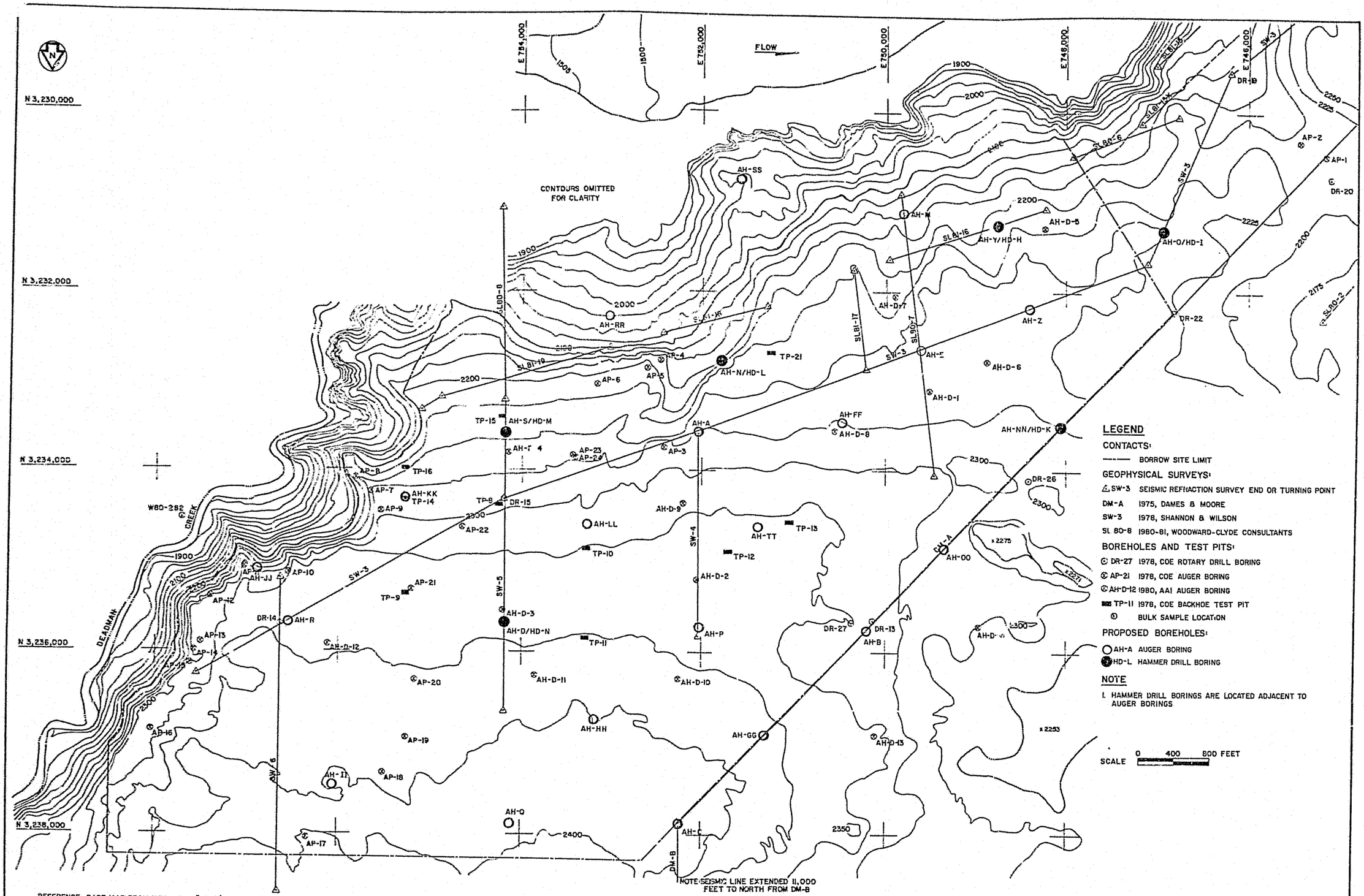
BORROW / QUARRY LIMITS

SCALE 0 1 2 MILES

WATANA
BORROW SITE MAP

FIGURE 3.1

ACRES



REFERENCE: BASE MAP FROM 1978, COE-1"=200' DAMSITE TOPOGRAPHY, SHEETS 13-15, 18-20 OF 26

BORROW SITE D
PROPOSED FY83 EXPLORATION PLAN

ACRES

FIGURE 3.2

4 - RELICT CHANNEL

4.1 - General

Two areas have been identified on the banks of the proposed Watana reservoir where bedrock falls below the proposed reservoir elevation and, hence, provides a potential for reservoir leakage. The preliminary explorations and geologic mapping indicate that both of these areas may be abandoned Susitna River channels or "relict channels", one between Deadman and Tsusena Creeks, and the second in the Fog Lakes area.

The potential concerns regarding these areas are:

(a) Potential for excessive reservoir leakage of such magnitude as to affect project economics.

(b) Potential for excessive local gradients under reservoir head which might cause piping of material and, hence, induce progressive failure of the rim material with ultimate breaching of the reservoir.

(c) Overburden instability or seismic liquefaction potential which could result in breaching of the reservoir confinement.

(d) Crest settlement due to saturation and permafrost thawing.

4.2 - Objectives

The objective at the FY83 program will be to assess the potential for these occurrences. The following factors must be adequately defined to allow proper evaluation of the physical behavior of the relict channels under project operating conditions.

- Stratigraphy;
- Material properties;
- Boundary conditions;

- Geohydrology;
- Permafrost conditions; and
- In-situ physical condition of materials.

4.3 - Approach

A two-phase program of exploration is proposed. The FY83 program will primarily address the more critical Deadman-Tsusena area relict channel which has been designated as the Watana Relict Channel. Preliminary assessment of the Fog Lakes Channel shows the freeboard at Fog Lakes is significantly higher than the Watana Relict Channel, and the local and overall gradient is much flatter and the flow path much longer than the Watana Relict Channel, which minimizes any hazard. It is therefore proposed to do only limited seismic refraction investigations in the Fog Lakes areas during FY83, with a more intense investigation being performed in the area during FY84 if needed (Figure 4.1 and Table 4.1). These investigations will be conducted to assure that significant flow paths or liquefiable zones are not present in the Fog Lakes Relict Channel.

The Watana Relict Channel has a flow path of approximately 1 to 2 miles with an average gradient of about ten percent and a stratigraphy which (based on the information to date) indicates potential for seepage. In addition, very limited subsurface data suggest that potentially liquefiable material may be present within the channel.

The FY83 explorations will be jointly conducted with the Borrow Site D program since the borrow site lies within the confines of the relict channel areas (Section 3). The principal objective of the FY83 program is to: obtain representative samples for stratigraphic identification; define material properties distribution; and determine geohydrologic conditions in the relict channel.

The FY83 program for the relict channel will be performed in two parts, a summer (Phase I) and winter (Phase II) program. This is principally due to field logistics and the inability of transporting large drilling equipment overland

until the winter. Therefore, the summer program will use smaller helicopter-transported drill rigs that will evaluate the upper 100-200 feet of the relict channel. These rigs will be the same rigs used in the Borrow Area D investigation (Section 3). Data from this program will be used in detailing the winter program. The objectives of the FY83 program are to:

(a) Phase I

- Perform surficial mapping of the relict channel;
- Define the surface and subsurface hydrologic regime in the upper 100-200 feet;
- Obtain undisturbed and disturbed samples at depth to identify stratigraphy and material properties;
- Install instrumentation for monitoring ground water and permafrost; and;
- Delineate extent of Fog Lakes Relict Channel.

(b) Phase II

- Confirm the geometry of the relict channel;
- Obtain large bulk and undisturbed samples at depth for stratigraphic delineation and material properties;
- Evaluate the geohydrologic regime where possible; and
- Install instrumentation for monitoring ground water and permafrost.

