SUSITNA HYDROELECTRIC PROJECT

FEASIBILITY REPORT

SUPPLEMENT

VOLUME 1

ENGINEERING AND ECONOMIC ASPECTS

APRIL 1983

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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1 - INTRODUCTION

1.1 - General

This supplement to the Feasibility Report has been prepared by Acres American Incorporated (Acres) for the Alaska Power Authority (the Power Authority) under the terms of Revision 4 to the Agreement, dated December 19, 1979, to conduct a feasibility study and preparation of a license application to the Federal Energy Regulatory Commission (FERC).

The original feasibility study was undertaken in accordance with the Plan of Study (POS) for the Susitna Hydroelectric Project, which was first issued to the Power Authority in February 1980 and subsequently revised four times since the original issue to account for scope changes and public, federal, and state agency comments and concerns.

A draft of the FERC license application was filed with FERC on November 15, 1982. Similarly, a draft of Exhibit E - Environmental Studies for the FERC license was submitted to the various state and federal agencies for review and comment. Comments regarding this draft were received during the month of December and January with the final submittal of the FERC license application in February 1983.

The Feasibility Report was issued for public review and comment on March 15, 1982 (Acres 1982a). Subsequent to that time, ongoing work continued in the areas of:

- Hydrology
- Environmental studies
- Survey and site facilities
- Geotechnical exploration
- Design development
- Transmission line
- Cost estimates and schedules
- FERC licensing
- Marketing and financing

As a result of this ongoing work, changes, additions, and modifications have been made to the original Feasibility Report. This Supplemental Report is intended to provide an update of information through January 1983. A comprehensive environmental study has been submitted as Exhibit E to the FERC license. Since extensive ongoing studies continue to be done in this area, no supplement to Volume 2 - Environmental Studies of the original Feasibility Report has been prepared for this submittal. Readers interested in the environmental studies to include environmental impacts and recommended mitigation measures are requested to consult Exhibit E to the FERC license.

This report is intended as a supplement to the March Feasibility Report and should be used in reference to that document.

1.2 - Objectives - Scope

The objective of the work performed from March 15 through December 1982, was to continue ongoing studies and submit the draft FERC license application. The work has been undertaken in a series of tasks which are:

Task 72 - Access Plan
Task 73 - Hydrologic Studies
Task 75 - Geotechnical Studies
Task 76 - Design Development
Task 77 - Environmental Studies
Task 78 - Transmission
Task 79 - Construction Cost Estimates and Schedule
Task 80 - Licensing
Task 81 - Marketing & Finance
Task 82 - Public Participation Program

These ongoing studies have resulted in some modifications to the design and development schemes for the Susitna Hydroelectric Project as set forth in the March Feasibility Report. Project parameters and design criteria are shown in Table 1.1. Details of these changes are presented in the preceding section. The principal changes to the Feasibility Report are in the areas of access, environment, and transmission. In addition, changes have also been made in the hydrologic flow regime of the dams to minimize downstream environmental impacts. These modifications have resulted in redesign of the intake structures which are presented in Volume 2 of this submittal.

1.3 - Organization of the Supplemental Report

The supplement to the Feasibility Report is presented in 11 sections.

Section 1 - Introduction
Section 1 is a brief summary of the project background and a general introduction to the report.

Section 2 - Summary
This section provides a summary of the results of Sections 4 through 11.

Section 3 - Scope of Work
This section outlines the scope of work undertaken in each of the tasks.

Section 4 - Access Roads
Section 4 is a detailed discussion of the access road alternative studies and the final access recommendation.

Section 5 - Refinement of Susitna Development
This section presents the refinement to the Susitna Development based on work carried out from March to December 1982.

Section 6 - Transmission Facilities
Section 6 addresses the recommended transmission routing for the Susitna Development.

Section 7 - Project Operation
This section presents the revised flow regime for the Susitna Development.

Section 8 - Reservoir and River Temperature Studies
This section presents refined reservoir and river temperature studies.

Section 9 - Estimates of Costs
This section presents the revised project cost estimate which incorporates the changes in the design scheme.

Section 10- Development Schedules
Section 9 presents the revised project schedule to reflect principally the changes in access routing.

Section 11- Economic, Marketing and Financial Evaluation
This section presents the revised economic and financial evaluation for the Susitna Development.

REFERENCES

Acres American Incorporated. 1982a. Susitna Hydroelectric Project Feasibility Report. Prepared for the Alaska Power Authority.

TABLE 1.1: PROJECT PARAMETERS AND DESIGN CRITERIA

Item	Watana	Devil Canyon
River Flows		
Average flow (over 32 yrs of record)	7,990 cfs*	9,050 cfs*
Probable maximum flood inflow	326,000 cfs	346,000 cfs (routed through Watana) 362,000 cfs (unrouted)
Maximum flood inflow with return period of 1:10,000 yrs (unrouted)	156,000 cfs	161,000 cfs (unrouted) 165,000 cfs (after routing through Watana) (increase attributed to the assumed overlap of Watana peak outflow and peak flow from intermediate catchment)
Maximum flood inflow with return period of 1:25 yrs	76,000 cfs	37,800 cfs 85,000 cfs (unrouted)
Maximum flood inflow with return period of 1:50 yrs (unrouted)	87,000 cfs	39,000 cfs (after routing through Watana) 98,000 cfs (unrouted)
Normal maximum operating level	2,185 ft MSL	1,455 ft MSL*
Average TWL	1,455 ft MSL	850 ft MSL
Minimum operating level	2,065 ft MSL*	1,405 ft MSL
Area of reservoir at maximum operating level	38,000 acres	7,800 acres
Reservoir live storage	3.74×10^6* acre ft	0.35×10^6 acre ft

* Modified from March 1982 Feasibility Report.
** Area control center for both Watana and Devil Canyon plants.
*** Based on a minimum reservoir level in peak demand month (December).

TABLE 1.1 (Cont'd)

Item	Watana	Devil Canyon
Reservoir total storage	9.47×10^6* acre ft	1.09×10^6* acre ft
<u>Dam</u>		
Type	Rockfill	Concrete arch
Crest elevation	2,210 ft MSL at center 2,207 ft MSL at abutments	1,463 ft MSL (+3 ft parapet wall)
Crest length	4,100 ft	1,650 ft (arch dam including thrust blocks)
Height	885 ft above foundation at core	646 ft above foundation
Cut-off and foundation treatment	Core founded on rock, grout curtain and down-stream drains	Founded on rock, grout curtain and downstream drains
Upstream slope	1V:2.4H	-
Downstream slope	1V:2H	-
Crest width	35 ft	20 ft
<u>Saddle Dam</u>	None	
Type		Earth/Rockfill
Crest Elevation		1472 ft MSL
Crest Length		950 ft
Height		245 ft
Cut-off and Foundation Treatment		Core founded on rock, grout curtain and downstream drains.
Upstream Slope		1V:2.4H
Downstream Slope		1V:2H
Crest Width		35 ft

TABLE 1.1 (Cont'd)

Item	Watana	Devil Canyon
Diversion		
Cofferdam types	Rockfill	Rockfill
Cut-off and foundation	Founded on alluvium with slurry trench to rock	Founded on alluvium with slurry trench to rock
Upstream cofferdam crest elevation	1,545 ft MSL	947 ft MSL
Downstream cofferdam crest elevation	1,472 ft MSL	898 ft MSL
Maximum pool level during construction	1,536 ft MSL	944 ft MSL
Water passages	2 concrete-lined tunnels, 38 ft dia.	1 concrete-lined tunnel, 30 ft dia.
Outlet structures	Low-level structure with high head slide closure gates	Low-level structure with high head slide closure gates
Diversion capacity	80,500 cfs	36,000 cfs
Final closure	Mass concrete plugs in line with dam grout curtain	Mass concrete plugs in line with dam grout curtain
Releases during impounding	6,000 cfs maximum via regulating gates in diversion plug	6,000 cfs maximum via low-level fixed cone valves
Emergency Reservoir Drawdown		
	Low level outlet tunnel	Fixed cone valves
Maximum capacity	30,000 cfs	38,500 cfs

TABLE 1.1 (Cont'd)

Item	Watana	Devil Canyon
Outlet Facilities		
- capacity	24,000 cfs	38,500 cfs
- control struc.	Fixed cone valves	Fixed cone valves
- energy dissip.	Six 78" dia. fixed cone valves	3-90" dia., four 102" dia. fixed cone valves
Spillway		
Design Floods	Passes pmf preserving integrity of dam	Passes pmf preserving integrity of dam
	Passes routed 1:10,000-yr flood (156,000 cfs) with no damage to structures	Passes routed 1:10,000-yr flood (165,000 cfs) with no damage to structures
Main Spillway capacity	115,000 cfs	125,000 cfs
- control struc.	Gated ogee crests	Gated ogee crests
- energy dissip.	Flip Bucket	Flip Bucket
- crest elev.	2,148 ft MSL	1,404 ft MSL
- gate sizes	3 - 49 ft H x 36 ft W	3 - 56 ft H x 30 ft W
Emergency Spillway		
- Capacity	Pmf minus 1:10,000-yr flood 140,000 cfs	Pmf minus routed 1:10,000-yr flood 160,000 cfs
- type	Fuse plug	Fuse plug
- crest elev.	2200/2201.5	1464/1465.5
- chute width	310/200	200

TABLE 1.1 (Cont'd)

Item	Watana	Devil Canyon
<u>Power Intake</u>		
Type	Massive concrete structure embedded in rock	Massive concrete structure embedded in rock
Number of intakes	6*	4*
Draw-off requirements	Multi-level	Multi-level
Drawdown	120 ft*	50 ft
Maximum discharge/unit	3,870 cfs	3,670 cfs
<u>Penstocks</u>		
Type	Concrete-lined rock tunnels with downstream steel liner	Concrete-lined rock tunnels with downstream steel liner
Number of penstocks	6	4
Diameter	17 ft conc/15 ft steel	20 ft conc/15 ft steel
<u>Powerhouse</u>		
Cavern size	455 ft x 74 ft x 126 ft	360 ft x 74 ft x 126 ft
Type	Underground	Underground
Transformer area	Separate gallery	Separate gallery
Control room & administration	Surface**	Underground
Access - vehicle	Rock tunnel	Rock tunnel
Access - personnel	Elevator from surface	Elevator from surface

TABLE 1.1 (Cont'd)

Item	Watana	Devil Canyon
Power Plant		
Number of units	6	4
Nominal unit output***	170 MW at 652 ft net head	150 MW at 542 ft net head
Turbines		
Rated net head	680 ft	575 ft
Rated full gate output	250,000 hp	225,000 hp
Rated discharge	3,490 ft^3/s*	3,680 ft^3/s*
Station output @ rated head		
- best gate	936 MW*	560 MW
- full gate	1,098 MW*	656 MW
Generator		
Type	Vertical synchronous	Vertical synchronous
Rated output (60°C)	190 MVA air-cooled	180 MVA air-cooled
Overload (80°C)	218 MVA	210 MVA
Power factor	0.9	0.9
Voltage	15 kV ± 5%	15 kV ± 5%
Frequency	60 Hz	60 Hz
Speed, rpm	225 rpm	225 rpm
Transformers	9 x 145 MVA 15/345 kV, single phase	12 x 70 MVA 15/345 kV, single phase
Tailrace		
Water passages	Two 34 ft dia. concrete-lined tunnels	One 38 ft dia. concrete-lined tunnel
Elevation of water passages	Below minimum tailwater	Below minimum tailwater
Surge	Single surge chamber	Single surge chamber

2 - SUMMARY

This section presents a summary discussion of the work performed on the Susitna Hydroelectric Project since the submission of the Feasibility Report (Acres 1982a) in March 1982.

2.1 - Scope of Work

The scope and objective of the work are set forth in Amendment No. 4 to the Acres Plan of Study (POS). Principal areas of work were:

- Access Plan;
- Hydrologic Studies;
- Geotechnical;
- Design;
- Environmental;
- Transmission;
- Construction Costs and Schedules;
- Licensing; and
- Marketing and Finance.

The scope of work performed in these areas are presented in Section 3. The comprehensive environmental studies undertaken during this period are presented in Exhibit E of the FERC license application (Acres 1983). These environmental studies supersede those presented in the Feasibility Report (Acres 1982a). Readers, therefore in these studies, are advised to consult the FERC license application.

2.2 - Access Plan

The access plan presented in the Feasibility Report (1982a) recommended, for reasons of project schedule, that the construction of a pioneer road into the site be completed prior to issuance of the FERC license. Subsequent to the submittal of the report, this concept was found unacceptable by the various resource agencies and the plan was discarded.

Consequently, the original evaluation criteria was refined and additional alternatives were developed. The most responsive plan in each of the three corridors was identified and subjected to a multidiscipline assessment and comparison. After detailed consideration of these alternatives, the Power Authority Board of Directors formally adopted the Denali-North Plan (Plan 18), as the Proposed Access Plan in September 1982.

This route originates at a railhead in Cantwell and follows the existing Denali Highway to a point 21 miles east of the junction of the George Parks and Denali Highways. A new road would be constructed from that point due south to the Watana damsite. Most of the new road would traverse relatively flat terrain, resulting in a minimum of disturbance to areas away from the alignment. This was found to be the most easily constructed route for initial access to the Watana site. Access to the Devil Canyon development would consist primarily of a railroad extension from the existing Alaska Railroad at Gold Creek to a railroad facility adjacent to the Devil Canyon camp area. To provide access to the Watana damsite and the existing highway system, a connecting road would be constructed from the Devil Canyon railhead following a northerly loop to the Watana damsite. Access to the north side of the Susitna River would be attained via a high-level suspension bridge constructed approximately one mile downstream from the Devil Canyon dam. In general, the alignment crosses terrain with gentle-to-moderate slopes which would allow road bed construction without deep cuts.

2.3 - Refinement of Susitna Development

(a) Geotechnical Design Considerations

(i) Damsite

Work performed in the damsite consisted of geologic mapping and seismic refraction. Results of that work confirmed and refined work performed during 1980-1981. No additional information was found that would aversely affect project arrangement or costs.

(ii) Watana Relict Channel

Additional drilling and seismic refraction surveys were performed in the Watana Relict Channel to better determine site stratigraphy and material properties. Previous work in this area raised several questions regarding the potential of either breaching of the reservoir and subsurface seepage resulting in potential downstream piping and/or loss of energy.

Although the work performed in 1982 did not totally eliminate these concerns, it did provide additional information in evaluating these potential problems. Based on this work, the likelihood of such catastrophic events to occur appear small considering (a) the materials within the channel are relatively competent; (b) no widespread permafrost has been found; and (c) low surface gradients.

(iii) Fog Lakes Relict Channel

Additional seismic refraction and geologic mapping was performed in the Fog Lakes relict channel to determine the channel's configurations and assess the potential for leakage and breaching of the reservoir rim. Although drilling in the area remains to be done to confirm the seismic data, seepage through the Fog Lakes relict channel is not considered to have any significant economic impact.

Similarly, breaching of the reservoir rim was considered impossible due to the more than 100 feet of freeboard above Maximum Pool Elevation.

(b) Main Dam Alternatives

In addition to the alternative dams addressed in the Feasibility Report (Acres 1982a), a concrete-faced rock-filled dam was evaluated. Although the concrete faced rock-filled dam appears to offer some advantages over the earth-filled dam, it was not considered appropriate for the Susitna Project because of:

- Increase of 70 percent in height over precedent; and
- Potential impacts on high seismicity and climate conditions.

(c) Refinement of General Arrangement

Based on design considerations since March 1982, changes were made in the following areas:

- Watana project power and outlet facilities intakes;
- Devil Canyon project power intake;
- Devil Canyon project main spillway gates;
- Devil Canyon project compensation flow discharge pipe; and
- Devil Canyon main access road.

2.4 - Transmission Facilities

The principal work with transmission facilities since March 1982 included a reassessment of the transmission line corridor within the Central Study Area, and a land acquisition analysis in the northern, southern, and central study areas for the purpose of fine-tuning the alignment and to determine the legal descriptions of the rights-of-way.

The routing of the transmission line corridor in the Central Study Area was changed so that it showed the same corridor as the access road between the dams and the railroad extension between Devil Canyon and Gold Creek. The final alignment within this section was chosen to parallel the access road and railroad extension to the maximum extent possible so as to minimize the mileage of new access trail development. The selected alignment represents the optimum alignment of the transmission line based on existing data.

Land acquisition and environmental studies performed in the transmission corridor resulted in the alignment being refined to the extent that most of the problem associated with these two areas would be avoided.

2.5 - Project Operation

Additional studies undertaken since March 1982 included refinements to operating rule curves, downstream flow, and energy demand. Based on these studies, it was determined that the Watana reservoir will be operated at a normal operating level of El 2183 with an annual drawdown to El 2093 with Watana operation and EL 2080 with Watana/Devil Canyon operation. The Devil Canyon reservoir will be operated at a normal operating level of El 1455 with an average annual drawdown of 28 feet.

The 1:30-year annual water volume was proportioned on a monthly basis according to the long-term average monthly distribution. This increased the WY 1969 average annual discharge at Gold Creek 1600 cfs from 5600 cfs to 7200 cfs, and increased the average annual discharge at Gold Creek for the 32 years of record by 0.5 percent.

Project operational flows have been scheduled to satisfy the water requirements in the slough spawning areas during the critical period when the salmon must gain access to the spawning areas in August and early September.

2.6 - Reservoir and River Temperature Studies

The dynamic reservoir simulation model DYRESM was used to predict reservoir temperature stratification and outflow temperature for Watana and Devil Canyon reservoirs. The temperature structure for Watana was found to follow the typical pattern for reservoirs and lakes of similar size and climate conditions. In general, stratification occurs during June, July, and August, with maximum surface temperature of 10.9°C occurring in July and August. The model, which includes natural inflow temperature and simulated outflow temperature, shows that, during summer months, the outflow temperature follows natural temperature trends but is cooler during July and slightly warmer in August.

A model of the Devil Canyon reservoir shows that reservoir stratification is weak in June but builds during July and August. Cooling at Devil Canyon is delayed to late September and early October due partly to the warmer inflows to the Devil Canyon reservoir from Watana. Maximum outflow temperature from Devil Canyon occurs in late July to mid-August and is about 8°C. Temperature from mid-September to December 31 falls from a high of 8°C to a low of 3.5°C.

2.7 - Estimates of Cost

Changes to the Watana cost estimate made subsequent to the submission of the Feasibility Report (Acres 1982a) included:

- Access Plan 18 replacing Plan 5;
- Work leading up to diversion was recosted for an accelerated schedule;
- Storage facilities were provided at Cantwell;
- Material prices were revised to reflect larger transportation route;
- Quantities were revised for the intake and spillway;

- All work (other than noted) was estimated on basis of 10-hour shifts;
- Construction power was re-estimated based on direct generation at site; and
- Contingencies were evaluated for each account.

Changes to Devil Canyon cost estimate included:

- Access Plan 18 revision;
- Intake quantities revised;
- 10-hour work shifts; and
- Cash flow curves revised.

In addition, a number of features designed to mitigate potential impacts on the natural environment and on residents and communities in the vicinity of the project were addressed. These mitigation costs have been estimated at $153 million. Costs for full reservoir clearing at both sites have been estimated at $65 million.

2.8 - Development Schedule

The project schedules as shown in Section 17 of the Feasibility Report (Acres 1982a), have been updated as a result of on-going studies and span the period from 1983 until 2004.

Principal revisions to the Watana schedule include the following:

- Replacement of the pioneer road with the Denali Access Plan 18. Work prior to receipt of the FERC license was eliminated.

- Activities leading up to diversion were revised for an accelerated schedule; and

- The pre-construction of one circuit of the permanent transmission line from Gold Creek was eliminated.

Revision to the Devil Canyon schedule included the following:

- Incorporation of the Denali Access Plan 18 and the start of access construction was advanced accordingly.

2.9 - Economic, Marketing, and Financial Evaluation

Several changes and modifications to the economic, marketing, and financial evaluations have been made subsequent to the Feasibility Report (1982a) based on on-going studies and FERC license requirements. These changes and additions are presented below.

(a) Financing

The Feasibility Report presented several plans for financing the Susitna project. Since that time, one plan has emerged as the most likely. This involves a combination of direct state-of Alaska appropriations and revenue bonds issued by the Power Authority. Watana is expected to be financed by issuance of approximately $0.9 billion (1982 dollars) of revenue bonds.

The completion of the Susitna project by the building of Devil Canyon is expected to be financed on the same basis with the issuance of approximately $2.2 billion of revenue bonds over the years 1994 to 2202.

(b) Cost Estimate Changes

Cost estimates have been changed to reflect adjustments to the project since the Feasibility Report. These changes, however, were relatively minor and made no change in the financial analysis.

(c) Comments on the Tussing Report

Following submittal of the Feasibility Report, a report entitled "Alaska Energy Planning Studies - Substantiative Issues and the Effects of Recent Events," a review by A.R. Tussing and G.K. Ericson, was prepared for the Division of Policy Development and Planning, Office of the Governor of the State of Alaska. A detailed response to that report has been provided in Section 10.