Phase I will involve drilling approximately 50 borings distributed throughout the Watana Relict Channel/Borrow Site D area and a limited geophysical program (Table 4.2). Proposed boring locations are shown in Figures 4.2 and 4.3.

The drill equipment will have capability of drilling a 6-inch sampler in the upper 20-50 feet; reducing to 4-inch samples to 75 feet, and subsequently reducing to standard 2-inch samples to full depth of 200 feet. The intent is to obtain as large a diameter sample as possible to maximum depth in order to determine the following conditions:

- Soil moisture content;
- Geohydrologic condition;
- Soil density;
- Soil gradation;
- Stratigraphy and sedimentary origin;
- Permafrost conditions; and
- Obtaining samples for laboratory testing to determine plasticity limits, compaction, permeability and dispersion potential.

The results of the summer investigations are expected to provide a model of stratigraphy, ground water and permafrost regime, and material properties in the upper 100-200 feet of the relict channel for use in subsequent design and estimates, and to assist in laying out the deep drilling program to be performed in the winter program.

Phase II will utilize the same large diameter hammer drill that was described for Borrow Site D (Section 3). Approximately 14 holes are planned to penetrate to bedrock in the relict channel (Table 3.2). The drill cuttings will be used in stratigraphic identification and borrow materials testing. In addition, the drive and drilled sampling methods utilized in Phase III will be used to obtain "undisturbed" samples for laboratory tests. Proposed boring location for the hammer drill are shown in Figures 4.3 through 4.5.

As in Borrow Site D, emphasis in the sampling program will be placed on obtaining maximum size samples for stratigraphic information and materials investigations. The various sampling methods that may be available are listed below.

(a) Full depth sampling and logging of drill cutting, which will provide limited supplemental material and stratigraphic information.

(b) Drive and coring sampling, using 2- and 3-inch standard split spoon samples, as well as special samplers such as the Denison.

(c) "Undisturbed" sampling, using special "floating tube" or piston type samples such as the "Gus" and "Osterberg" and various diameters of "Shelby" and similar split or solid thin wall tube sampling.

(d) Casing drive testing, using the hammer drill to ascertain relative variations in density.

(e) Water level detection and monitoring, both during and after drilling operations.

(f) Installation of well casing screens and piczometers for subsequent observations and aquifer testing.

(g) Permafrost monitoring through drill cuttings temperature measurement, observation of ice in the samples taken, and installation of frost probe PVC pipe for continued observation. If significant frost is detected at depth, full thermistor strings may be installed if thought to be appropriate.

(h) Downhole geophysical logging, as appropriate, to provide correlation of geologic interpretation between borings. Logging will be conducted in both the hammer drill holes and the summer (Phase I) rotary larger borings through 2-inch PVC pipe, which will be installed during drilling.

TABLE 4.1: FY83 EXPLORATORY PROGRAM
FOG LAKES RELICT CHANNEL
GEOPHYSICAL SURVEY

Seismic Refraction Line No.*	Location**	Approximate Length (ft)	Purpose
SL82-FL-A	Channel A	22,000	Determine gradient of channel.
SL82-FL-B	Channel B	15,400	Determine bedrock gradient of channel.
SL82-FL-C	Channel A and B	22,000	Width of Channel A and B.
SL82-FL-D	Channel A	22,000	Determine bedrock gradient of possible additional channels.
SL82-FL-E	Channel A	15,400	Upstream width of channel.
SL82-FL-F	Channel B	9,900	Width of channel.
SL82-FL-G	Channel B	5,500	Width of channel.

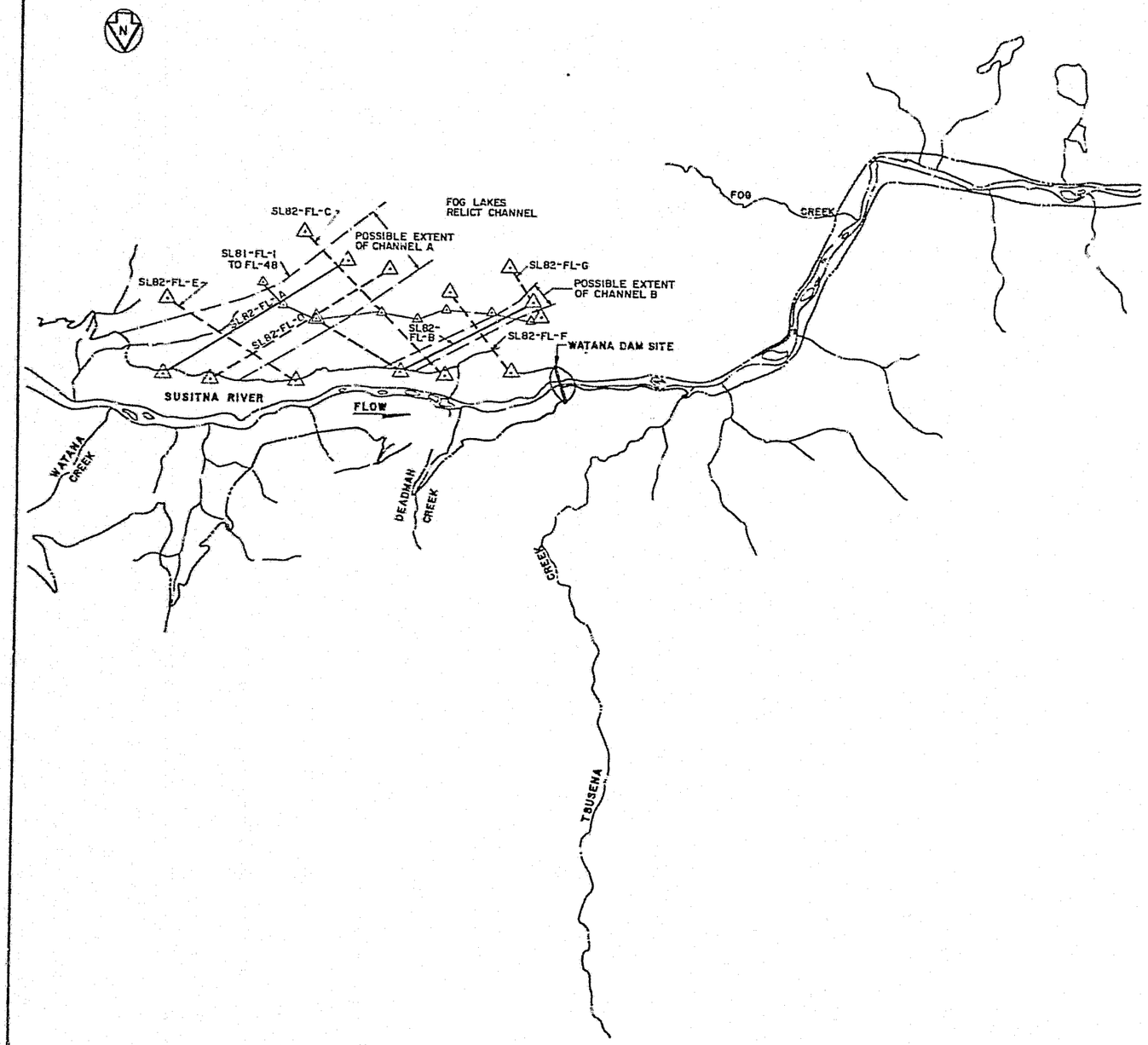
*The seismic lines shown here are based on limited geologic data suggested for more complete definition of the channels. The number and orientations of seismic lines will be based on additional geologic mapping and interim field results obtained during the program.

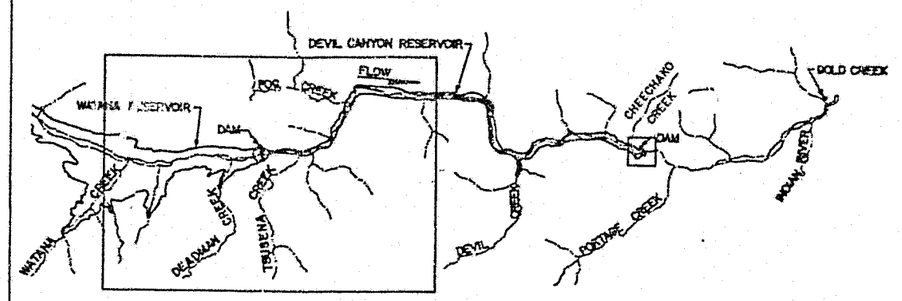
**See Figure 4.1

TABLE 4.2: FY83 EXPLORATORY PROGRAM - PHASE I
WATANA RELICT CHANNEL GEOPHYSICAL SURVEY

Seismic Refraction Line No.*	Location**	Approximate Length (ft)	Purpose
SL82-A	Relict channel	6,600	Bedrock depth, overburden conditions.
SL82-B	Relict channel	6,600	Bedrock depth, overburden conditions.
SL82-C	Relict channel	1,100	Tie in lines SL81-14 and SL80-2 to complete coverage.
SL82-S Or	Relict channel	6,600	Detail of main relict channel thalweg.
SL82-T	Relict channel	6,600	Same as above.
SL82-U	Relict channel	1,500	Tie in lines SL81-16 and SL81-15X to complete coverage.
SL82-V	Borrow Site D and relict channel	1,100	Tie in lines SL81-16 and SL81-18 to complete coverage.
SL82-W	Relict channel	3,500	From SL81-13 to Tsusena Creek to complete coverage.

*Seismic lines listed in order of priority, SL82-D through SL82-R on Table 2.1.
**See Figure 4.2.





LEGEND

GEOPHYSICAL SURVEYS:

SL82-FL-1 TO FL-48 — SEISMIC REFRACTION SURVEY LINE

PROPOSED GEOPHYSICAL SURVEYS:

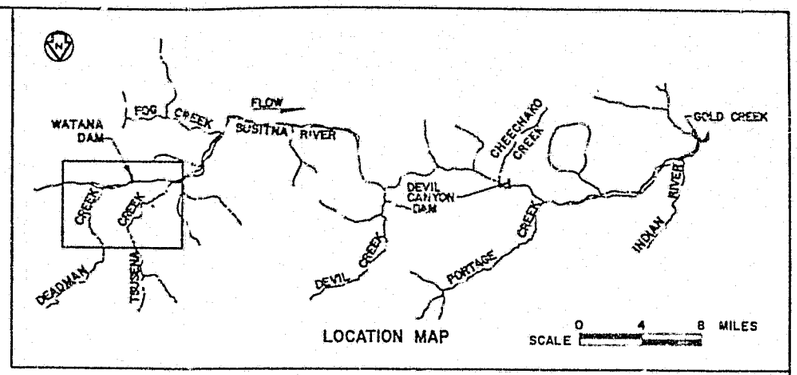
SL82-FL-A — SEISMIC REFRACTION SURVEY - PHASE I. DASHED LINES ARE ALTERNATIVE ALIGNMENTS, DEPENDING ON FIELD GEOLOGY INTERPRETATION.

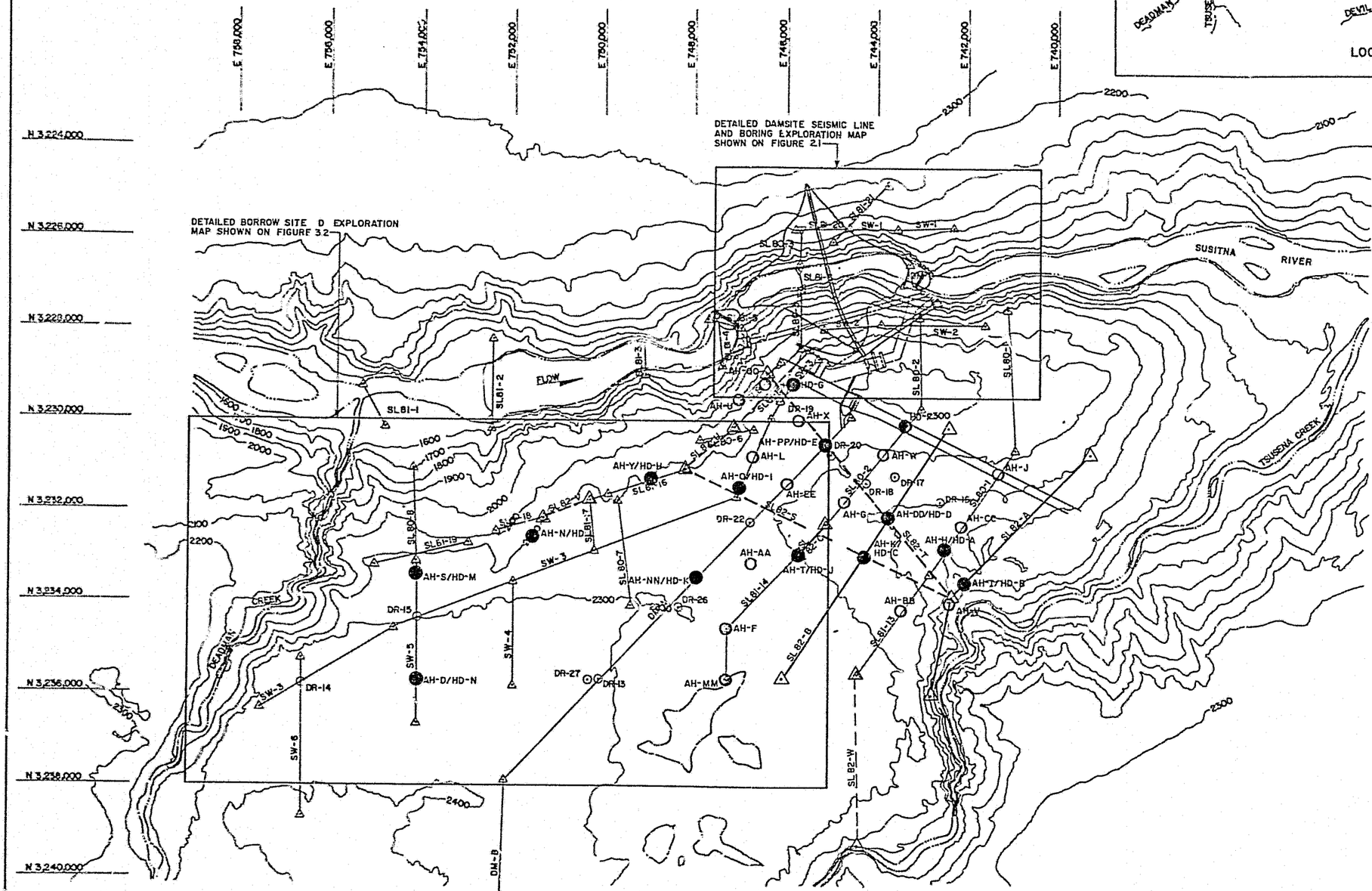
SCALE 0 1 2 MILES

FOG LAKES RELICT CHANNEL
PROPOSED FY83 EXPLORATION PLAN

FIGURE 4.1

ACRES





LEGEND

BOREHOLES AND TEST PITS:

- ⊙ DR-16 1978, COE ROTARY DRILL BORING

GEOPHYSICAL SURVEYS:

- △ SEISMIC REFRACTION SURVEY END OR TURNING POINT
- DM-C 1975, DAMES & MOORE
- SW-2 1978, SHANNON & WILSON
- SL81-5 1980-81, WOODWARD-CLYDE CONSULTANTS

PROPOSED BOREHOLES:

- ○ AH-G AUGER BORINGS
- ⊕ HD-F HAMMER DRILL BORING

PROPOSED GEOPHYSICAL SURVEYS:

- △SL 82-A△ SEISMIC REFRACTION LINES, DASHED LINES ARE OPTIONAL.