(d) Generating Planning Studies

The generating planning studies which formed the basis of the project economic analysis has been updated since the Feasibility Report, based on comments and review of the March report.

REFERENCES

Acres American Incorporated. 1982a. Susitna Hydroelectric Project Feasibility Report. Prepared for the Alaska Power Authority.

______. 1983. Susitna Hydroelectric Project FERC License Application. Prepared for the Alaska Power Authority

3 - OBJECTIVES

3.1 - Introduction

The scope of work undertaken from the March 15, 1982, submittal of the Susitna Hydroelectric Feasibility Report to present is set forth in Amendment No. 4, dated September 27, 1982. The principal technical tasks undertaken during this period included:

- Access Plan;
- Hydrologic Studies;
- Geotechnical Explorations;
- Design Development;
- Environmental Studies;
- Transmission;
- Construction Cost Estimates & Schedules;
- Licensing; and
- Marketing and Finance.

3.2 - Access Plan

The March 1982 Feasibility Report recommended an access plan which, for reasons of project schedule, would necessitate the construction of a pioneer road prior to the FERC license being issued. Subsequent to the issuance of the Feasibility Report, this concept was found unacceptable by the various reviewing agencies.

Consequently, this study involved the development of a new access criteria and the development of additional access alternatives within the three potential corridors detailed in 1981 studies. The objective was to delineate the most responsive plan in each corrider and to subject these plans to a multidisciplinary assessment and comparison to ultimately arrive at the most acceptable route. Results of this study are presented in Section 4.

3.3 - Hydrology Studies

Work performed under this subtask involved:

- The continued collection of baseline climatic, water quality, sediment, discharge, ice, thermal, ground water, stage, and snow creep data;

- Preparation of reports on ground water analyses, sedimentation, and post-project esturine effects;

- Further refine energy and minimum flow requirements for downstream fisheries;

- Prepare ground water report with ground water contours of the study sloughs, ground water sources, and ground water inflow rates; and

- Continue reservoir and instream flow studies to enable the project impacts to be assessed and a mitigation plan to be adopted.

3.4 - Geotechnical Exploration

The following tasks were performed:

- Additional soil drilling and testing in the Watana relict channel;
- Prepare an amendment to the 1980-81 Geotechnical Report;
- Develop a scope of a 1982 winter program; and
- Prepare necessary contracts to perform the work.

3.5 - Design Development Update

The scope of this subtask involved the continued updating of various design aspects of the project with particular attention directed to those design changes necessary to meet changing environmental criteria and improve application. Particular areas to be addressed were:

- Intake structures;
- Construction haul roads;
- Transmission line routing; and
- Access roads.

3.6 - Environmental Studies

(a) Introduction

The principal objective of the environmental studies was to continue coordination among environmental study subtasks and subcontractors, establish and maintain reporting schedules, continue informal agency contact, and prepare Exhibit E for the FERC license application.

(b) Cultural Resource Investigations

Work under this program involved:

- Conducting a reconnaissance Level 1 survey along the proposed transmission corridor from Fairbanks to Healy, Willow to Anchorage, and Watana damsite to the Intertie;
- Conducting a Reconnaissance Level 1 survey at the "new" segment of the proposed access route on the north side of the Susitna River, from Devil Canyon to the Parks Highway;
- Conducting archaeological evaluations of areas to be impacted by geotechnical testing;

- Conducting reconnaissance Level 2 survey on the Tsusena Creek "cat trail" from the Watana Camp area to the mouth of the Tsusena Creek; and

- Preparing the cultural resource components of the FERC license.

(c) Land Ownership and Acquisition

To further define land ownership and acquisition in connection with access road and transmission line corridor and assist in preparation of Exhibit G for the FERC license application.

(d) Land Use Analysis - Mitigation of Aesthetic Impact

To further assess aesthetic impacts and develop a draft plan for mitigation of impacts of the Project on the aesthetic resources of the upper Susitna River Basin.

(e) Recreation Planning

To develop specific proposed sites for recreation facilities to include cost and schedules for development of the facilities.

(f) Aquatic Impact Assessment

To analyze and interpret available baseline knowledge of the Susitna River aquatic system and examine and present in models and reports the impacts on fishery resources of hydroelectric development in the upper Susitna Basin. Work undertaken during this period included:

- Coordination with the Alaska Department of Fish and Game and the Susitna Hydro Study Group on the fishery and aquatic habitat studies and other groups and agencies involved in assessing impacts on fishery.

- Assemble an information management program to collect and compile available knowledge of the Susitna River aquatic system relating specifically to the examination of project impact on fishery resources.

- Construction of a dynamic model of the Susitna River Basin which will be used to develop quantitative relationships between aquatic habitats and resources pursuant to various hydro operational scenarios.

- Establish a format, schedule, and content of periodic briefings on aquatic study, analysis, and impact assessment efforts to the Alaskan resource agencies.

(g) Fisheries Mitigation Planning

To develop a mitigation plan consisting of quantified mitigation options for each phase of the project as well as to identify deficiencies and prioritize studies needed to fulfill the quantification requirements of the mitigation plan.

(h) Fisheries Mitigation Planning

The primary objective of the fisheries mitigation planning effort was to develop a mitigation plan consisting of quantified mitigation options for each phase of the project with the ultimate goal of providing the mitigation documents required by the FERC for license approval.

(i) Susitna Hatchery Siting Study

To determine if it is appropriate that consideration be given to the feasibility of siting an enhancement hatchery to insure maintenance of the existing stocks at or above their present population levels.

(j) Wildlife and Habitat Impact Assessment and Mitigation Planning

To continue with ongoing data collection and workshop and field studies; prepare supporting reference documents; assess various project impacts; and develop final comprehensive mitigation plans for inclusion in FERC license application.

(k) Transmission Line Survey

To locate the centerline of the transmission lines to include width and location of right-of-way:

- Define all points of intersection (P.I.) along the centerline by measuring the station for each P.I. and its bearings;

- Provide information regarding the transmission equipment and appurtenance; and

- Prepare drawings and documentations as required to meet the FERC requirements for license application.

3.7 - Cost Estimate Update

To update project cost estimate in connection with the elimination of the pioneer road and the selected access route and to update other planning and design changes for inclusion in the FERC license application.

3.8 - Update Engineering/Construction Schedule

To update construction schedules in connection with the elimination of the pioneer road and the selected access route and other planning and design changes for inclusion in FERC license application.

3.9 - Preparation of FERC License Application

To prepare and coordinate all engineering and support activities necessary for the preparation of the FERC license application.

3.10 - Marketing and Finance

Marketing and finance work was directed to:

- Further review A. Tussing's draft report "Alaska Energy Planning Studies"; hold meeting to resolve outstanding differences between Tussing's and Acres reports on Susitna project risk analysis; and prepare appropriate responses; and

- Resolve issues concerning sources and extent of financing and annual revenues as the basis for preparing applicable portions of Exhibit D.

4 - ACCESS PLAN

4.1 - Introduction

This section describes the development of alternative access plans from the original Acres POS of February 1980 through to the final selection of the proposed access plan as approved by the Power Authority Board of Directors in September 1982. The main body of this section is concerned with the access planning studies which have taken place subsequent to the issuance of the Susitna Hydroelectric Project Feasibility Report in March 1982 (Acres 1982a). In the latter part of this section, the modifications and improvements that have been made since the selection of the proposed plan in September 1982 are discussed. In addition, the general guidelines that have been developed for roadway construction and mining of borrow sites are described.

4.2 - Background

The original POS proposed that a single access route would be selected by May 1981, to be followed by a detailed environmental investigation.

Early in the study, three main access corridors were identified. Plans developed within these three corridors were evaluated on the basis of available information, comments and concerns of various state agencies, and recommendations from the Susitna Hydroelectric Steering Committee (SHSC). After an initial evaluation, the decision was made to assess all three alternative corridors in more detail throughout 1981 and recommend a selected route later in the year. This assessment included environmental studies, engineering studies, aerial photography, and geologic mapping of all three alternative routes.

In March of 1982, the Power Authority presented the results of the Susitna Hydroelectric Feasibility Report to the public, resource agencies, and organizations. This report recommended an access plan which, for reasons of project schedule, would have necessitated the construction of a pioneer road prior to the FERC license being issued. The construction of a pioneer road, however, was considered unacceptable by the resource agencies and the plan was discarded.

Consequently, the evaluation criteria were refined and additional access alternatives were developed. The most responsive plan in each of the three corridors was identified and subjected to a multidisciplinary assessment and comparison. After consideration of these alternatives, the Power Authority Board of Directors formally adopted the Denali-North Plan, Plan 18, as the Proposed Access Plan in September 1982 (Figure 4.5).

4.3 - Objectives

Throughout the development, evaluation, and selection of the access plans, the foremost objective was to provide a transportation system that would support construction activities and allow for the orderly development and maintenance of site facilities.

Meeting this fundamental objective involved the consideration not only of economics and technical ease of development but also many other diverse factors. Of prime importance was the potential for impacts to the environment, namely, impacts to the local fish and game populations. In addition, since the Native villages and the Cook Inlet Region will eventually acquire surface and subsurface rights, their interests were recognized and taken into account as were those of the local communities and general public.

With so many different factors influencing the choice of an access plan, it was evident that no one plan would satisfy all interests. The aim during the selection process was to consider all factors in their proper perspective and produce a plan that represented the most favorable solution to both meeting project-related goals and minimizing impacts to the environment and surrounding communities.

4.4 - Existing Access Facilities

The proposed Devil Canyon and Watana damsites are located approximately 115 miles northeast of Anchorage and 140 miles south of Fairbanks (Figure 4.1). The Alaska Railroad, which links Anchorage and Fairbanks, passes within 12 miles of the Devil Canyon damsite at Gold Creek. The George Parks Highway (Route 3) parallels the Alaska Railroad for much of its route, although between the communities of Sunshine and Hurricane the highway is routed to the west of the railroad, to the extent that Gold Creek is situated approximately 16 miles south of the intersection of the railroad and highway. At Cantwell, 51 miles north of Gold Creek, the Denali Highway (Route 8) leads easterly approximately 116 miles to Paxson where it intersects the Richardson Highway. To the south, the Glenn Highway (Route 1) provides the main access to Glenallen and intersects the Richardson Highway which leads south to Valdez. A location map with the proposed access route is shown in Figure 4.1.

4.5 - Corridor Identification and Selection

The Acres POS, February 1980, identified three general corridors leading from the existing transportation network to the damsites. This network consists of the George Parks Highway and the Alaska Railroad to the west of the damsites and the Denali Highway to the north. The three general corridors are identified in Figure 4.2.

Corridor 1 - From the Parks Highway to the Watana damsite via the north side of the Susitna River.

Corridor 2 - From the Parks Highway to the Watana damsite via the south side of the Susitna River.

Corridor 3 - From the Denali Highway to the Watana damsite.

The access road studies identified a total of eighteen alternative plans within the three corridors. The alternatives were developed by laying out routes on topographical maps in accordance with accepted road and rail design criteria. Subsequent field investigations resulted in minor modifications to reduce environmental impacts and improve alignment.

The preliminary design criteria adopted for access road and rail alternatives were selected on the basis of similar facilities provided for other remote projects of this nature. Basic roadway parameters were as follows:

- Maximum grade of 6 percent;
- Maximum curvature of 5 degrees;
- Design loading of 80^k axle and 200^k total during construction; and
- Design loading of HS-20 after construction.

Railroad design parameters utilized were as follows:

- Maximum grade of 2.5 percent;
- Maximum curvature of 10 degrees; and
- Loading of E-72.

Once the basic corridors were defined, alternative routes which met these design parameters were established and evaluated against technical, economic, and environmental criteria. Next, within each corridor, the most favorable alternative route in terms of length, alignment, and grade was identified. These routes were then combined together and/or with existing roads or railroads to form the various access plans. The development of alternative routes is discussed in more detail in the R & M Access Planning Study (R&M 1982).

4.6 - Development of Plans

At the beginning of the study, a plan formulation and initial selection process was developed. The criteria that most significantly affected the selection process were identified as:

- Minimizing impacts to the environment;
- Minimizing total project costs;
- Providing transportation flexibility to minimize construction risks;
- Providing ease of operation and maintenance; and
- Preconstruction of a pioneer road.

This led to the development of eight alternative access plans.

During evaluation of these access plans, input from the public, resource agencies, and Native organizations was sought and their response resulted in an expansion of the original list of eight alternative plans to eleven. Plans 9 and 10 were added as a suggestion by the SHSC as a means of limiting access by having rail-only access as far as the Devil Canyon damsite to reduce adverse environmental impacts in and around the project area. Plan 11 was added as a way of providing access from only one main terminus, Cantwell, and thus alleviate socio-economic impacts to the other communities in the Railbelt (principally Gold Creek, Trapper Creek, Talkeetna, and Hurricane).

Studies of these eleven access plans culminated in the production of the Acres Access Route Selection Report (Acres 1982b) which recommended Plan 5 as the route which most closely satisfied the selection criteria. Plan 5 starts from the George Parks Highway near Hurricane and traverses along the Indian River to Gold Creek. From Gold Creek, the road continues east on the south side of the Susitna River to the Devil Canyon damsite, crosses a low level bridge, and continues east on the north side of the Susitna River to the Watana damsite. For the project to remain on schedule, it would have been necessary to construct a pioneeer road along this route prior to the FERC license being issued.

In March of 1982, the Power Authority presented the results of the Susitna Hydroelectric Feasibility Report, of which Access Plan 5 was a part, to the public, agencies, and organizations. During April, comment was obtained relative to the feasibility study from these groups. As a result of these comments, the pioneer road concept was eliminated, the evaluation criteria were refined, and six additional access alternatives were developed.

During the evaluation process, the Power Authority staff formulated a further plan, thus increasing the total number of plans under evaluation to eighteen. This subsequently became the plan recommended by Power Authority staff to the Power Authority Board of Directors, and was formally adopted as the Proposed Access Plan in September 1982 (Acres 1982c).

A description of each of the eighteen alternative access plans, together with a breakdown of costs, is given in Table 4.1.

4.7 - Evaluation of Plans

The refined criteria used to evaluate the eighteen alternative access plans were:

- No pre-license construction;

- Provide initial access within one year;

- Provide access between sites during project operation phase;

- Provide access flexibility to ensure project is brought on-line within budget and schedule;

- Minimize total cost of access;

- Minimize initial investment required to provide access to the Watana damsite;

- Minimize risks to project schedule;

- Minimize environmental impacts;

- Accommodate current land uses and plans;

- Accommodate agency preferences;

- Accommodate preferences of Native organizations;

- Accommodate preferences of local communities; and

- Accommodate public concerns.

All eighteen plans were evaluated using these refined criteria to determine the most responsive access plan in each of the three basic corridors. An explanation of the criteria and the plans which were subsequently eliminated is given below.

To meet the overall project schedule requirements for the Watana development, it is necessary to secure initial access to the Watana damsite within one year of the FERC license being issued. The constraint of no pre-license construction resulted in the elimination of any plan in which initial access could not be completed within one year. This constraint led to the elimination of the access plan submitted in the Susitna Hydroelectric Project Feasibility Report (Plan 5) and five other plans (2, 8, 9, 10, and 12).

Upon completion of both the Watana and Devil Canyon dams, it is planned to operate and maintain both sites from one central location (Watana). To facilitate these operation and maintenance activities, access plans with a road connection between the sites were considered superior to those plans without a road connection. Plans 3 and 4 do not have access between the sites and were discarded.

The ability to make full use of both rail and road systems from southcentral ports of entry to the railhead facility provides the project management with far greater flexibility to meet contingencies and control costs and schedule. Limited access plans utilizing an all rail or rail link system with no road connection to an existing highway have less flexibility and would impose a restraint on project operation that could result in delays and significant increases in cost. Four plans with limited access (Plans 8, 9, 10, and 15) were eliminated because of this constraint.

Residents of the Indian River and Gold Creek communities are generally not in favor of a road access near their communities. Plan 1 was discarded because Plans 13 and 14 achieve the same objectives without impacting the Indian River and Gold Creek areas.

Plan 7 was eliminated because it includes a circuit route connecting to both the George Parks and Denali Highways. This circuit route was considered unacceptable by the resource agencies, since it aggravated the control of public access.

The seven remaining plans found to meet the selection criterion were Plans 6, 11, 13, 14, 16, 17, and 18. Of these, Plans 13, 16, and 18 in the North, South, and Denali corridors, respectively, were selected as being the most responsive plan in each corridor. The three plans are described below and the route locations shown in Figures 4.3 through 4.5.

4.8 - Description of Most Responsive Access Plans

Plan 13 "North" (See Figure 4.3)

This plan utilizes a roadway from a railhead facility adjacent to the George Parks Highway at Hurricane to the Watana damsite following the north side of the Susitna River. A spur road seven miles in length would be constructed at a later date to service the Devil Canyon development. Traveling southeast from Hurricane, the route passes through Chulitna Pass, avoids the Indian River and Gold Creek areas, then parallels Portage Creek at a high elevation on the north side. After crossing Portage Creek, the road continues at a high elevation to the Watana damsite. Access to the south side of the Susitna River at the Devil Canyon damsite would be attained via a high-level suspension bridge approximately one mile downstream from the Devil Canyon dam. This route crosses mountainous terrain at high elevations and includes extensive sidehill cutting in the region of Portage Creek. Construction of the road, however, would not be as difficult as Plan 16, the South route.

Plan 16 "South" (See Figure 4.4)

This route generally parallels the Susitna River, traversing west to east from a railhead at Gold Creek to the Devil Canyon damsite, and continues following a southerly loop to the Watana damsite. To achieve initial access within one year, a temporary, low-level crossing to the north side of the Susitna River is required approximately twelve miles downstream from the Watana damsite. This would be used until completion of a permanent, high-level bridge. In addition, a connecting road from the George Parks Highway to Devil Canyon, with a major high-level bridge across the Susitna River, is necessary to provide full road access to either site. The topography from Devil Canyon to Watana is mountainous, and the route involves the most difficult construction of the three plans, requiring a number of sidehill cuts and the construction of two major bridges. To provide initial access to the Watana damsite, this route presents the most difficult construction problems of the three routes, and has the highest potential for schedule delays and related cost increases.

Plan 18 "Denali-North" (See Figure 4.5)

This route originates at a railhead in Cantwell, and then follows the existing Denali Highway to a point 21 miles east of the junction of the George Parks and Denali highways. A new road would be constructed from this point due south to the Watana damsite. Most of the new road would traverse relatively flat terrain which would allow construction using side-borrow techniques, resulting in a minimum of disturbance to areas away from the alignment. This is the most easily constructed route for initial access to the Watana site. Access to the Devil Canyon development would consist primarily of a railroad extension from the existing Alaska Railroad at Gold Creek to a railhead facility adjacent to the Devil Canyon camp area. To provide access to the Watana damsite and the existing highway system, a connecting road would be constructed from the Devil Canyon railhead following a northerly loop to the Watana damsite. Access to the north side of the Susitna River would be attained via a high-level suspension bridge constructed approximately one mile downstream from the Devil Canyon dam. In general, the alignment crosses terrain with gentle-to-moderate slopes which would allow roadbed construction without deep cuts.

4.9 - Comparison of the Selected Alternative Plans

To determine which of the three access plans best accommodated both project-related goals and the concerns of the resource agencies, Native organizations, and affected communities, the plans were subjected to a multidisciplinary evaluation and comparison. Among the issues addressed in this evaluation and comparison were:

- Costs;
- Schedule;
- Environmental issues;
- Cultural resources;
- Socioeconomics/Community preferences;
- Preferences of Native organizations;
- Relationship to current land stewardships, uses and plans; and
- Recreation.

(a) Costs

The relative cost of the three access alternatives is presented in Table 4.2. This table outlines the total costs of the three plans with the schedule constraint that initial access must be completed within one year of receipt of the FERC license. Costs to complete the access requirement for the Watana development only are also shown. The costs of the three alternative plans can be summarized as follows:

Estimated Total Cost ($\$ \times 10^6$)

Plan	Watana	Devil Canyon	Total	Discounted Total
North (13)	241	127	368	287
South (16)	312	104	416	335
Denali-North (18)	224	213	437	326

The costs are in terms of 1982 dollars and include all costs associated with design, construction, maintenance, and logistics. Discounted total costs (present worth as of 1982) have been shown here for comparison purposes to delineate the differences in timing of expenditure.

For the development of access to the Watana site, the Denali-North Plan has the least cost and the lowest probability of increased costs resulting from unforeseen conditions. The North Plan is ranked second. The North Plan has the lowest overall cost while the Denali-North has the highest. However, a large portion of the cost of the Denali-North Plan would be incurred more than a decade in the future. When converting costs to equivalent present value, the overall costs of the Denali-North and the South plans are similar.