NOTES

1 HAMMER DRILL BORINGS, EXCEPT HD-F AND HD-G, ARE LOCATED ADJACENT TO AUGER BORINGS.

2 SEISMIC REFRACTION LINES SL82-D THROUGH SL82-R ON FIGURE 2.1.

SCALE 0 1000 2000 FEET

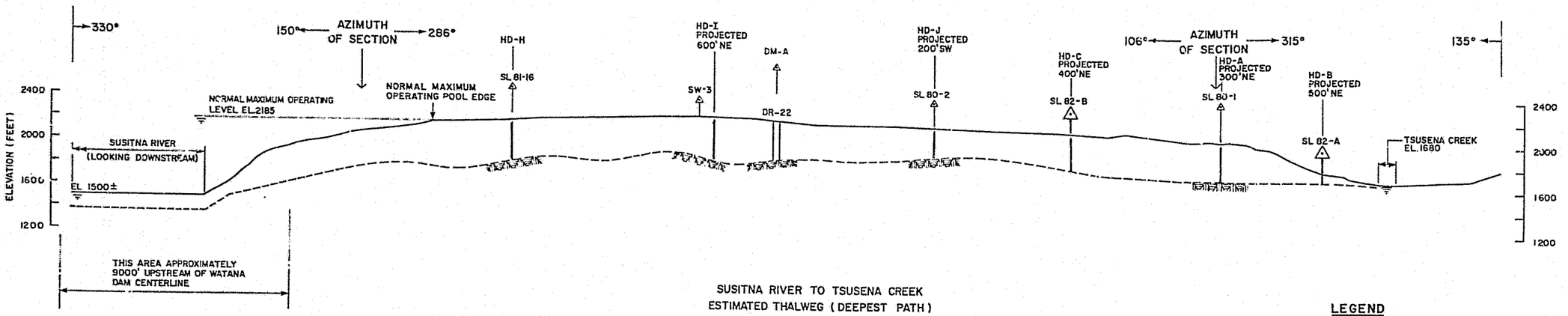
REFERENCE: 1"=200' COE, 1978 WATANA DAMSITE TOPOGRAPHY, SHEET 1 THROUGH 26

CONTINUES OFF PAGE

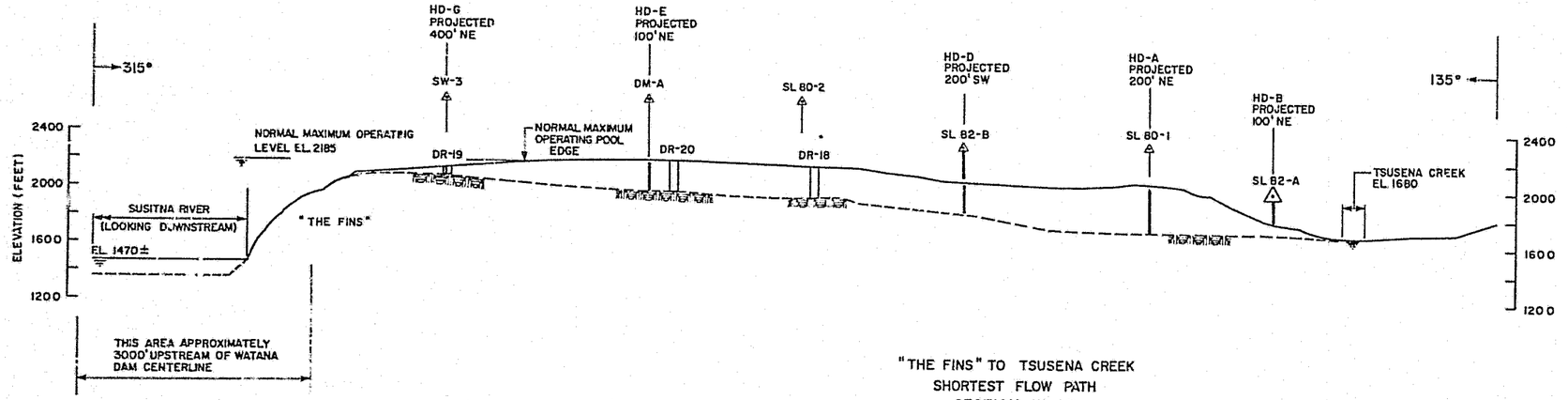
WATANA RELICT CHANNEL PROPOSED FY83 EXPLORATION PLAN

FIGURE 4.2

ACRES



SUSITNA RIVER TO TSUSENA CREEK
ESTIMATED THALWEG (DEEPEST PATH)
SECTION W-17



"THE FINS" TO TSUSENA CREEK
SHORTEST FLOW PATH
SECTION W-16

SCALE 0 400 800 FEET

LEGEND

CONTACTS:

----- APPROXIMATE TOP OF ROCK

GEOPHYSICAL SURVEYS:

SW-1 INTERSECTION WITH SEISMIC REFRACTION LINE

DM-C 1975, DAMES & MOORE

SW-1 1978, SHANNON & WILSON

SL 80-1 1980, WOODWARD-CLYDE CONSULTANTS

SL 81-2 1981, WOODWARD-CLYDE CONSULTANTS

BOREHOLES:

DR-19 COE ROTARY DRILL BORING

PROPOSED BOREHOLES:

HD-A HAMMER DRILL BORING

PROPOSED GEOPHYSICAL SURVEY:

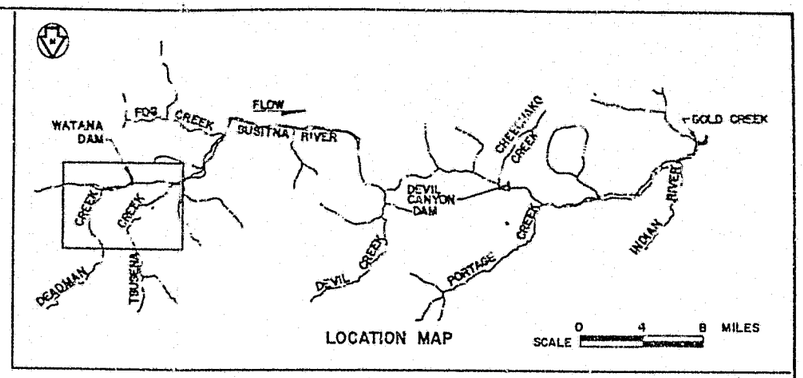
SL 82-A SEISMIC REFRACTION LINE

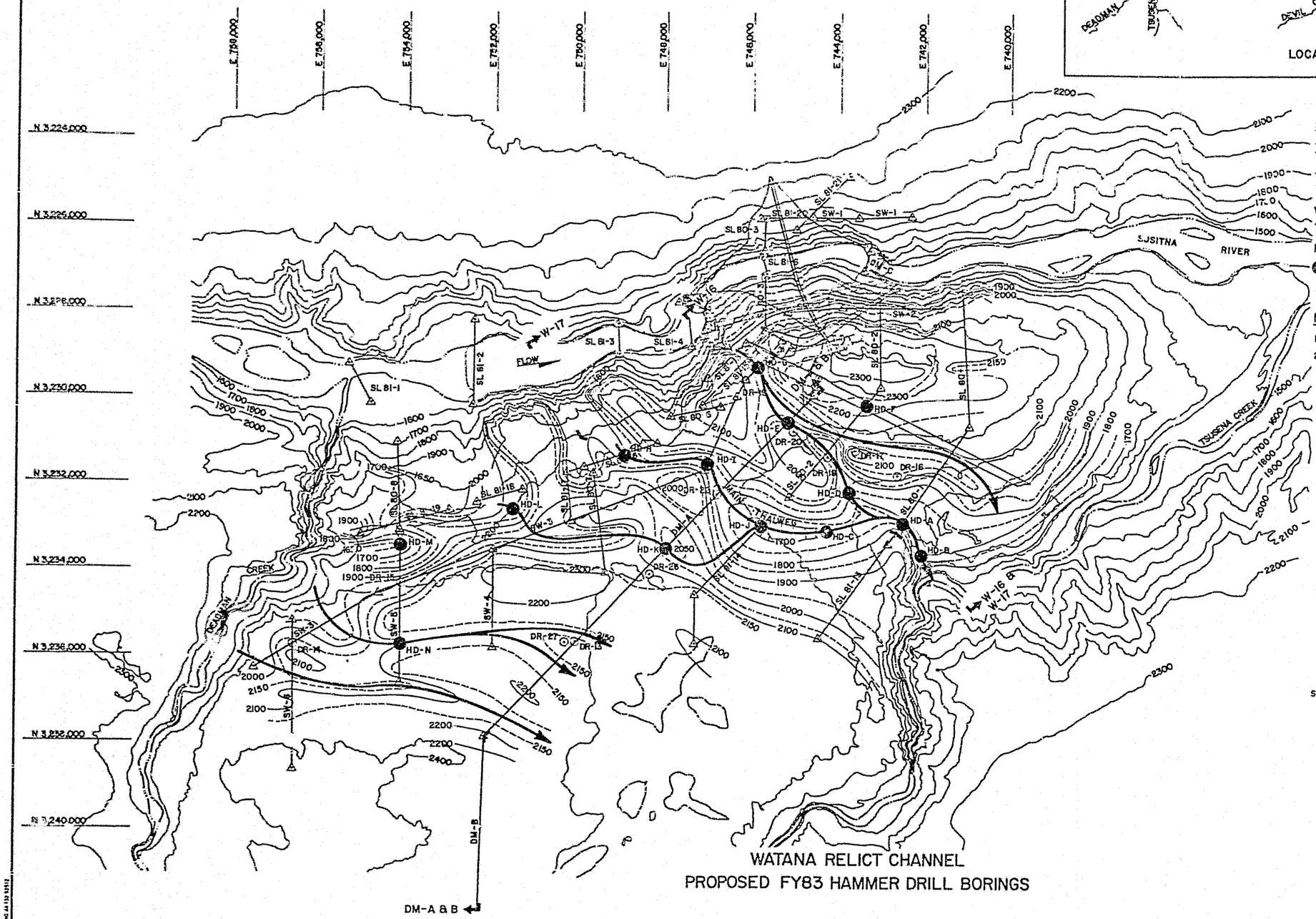
NOTES

1. PROFILE AND SEISMIC LINE LOCATIONS SHOWN ON FIGURE 4.4.
2. SECTION ALONG DM-A SHOWN ON FIGURE 4.5.
3. VERTICAL AND HORIZONTAL SCALE EQUAL.
4. SURFACE PROFILE FROM 1"= 200' TOPOGRAPHY, COE 1978 TOPOGRAPHY GENERALIZED TO ±25 FEET.
5. TOP OF ROCK NORTHWEST OF SL 80-1 IS PROJECTED UP TO 300 FEET TO PORTRAY ACTUAL THALWEG PROFILE.
6. AUGER BORINGS IN RELICT CHANNEL ARE SHOWN ON FIGURE 4.2.

WATANA RELICT CHANNEL PROFILES

FIGURE 4.3





LEGEND

- TOP OF BEDROCK, CONTOUR INTERVAL 50 FEET, 50 FOOT CONTOURS DASHED.
- TOPOGRAPHY, CONTOUR INTERVAL 100 FEET.
- POTENTIAL CHANNEL THALWEGS
- W-16 W-16 PROFILE OR CROSS-SECTION LOCATION (SEE NOTES 1 AND 2)

PROPOSED BOREHOLES:

- HD-A HAMMER DRILL BORING

NOTES

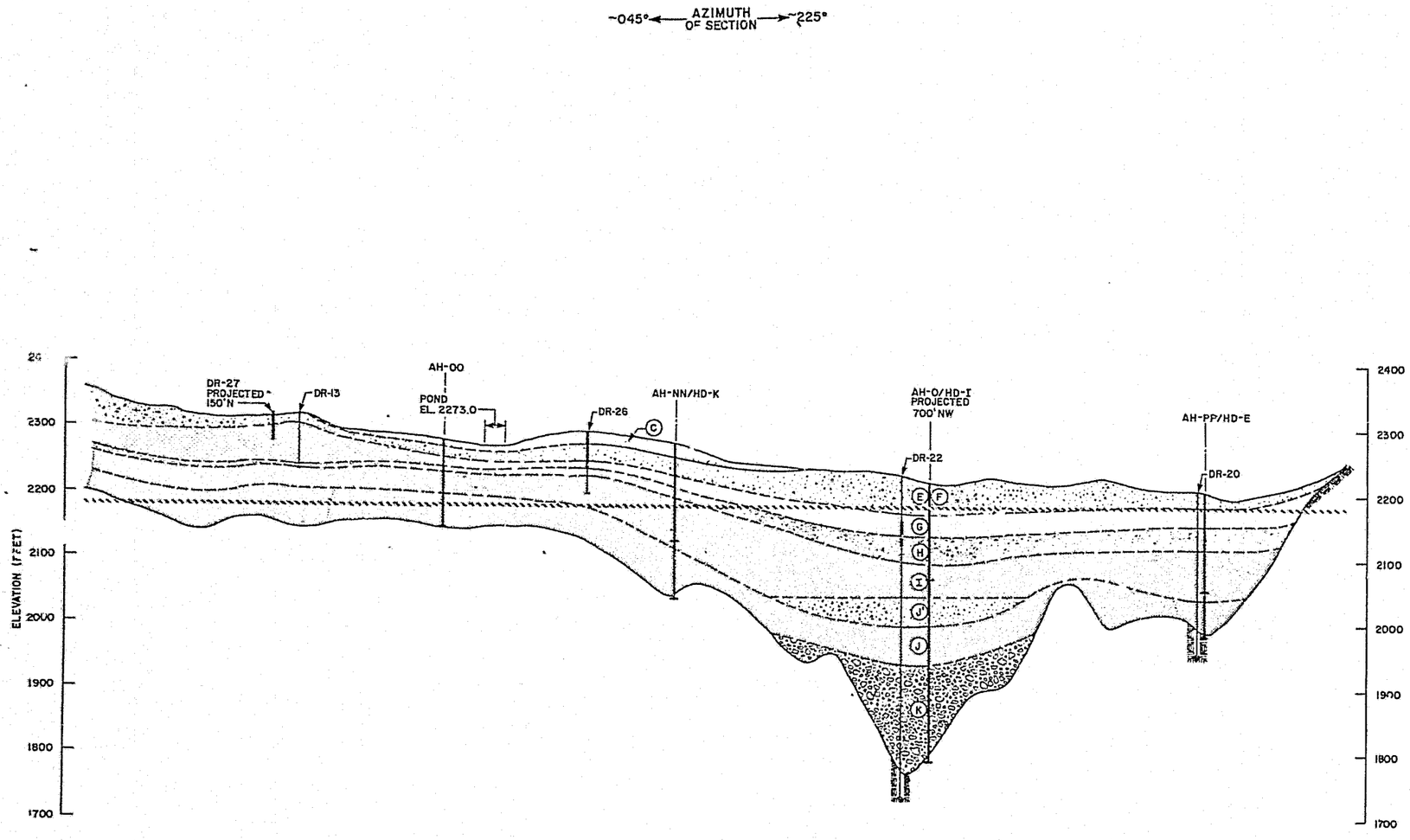
1. SECTION DM-A AND B SHOWN ON FIGURE 4.2.
2. PROFILES W-16 AND W-17 SHOWN ON FIGURE 4.3.