(b) Schedule

The schedule for providing initial access to the Watana site was given prime consideration, since the cost ramifications of a schedule delay are highly significant. The elimination of pre-license construction of a pioneer access road has resulted in the severe compression of onsite construction activities in the 1985-86 period. With the present overall project scheduling, should diversion not be completed prior to spring runoff in 1987, dam foundation preparation work would be delayed one year and, hence, cause a delay to the overall project of one year. It has been estimated that the resultant increase in cost would likely be in the range of 100-200 million dollars. The access route that assures the quickest completion and, hence, the earliest delivery of equipment and materials to the site has a distinct advantage. The forecasted construction periods for initial access, including mobilization, for the three plans are:

Denali-North	6 months
North	9 months
South	12 months

It is evident that, with the Denali-North Plan, site activities can be supported at an earlier date than by either of the other routes. Consequently, the Denali-North Plan offers the highest probability of meeting schedule and the least risk of project delay and increase in cost. The schedule for access in relation to diversion is shown for the three plans in Figure 4.6.

(c) Environmental Issues

Environmental issues have played a major role in access planning to date. The main issue is that a road will permit human entry into an area which is relatively inaccessible at present, causing both direct and indirect impacts. A summary of these key impacts with regard to wildlife, wildlife habitat, and fisheries for each of the three alternative access plans is outlined below.

(i) Wildlife and Habitat

The three selected alternative access routes are made up of five distinct wildlife and habitat segments:

1. Hurricane to Devil Canyon: This segment is composed almost entirely of productive mixed forest, riparian, and wetlands habitats important to moose, furbearers, and birds. It includes three areas where slopes of over 30 percent will require side-hill cuts, all above wetland zones vulnerable to erosion-related impacts.

2. Gold Creek to Devil Canyon: This segment is composed of mixed forest and wetland habitats, but includes less wetland habitat and fewer wetland habitat types than the Hurricane to Devil Canyon segment. Although this segment contains habitat suitable for moose, black bears, furbearers, and birds, it has the least potential for adverse impacts to wildlife of the five segments considered.

3. Devil Canyon to Watana (North Side): The following comments apply to both the Denali-North and North routes. This segment traverses a varied mixture of forest, shrub, and tundra habitat types, generally of medium-to-low productivity as wildlife habitat. It crosses the Devil and Tsusena Creek drainages and passes by Swimming Bear Lake which contains habitat suitable for furbearers.

4. Devil Canyon to Watana (South Side): This segment is highly varied with respect to habitat types, containing complex mixtures of forest, shrub, tundra, wetlands, and riparian vegetation. The western portion is mostly tundra and shrub, with forest and wetlands occurring along the eastern portion in the vicinity of Prairie Creek, Stephan Lake, and Tsusena and Deadman Creeks. Prairie Creek supports a high concentration of brown bears, and the lower Tsusena and Deadman Creek areas support lightly hunted concentrations of moose and black bears. The Stephan Lake area supports high densities of moose and bears. Access development in this segment would probably result in habitat loss or alteration, increased hunting, and human-bear conflicts.

5. Denali Highway to Watana: This segment is primarily composed of shrub and tundra vegetation types, with little productive forest habitat present. Although habitat diversity is relatively low along this segment, the southern portion along Deadman Creek contains an important brown bear concentration and browse for moose. This segment crosses a peripheral portion of

the range of the Nelchina caribou herd; and there is evidence that as herd size increases, caribou are likely to migrate across the route and calve in the vicinity. Although it is not possible to predict with any certainty how the physical presence of the road itself or traffic will affect caribou movements, population size, or productivity, it is likely that a variety of site-specific mitigation measures will be necessary to protect the herd.

These segments combine, as illustrated below, to form the three alternative access plans:

North	Segments 1 and 3
South	Segments 1, 2, and 4
Denali-North	Segments 2, 3, and 5

Table 4.3 summarizes the three alternative access plans with respect to potential adverse impacts on wildlife and their supporting habitat.

The North route has the least potential for creating adverse impacts to wildlife and habitat, for it traverses or approaches the fewest areas of productive habitat and zones of species concentration or movement. The wildlife impacts of the South Plan can be expected to be greater than those of the North Plan because of the proximity of the route to Prairie Creek, Stephan Lake, and the Fog Lakes, which currently support high densities of moose and black and brown bears. In particular, Prairie Creek supports what may be the highest concentration of brown bears in the Susitna Basin. The Denali-North Plan crosses the periphery of the Nelchina caribou range and movement zone between the Denali Highway and Susitna River. In addition, this route has the potential for disturbances to brown and black bear concentrations and movement zones in the Deadman and Tsusena Creek areas. Overall, however, the potential for adverse impacts with the Denali-North Plan is similar to the South Plan.

(ii) Fisheries

All three alternative routes would have direct and indirect impacts on fisheries. Direct impacts include the effects on water quality and aquatic habitat, whereas increased angling pressure is an indirect impact. A qualitative comparison of the fishery impacts related to the alternative plans was undertaken. The parameters used to assess impacts along each route included the number of streams crossed, the number and length of lateral transits (i.e., where the roadway parallels the streams and runoff from the roadway can run directly into the stream), the number of watersheds affected, and the presence of resident and anadromous fish.

The three access plan alternatives incorporate combinations of seven distinct fishery segments.

1. Hurricane to Devil Canyon: Seven stream crossings will be required along this route, including Indian River, which is an important salmon spawning river. Both the Chulitna River watershed and the Susitna River watershed are affected by this route. The increased access to Indian River will be an important indirect impact to the segment. Approximately 1.8 miles of cuts into banks greater than 30 degrees occur along this route requiring erosion control measures to preserve the water quality and aquatic habitat.

2. Gold Creek to Devil Canyon: This segment crosses six streams and is expected to have minimal direct and indirect impacts. Anadromous fish spawning is likely in some streams, but impacts are expected to be minimal. Approximately 2.5 miles of cuts into banks greater than 30 degress occur in this section. In the Denali-North Plan, this segment would be railroad, whereas in the South Plan it would be road.

3. Devil Canyon to Watana (North Side, North Plan): This segment crosses 20 streams and laterally transits 4 rivers for a total distance of approximately 12 miles. Seven miles of this lateral transit parallels Portage Creek, which is an important salmon spawning area.

4. Devil Canyon to Watana (North Side, Denali-North Plan): The difference between this segment and Segment 3 described above is that it avoids Portage Creek by traversing through a pass 4 miles to the east. The number of streams crossed is consequently reduced to 12, and the number of lateral transits is reduced to 2 with a total distance of 4 miles.

5. Devil Canyon to Watana (South Side): The portion between the Susitna River crossing and Devil Canyon requires nine steam crossings, but it is unlikely that these contain significant fish populations. The portion of this segment from Watana to the Susitna River is not expected to have any major direct impacts; however, increased angling pressure in the vicinity of Stephan Lake may result because of the proximity of the access road. The segment crosses both the Susitna and the Talkeetna watersheds. Seven miles of cut into banks of greater than 30 degrees occur in this segment.

6. Denali Highway to Watana: The segment from the Denali Highway to the Watana damsite has 22 stream crossings and passes from the Nenana into the Susitna watershed. Much of the route crosses, or is in proximity to seasonal grayling habitat and runs parallel to Deadman Creek for nearly 10 miles. If recruitment and growth rates are low along this segment, it is unlikely that resident populations could sustain heavy fishing pressure. Hence, this segment has a high potential for impacting the local grayling population.

7. Denali Highway: The Denali Highway from Cantwell to the Watana access turnoff will require upgrading. The upgrading will involve only minor realignment and negligible alteration to present stream crossings. The segment crosses 11 streams and laterally transits 2 rivers for a total distance of 5 miles. There is no anadromous fish spawning in this segment, and little direct or indirect impact is expected.

The three alternative access routes comprised the following segments:

North	Segments 1 and 3
South	Segments 1, 2, and 5
Denali-North	Segments 2, 4, 6 and 7

The Denali-North Plan is likely to have a significant direct and indirect impact on grayling fisheries, given the number of stream crossings, lateral transits, and watersheds affected. Anadromous fisheries impact will be minimal and will only be significant along the railroad spur between Gold Creek and Devil Canyon.

The South Plan is likely to create significant direct and indirect impacts at Indian River, which is an important salmon spawning river. Anadromous fisheries impacts will occur in the Gold Creek to Devil Canyon segment the same as for the Denali-North Plan. In addition, indirect impacts may occur in the Stephan Lake area.

The North Plan, like the South Plan, may impact salmon spawning activity in Indian River. Significant impacts are likely along Portage Creek because of water quality impacts through increased erosion and because of indirect impacts such as increased angling pressure.

With any of the selected plans, direct and indirect effects can be minimized through proper engineering design and prudent management. Criteria for the development of borrow sites and the design of bridges and culverts together with mitigation recommendations are discussed in Exhibit E of the FERC License Application.

(d) Cultural Resources

A Level 1 cultural resources survey was conducted over a large portion of the three access plans. The segment of the Denali-North Plan between the Watana damsite and the Denali Highway traverses an area of high potential for cultural resource sites. Treeless areas along this segment lack appreciable soil desposition, making cultural resources visible and more vulnerable to secondary impacts. Common to both the Denali-North and the North Plan is the segment on the north side of the Susitna River from the Watana damsite to where the road parallels Devil Creek. This segment is also largely treeless, making it highly vulnerable to secondary impacts. The South Plan traverses less terrain of archaeological importance than either of the other two routes. Several sites exist along the southerly Devil Canyon to Watana segment; however, since much of the route is forested, these sites are less vulnerable to secondary impacts.

The ranking from the least to the highest with regard to cultural resource impacts is South, North, Denali-North. However, impacts to cultural resources can be fully mitigated by avoidance, protection or salvage; consequently, this issue was not critical to the selection process.

(e) Socioeconomics/Community Preferences

Socioeconomic impacts on the Mat-Su Borough as a whole would be similar in magnitude for all three plans. However, each of the three plans affects future socioeconomic conditions in differing degrees in certain areas and communities. The important differences affecting specific communities are outlined below.

(i) Cantwell

The Denali-North Plan would create significant increases in population, local employment, business activity, housing, and traffic. These impacts result because a railhead facility would be located at Cantwell and because Cantwell would be the nearest community to the Watana damsite. Both the North and South Plans would impact Cantwell to a far lesser extent.

(ii) Hurricane

The North Plan would significantly impact the Hurricane area, since currently there is little population, employment, business activity or housing. Changes in socioeconomic indicators for Hurricane would be less under the South Plan and considerably less under the Denali-North plan.

(iii) Trapper Creek and Talkeetna

Trapper Creek would experience slightly larger changes in economic indicators with the North plan than under the South or Denali-North Plans. The South Plan would impact the Talkeetna area slightly more than the other two plans.

(iv) Gold Creek

With the South Plan, a railhead facility would be developed at Gold Creek creating a significant increase in socio-economic indicators in this area. The Denali-North Plan includes construction of a railhead facility at the Devil Canyon site which would create impacts at Gold Creek, but not to the same extent as the South Plan. Minimal impacts would result in Gold Creek under the North Plan.

The responses of people who will be affected by these potential changes are mixed. The people of Cantwell are generally in favor of some economic stimulus and development in their community. Some concern was expressed over the potential effects of access on fish and wildlife resources, but with stringent hunting regulations implemented and enforced, it was considered that this problem could be successfully mitigated. The majority of residents in both Talkeetna and Trapper Creek have indicated a strong preference to maintain their general lifestyle patterns and do not desire rapid, uncontrolled change. The Denali-North Plan would impact these areas the least. The majority of landholders in the Indian River subdivision favor retention of the remote status of the area and do not want road access through their lands. This and other feedback to date indicate that the Denali- North Plan will come closest to creating socioeconomic changes that are acceptable to or desired by landholders and residents in the potentially impacted areas and communities.

(f) Preferences of Native Organizations

Cook Inlet Region Inc. (CIRI) has selected lands surrounding the impoundment areas and south of the Susitna River between the damsites. CIRI has officially expressed a preference for a plan providing road access from the George Parks Highway to both damsites along the south side of the Susitna River. The Tyonek Native Corporation and the CIRI village residents have indicated a similar preference. The South Plan provides full road access to their lands south of the Sutina River and thus comes closest to meeting these desires. The AHTNA Native Region Corporation presently owns land bordering the Denali Highway and, together with the Cantwell Village Corporation, has expressed a preference for the Denali-North Plan. None of the Native organizations support the North Plan.

(g) Relationship to Current Land Stewardships, Uses and Plans

Much of land required for project development has been or may be conveyed to Native organizations. The remaining lands are generally under state and federal control. The South Plan traverses more Native-selected lands than either of the other two routes, and although present land use is low, the Native organizations have expressed an interest in potentially developing their lands for mining, recreation, forestry, or residential use.

The other land management plans that have a large bearing on access development are the Bureau of Land Management's (BLM) recent decision to open the Denali Planning Block to mineral exploration and the Denali Scenic Highway Study being initiated by the Alaska Land Use Council. The Denali Highway to Deadman Mountain segment of the Denali-North Plan would be compatible with BLM's plans. During the construction phase of the project, the Denali-North Plan could create conflicts with the development of a Denali scenic highway; however, after construction, the access road and project facilities could be incorporated into the overall scenic highway planning.

By providing public access to a now relatively inaccessible, semi-wilderness area, conflict may be imposed with wildlife habitats necessitating an increased level of wildlife and people management by the various resource agencies.

In general, however, none of the plans will be in major conflict with any present federal, borough, or Native management plans.

(h) Recreation

Following meetings, discussions, and evaluation of various access plans, it became evident that recreation plans are flexible enough to adapt to any of the three selected access routes. No one route was identified which had superior recreational potential associated with it. Therefore, compatibility with recreational aspects was essentially eliminated as an evaluation criterion.

4.10 - Summary of Final Selection of Plans

In reaching the decision as to which of the three alternative access plans was to be recommended, it was necessary to evaluate the highly complex interplay that exists between the many issues involved. Analysis of the key issues described in the preceding pages indicates that no one plan satisfied all the selection criteria nor accommodated all the concerns of the resource agencies, Native organizations, and public. Therefore, it was necesary to make a rational assessment of tradeoffs between the sometimes conflicting environmental concerns of impacts on fisheries, wildlife, socioeconomics, land use, and recreational opportunities on the one hand, with project cost, schedule, construction risk, and management needs on the other. With all these factors in mind, it should be emphasized that the primary purpose of access is to provide and maintain an uninterrupted flow of materials and personnel to the damsite throughout the life of the project. Should this fundamental objective not be achieved, significant schedule and budget overruns will occur.

(a) Elimination of "South Plan"

The South route, Plan 16, was eliminated primarily because of the construction difficulties associated with building a major low-level crossing 12 miles downstream from the Watana damsite. This crossing would consist of a floating or fixed temporary bridge which would need to be removed prior to spring breakup during the first three years of the project (the time estimated for completion of the permanent bridge). This would result in a serious interruption in the flow of materials to the site. Another drawback is that floating bridges require continual maintenance and are generally subject to more weight and dimensional limitations than permanent structures.

A further limitation of this route is that, for the first three years of the project, all construction work must be supported solely from the railhead facility at Gold Creek. This problem arises because it will take an estimated three years to complete construction of the connecting road across the Susitna River at Devil Canyon to Hurricane on the George Parks Highway. Limited access such as this does not provide the flexibility needed by the project management to meet contingencies and control costs and schedule.

Delays in the supply of materials to the damsite, caused by either an interruption of service of the railway system or the Susitna River not being passable during spring breakup, could result in significant cost impacts. These factors, together with the realization that the South Plan offers no specific advantages over the other two plans in any of the areas of environmental or social concern, led to the South Plan being eliminated from further consideration.

(b) Schedule Constraints

The choice of an access plan thus narrowed down to the North and Denali-North Plans. Of the many issues addressed during the evaluation process, the issue of "schedule" and "schedule risk" was determined as being the most important in the final selection of the recommended plan.

Schedule plays such an important role in the evaluation process because of the special set of conditions that exist in a subarctic environment. Building roads in these regions involves the consideration of many factors not found elsewhere in other environments. Specifically, the chief concern is one of weather and the consequent short duration of the construction season. The roads for both the North and Denali-North plans will, for the most part, be constructed at elevations in excess of 3,000 feet. At these elevations, the likely time available for uninterrupted construction in a typical year is five months, and at most six months.

The forecasted construction period for initial access, including mobilization, is six months for the Denali-North Plan and nine months for the North Plan. At first glance, a difference in schedule of three months does not seem great; however, when considering that only six months of the year are available for construction, the additional three months become highly significant, especially when read in the context of the likely schedule for issuance of the FERC license.

The date the FERC license will be issued cannot be accurately determined at this time, but is forecast to be within the first nine months of 1985. Hence, the interval between licensing and the scheduled date of diversion can vary significantly, as shown graphically in Figure 4.6. This illustrates that the precise time of year the license is issued is critical to the construction schedule of the access route, for if delays in licensing occur, there is a risk of delay to the project schedule to the extent that river diversion in 1987 will be missed. If diversion is not achieved prior to spring runoff in 1987, dam foundation preparation work will be delayed one year, and hence, a delay to the overall project of one year will result.

(c) Cost Impacts

The increase in costs resulting from a one-year delay has been estimated to be in the range of 100-200 million dollars. This increase includes the financial cost of investment by spring of 1987, the financial costs of rescheduling work for a one-year delay, and replacement power costs.

(d) Conclusion

The Denali-North Plan has the highest probability of meeting schedule and least risk of increase in project cost for two reasons. First, it has the shortest construction schedule (six months). Second, a passable route could be constructed even under winter conditions, since the route traverses relatively flat terrain almost its entire length. In contrast, the North route is mountainous and involves extensive sidehill cutting, especially in the Portage Creek area. Winter construction along sections such as this would present major problems and increase the probability of schedule delay.

(e) Plan Recommendation

It is recommended that the Denali-North route be selected so as to ensure completion of initial access to the Watana damsite by the end of the first quarter of 1986, for it is considered that the risk of significant cost overruns is too high with any other route.

4.11 - Modifications to Recommended Access Plan

Following approval of the recommended plan by the Power Authority Board of Directors in September 1982, further studies were conducted to optimize the route location in terms of both cost and minimizing impacts to the environment. Each of the specialist subconsultants was asked to review the proposed plan to identify specific problem areas, develop modifications and improvements, and contribute to drawing up a set of general guidelines for access development. The results of this review are capsulized below.

(a) An important red fox denning area and a bald eagle nest were identified close to the proposed road alignment, so consequently the road was realigned to create a buffer zone of at least one-half mile between the road and the sites.

(b) Portions of the access road between the Denali Highway and the Watana damsite will traverse flat terrain. In these areas, a berm type cross section will be formed with the crown of the road being "two to three feet" above the elevation of adjacent ground. Steep side slopes would present an unnatural barrier to migrating caribou, exaggerate the visual impact of the road itself, and aggravate the problem of snow removal. To reduce these problems, the side slopes will be flattened using excavated peat material and rehabilitated through scarification and fertilization.

(c) The chief fisheries concern was the proximity of the proposed route to Deadman Creek, Deadman Lake, and Big Lake. For a distance of approximately 16 miles, the road parallels Deadman Creek, which contains good to excellent grayling populations. To alleviate the problem of potential increased angling pressure, the road was moved one half to one mile west of Deadman Creek.

(d) The preliminary, reconniassance-level, cultural resource survey conducted on the proposed access route located and documented sites on or in close proximity to the right-of-way and/or potential borrow sites. The number of these sites that will be directly or indirectly affected will not be known until a more detailed investigation is completed. However, indications are that all sites can be mitigated by avoidance, protection, or salvage.

(e) The community that will undergo the most growth and socioeconomic change with the proposed access plan is Cantwell. Subsequent to the selection of this access plan, the residents of Cantwell were solicited for their comments and suggestions. Their responses resulted in the following modifications and recommendations:

(i) The plan was modified to include paving the road from the railhead facility to four miles east of the junction of the George Parks and Denali Highways. This will eliminate any problem with dust and flying stones in the residential district.

(ii) For safety reasons, it is recommended that:

- Speed restrictions be imposed along the above segment;
- A bike path be provided along the same segment, since the school is adjacent to the access road; and
- Improvements be made to the intersection of the George Parks and Denali Highways including pavement markings and traffic signals.

(f) The main concern of the Native organizations represented by CIRI is to gain access to their land south of the Susitna River. Under the proposed access plan, these lands will be accessible by both road and rail, the railroad being from Gold Creek to the Devil Canyon damsite on the south side of the Susitna River. After completion of the Watana dam, road access will be provided across the top of the dam to Native lands. Similarly, a road across the top of the Devil Canyon dam will be constructed once the main works at Devil Canyon are completed. In addition, alternative road access will be available via the high-level suspension bridge one mile downstream from the Devil Canyon dam.

(g) From an environmental standpoint, it is desirable to limit the number of people in the project area in order to minimize impacts to wildlife habitat and fisheries. In comparison with a paved road, an unpaved road would deter some people from visiting the area and thus create less of an impact to the environment. An unpaved road would also serve to maintain as much as possible the wilderness character of the area. An evaluation of projected traffic volumes and loadings confirmed that an unpaved gravel road with a 24-foot running surface and 5-foot wide shoulder would be adequate.