SCALE 0 1000 2000 FEET

WATANA RELICT CHANNEL
PROPOSED FY83 HAMMER DRILL BORINGS

FIGURE 4.4

ACRES



LEGEND

LITHOLOGY:

C		I	
E,F		J'	
G		J	
H		K	

CONTACTS:

——— KNOWN UNIT CONTACT

– – – – INFERRED UNIT BOUNDARY

BEDROCK SURFACE WHERE DRILLED.

NORMAL MAXIMUM OPERATING LEVEL EL 2185

BOREHOLES:

DR-26 COE ROTARY CORE BORINGS

NOTED AS FROZEN DURING DRILLING

PROPOSED BOREHOLES:

HD-E HAMMER DRILL BORING

AH-B AUGER BORING

NOTE

1. LOCATION OF SECTION ALONG SEISMIC LINE DM-B, ON FIGURE 4.4.

SCALE 0 80 160 FEET VERTICAL

SCALE 0 400 800 FEET HORIZONTAL

WATANA RELICT CHANNEL-EXPANDED THALWEG SECTION

FIGURE 4.5

5 - BORROW SITES E and I

5.1 - General

Borrow Sites E and I include the Tsusena Creek outwash plain and Susitna River floodplain from a point approximately 2-1/2 miles downstream from the Watana dam site to a maximum distance of approximately 12 miles downstream (Figure 3.1). This material has been identified as the most favorable source for concrete aggregate, filter sand and gravel, and dam shell gravel requirements totaling approximately 40 million cubic yards. The information in these areas, to date, has been compiled from seismic refraction surveys, air photo interpretation, and various test pits and shallow auger holes.

5.2 - Objectives

The overall objective of the Borrow Site E and I investigation is to obtain four types of information needed for refinement of construction processing and costs and material properties. These are:

(a) Borrow site configuration to include lateral and vertical extent of suitable materials and groundwater conditions. This information is needed to define type and method of excavation and placement.

(b) Limits of reasonable excavation depth based on geologic constraints, stratification of deposit, and inherent stability of the materials. These limitations will have significant impact on the actual economically recoverable reserves which, in turn, can be expected to influence maximum excavation depth, net excavation losses, and, consequently, equipment selection and overall land requirements for adequate development.

(c) Material gradations, including both typical and local variations in the material quality, which will influence production methods and requirements and possible processing.

(d) Suitability of the material for use in concrete, filters, and dam shells. This information will be used in selection of the type of processing requirements and optimization of placement utilization as determined by cost.

The objectives of the FY83 program are to:

(a) Confirm the accuracy of previous seismic data and, therefore, borrow site quantity and reserve calculations; and

(b) Determine material properties.

5.3 - Approach

The amount of work that can be done within the FY83 is limited by time and the sampling equipment which will be mobilized to the site. The large hammer drill, which is planned for use in the relict channel and river areas (Sections 2 through 4), will be utilized to drill several confirmatory borings to maximum practical excavation depth below river level in the primary source area of Borrow Site E with the intent of verifying the seismic data and obtaining samples for gradations and laboratory testing (Figure 5.1 and Table 5.1). This drilling program should: verify the general overall suitability of the source; ascertain the approximate upper size limits and range of the gradation; provide adequate samples for physical and durability suitability; and give an indication of variability of the deposit with depth.

Subsequent studies for final design investigations will determine the actual mineable limits, extent of variation in materials, ground water elevation, and the processing that will be required for each of the major gradation variations.

The FY83 summer program in Borrow Sites E and I will be limited to completion of surficial geologic mapping during Phase I to delineate all exposures of rock and borrow materials with the intent of defining material limits and geomorphologic features which may give indications of expected material properties. It is anticipated that the information obtained from the mapping will be limited to identification of relict terraces, alluvial fan deposits, and river floodplain limits within the borrow site. Phase II borehole locations will also be established during the summer program.

The winter program will involve use of the large hammer drill which will continuously sample from ground surface to the maximum practical excavation depth (which is estimated at 125 feet below water level). The drilling will be distributed over the length of Borrow Site E to provide a general overall view of the borrow materials. Due to the wide spacing of these borings, stratigraphic correlation is not expected to result from this drilling. The borings will be concentrated along the margins of the site to meet the criteria below:

(a) Ready access and relatively level drill setup to minimize setup time and, thereby, maximize the number of holes drilled.

(b) Placement of at least ten of the holes on previous seismic lines to verify the seismic data interpretation.

(c) Placement of several holes along the active river margin to verify the off-end-of-line seismic interpretation of alluvial depth and composition.

(d) Placement of a line of holes near the north limit of the floodplain to confirm the average depth of alluvium and to assure that bedrock level does not rise rapidly in the north and east portions of the borrow site.

(e) Spacing of the borings so as to maximize the information concerning the variability of stratigraphic conditions within the borrow site.

Borehole sampling will be conducted as listed below:

(a) Primary sampling will be continuous cuttings sampling up to 4-inch size particles.

(b) Split spoon or Denison/Core Barrel sampling, as necessary, to sample fine sand, silt, or clay layers which may be encountered.

(c) Casing dive tests (open casing drive tests) for general correlation of stratigraphy versus density for use in estimating excavation requirements. Since the borrow site is planned for dragline excavation, detailed density testing is not considered necessary at this time.

(d) Water table detection and monitoring to provide information on potential dry versus wet excavation. Because the water table is expected to range from 10-30 feet below ground surface, simple standpipe piezometric monitoring will be utilized to allow continued monitoring of seasonal variations of the water table.

(e) Frost detection will be limited to direct observation of drilling rate and temperature measurements of cuttings. No permafrost is expected in the borrow site; however, the depth of seasonal frost will be measured and checks will be made throughout drilling operations to record any indications of possible permafrost. If any permafrost is detected, thermal probe standpipes will be installed in the appropriate zones to detect the extent of the affected zone. In the remaining holes, standpipes will be installed to approximately 30 feet deep for detection of annual frost penetration thermal probe headings.