(h) For the efficient, economical, and safe movement of supplies, the following design parameters were chosen:

- Maximum grade	6 percent
- Maximum curvature	5 degrees
- Design loading:	
. during construction	80^k axle, 200^k total
. after construction	HS-20

Adhering to these grades and curvatures, the entire length of the road would result in excessively deep cuts and extensive fills in some areas, and could create serious technical and environmental problems. From an engineering standpoint, it is advisable to avoid deep cuts because of the potential slope stability problems, especially in permafrost zones. Also, deep cuts and large fills are detrimental to the environment, for they act as a barrier to the migration of big game and disrupt the visual harmony of the wilderness setting. Therefore, in areas where adhering to the aforementioned grades and curvatures involves extensive cutting and filling, the design standards will be reduced to allow steeper grades and shorter radius turns.

This flexibility of design standards provides greater latitude to "fit" the road within the topography and thereby enhance the visual quality of the surrounding landscape. For reasons of driver safety, the design standards will in no instance be less than those applicable to a 40-mph design speed.

(i) One of the most important issues associated with the construction of the access road is the development of borrow sites. Potential impacts can be mitigated through selective siting of borrow sites and the use of state-of-the-art gravel-removal techniques. After close consultation with fish and wildlife, recreational, aesthetic, and cultural resource specialists, the following guidelines were developed to ensure that any impacts are minimized.

- Active floodplain and streambed locations should be avoided;

- In locating borrow sites, first priority is to be given to well-drained upland locations, and second priority to first-level terrace sites;

- First-level terrace sites should be located on the inactive side of the floodplain and mined by pit excavation rather than by shallow scraping;

- If wet processing is required, water withdrawal and discharge locations should be carefully sited to minimize fish and wildlife disturbance. Drawdown in overwintering pools used by fish or aquatic mammals and any disturbances to spawning areas are to be avoided. In addition, water intake structures should be enclosed in screened boxes;

- All material sites should be developed in phases by aliquots, and portions of the site which are more sensitive from an environmental standpoint should be left until last;

- For rehabilitation purposes, sites should have irregular boundaries, including projections of undisturbed, vegetated terrain into the site. Where ponding will occur, as in first-level terrace sites, islands of undisturbed vegetated terrain should be left within the perimeter of the operational site; and

- Organic overburden, slash, and debris stockpiled during cleaning should be distributed over the excavated area prior to fertilization. The rehabilitation of sites is to be completed by the end of the growing season immediately following last use.

The modifications and improvements to the proposed access plan, together with the general guidelines that have been developed for roadway construction and mining of borrow sites, have been fully incorporated into the draft FERC License Application. A more detailed description of specific mitigation plans is given in the relevant sections of Exhibit E of the Application.

4.12 - Description of Proposed Access Plan

(a) Watana Access

Access to the Watana damsite will connect with the existing Alaska Railroad at Cantwell where a railhead and storage facility occupying 40 acres will be constructed. This facility will act as a transfer point from rail to road transport and as a storage area for a two-week backup supply of materials and equipment. From the railhead facility, the road will follow an existing route to the junction of the George Parks and Denali Highways (a distance of 2 miles), then proceed in an easterly direction for a distance of 21.3 miles along the Denali Highway. A new road, 41.6 miles in length, will be constructed from this point due south to the Watana campsite. On completion of the dam, access to Native lands on the south side of the Susitna River will be provided from the Watana campsite, with the road crossing along the top of the dam. This will involve the construction of an additional 2.6 miles of road, bringing the total length of new road to 44.2 miles.

The majority of the new road will traverse relatively flat terrain involving only isolated sections of cut and fill. Where it is not possible to locate the road on sidehill slopes of gentle to moderate steepness, the road will be formed using side borrow techniques; with the crown of the road being two to three feet above the elevation of adjacent ground. By balancing cut and fill and using side borrow techniques, the need for borrow material from pits and consequent disturbance to areas away from the alignment will be minimized.

It has been estimated that it will take approximately six months to secure initial access, with an additional year for completion and the upgrading of the Denali Highway section.

(b) Devil Canyon Access

Access to the Devil Canyon development will consist primarily of a railroad extension from the existing Alaska Railroad at Gold Creek to a railhead and storage facility adjacent to the Devil Canyon camp area. To provide flexibility of access, the railroad extension will be augmented by a road between the Devil Canyon and Watana damsites.

(i) Rail Extension

Except for a 2-mile section where the route traverses steep terrain alongside the Susitna River, the railroad will climb steadily for 12.2 miles from Gold Creek to the railhead facility near the Devil Canyon camp. Nearly all of the route traverses potentially frozen, basal till on side slopes varying from flat to moderately steep. Several streams are crossed, requiring the construction of large culverts. However, where the railroad crosses Jack Long Creek, small bridges will be built to minimize impacts to the aquatic habitat. In view of the construction conditions, it is estimated that it will take eighteen months to two years to complete the extension.

(ii) Connecting Road

From the railhead facility at Devil Canyon, a connecting road will be built to a high-level suspension bridge approximately one mile downstream from the damsite. The route then proceeds in a northeasterly direction, crosses Devil Creek and swings round past Swimming Bear Lake at an elevation of 3500 feet before continuing in a south easterly direction through a wide pass. After crossing Tsusena Creek, the road continues south to the Watana damsite. The overall length of the road is 37.0 miles.

In general, the alignment crosses good soil types with bedrock at or near the surface. Erosion and thaw settlement should not be a problem, since the terrain has gentle to moderate slopes which will allow roadbed construction without deep cuts. The connecting road will be built to the same standard and in accordance with the design parameters used for the Watana access road. However, as is the case for the Watana damsite access road, the design standards will be reduced to as low as 40 mph in areas where it is necessary to minimize the extent of cutting and filling. The affected areas are the approaches to some of the stream crossings, the most significant being those of the high-level bridge crossing the Susitna River downstream from Devil Canyon.

The 1,790-foot-long, high-level suspension bridge crossing the Susitna River is the controlling item in the construction schedule, requiring three years for completion. Therefore, it will be necessary to begin construction three years prior to the start of the main works at the Devil Canyon damsite.

Figure 4.7 shows the proposed access plan route. Figure 4.8 shows details, for both the Watana and Devil Canyon developments, of typical road and railroad cross sections, railhead facilities, and the high-level bridge at Devil Canyon.

REFERENCES

Acres American Incorporated. 1982a. Susitna Hydroelectric Project Feasibility Report. Prepared for the Alaska Power Authority.

______. 1982b. Susitna Hydroelectric Project Subtask 2.10 - Access Route Selection Report. Prepared for the Alaska Power Authority.

______. 1982c. Susitna Hydroelectric Project Access Plan Recommendation Report. Prepared for the Alaska Power Authority.

R&M Consultants, Inc. 1982. Access Planning Study. Prepared for Acres American Incorporated.

TABLE 4.1: ACCESS PLAN COSTS

Plan	1	2	3	4	5	6
Description	Roadway: Parks Highway to Devil Canyon & Watana on South Side of Susitna	Rail: Gold Creek To Devil Canyon & Watana on South Side of Susitna	Roadway: Denali Highway to Watana Parks Highway to Devil Canyon on South Side of Susitna. No Connecting road.	Roadway: Denali Highway to Watana Rail: Gold Creek to Devil Canyon on South Side of Susitna. No Connecting road.	Roadway: Parks Highway to Devil Canyon on South Side of Susitna Devil Canyon to Watana on North Side of Susitna.	Roadway: Denali Highway to Watana Rail: Gold Creek to Devil Canyon on South Side of Susitna. Connecting road on North Side of Susitna.
Mileage Road	62	--	91*	65*	81	107*
Rail	--	58		16	--	16
Design and Construction Cost ($ x 1,000,000)	170	149	157	123	160	180
Maintenance Cost ($ x 1,000,000)	9	5	7	5	8	12
Logistics Cost ($ x 1,000,000)	214	214	228	228	216	228
Total Cost ($ x 1,000,000)	393	368	392	356	384	420
Construction Schedule for Initial Access (Years)	1	3-4	1	1	2-3	1
Construction Schedule for Full Access (Years)	3-4	3-4	2-3	2-3	3-4	3
Bridges Major (>1000 ft)	3	2	1	0	2	0
Minor (<1000 ft)	2	0	1	0	1	0

* Includes upgrading 21 miles of the Denali Highway.

Revision: E

Plan	7	8	9	10	11	12
Description	Roadway: Denali Highway to Watana Parks Highway to Devil Canyon on South Side of Susitna. Connecting Road on North Side of Susitna	Roadway: Gold Creek to Devil Canyon on South Side of Susitna. Devil Canyon to Watana on North Side of Susitna.	Rail: Gold Creek to Devil Canyon on South Side of Susitna. Roadway: Devil Canyon to Watana on North Side of Susitna.	Rail: Gold Creek to Devil Canyon on South Side of Susitna. Roadway: Devil Canyon to Watana on South Side of Susitna.	Roadway: Denali Highway to Watana. Connecting Road between Watana and Devil Canyon on North Side of Susitna.	Roadway: Parks Highway to Devil Canyon and Watana on North Side of Susitna.
Mileage Road	132*	69	56	36	114*	61*
Rail	--	--	16	16	--	--
Design and Construction Cost ($ x 1,000,000)	215	117	126	136	172	127
Maintenance Cost ($ x 1,000,000)	9	7	6	6	11	7
Logistics Cost ($ x 1,000,000)	228	216	216	214	258	225
Total Cost ($ x 1,000,000)	452	340	348	356	441	359
Construction Schedule for Initial Access (Years)	1	2-3	3	2	1	2
Construction Schedule for Full Access (Years)	3	3	3	3	2-3	3-4
Bridges Major (>1000 ft)	1	0	0	2	0	1
Minor (<1000 ft)	1	1	1	1	1	2

* Includes upgrading 21 miles of the Denali Highway.

TABLE 4.1 (Page 3 of 3)

Revision: E

Plan	13	14	15	16	17	18
Description	Roadway: Parks Highway to Watana on North Side of Susitna with Branch Road to South Bank at Devil Canyon.	Rail/Roadway: Gold Creek Railroad Extension. Roadway: To Devil Canyon and Watana on South Side of Susitna. Connecting Road tp Parks Highway.	Rail/Roadway: Gold Creek Railroad Extension. Roadway: To Devil Canyon and Watana on South Side of Susitna.	Roadway: Gold Creek to Watana on South Side of Susitna. Connecting Road to Devil Canyon and Parks Highway.	Roadway: Denali Highway to Watana. Connecting Road to Devil Canyon on South Side of Susitna. Rail: Gold Creek to Devil Canyon on South Side of Susitna.	Roadway: Denali Highway to Watana Connecting Road to Devil Canyon on North Side of Susitna. Rail: Gold Creek to Devil Canyon on South Side of Susitna.
Mileage Road	59	64	49	69	102*	97*
Rail	--	7	7	--	14	14
Design and Construction Cost ($ x 1,000,000)	115	174	128	156	200	188
Maintenance Cost ($ x 1,000,000)	7	9	6	10	12	11
Logistics Cost ($ x 1,000,000)	223	215	215	216	227	227
Total Cost ($ x 1,000,000)	345	398	349	382	439	426
Construction Schedule for Initial Access (Years)	1	1	1	1	1	1
Construction Schedule for Full Access (Years)	3	3-4	3	3	3-4	3
Bridges Major (>1000 ft)	1	2	1	2	1	1
Minor (<1000 ft)	2	2	1	2	1	1

* Includes upgrading 21 miles of the Denali Highway.

TABLE 4.2: ACCESS PLAN COSTS

INITIAL ACCESS WITHIN ONE YEAR

Description	North Plan 13			South Plan 16			Denali-North Plan 18		
	Watana	Devil Canyon	Combined	Watana	Devil Canyon	Combined	Watana	Devil Canyon	Combined
Mileage Road Rail	52 0	7 0	59 0	69 0	0 0	69 0	61* 0	36 14	97* 14
Construction Cost ($ x 1,000,000)	95	20	115	156	0	156	82	106	188
Logistics Cost ($ x 1,000,000)	118	105	223	115	101	216	127	100	227
Maintenance ($ x 1,000,000)	5	2	7	7	3	10	4	7	11
Subtotal ($ x 1,000,000)	218	127	345	278	104	382	213	213	426
Impact of Accelerated Schedule ($ x 1,000,000)	23	0	23	34	0	34	11	0	11
Total ($ x 1,000,000)	241	127	368	312	104	416	224	213	437
Construction Schedule for Initial Access (Years)	1			1			1		
Construction Schedule for Full Access (Years)	3			3			3		

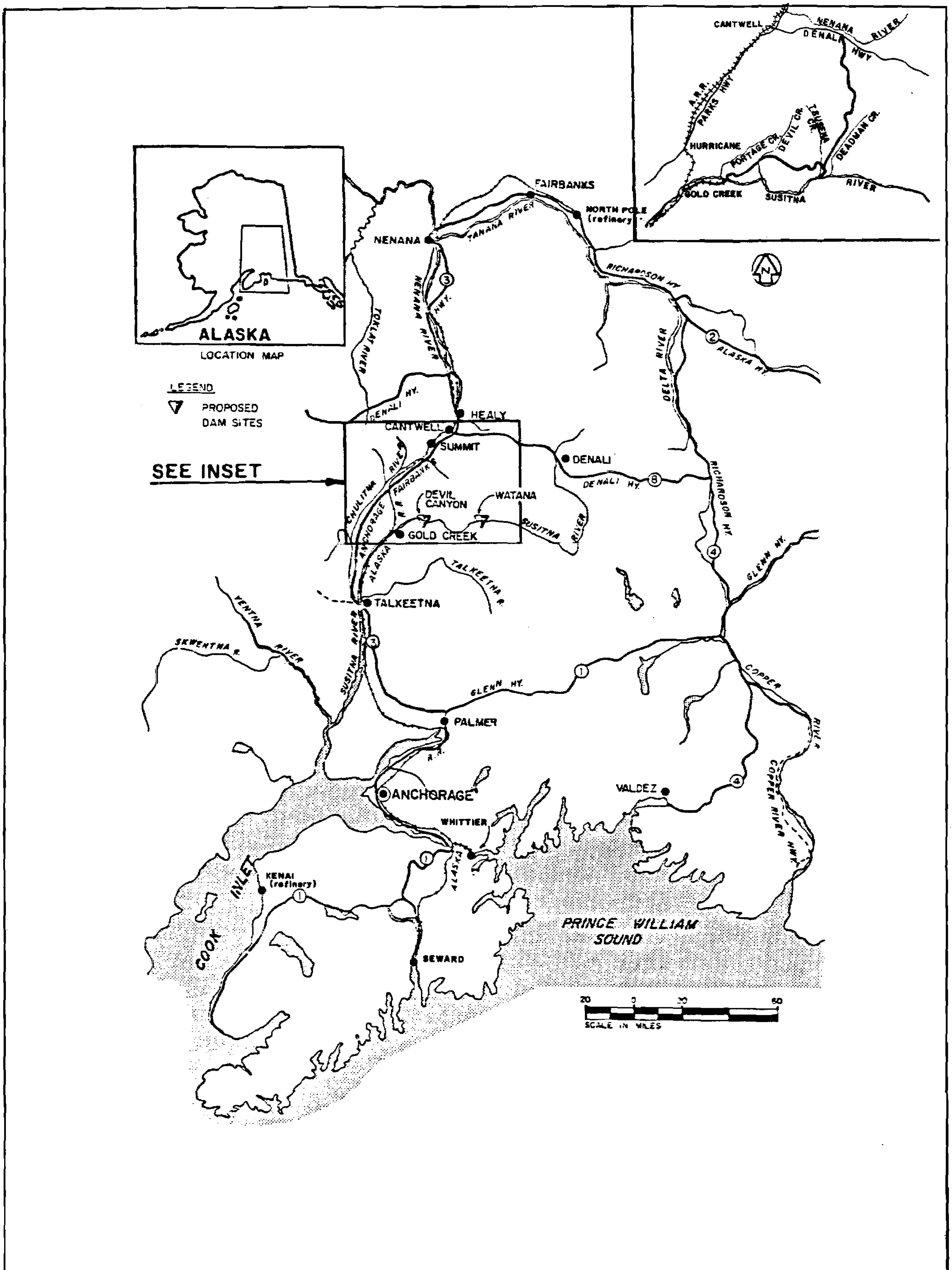
* Includes upgrading 21 miles of the Denali Highway.

TABLE 4.3: SUMMARY OF WILDLIFE HABITAT ISSUES ASSOCIATED WITH ACCESS ALTERNATIVES

Issue	North (13)	South (16)	Denali-North (18)
Waterfowl	No waterbodies of high relative importance along route.	Stephan Lake is of high relative importance to waterfowl.	No waterbodies of high relative importance along route.
Raptor Nests	Avoids known nest sites.	Avoids known nest sites.	One-half mile from bald eagle nest on Deadman Creek.
Breeding Birds	Least amount of productive forest habitat removed.	Greatest amount of productive forest habitat removed.	Amount of forest removed less than South Route but greater than North Route.
Aquatic Furbearers	Avoids Fog Lakes-Stephan Lake wetlands.	Near Fog Lakes-Stephan Lake wetlands.	Avoids Fog Lakes-Stephan Lake wetlands.
	Crosses highly productive habitat in Chulitna Pass area.	Crosses highly productive habitat in Chilitna Pass area.	Avoids Chulitna Pass area.
	Near productive habitat along Portage Creek.	Avoids Portage Creek area.	Avoids Portage Creek area.
	Avoids Jack Long Creek beaver concentration area.	Disturbs Jack Long Creek beaver concentration area.	Disturbs Jack Long Creek beaver concentration area.
Red Fox Den: Concentration Areas	Within 1/4 mile of Swimming Bear Lake den sites.	Avoids red fox den concentration areas.	Within 1/4 mile of Swimming Bear Lake den sites.
	Avoids Deadman Creek and Deadman Lake den areas.		One-half mile from Deadman Creek and Deadman Lake den concentration areas.

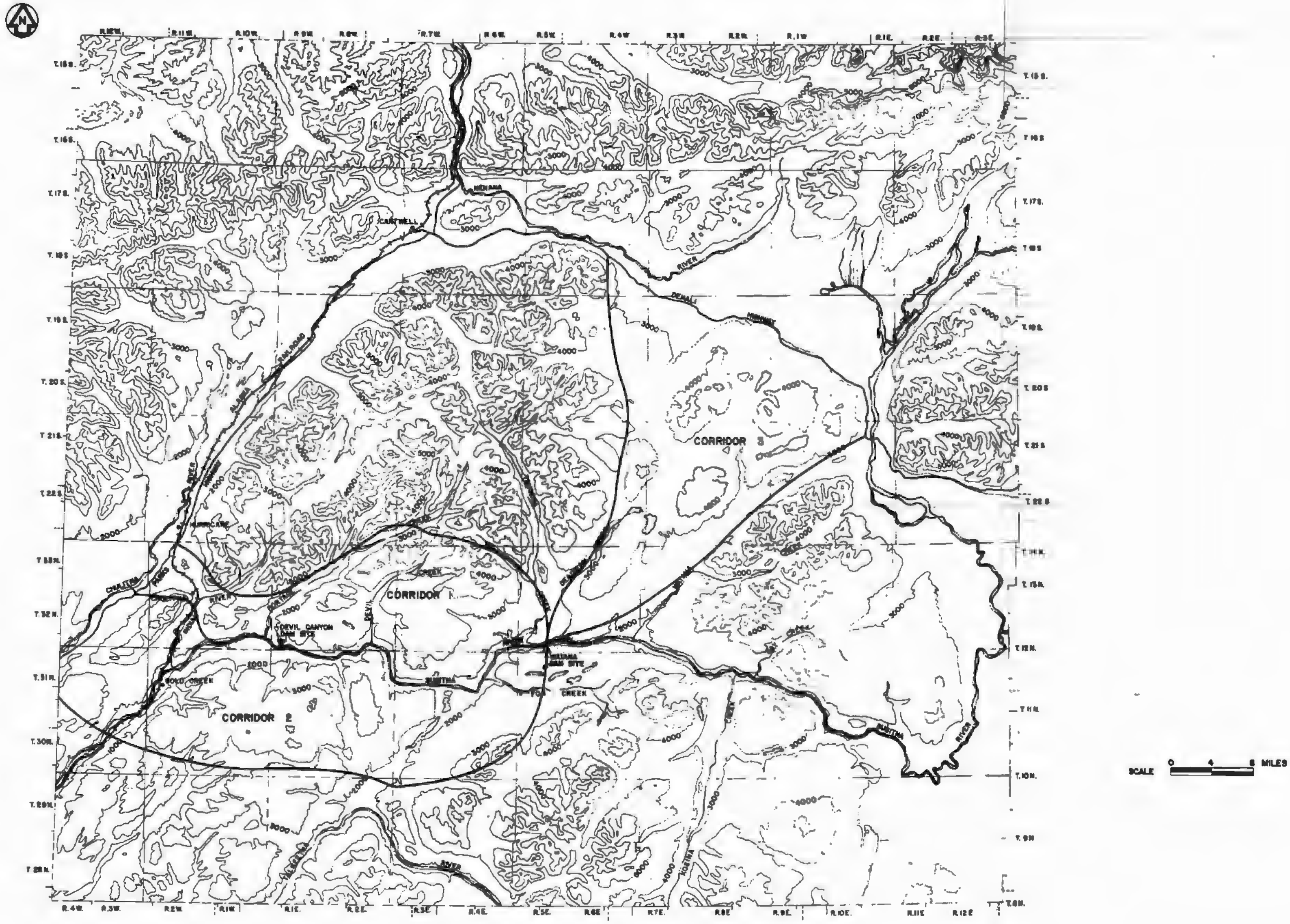
TABLE 4.3 (Cont'd)

Issue	North (13)	South (16)	Denali-North (18)
Brown Bears	Avoids Prairie Creek concentration area.	Near Prairie Creek concentration area; crosses movement corridor between Prairie Creek and Susitna River.	Avoids Prairie Creek concentration area.
	Avoids Deadman Creek concentration area.	Avoids Deadman Creek area.	Crosses Deadman Creek concentration area.
Black Bears	Avoids den sites.	Near several den sites west of Tsusena Creek.	Near several den sites west of Tsusean Creek.
	Traverses important south-facing slopes.	Fewer south-facing slopes are traversed.	Traverses important south-facing slopes.
	Least amount of forest is removed.	Removes greatest amount of forest.	Removes more forest than North Routh but less than South Route.
Caribou	Avoids caribou range and movement corridor between Denali Highway and Susitna River.	Avoids caribou range and movement between Denali Highway and Susitna River.	Crosses caribou range and movement corridor between Denali Highway and Susitna River.
	Avoids Fog Lakes-Stephan Lake caribou range.	Near Fog Lakes-Stephan Lake caribou ranges.	Avoids Fog Lakes-Stephan Lake caribou range.
Moose	Traverses important south-facing slopes.	Fewer south-facing slopes are traversed.	Traverses important south-facing slopes.
	Least amount of forest is removed.	Removes greatest amount of forest.	Removes less forest than South Route but more than North Route.
	Avoids Fog Lakes-Stephan Lake area.	Near Fog Lakes-Stephan Lake wetlands.	Avoids Fog Lakes-Stephan Lake wetlands.
Secondary Effects:	Least potential for secondary effects through public access and recreational development.	Potential for secondary effects through public access less than Denali-North Route but greater than North Route. High potential for secondary effects through recreational development of lands south of Susitna River.	Highest potential for secondary effects through public access and recreational development.