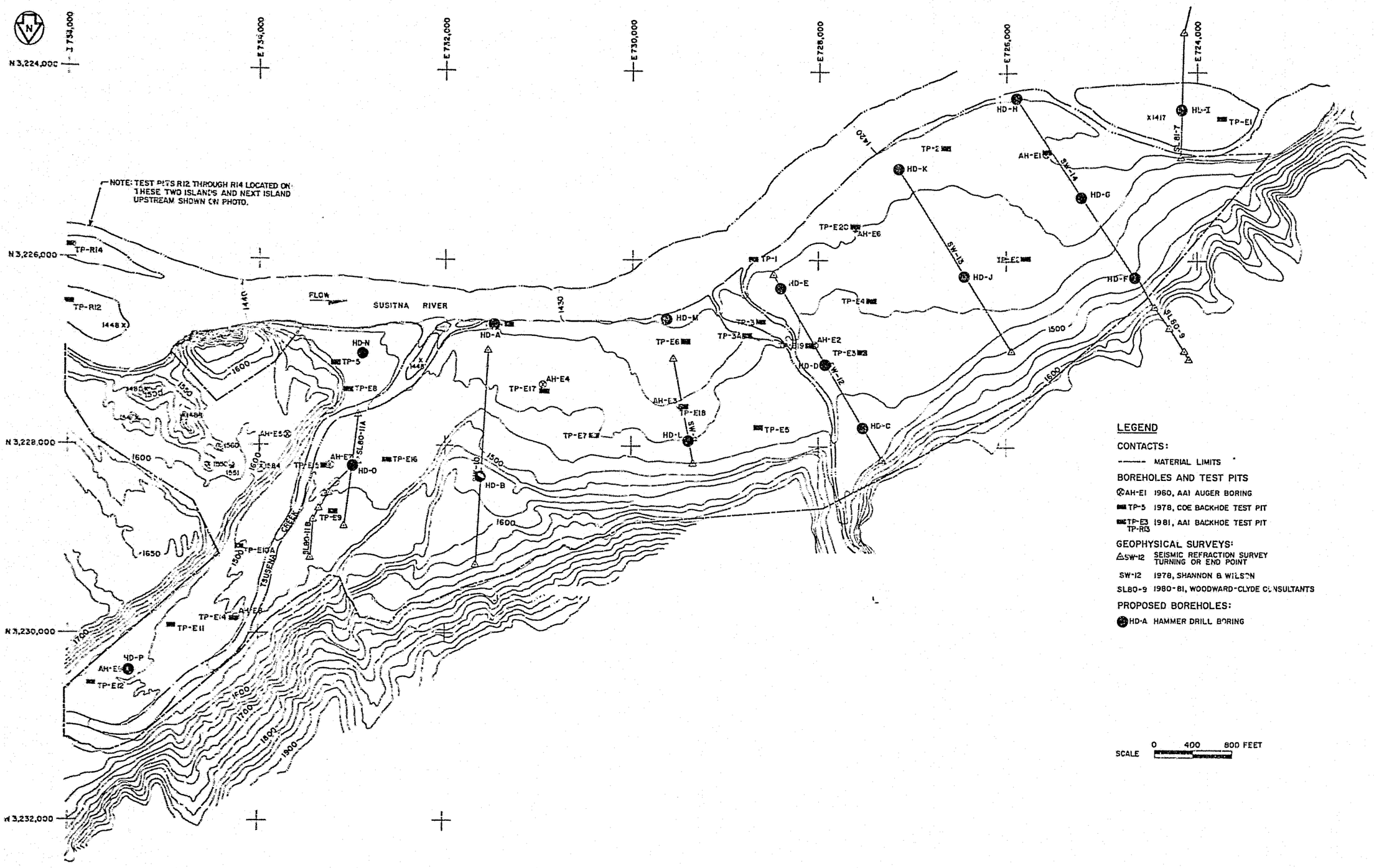
TABLE 5.1: FY83 EXPLORATORY PROGRAM - PHASE II
BORROW SITE E HAMMER DRILLING PROGRAM

Boring* Number	Approximate Location**	Approximate Depth (ft)	Instrumentation***		Purpose
HD-A	SW-10, south end	60			Define stratigraphy, check on seismic line picks, material sampling.
HD-B	SW-10, north end	125	SP	FP	Same as above.
HD-C	SW-12, north end	110	SP	FP	Same as above.
HD-D	SW-12, center	75	SP		Same as above.
HD-E	SW-12, south end	125		FP	Same as above.
HD-F	SL80-9, north end	125	SP	FP	Same as above.
HD-G	SL80-9, center	110	SP	FP	Same as above.
HD-H	SL80-9, south end	120		FP	Same as above.
HD-I	SL81-17	75			Same as above.
HD-J	SW-13, center	75	SP	FP	Same as above.
HD-K	SW-13, south end	175			Same as above.
HD-L	SW-13, north end	60	SP	FP	Same as above.
HD-M	On river bank	90			Same as above.
HD-N	On river bank upstream of Tsusena Creek	70			Same as above.
HD-O	At intersection of SL80-11A & SL80-11B	60	SP		Same as above.
HD-P	Upstream on Tsusena Creek	100	SP		Same as above.
	TOTAL	1,555			

SP = 9 installations, allow 1 miscellaneous installation.

FP = 8 installations, allow 2 miscellaneous installtions.

*Borings listed by priority.
**See Figure 5.1.
***SP = Standpipe piezometer.
FP = Frost probe.



REFERENCES: BASE MAP FROM COE, 1978-1" = 200' WATANA TOPOGRAPHY, SHEET 6 & 11 OF 26
R&M, 1981-1" = 400' DEVIL CANYON RESERVOIR MAPPING, FLIGHT 5 (6-8), MANUSCRIPT 2
COORDINATES IN FEET, ALASKA STATE PLANE (ZONE 4)

BORROW SITE E
PROPOSED FY83 EXPLORATION PLAN

FIGURE 5.1

ACRES

6 - LABORATORY TESTING

6.1 - General

The material testing program for FY83 will be designed for providing ready assistance in data interpretation. To expedite the testing program, a field laboratory will be established for performing routine soil tests to include:

- Gradation;
- Hydrometer;
- Moisture;
- Atterberg limits; and
- Proctor.

The more sophisticated tests will be performed by outside laboratories as required.

6.2 - Damsite

As discussed in Section 2, petrographic analyses will be performed on specimens of rock and sheared material obtained during geologic mapping activities. While petrologic rock type identification in slab section will suffice for delineation of the different rock types, full thin section petrographic analysis may be required for samples taken in contact or shear zones. The greater detail of the thin section identification can provide valuable data concerning the emplacement sequence and subsequent shearing and vein injection history, which will be of significance in evaluation of anticipated alteration and rock strength at depth in the pluton. The samples will be taken from outcrops and from core drilling to date, with an estimated 30 identifications and descriptions being performed.

During Phase II, approximately 20 holes averaging 100 feet deep (60 feet of overburden) are planned using a hammer drill. Limited spoon and barrel sampling will be performed, but a majority of the sampling will be retrieval of air-educted alluvium through use of a cyclone separator. The estimated number of samples and routine tests to be performed on these samples are shown in Table 7.1.

More detailed tests to be performed on undisturbed and other material samples will be undertaken following Phase II activities when an understanding of the subsurface materials in the damsite has been determined.

6.3 - Relict Channels/Borrow Site D

The material properties in the relict channel are of significance to the geologic understanding of the region as well as in evaluation of the long-term stability of the area. The Fog Lakes Relict Channel geologic mapping may produce a limited number of bagged samples of alluvial deposits collected from face exposures, which can be submitted to standard sieve and hand specimen descriptive analyses. No detailed material testing is planned for the FY83 period in the Fog Lakes Relict Channel.

The material testing program in the Watana Relict Channel will be conducted in conjunction with the Borrow Site D testing. The principal objective of the Phase I work is to identify and define the type and extent of stratigraphic units in Borrow Site D and the relict channel. Therefore, the soils testing program during Phase I will be limited to routine tests as shown in Table 7.1. Undisturbed and disturbed samples taken during this phase will be stored until data interpretation has advanced to the level where a sophisticated material testing program can be planned. However, the type of tests that may likely be undertaken for the relict channel and Borrow Site D are:

(a) Relict Channel

- Permeability;
- Consolidation;
- Dispersion;
- Strength/density testing; and
- "In situ" triaxial strength.

(b) Borrow Site D

- Remolded permeability;
- Dispersion;
- Triaxial strength on remolded material;

- Dilation (dynamic);
- Dynamic shear strength;
- Freez-thaw; and
- Thermal properties.

It is expected that the detailed testing program will be prepared after Phase I activities.

6.4 - Borrow Sites E and I

Because this area is intended for use as concrete aggregate, filter, and shell material, a number of tests may be run after the completion of the winter program, as shown in Table 7.1. Since this borrow material will be processed, it will not be necessary to test for in situ properties such as moisture, strength, and density. However, extensive samples obtained during the drilling program will be run for gradations. A few representative hydrometers will be performed to provide typical data on settling times and water quality effects of the fines in washing and processing operations. Other sophisticated laboratory testing that may be run on composite samples are:

- Sulphate-soundness;
- L.A. abrasion;
- Freeze-thaw;
- Soundness (wetting-drying);
- Proctor compaction;
- Density-strength testing; and
- Bulk permeability after washing.

7 - RESULTS OF PHASE I INVESTIGATION

As previously specified, the majority of data reduction for the FY83 program will be performed in the field. This will allow use of the data in scoping the subsequent phases of study. The Phase I data will be used to update and refine those geologic and geotechnical interpretations presented in the Feasibility Report and the 1980-81 Geotechnical Report. As additional data become available, addenda to these reports reflecting these new data will be prepared as required. Finalization of these addenda are expected to be completed in November-December 1982.

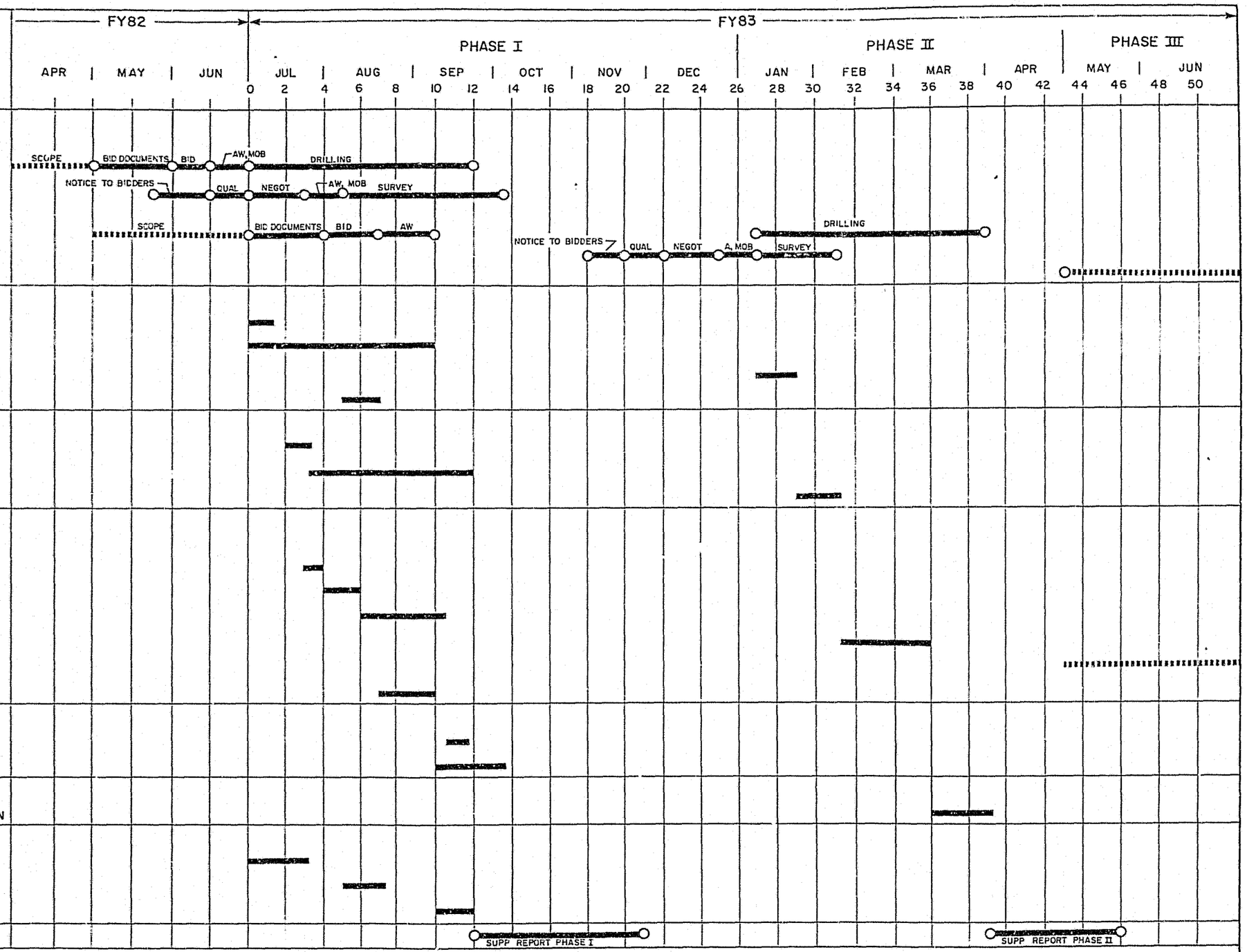
TABLE 7.1: ESTIMATED FY83 FIELD LABORATORY TESTING

Source	No. of Holes	Grab Sample Gradation	Sample Type		Testing					Retain for Future Testing
			Drive/Core	Cyclone	Gradation	Hydrometer	Moisture	Atterberg	Proctor Series (Modified & Standard)	
Summer 1982:										
Fog Lakes Relict Channel	0	15	0	0	15	15	5	5	0	15
Watana Relict Channel & Borrow Site	24	10	800	0	200	50	50	50	0	100
	26	20	850	0	200	100	100	100	5	100
Winter 1982-83:										
Damsite River Alluvium	20	-	100	220	200	20	0	20	5	50
Watana Relict Channel & Borrow Site D	9	0	200	300	150	25	50	50	5	100
	5	0	150	300	150	25	150	150	20	100
Borrow Site E and I	16	0	300	200	20	0	20	20	20	150
TOTAL (13,850 LF of drilling)	100	45	2,200	1,120	1,015	255	355	395	55	615

8 - PROJECT SCHEDULE

Figure 8.1 is the proposed schedule for FY83 Geotechnical Program. Key milestone dates to ensure performance of the work specified in Sections 2 through 5 are the mobilization of drilling equipment and personnel for Phase I into the field by July 6. Similarly, the mobilization of the hammer drill overland during December will be critical to allow for drilling in the relict channel and dam foundation. Therefore, to accomplish this, a contract for Phase I work must be in place by the second to the third week of June. The contract for the hammer drill must be let by September to allow adequate time for mobilization of the equipment to the site.

TASK	DESCRIPTION
1	CONTRACTS
	PHASE I
	DRILLING
	SEISMIC REFRACTION SURVEY
	PHASE II
	DRILLING
	SEISMIC REFRACTION SURVEY
	PHASE III
2	WATANA RELICT CHANNEL
	GEOLOGIC MAPPING
	AUGER DRILLING & INSTRUMENTATION
	HAMMER DRILLING & INSTRUMENTATION
	SEISMIC REFRACTION SURVEY
3	BORROW SITE D
	GEOLOGIC MAPPING
	AUGER DRILLING & INSTRUMENTATION
	HAMMER DRILLING & INSTRUMENTATION
4	MAIN DAM SITE
	GEOLOGIC MAPPING
	LOCATE SURVEY CONTROL POINTS
	CIVIL STRUCTURES
	GEOLOGIC STRUCTURES
	HAMMER DRILLING (RIVER BED)
	CORE BORINGS (ABUTMENTS)
	SEISMIC REFRACTION SURVEY
5	FOG LAKES RELICT CHANNEL
	GEOLOGIC MAPPING
	SEISMIC REFRACTION SURVEY
6	BORROW SITE E
	HAMMER DRILLING & INSTRUMENTATION
7	SURVEY CONTROL
	SET UP MAPPING GRID POINTS
	LOCATE SEISMIC LINES
	LOCATE DRILLHOLES
8	SUPPLEMENTAL REPORTS



GEOTECHNICAL SCHEDULE
TASK 55 FY83

FIGURE 8.1

ACRES

FOLD LENGTH
12
11
8.5
8
AUTO
MANUAL
FEED