LOCATION MAP

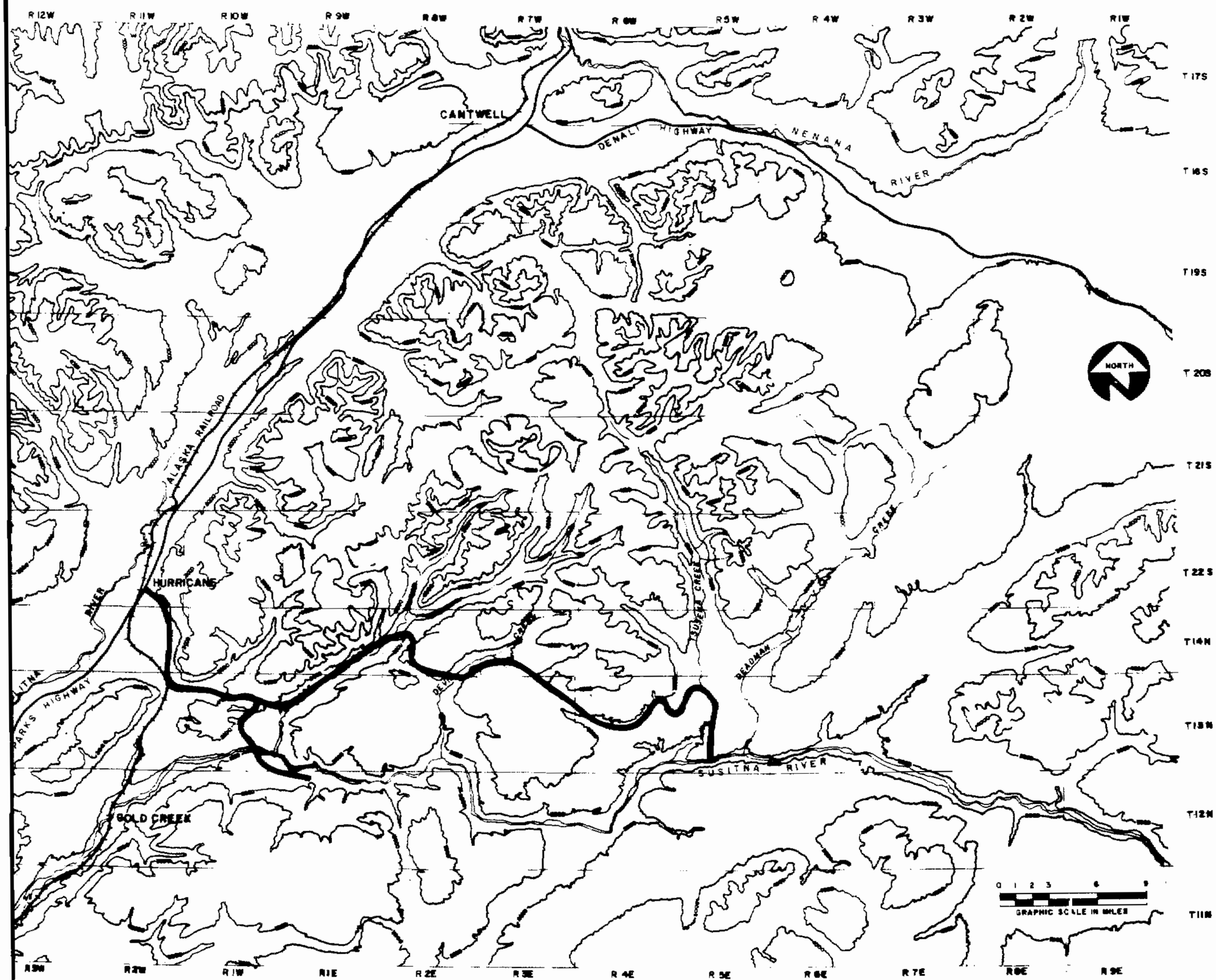
FIGURE 4.1



REFERENCE: BASE MAP FROM USGS, 1:250,000
HEALY, ALASKA
TALKEETNA MOUNTAINS, ALASKA

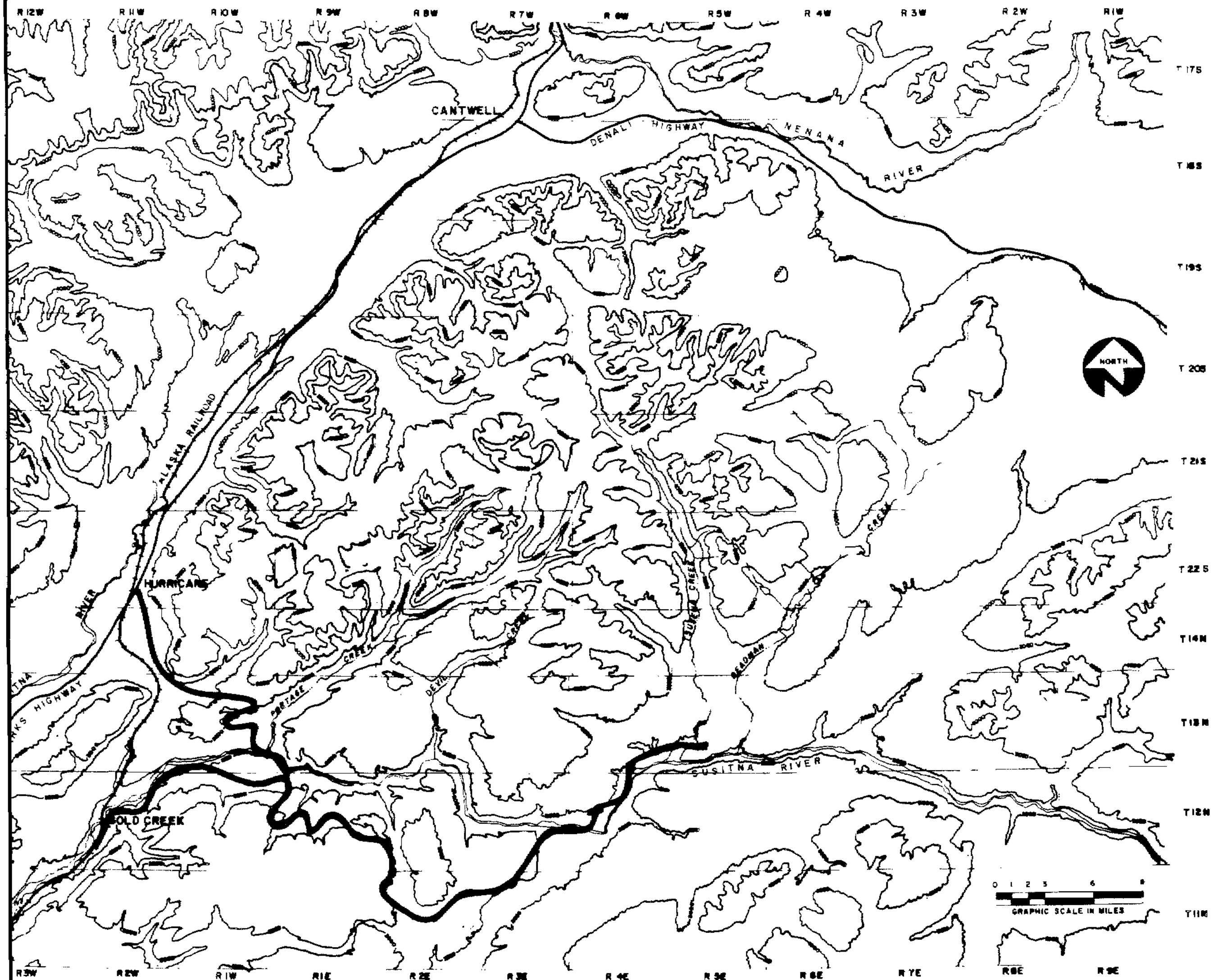
ALTERNATIVE ACCESS CORRIDORS

FIGURE 4.2



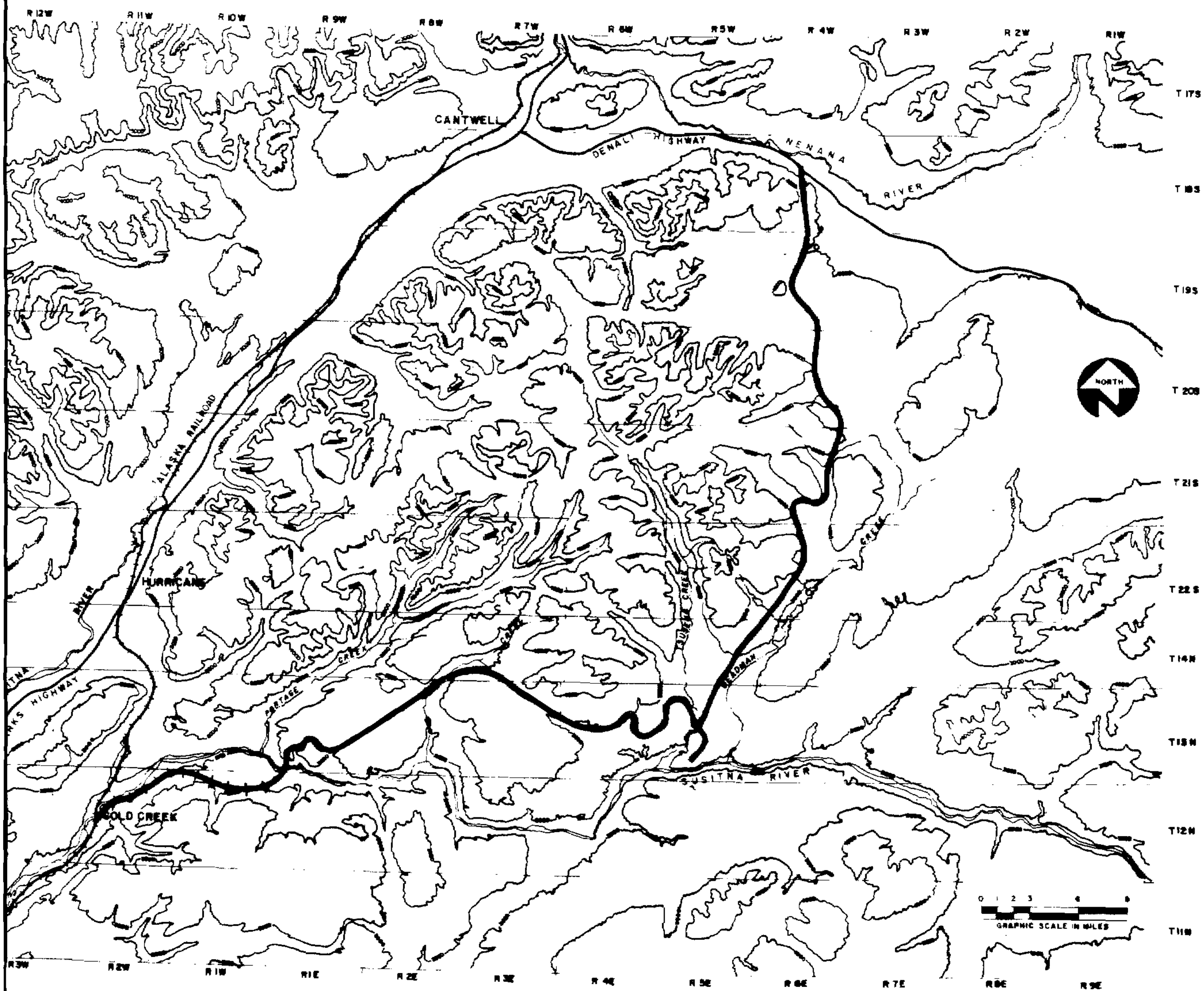
ACCESS PLAN 13 (NORTH) "SUSITNA HYDROELECTRIC PROJECT ALTERNATIVE ACCESS PLAN"

FIGURE 4.3



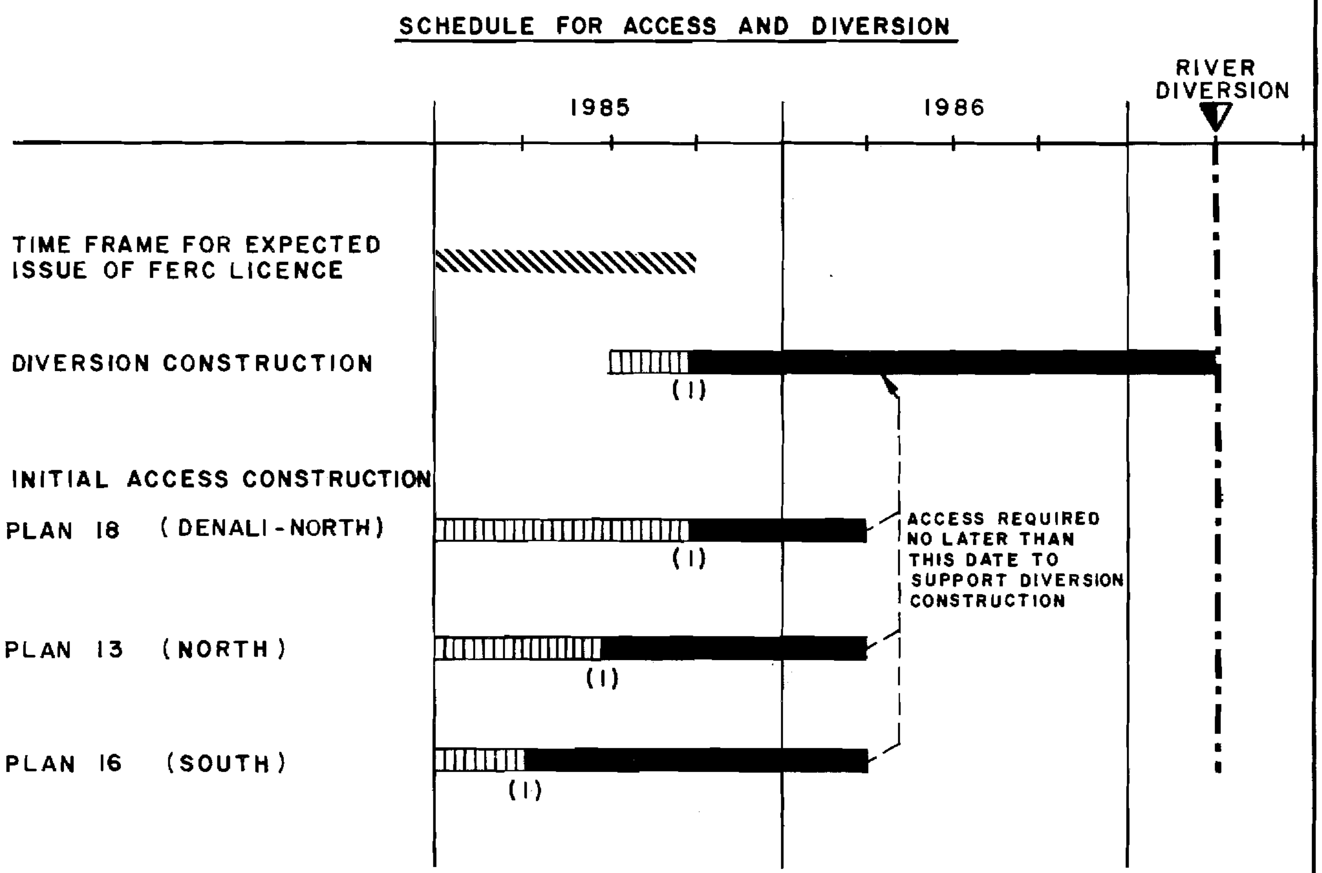
ACCESS PLAN 16 (SOUTH)
"SUSITNA HYDROELECTRIC PROJECT
ALTERNATIVE ACCESS PLAN"

FIGURE 4.4



ACCESS PLAN 18 (PROPOSED)
"SUSITNA HYDROELECTRIC PROJECT
ALTERNATIVE ACCESS PLAN"

FIGURE 4.5

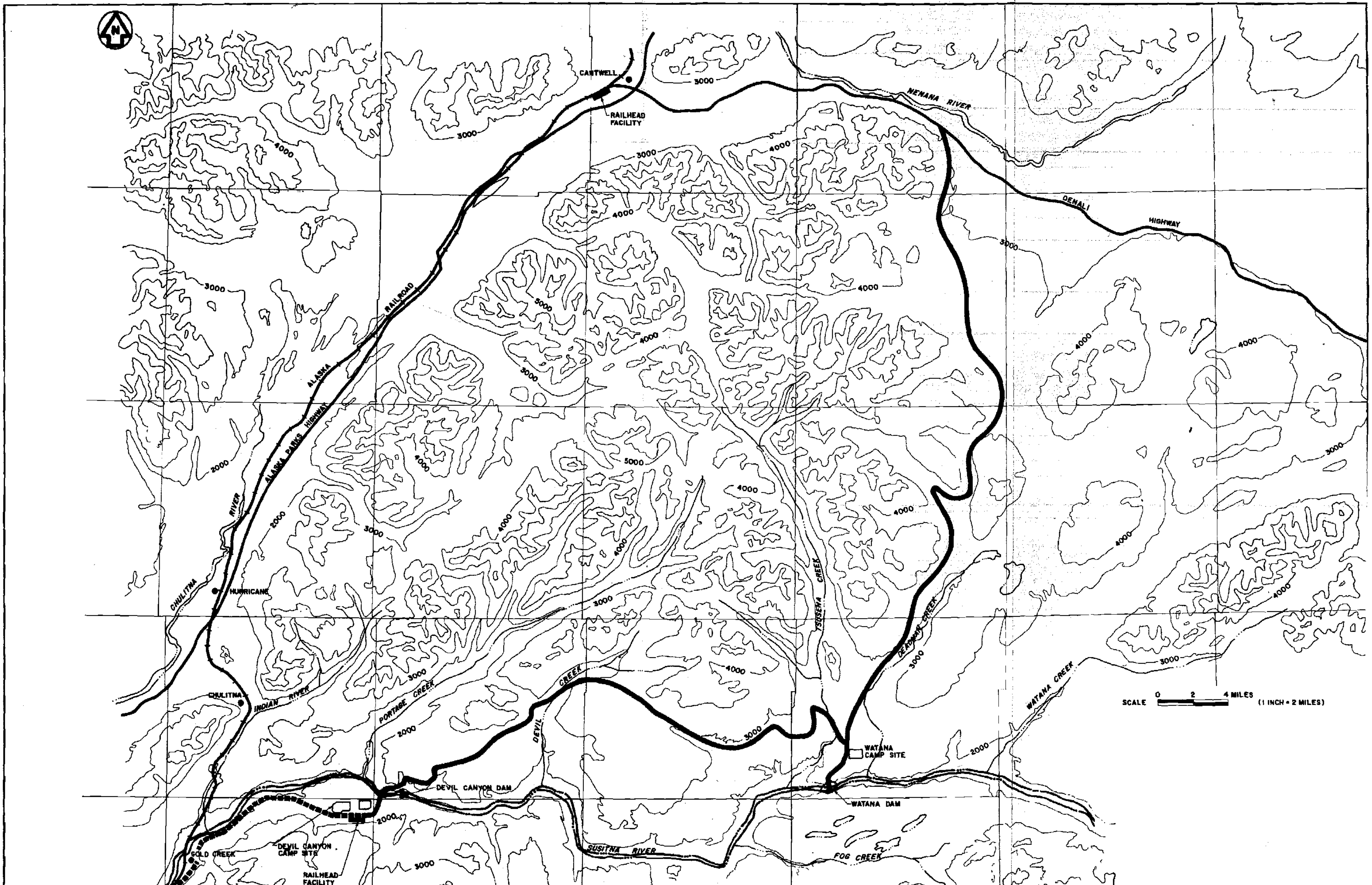


NOTES:

ACTIVITY START COULD BE DELAYED AND DIVERSION STILL MET.

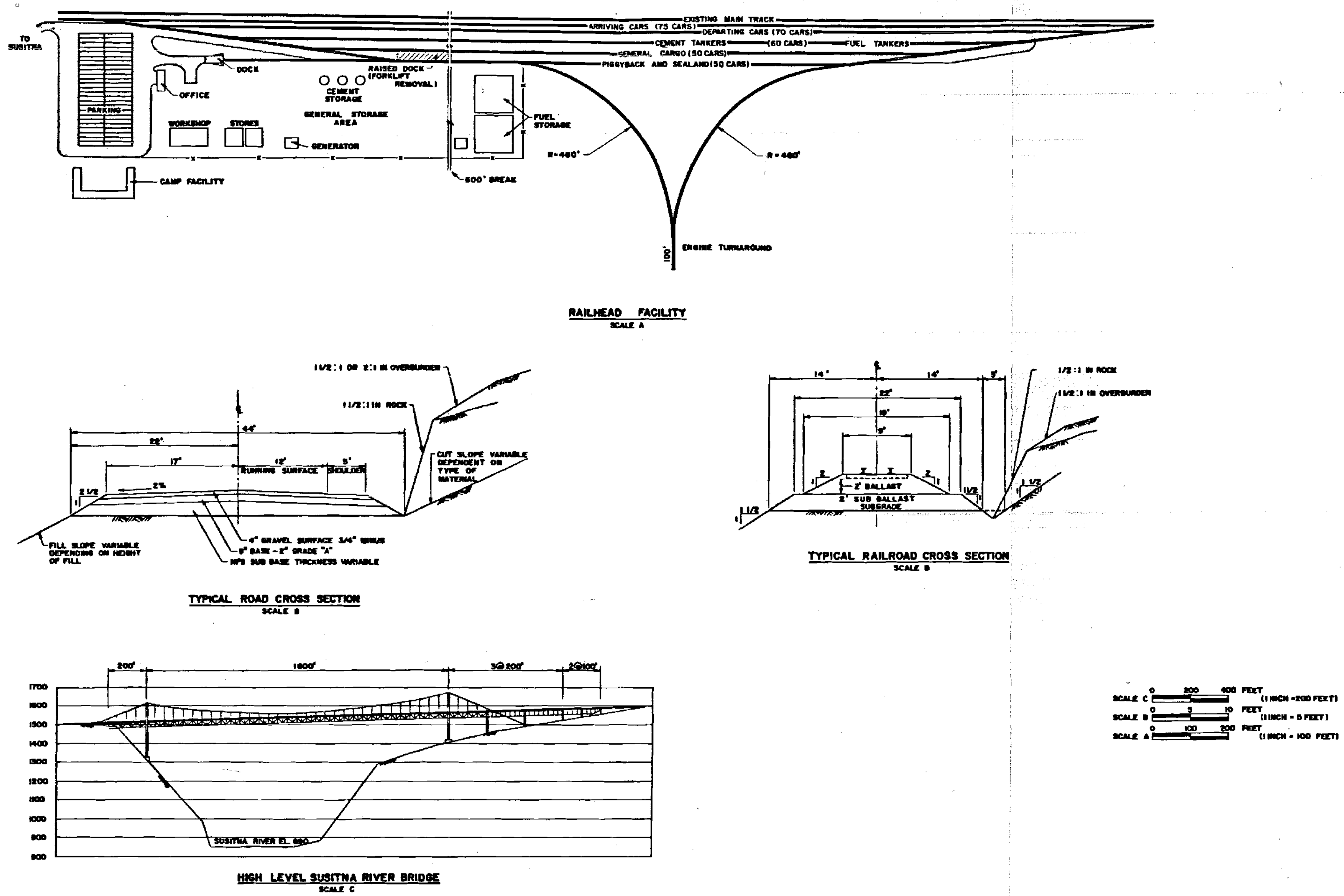
(1) LATEST START DATE OF CONSTRUCTION ACTIVITY.

FIGURE 4.6



ACCESS PLAN PROPOSED ROUTE

FIGURE 4.7



ACCESS PLAN DETAILS PROPOSED ROUTE

FIGURE 4.8

5 - REFINEMENT OF SUSITNA DEVELOPMENT

5.1 - 1982 Geotechnical Design Considerations

The purpose of this section is to update the Feasibility Report (Acres 1982a) based on the results of the geotechnical investigations performed during the 1982 summer field season.

Details of the geotechnical program are provided in the 1980-81 Geotechnical Report (Acres 1982b) and the 1982 Supplement to the 1980-81 Geotechnical Report (Acres 1982c). The reader should refer to these referenced reports for a comprehensive understanding of the site geotechnical conditions. Information provided in the following sections is a summary of that provided in those reports.

(a) 1982 Geotechnical Exploration Program

The objective of the geotechnical program was to determine the surface and subsurface geology and geotechnical conditions for the feasibility of constructing the proposed Susitna Hydroelectric Project, including access roads and transmission line corridors. This was accomplished by a comprehensive program of field exploration, geotechnical evaluation, and dam studies over more than a three year period, commencing in early 1980. The scope of the geotechnical program was increased in 1982 under Amendments 4 and 5 of the Acres contract to respond to concerns raised by Acres and the Power Authority's External Review Board. The following subsections discuss the objectives and results of the 1982 program.

(i) Watana

Studies performed during the 1980-81 investigations raised a number of unanswered geologic and geotechnical questions regarding the Watana damsite, the Watana relict channel, Borrow Site D, and the Fog Lakes relict channel. The objective of the 1982 geotechnical exploration program was to supplement the results of the previous investigations by performing additional detailed explorations of the particular areas of concern. These explorations consisted of:

- Watana Damsite

  Geologic Mapping to determine:

  - Extent of geologic features identified in previous investigations to include shears, alteration, and fracture zones;
  - Bedrock conditions in the upstream and downstream portal areas; and
  - Geology of "The Fins" and "Fingerbuster" shear zones.

- Watana Relict Channel

Geologic mapping, seismic refraction surveys, laboratory testing, and subsurface drilling to depths of 250 feet to determine:

. Channel geometry;
. Stratigraphy of the channel sediments;
. Continuity of stratigraphic sequence;
. Material properties;
. Ground water conditions; and
. Permafrost conditions.

- Borrow Site D

Geologic mapping, seismic refraction surveys, laboratory testing, and subsurface drilling to depths of 250 feet to determine:

. Material properties;
. Stratigraphy;
. Material quantities;
. Ground water conditions; and
. Permafrost conditions.

- Fog Lakes Relict Channel

Performing geologic mapping and seismic refraction surveys to determine:

. Channel geometry;
. Stratigraphy of the channel sediments;
. Ground water conditions; and
. Permafrost conditions.

(ii) Devil Canyon

1982 Geotechnical explorations for the Devil Canyon site were limited to the completion of the long-term laboratory testing of quarry and concrete aggregate materials begun in 1981 and reading of borehole instrumentation installed in 1980-81 for monitoring ground water and permafrost regimes at the damsite.

(b) Results of Geotechnical Investigations - Watana

The results of the summer of 1982 geotechnical explorations for the Watana damsite, Watana relict channel/Borrow Site D, and Fog Lakes relict channel are summarized below. Detailed descriptions of the geology at the Watana site are given in the 1980-81 Geotechnical Report (Acres 1982b) and the 1982 Supplement to the 1980-81 Geotechnical Report (Acres 1982c).

(i) Damsite

The Watana damsite refers to the main dam area, as well as the upstream and downstream cofferdam and portal areas.

- Overburden

The 1982 study found no significant differences in over burden thickness or material types from those previously reported. A map showing the top of bedrock surface contours and the type and distribution of surficial sediments is shown in Figure 5.1. This map is based on additional seismic refraction surveys and geologic mapping.

- Bedrock Lithology

No significant additional information pertaining to bedrock lithology was found during the 1982 investigation. A geologic map, showing bedrock lithology, is shown in Figure 5.2.

- Bedrock Structures

. Joints

The addition of more than 500 joint measurements to the statistical joint plots has resulted in minor changes to the average orientations and dips of the four joint sets found at the site. Table 5.1 is a summary of joint orientations for the overall damsite area as well as the specific areas of the proposed upstream and downstream portals. Joint plots of the damsite area are in the 1982 Supplement to the 1980-81 Geotechnical Report (Acres 1982c). Plots for the upstream and downstream portal areas are in Figures 5.3 and 5.4. Sets I and II remain the major sets with Sets III and IV being minor, although locally pronounced. Set I trends northwestward with high angle to vertical dips and is the most prominent set. Set I parallels most discontinuities at the site. Set II trends northeastward and is best developed upstream from the dam centerline. Set II is parallel to fracture zones in this area. Set III joints trend northward with moderate to steep dips to east and west. Set III is not present in the upstream portal area; however, it is well developed in the downstream portal area where it parallels shear and fracture zones. Set IV joints are generally discontinuous and appear to be caused by stress relief. Orientations are quite variable, but many trend east-west with shallow to moderate dips to the north and south. These joints are discontinuous and appear to be related to stress relief from glacial unloading.

The Susitna River is joint controlled in the damsite area. Upstream from the dam centerline, the river parallels Set II joints. Near the dam centerline it is controlled by both Sets I and II; and in the downstream area it is controlled by shear and fracture zones related to Set I joints.

- Shears, Fracture Zones, and Alteration Zones

These features are defined in the Acres Reports 1982a and 1982c. A geologic map showing the extent of these features is shown in Figure 5.3. Significant geologic features are discussed below.

Three structural features, geologic structures previously identified in the damsite as having potential impact on civil design, are "The Fins," "Fingerbuster," and a wide, hydrothermally altered zone. "The Fins" and "Fingerbuster" were explored in more detail during the 1982 field season. The following paragraphs are a summary of the findings. No additional explorations were performed in the area of the left bank alteration zone.

"The Fins" is shown in relation to the damsite in Figure 5.2 and in detail in Figure 5.3 This is located on the north bank near the present planned location for the upstream cofferdam and diversion portals. Reconnaissance mapping in this area indicated major shears underlying a series of deep gullies separated by intact rock ribs. Detailed mapping showed that most structural discontinuities crosscut the gullies rather than lie within them. "The Fins" is an area of major shears, fracture zones, and alteration zones of various orientations. The strongest trend of these discontinuities is northwest southeast parallel to Set I joints and northeast-southwest parallel to Set II joints. Minor shears were also found trending at various orientations. The northwest trending structures are near-vertical to vertical and consist of shears, fracture zones, and alteration zones from less than 1 foot up to 10 feet wide. The most significant of these features are found upstream from the proposed portal area. The northeast trending structures consist of fracture zones which are discontinuous and only occur downstream from the proposed portal cuts. These features are up to 6 feet wide and dip moderately southeastward, towards the river, to vertical. A series of low angle (less than 45°) shears dipping towards the river were mapped primarily above the portal area. These shears may cause rock stability problems during excavation.

"The Fins" structure trends generally from 300° to 310°. To the southwest, the structure trend across the Susitna River beneath the upstream cofferdam and is exposed to a limited extent on the south bank. To the northwest, "The Fins" is inferred to correlate with a hydrothermally altered zone on Tsusena Creek.

The "Fingerbuster" is an area of shears, fracture zones, and alteration zones which are best exposed on the north bank of the Susitna River in the area of the proposed downstream diversion and tailrace portals (Figure 5.4). Exposure shows two strong trends of discontinuities: northwest-southeast and north-south. The northwest trending discontinuities consist primarily of shears and associated alteration zones parallel to Set I joints. These structures are up to 2 feet wide. Related to the northwest trending structures are areas of open joints and loose unstable rock. Large blocks of detached rock are slumping along the intersection of Sets I, III, and IV joints. The most significant of these areas occurs in the proposed area for the spillway flip-bucket.

The north trending discontinuities are primarily fracture zones with minor shears which parallel Set I joints. An exception to this is a major shear zone labeled GF7Q, which corresponds with the andesite porphyry/diorite contact (Figure 5.2). This feature is up to 30 feet wide; however, most of the north trending structures are less than 5 feet wide.

The main trend of the "Fingerbuster" is northwest-southeast. To the southeast, the "Fingerbuster" is projected beneath the river and tentatively correlated with shears on the south bank. The extent of this feature to the northwest is uncertain because of lack of bedrock exposure

- Ground Water Conditions

Results of the 1982 geotechnical explorations support the findings and conclusions set forth in the Feasibility Report (Acres 1982a) except for the depth of water levels on the right abutment. The previously reported (Acres 1982b) ground water levels of 110 to 280 feet deep were erroneous and should read 110 to 150 feet. In addition, geologic mapping revealed additional springs on slopes at the overburden/bedrock contacts (Figure 5.2), and persistent 1-2 gpm ground water flows from all boreholes except DH-24 and DH-28 on the south abutment.

- Permafrost Conditions

The interpretation of the permafrost regime at the damsite remains unchanged from that presented in the Feasibility Report, except that the instrumentation in BH-6 indicated permafrost in the "shadow zone" of the north abutment.

- Permeability

No additional data pertaining to rock permeability was gathered during 1982. The interpretation presented in the Feasibility Report remains unchanged.

- Reservoir Geology

Geologic mapping in the proposed Watana Reservoir area was undertaken as part of the regional mapping of the Watana and Fog Lakes Relict investigations. The results of this investigation are discussed in Section 5.1(b), 5.1(c)(ii), and 5.1(c)(iii) and are shown on the damsite area geologic map (Figure 5.5).

(ii) Watana Relict Channel/Borrow Site D

During the course of investigations carried out by the U.S. Army Corps of Engineers (COE) and Acres, subsequent studies in 1980-81 confirmed the existence of a possible buried relict channel running from the Susitna River gorge immediately upstream from the proposed damsite to Tsusena Creek, a distance of approximately 1.5 miles.

The major potential problems associated with the relict channel are:

- Breaching of the reservoir rim resulting in catastrophic failure of the reservoir; and

- Subsurface seepage resulting in potential downstream piping and/or loss of energy.

Breaching of the reservoir rim can be caused by saturation of the unconsolidated sediments within the channel resulting in surface settlement or by liquefaction during an earthquake.

Excessive subsurface seepage can be caused by highly permeable unit(s) within the channel that would provide a continuous flow path between the reservoir and Tsusean Creek.

As a result of these potential problems a supplemental geotechnical investigation was undertaken in the summer of

1982 to define this feature in more detail. This investigation was to be followed by a more detailed investigation to be performed in the winter 1982-83. Results of that investigation are not expected to be completed until late spring 1983.

- Location and Configuration

The Watana relict channel is located between the present course of the Susitna River and Tsusena Creek and fills an area from the emergency spillway location to Deadman Creek. Borrow Site D is located in the southeast quarter of the channel and overlies the major portion of the inlet area near the Susitna River. The location of the channel is shown on the top of bedrock map (Figure 5.6). The orientation of the relict channel is somewhat irregular, but overall it trends northwest southeast. Maximum overburden thickness is 450 feet.

- Geology

Twelve stratigraphic units have been delineated in the Watana relict channel/Borrow Site D area (Figure 5.7). These units were differentiated by their physical characteristics, as identified in the field, and by their material properties. These characteristics and properties were used to identify the basic modes of deposition which are described on Figure 5.7. The sediments in the relict channel are interpreted to be Quaternary (Table 5.2) in age and are primarily glacial or glacially related in origin. The oldest sediment in the relict channel are unconsolidated boulders, cobbles, and gravels (Unit K) found in the deepest part of the thalweg (Figure 5.8). Following deposition of this Unit K, a major glacial advance deposited the basal till (Unit J). It is likely that during this time the Susitna River was blocked from its old channel and forced south to its present day courses. As this glacier retreated, a peroglacial environment of ponded lakes and braided streams developed and deposited Unit J'. Further glacial retreat accompanied by a minor readvance is shown by the deposition of Unit I. Following deposition of Unit I, the area experienced an interglacial stade which resulted in the erosion of the surface of Unit I. Stream channels cut into this surface and later infilled with Unit H alluvium. At the close of the interglacial stade, a new ice front advanced across the area depositing the dense basal till of Unit G'. As melting occurred, a proglacial environment developed. Meltwaters appear to have been blocked, resulting in the formation of glacial lakes at or near the ice margin. The varied clays and silts of Unit G were deposited in these lakes. As the glacier retreated the lakes drained eroding the upper Unit G, eventually depositing the outwash silty sands and gravels of Units E and F.

After retreat of the glacier, the area was again subjected to an interglacial period. During this time, erosion took place, resulting in surface streamflows and inception of lakes in lowland areas. Unit D alluvium and Unit D' lacustrine clays and silts were deposited during this time. Also, a minor readvance of the glacier occurred in the southeastern portion of the Borrow Site D area which resulted in the deposition of the Unit M basal till. At the end of the D/D' interglacial, glaciers again advanced, reworking the upper sediments of Units D, D', E and F. The glacier became stagnated resulting in the in-place mass wasting of the ice and deposition of the ice disintegration Unit C. Meltwater from this ice mass reworked Unit D. The mass wasting of this last ice mass resulted in the formation of the hummocky knob-and-kettle features which form the present topography. Recent geologic events in the area are confined to post glacial erosion and frost heaving, as represented by Unit A/B.

- Ground Water Conditions

The ground water regime in the relict channel is complex and poorly understood because of the presence of intermittent permafrost, aquicludes, perched water tables, and confined aquifers. Based on limited drilling information, it appears that possible artesian or confined water tables exist in Units H and J', while several other units appear to be unsaturated.

A perched water table exists locally on top of the impervious Unit G, and possibly on top of Units M, I and J. Limited permeability testing shows an average value of 10^{-3} cm/sec for most gravelly materials, and 10^{-4} to 10^{-5} cm/sec for tills and lacustrine deposits.

- Permafrost Conditions

Drillhole samples and ground temperature envelopes from thermistor installations indicate that permafrost in the Watana relict channel/Borrow Site D area is primarily freezing temperature soil rather than solid phase ice. Maximum observed depth of permafrost is about 40 feet. Most of the visible ice is confined in the annual frost zone (averaging 10 to 15 feet deep) in Units C, D, E, and F; and to Units G, G', and H in permafrost zones. Average ground temperature at depth, with the exception of several frozen shallow holes, range from 0.5°C to about 1.5°C.

- Engineering Impacts

As previously stated, the principal impacts of the relict channel on project design is the potential of breaching the reservoir rim and excessive seepage resulting in either downstream piping or loss of energy. Although the 1982 work has not totally eliminated these concerns, it did provide additional information in evaluating these potential problems. The results and preliminary conclusions derived from this program are presented below.

- Reservoir Rim Stability

Breaching of the reservoir rim may occur by either settlement and/or slumping under static or dynamic conditions. Static failure may be either progressive or catastrophic. Several conditions must exist for slides to develop. These are:

- Widespread, relatively pervious, loose unconsolidated material;
- Widespread permafrost in granular material; and/or
- Slide surface with gradients sufficient to cause movement.

A slide occurring in the Watana relict channel is considered unlikely because of the following:

- A low potential slide gradient exists in the narrow thalweg section near "The Fins" as the result of the rise in the bedrock surface in this area. A slide further upstream near Deadman Creek would require an extremely large quantity of material moving on a low gradient to result in a breaching of the reservoir. Similarly, a failure on the Tsusena Creek side of the channel would likewise be on a low gradient and would involve a large volume of material.

- The density of the sediments within the relict channel, as determined by the Standard Penetration Tests (SPT) method, are in excess of 60 per foot below unit C, indicating a relatively dense compact material. This is supported by field observations which show that the majority of units exposed on bank cuts are, for the most part, free standing in steep forests.

- As previously stated, only localized permafrost exists within the relict channel thereby minimizing the possibility of large-scale slides or settlement resulting from thawing and sediment.

- Although only preliminary data is available, the permeability of the upper units appear to be relatively low (10^{-3} to 10^{-5} cm/sec).

- Work performed during 1982 failed to show any continuous uniform unconsolidated material in the relict channel.

In conclusion, although work performed to date does not fully eliminate the potential for static failure within the relict channel, the likelihood of such a catastrophic event occurring appears to be small considering: (a) the materials within the channel are relatively competent; (b) no widespread permafrost; and (c) low surface gradients.

An alternative method for rim failure may be caused by dynamic shaking by an earthquake resulting in liquefaction of the channel sediments. Liquefaction generally occurs in loose, unconsolidated, well-sorted, saturated materials. Earthquake shaking results in the decrease of the shearing resistance of a cohesionless soil and is associated with a sudden, but temporary increase of the pore fluid pressure. The liquefied material is then temporarily transformed into a fluid mass that could settle and/or flow.

To initiate a major liquefaction failure within the Watana relict channel requires the existence of a relatively continuous liquefiable material throughout the area.

Although a few sorted sands and silts occur in the various units such as Units D, D', E/F, H, and J' (Figure 5.7), these materials occur only as discontinuous lenses. In addition, the high SPT indicates that the material below Unit C is relatively dense compact material.

The majority of material in Unit C has blow counts below 20 per foot. This unit, however, is not a critical unit to the reservoir rim stability as it is relatively freely drained on the surface and makes up only a small portion of the rim near maximum pool elevation.

Results of work performed in 1982 show that there are no large-scale, liquefiable materials in the upper 250 feet of the relict channel. However, additional drilling and testing will be required during FY83 to further characterize the units at depth and provide further evidence against potential for liquefaction.

- Leakage Potential

Tests performed during the 1982 program gave permeabilities of the units in the upper 200 to 250 feet in the range between $1x10^{-3}$ and $5x10^{-4}$ cm/sec. These tests were performed in those portions of the borehole which appeared to have very coarse gradations, or where drill fluid was lost. Therefore, these results represent the high permeability range within these units.

For the purposes of estimating the maximum probable flow which could leak out of the reservoir under full head, the following assumptions were made, all of which represent worst possible cases.

- That a continuous flow path exists from inlet to outlet on each unit;
- That units are not blocked or occluded at inlet or outlet;
- That the average gradient is 9 percent (Elevation 2200 pool to Elevation 1675 at Tsusena Creek, over minimum flow path of about 6000 feet);
- That the inlet section can provide all the flow that the critical "weir" section can pass; and
- That average permeability over the entire cross-section is 10^{-3} cm/sec.

Under these assumptions, for the known channel width of about 14,000 feet and average depth of 200 feet, the loss at full pool would be about 9 cfs. This loss was not considered to have significant effects on project power economics. Therefore, unless one or more of the permeable units (such as H, J', and K) are found in subsequent drilling to extend continuously in significant cross-sections and are exposed to the reservoir, the chance of high flows that would impact project economics is considered highly unlikely.

- <u>Potential for Failure by Piping</u>

Major leakage through the relict channel could result in piping along Tsusena Creek that would cause erosion and progressive failure working back up the channel. Although the geologic model to date does not indicate piping to be a problem, further geotechnical studies planned for the winter of 1983 are intended to determine permeabilities of the lower stratigraphic units in the relict channel. If, subsequent to this program piping is considered a potential problem, then discharge points along Tsusena Creek will likely be controlled by the placement of properly graded materials to form a filter blanket over the zones of emergence.

(iii) Fog Lakes Relict Channel

During the 1980-82 geotechnical investigation, a review of the site and regional geology was undertaken to determine if there were any other places in the Watana reservoir where bedrock dropped below maximum pool elevation. The results of that study indicated that bedrock drops below reservoir level in several areas on the south bank of the Susitna River in the area of Fog Lakes (Figure 5.9). Preliminary seismic refraction surveys were undertaken in this area during 1981 with supplemental refraction surveys performed in 1982 (Acres 1982c).

- Location and Configuration

The location of the Fog Lakes Relict Channel is shown on Figure 5.9. The relict channel lies between the bedrock high of the proposed Quarry Site A and the hills of the Mount Watana area approximately seven miles to the east. For discussion purposes, the relict channel can be divided into three sections: west, central, and east. The west section lies between the bedrock high of Quarry A and the bedrock high of the central section. The bedrock surface in this area appears to be a series of ridges and valleys. Three of these valleys (from 200 to 800 feet wide) fall below reservoir level.

The central section extends for approximately 4.5 miles east-west. Bedrock in this area is relatively shallow with the majority of the section having bedrock surface above maximum pool level.

The east section of the channel is the largest with a width of from 6000 to 7000 feet wide. This section of the channel consists of a broad area of bedrock above Elevation 2000 flanking a steep sided bedrock gorge trend northeast-southwest.

- Geology

Based on seismic refraction surveys and limited soil outcrops, three types of sediments were delineated in the Fog Lakes relict channel:

- Surficial deposits
- Poorly consolidated glacial sediments, and
- Well consolidated glacial sediments

The surficial deposits generally varies from 0 to 40 feet and overlies bedrock and the glacial units. The glacial sediments range up to a maximum thickness of 580 feet with seismic velocities from 4,300 to 10,000 feet per second. The higher velocity material may be partially to completely frozen. Outcrops of glacial sediments are rare. Only till was observed in outcrop; however, it is likely that other types of glacial and/or glacially-derived sediments, similar to the Watana relict channel, may be present.

Bedrock in the relict channel area consists of the Cretaceous argillite and graywacke on the west side and Triassic metavolcanic rock to the east (Figure 5.5 and Table 5.2). The contact between these two units is the Talkeetna Thrust Fault whose location and trend is nearly coincident with the main thalweg of the Fog Lakes relict channel.

- Ground Water Conditions

The ground water table in the area appears to be relatively shallow, as evidenced by poor surface drainage and numerous ponds, lakes, and bogs. Drainage of the area is toward the Susitna River to the north and Fog Creek to the south. Ground water gradients are expected to be steep in the Susitna drainage area and very low toward Fog Creek.

- Permafrost Conditions

Permafrost conditions are likely to be sporadic throughout the area, as evidenced by the existence of typical permafrost features which include black spruce, hummocky tundra, perched ponds on hills, and skin flows. Higher seismic velocities of sediments at depth indicate partially to completely frozen material.

(iv) Engineering Impacts

As with the Watana relict channel, the potential engineering impacts of the Fog Lakes relict channel are seepage and liquefaction potential. Surface flow are not considered a potential problem in that the topographic low in this area is at a minimum of Elevation 2300, one hundred feet above maximum flood level.

- Leakage

Estimated maximum gradient from maximum pool level to Fog Creek is about three percent over a maximum possible flow area 8000 feet wide, 150 feet deep, and 5 miles long. To achieve a flow in excess of 60 cfs, the average permeability over this area would have to be approximately $5x10^{-1}$ cm/sec. This high an average permeability would require an extremely clean sorted gravel or sand over the entire area. Although no borings have been performed in this area, the geologic history and seismic velocities measured in this area indicate significant presence of densely compacted glacial tills which are expected to exhibit permeabilities in the range of 10^{-3} to 10^{-5} cm/sec. Although drilling should be carried out in this area to confirm the seismic data, the Fog Lakes relict channel is not considered to have any significant economic impact on the project as a result of leakage.

- Piping

The potential for piping failure is not considered likely because of the low gradient and long flow path (about 5 miles).

- Liquefaction

Liquefaction failure would require that three conditions be present: (a) material of low relative density which is saturated, and could thereby be shaken to a denser state or trend to "flow" under earthquake vibrations; (b) exposure of this unit to or near a free surface so that it can escape confinement; and (c) continuity of the unit from the free surface to the point where the topography is low enough to cause breaching.

For the Fog Lakes relict channel, it is highly unlikely that a liquefiable unit exists in adequate continuity, thickness, and susceptibility that a section of reservoir rim could fail to a depth of more than 100 feet. This magnitude of failure, on a ground surface with a slope of not more than 5 percent, would involve probable quantities in excess of 30 million cubic yards. Field verification by drilling will likely dispel any concerns regarding liquefaction.

(v) Construction Material Investigation

Investigation of quarry and borrow sites continued during 1982; however, the emphasis on this work was in Borrow Site D. Detailed discussion of these sites is presented in Acres (1982b).

- Rockfill Material

Long-term freeze thaw durability testing was completed in 1982. The rock samples from Quarry Site A consisting of andesite showed a maximum loss of just over 2 percent after 150 cycles. It is concluded that Quarry A is a good source of thermal and water-deterioration resistant rock; for construction material, however, reactivity tests on the andesite should be performed to determine its suitability for concrete aggregate.

No further direct exploration or testing was conducted in Quarry B. However, mapping in the area related to the Watana relict channel confirmed the previous conclusions regarding the general unsuitability of this site.

- Core Material

Two potential sources (Borrow Site D and H) of impervious, semipervious core material were previously identified (Acres 1982b). In 1982, exploration of Borrow Site D consisted of geologic mapping, drilling, and laboratory testing. Results of this investigation showed that most stratigraphic units above Unit G are suitable borrow material with Unit E/F exhibiting the most consistent suitable properties. Total volume of borrow material is about 180 million cubic yards over an area of 1130 acres with an excavated depth of 100 feet. The borrow materials consist of nonplastic silty to silty gravelly sands derived from ice disintegration, alluvial outwash deposits (Units C, D, E/F); and local zones of till (Unit M) and lacustrine deposits (Unit D'). Detailed material properties for Borrow Site D are included in Acres Reports (1982b, 1982c).

The material properties for Borrow Site D as presented in Section 12.6(e)(v) of Acres Report (1982a) remains valid. Although liquid limits range from a low of 4 to greater than 25 with plasticity indexes as high as 16 percent, the majority of samples lie between the non-plastic and 2 percent plasticity index range. The material water contents were found to range from 5 to 29 percent, with an average of 11.6 percent. Therefore, in selective mining, the average moisture content of 10 percent or less should readily be obtained.

Thermometer readings indicate that a significant portion of the borrow materials are below freezing in the natural state; however, no temperature below -0.2°C has been detected. In addition, little evidence of ice was observed in the boring. Based on the above, permafrost is not considered to be a problem in borrow site development.

No work, with the exception of continued thermistor readings, was performed in Borrow Site H. These readings showed that in all but one hole, the temperatures below the active zone are about +1°C.

- Granular Material

Granular material for filter, shells, and concrete aggregate will come primarily from Borrow Sites E and I. Work in these areas consisted of geologic mapping of surficial deposits and completion of laboratory testing. Mapping did not reveal any conditions which would change the data assumptions or reserve calculations presented in Acres Report (1982c).

Freeze-thaw tests performed on aggregate from the Borrow Sites E and I showed losses of 2.3 to 7.8 percent after 140 cycles. The results of the absorption, soundness, and abrasion tests show that the aggregate meets the applicable standards for general structural and dam construction. Reactivity test results of the aggregate with cement show negligible adverse reactivity.

(c) Devil Canyon Site

This section summarizes the results of the 1982 geotechnical investigations for the Devil Canyon damsite. The work during this time involved completion of laboratory testing of quarry and concrete aggregate material begun in 1981 and reading of borehole instrumentation installed in 1980-81 for ground water and temperature monitoring at the damsite. Detailed discussions of the results of this work are in Acres Report (1982c).

(i) Geologic Conditions

No geologic investigations were performed at the Devil Canyon damsite in 1982.

(ii) Ground Water Conditions

Ground water readings during 1982 continued to show a seasonal fluctuation in the two north abutment holes (BH-1 and BH-2) with the level in BH-1 fluctuating from about 50 to 150 vertical feet below the surface, and BH-2 showing water levels equal to or slightly exceeding the collar elevation of the hole. Until failure of the BH-4 piezometer near the lake on the south bank, the readings indicated water levels varying only a few feet from lake level.

(iii) Permafrost Conditions

Thermistor readings in BH-1, BH-2, and BH-3 during 1982 confirm the previous data presented in the 1980-81 Geotechnical Report (Acres 1982b). No permafrost was found in either the bedrock or surficial material at or around the damsite. The depth of annual frost penetration in bedrock is about 10 to 18 feet, with the deepest frost penetration occurring in May and June. Depth to zero annual amplitude ranges from 40 to 100 feet.

(iv) Permeability

No additional data pertaining to rock permeability were gathered during 1982. The interpretation presented in the Acres Report (1982b) remains unchanged.

(v) Devil Canyon Reservoir Geology

Geologic mapping was performed in the upper reaches of the proposed Devil Canyon reservoir as part of the Watana damsite area regional mapping. This area is discussed in Section 5.1(b).

(vi) Construction Material Investigation

Construction material investigation during 1982 was limited to the completion of laboratory testing begun during 1981 of granular materials for filters, shells, and aggregate. No further investigation for core material for the saddle dam was undertaken.

- Granular Material

Granular materials will come from Borrow Site G and possibly Quarry Site K (Acres 1982b). Samples from both areas were tested for suitability as a construction material.

- Borrow Site G

This area was identified as the source for all concrete aggregate, grout sand, and filter gravels and sands. The results of general aggregate suitability tests show that the materials are well within the limits for general construction use in concrete, and the low absorption and high abrasion resistance indicate probable suitability for general aggregate use in roads, filters, and related uses. The freeze-thaw durability tests show only moderate losses up to 150 cycles.

Petrographic analysis of the various material types in Borrow Site G show that the material near river level has a more favorable composition and quality than the material in the upper terrace. Chemical reactivity tests to determine the effect of free silicates on concrete were run on this lower level material. Results indicate the aggregate may have an adverse silicate reaction. Based on these test results, Borrow Site G appears suitable for all uses at the damsite.

- Quarry Site K

Laboratory testing of granodiorite from Quarry Site K consisted of freeze-thaw durability tests. The tests results showed an 8 percent loss after 150 cycles, which is generally considered unacceptable. However, these samples, which were obtained from a surface exposure, were weathered and not believed to be representative of clean, fresh quarry rock.

5.2 - Main Dam Alternatives - Watana

(a) Introduction

Assessment between an embankment type and a concrete arch type dam for Watana was presented in Section 9.8 of Acres Report (1982a). Subsequent to the submittal of the Feasibility Report, questions arose regarding the potential feasibility of a concrete-faced dam at Watana in lieu of an embankment type. A comparison of these two dam types for Watana is presented in the following section.

(b) Concrete Face Rockfill Type Dam

The selection of a concrete-faced rockfill dam at Watana would initially appear to offer economic and schedule advantages when compared to a conventional impervious-core rockfill dam. For example, one of the primary areas of concern with the earth-core rockfill dam is the control of water content for the core material and the available construction period during each summer. The core material will have to be protected against frost penetration at the end of each season and the area cleared and prepared to receive new material after each winter. On the other hand, rock-fill materials can be worked almost year-round and the quarrying and placing/compacting operations are not affected by rain and only marginally by winter weather.

The concrete-faced rockfill dam would also require less foundation preparation, since the critical foundation contact area is much less than that for the impervious-core/rock foundation contact. The side slopes for faced rockfill could probably be on the order of 1.5:H to 1:V or steeper as compared to the 2.5 and 2.0:H to 1:V for the earth-core rockfill. This would allow greater flexibility for layout of the other facilities, particularly the upstream and downstream portals of the diversion tunnels and the tailrace tunnel portals. The diversion tunnels could be shorter, giving further savings in cost and schedule.

However, the height of the Watana dam as currently proposed is 885 feet, some 70 percent higher than the highest concrete-faced rockfill dam built to date (the 525-foot high Areia Dam in Brazil completed in 1980). A review of concrete face rockfill dams indicates that increases in height have been typically in the range of 20 percent; for example, Paradela - 370 feet completed in 1955; Alto Anchicaya - 460 feet completed in 1974; Areia - 525 feet completed in 1980. Although recent compacted-rockfill, concrete-faced dams have generally performed well and are inherently stable even with severe leakage through the face, a one-step increase in height of 70 percent over existing structures is well beyond precedent.

In addition to the height of the dam, other factors that are beyond precedent include the seismic and climatic conditions at Susitna. It has been stated that concrete-faced rockfill dams are well able to resist earthquake forces, and it is admitted that they are very stable structures in themselves. However, movement of rock leading to failure of the face slabe near the base of the dam could result in excessive leakage through the dams. To correct such an occurrence would require lowering the water level in the reservoir which would take many years and involve severe economic penalties from loss of generating capacity.

No concrete-faced rockfill dam has yet been built in an arctic environment. The drawdown at Watana is in excess of 100 feet and the upper section of the face slab will be subjected to severe freeze/thaw cycles.

Although the faced rockfill dam appears to offer schedule advantages, the overall gain in impoundment schedule would not be so significant. With the earth-core rockfill dam, impoundment can be allowed as the dam is constructed. This is not the case for a concrete faced rockfill since the concrete face slab is normally not constructed until all rockfill has been placed and construction settlement completed. The slab is then poured in continuous strips from the foundation to the crest. Most recent high-faced rockfill dams also incorporate an impervious earthfill cover over the lower section to minimize the risk of excessive leakage through zones which, because of their depth below normal water level, are difficult to repair. Such a zone at Watana might cover the lower 200 to 300 feet of the slab and require considerable volumes of impervious fill, none of which could be placed until all other construction work had been completed. This work would be on the critical path with respect to impoundment and, at the same time, be subject to interference by wet weather.

The two types of dam were not costed in detail because cost was not considered to be a controlling factor. It is of interest to note, however, that similar alternatives were estimated for the LG 2 project in northern Quebec and the concrete face alternative was estimated to be about 5 per cent cheaper. However, the managers, on the recommendation of their consultants, decided against the use of a concrete faced rockfill dam for the required height of 500 feet in that environment.

In summary, a concrete-faced rockfill dam at Watana is not considered appropriate as a firm recommendation for the feasibility stage of development of the Susitna project because of the following:

- Increase of 70 percent in height over precedent; and
- Possible impacts of high seismicity and climatic conditions.

5.3 - Refinements to General Arrangement

(a) Introduction

This section describes refinements made to the general arrangements of the Watana and Devil Canyon projects since the presentation of the Susitna Hydroelectric Project Feasibility Report (Acres 1982a). Changes have been made in the following areas:

- Watana project power and outlet facilities intakes;
- Devil Canyon project power intake;
- Devil Canyon project main spillway gates;
- Devil Canyon project compensation flow discharge pipe; and
- Devil Canyon main access road.

Table 5.3 is a correlation of the Feasibility Report drawings with those contained in the report. Revisions to the drawings are noted on the table.

(b) Watana Project Power and Outlet Facilities Intakes

Based upon the change in minimum operating level of the Watana reservoir from Elevation 2045 to Elevation 2065, as described in Section 7, the invert elevation of the approach channel and intakes has been raised by approximately the same amount to Elevation 2025 minimum (Plate F4). This change saves in rock excavation while still maintaining the required degree of submergence. Also, the cross section of each intake was revised to ensure constant velocity from the intake gate through the transition to the 17-foot-diameter, concrete-lined penstock. It was thus possible to reduce the power intake gate nominal width by 3 feet 7 inches to 13 feet 5 inches, and the bulkhead gate nominal width by 2 feet to 19 feet.

A further change incorporated into the power intake was the provision of a common headpond for all intakes. This additional requirement was deemed necessary to provide better water temperature control and mixing, thus further mitigating the environmental impacts on downstream river temperatures (see Section 8). A low-level splitter wall between groups of two intakes has been retained to facilitate dewatering and maintenance of the lowest shutters.

(c) Devil Canyon Project Power Intake

A common headpond has been created for each intake penstock similar to the Watana project power intake (Plate F62). In addition, in order to draw from the reservoir surface over a drawdown range of 50 feet, two openings have been introduced in the upstream concrete wall for each of the four independent power intakes. The upper opening will always be open, but the lower opening can be closed by a sliding steel shutter. Trashracks are located upstream from the openings, and a heated ice bulkhead will operate in guides upstream from the racks following the water surface, thus keeping the racks free from ice. The approach channel for the power intake has also been raised by 6 feet to Elevation 1361, thereby reducing the required quantity of rock excavation.

(d) Devil Canyon Main Spillway Gate

A minor refinement has been made to the height of the main spillway fixed wheel gates. An increase in height of 2 feet has been incorporated after further review of the detailed arrangement. This results in gates 56 feet high by 30 feet wide.

(e) Devil Canyon Compensation Flow Discharge Pipe

The compensation flow discharge pipe has been eliminated from the design. Environmental studies performed subsequent to March 1982 show no need to maintain minimum flows in the river bed from the downstream toe of the dam to the tailrace discharge.

(f) Devil Canyon Main Access Road Realignment

The feasibility study previously indicated an access route which followed the crest of the main arch dam, saddle dam, and fuse plug channel bridge. As a result of the introduction of the Susitna river crossing, the alignment of the main access road has been modified from the vicinity of the Devil Canyon switchyard to the railhead. The previously proposed access route has been retained but downgraded to a permanent site road providing access to the dams and an alternative means of access to the railhead.

(g) Haul Roads and Disposal Areas

Plates F35 and F71 have been added to the drawings showing proposed construction roads and disposal areas. This information has been added to assist in a more detailed environmental assessment of the project area.

REFERENCES

Acres American Incorporated. 1982a. Susitna Hydroelectric Project Feasibility Report. Prepared for the Alaska Power Authority.

______. 1982b. Susitna Hydroelectric Project 1980-81 Geotechnical Report. Prepared for the Alaska Power Authority.

______. 1982c. Susitna Hydroelectric Project 1982 Supplement to the 1980-81 Geotechnical Report. Prepared for the Alaska Power Authority.

TABLE 5.1: WATANA DAMSITE
JOINT CHARACTERISTICS*

JOINT SET	SITE QUADRANT	STRIKE		DIP		SPACING***		SURFACE CONDITIONS		REMARKS
		RANGE	AVERAGE**	RANGE	AVERAGE**	RANGE	AVERAGE	TEXTURE	COATING	
I****	All	265°-335°	300°	55°NE-65°SW	75°NE	1"-15'	2'	Planar, smooth to locally rough, continuous		Parallel to major shears, fracture zones, and alteration zones.
	NE	280°-345°	330° 310°	55°NE-70°SW	80°NE 80°NE	2"-10'	2'	Same as above	Carbonate and alteration, locally. Major carbonate at WJ-6	
	SE	270°-350°	320°	60°NE-70°SW	80°NE	2"-10'	2'	Same as above		
	SW	270°-340°	325° 295°	60°NE-70°SW	90° 75°NE	1"-15'	2'	Same as above	Major carbonate at WJ-7	
	NW	265°-335°	325° 295°	45°NE-60°SW	85°SW 75°NE	1"-15'	2'	Same as above	Minor carbonate and alteration, locally. Major carbonate at WJ-4	
II	All	015°-075°	055°	60°NW-60°SE	85°NW	1"-5'	1-2'			Parallel to fracture zones in NE quadrant; no shears or alteration zones.
	NE	015°-065°	040°	60°NW-60°SE	80°NW	1"-10'+	1-2'	Planar to irregular, smooth to slightly rough	Minor carbonate	
	SE	025°-080°	050°	65°NW-60°SE	85°NW	1"-10'+	1-2'	Same as above	Same as above	
	SW	040°-080°	065°	70°NW-70°SE	85°NW	1"-10'+	1-2	Planar, smooth to rough	Same as above	
	NW	050°-070°	065°	60°NW-70°SE	90°	1"-10'+	1-2'	Same as above	Same as above	

* Surface data only
** Major joint concentration
*** Where set is present
**** Includes Subsets Ia and Ib (see Section 5.1)

TABLE 5.1 (Cont'd)

JOINT SET	SITE QUADRANT	STRIKE		DIP		SPACING***		SURFACE CONDITIONS		REMARKS
		RANGE	AVERAGE**	RANGE	AVERAGE**	RANGE	AVERAGE	TEXTURE	COATING	
III	All	335°-035°	350°	45°E-60°W	75°E	0.5"-5'	1-2'	Planar to slightly curved, smooth to slightly rough		Parallel to minor shears, fracture zones, and alteration zones.
	NE	325°-025°	350°	55°E-60°W	60°E	2"-10'	1-2'	Same as above	Minor carbonate and alteration, locally	Weakly developed.
	SE	---	---	---	---	---	---	---	---	Not observed.
	SW	340°-020°	345°	60°E-80°W	80°E	0.5"-10'	1-2'	Planar to irregular smooth to rough	Minor carbonate and alteration, locally	Strongly developed.
	NW	335°-035°	005°	45°E-60°W	80°E	0.5"-10'	1-2'	Same as above.	Same as above	Same as above.
IV	All	Variable		Shallow to Moderate				Planar to irregular		Probably stress relief, near surface.
	NE		075°		15°S 10°N	2"-5'+	1-2'	Same as above.	---	Same as above.
	SE		090° 310°		25°S 40°NE	2"-5'+	1-2'	Same as above.	---	Same as above.
	SW		000° 090°		05°E 25°N	6"-10' 6"-10'	2' 2'	Same as above.	---	Same as above.
	NW		090°	10°N-10°S	---	2"-5'+	2-3'	Same as above.	---	Same as above.

* Surface data only
** Major joint concentration
*** Where set is present
**** Includes Subsets Ia and Ib, (see Section 5.1)

TABLE 5.2: GEOLOGIC TIME SCALE

ERA	PERIOD	EPOCH	GLACIATION	MILLION OF YEARS AGO
Cenozoic	Quaternary	Holocene Pleistocene	Wisconsinan Illinoian Kansan Nebraskan	1.8
	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene		70
Mesozoic	Cretaceous Jurassic Triassic			230
Paleozoic	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian			600
Precambrian				

TABLE 5.3: CORRELATION OF PLATE NUMBERS

Plate Number: Current	March Feasibility Report	Title	Revised Item
		WATANA	
F1	1	Railbelt Area	
F2	2	Reservoir Plan	
F3	3	Site Layout	Main access road. Permanent airstrip.
F4	4	General Arrangement	Intake approach channel
-	5	Hydrological Data - Sheet 1	
-	6	Hydrological Data - Sheet 2	
-	7	Simulated Reservoir Operation	
F5	8	Main Dam - Plan	Intake approach channel
F6	-	Maim Dam - Section	New drawing
F7	9	Main Dam - Profile & Detail	Crest elevation profile
F8	10	Main Dam - Grouting & Drainage	Power intake
F9	11	Diversion - General Arrangement	
F10	12	Diversion - Sections	
F11	13	Diversion - Intake Structures	
F12	14	Main Spillway - General Arrangement	
F13	15	Main Spillway - Control Structure	
F14	16	Main Spillway - Chute Sections	
F15	17	Main Spillway - Flip Bucket	
F16	18	Outlet Facilities-General Arrangement	Intake structure
F17	19	Outlet Facilities - Gate Structure	Intake structure invert elevation
F18	20	Emergency Spillway	
F19	21	Emergency Release - Sections	
F20	22	Downstream Portals - Plan & Section	
F21	23	Power Facilities - General Arrangement	Power intakes
F22	24	Power Facilities - Access	
F23	25	Power Facilities - Plan & Sections	
F24	26	Power Intake - Sections	Intake invert elevation
F25	27	Powerhouse - Plans	
F26	28	Powerhouse - Sections	

TABLE 5.3 (Page 2)

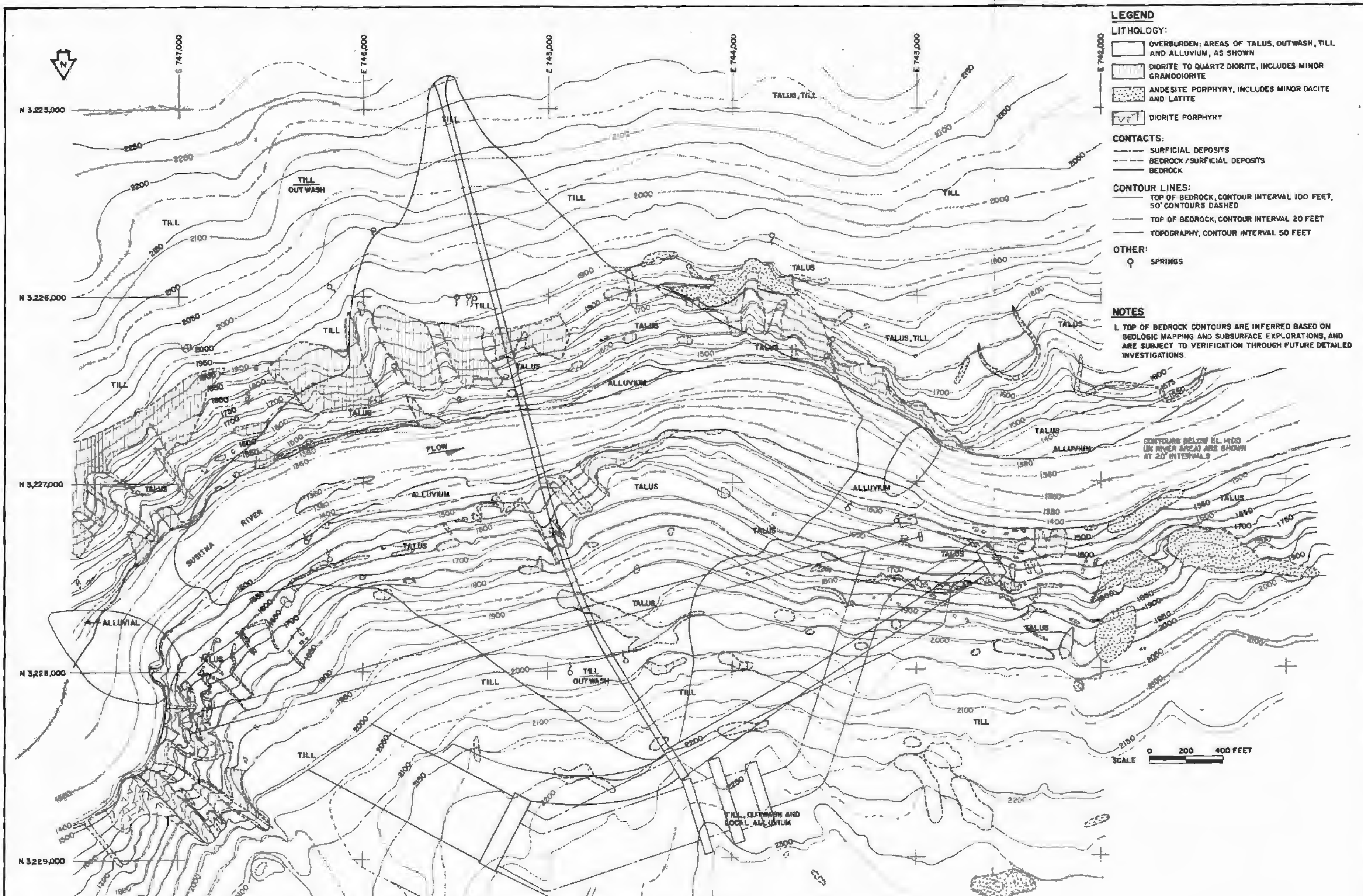
Plate Number			
Current	March Feasibility Report	Title	Revised Item
F27	29	Transformer Gallery - Plan & Section	
F28	30	Surge Chamber & Tailrace - Sections	
F29	31	Electrical Legend	
F30	32	Powerhouse - Single-Line Diagram	
F31	33	Switchyard-Single-Line Diagram & Plan	Switchyard Plan
-	34	Block Schematic Computer-Aided Control System	Drawing deleted
F32	35	Access Plan - Proposed Route	Access road. Transmission line.
F33	-	Access Plan - Typical Details	New drawing
F34	36	General Layout - Site Facilities	Access road. Permanent airstrip.
F35	-	General Layout - Construction and Haul Roads	New drawing
F36	37	Main Construction Campsite	
F37	38	Village and Town Site	
F38	39	Watana and Devil Canyon - Construction Camp Details	
		DEVIL CANYON	
F39	40	Reservoir Plan	
F40	41	Site Layout	Main access road. Transmission lines
F41	42	General Arrangement	Main access road
-	43	Hydrological Data - Sheet 1	
-	44	Hydrological Data - Sheet 2	
-	45	Simulated Reservoir Operation	
F42	46	Dams - Plan & Profile	
F43	47	Main Dam - Geometry	
F44	48	Main Dam - Crown Section	
F45	49	Main Dam - Sections	
F46	50	Main Dam - Thrust Blocks	
F47	51	Main Dam - Grouting & Drainage	
F48	52	Main Dam - Outlet Facilities	
F49	53	Saddle Dam - Section	

TABLE 5.3 (Page 3)

Plate Number			
Current	March Feasibility Report	Title	Revised Item
F50	-	Saddle Dam - Profile & Detail	New drawing
F51	54	Diversion - General Arrangement	
F52	-	Diversion - Cofferdam Sections	New drawing
F53	55	Diversion - Sections	
F54	56	Main Spillway - General Arrangement	Compensation flow system
F55	57	Main Spillway - Control Structure	
F56	58	Main Spillway - Chute Sections	
F57	59	Emergency Spillway - General Arrangement	
F58	60	Emergency Spillway - Sections	
F59	61	Power Facilities - General Arrangement	Power intake. Compensation flow system
F60	62	Power Facilities - Access	Compensation flow system
F61	63	Power Facilities - Plan & Sections	
F62	64	Power Intake - Sections	Common headpond. Invert elevation.
F63	65	Powerhouse - Plans	Compensation flow pumps
F64	66	Powerhouse - Sections	Compensation flow pumps
F65	67	Transformer Gallery - Plan & Sections	
F66	68	Surge Chamber & Tailrace - Sections	Compensation flow inlet
F67	69	Tailrace Portal - Plan & Sections	
F68	70	Powerhouse - Single-Line Diagram	
F69	71	Switchyard - Single-Line Diagram	New drawing
F70	72	General Layout - Site Facilities	Access road. Transmission line.
F71	-	General Layout - Construction & Haul Roads	New drawing
F72	73	Construction Camp - Plan	Main access road
F73	74	Temporary Village	
		TRANSMISSION	
F74	-	Railbelt 345 kV Single-Line Diagram	New drawing
F75	-	Ester Substation - Single-Line Diagram & Plan	New drawing
F76	-	Gold Creek - Single-Line Diagram & Plan	New drawing
F77	-	Willow Substation - Single-Line Diagram & Plan	New drawing

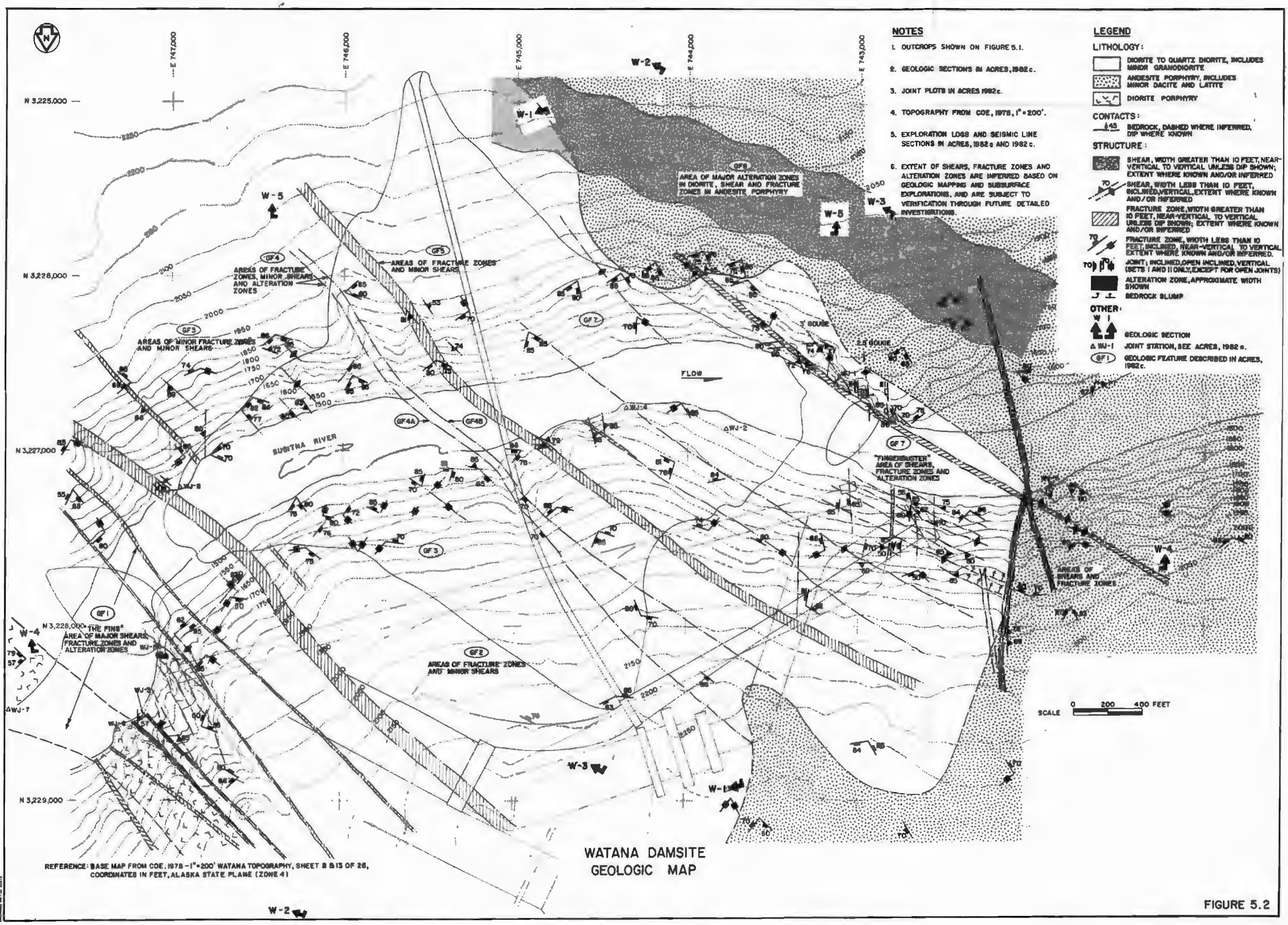
TABLE 5.3 (Page 4)

Plate Number			
Current	March Feasibility Report	Title	Revised Item
F78	-	Knick Arm Substation - Single-Line Diagram & Plan	New drawing
F79	-	University Substation - Single-Line Diagram & Plan	New drawing
F80	-	Typical Transmission Line Structures	New drawing
F81	-	345 kV System Single Diagram & Transmission Corridor	New drawing
		CONSTRUCTION SCHEDULES	
-	75	Watana - Construction Schedule	See Figure 9.1
-	76	Devil Canyon - Construction Schedule	See Figure 9.2



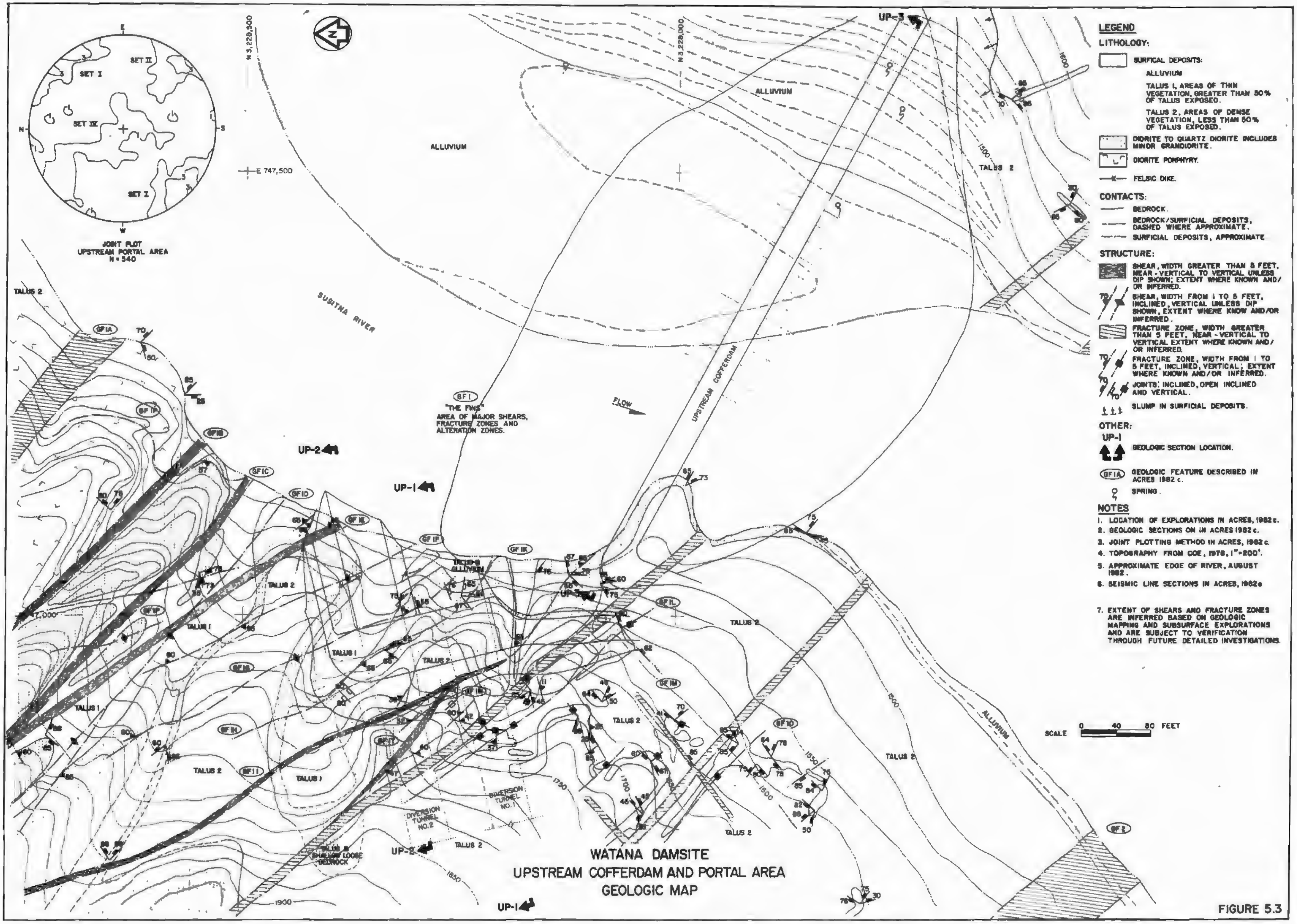
WATANA DAMSITE
TOP OF BEDROCK
AND SURFICIAL GEOLOGIC MAP

FIGURE 5.1



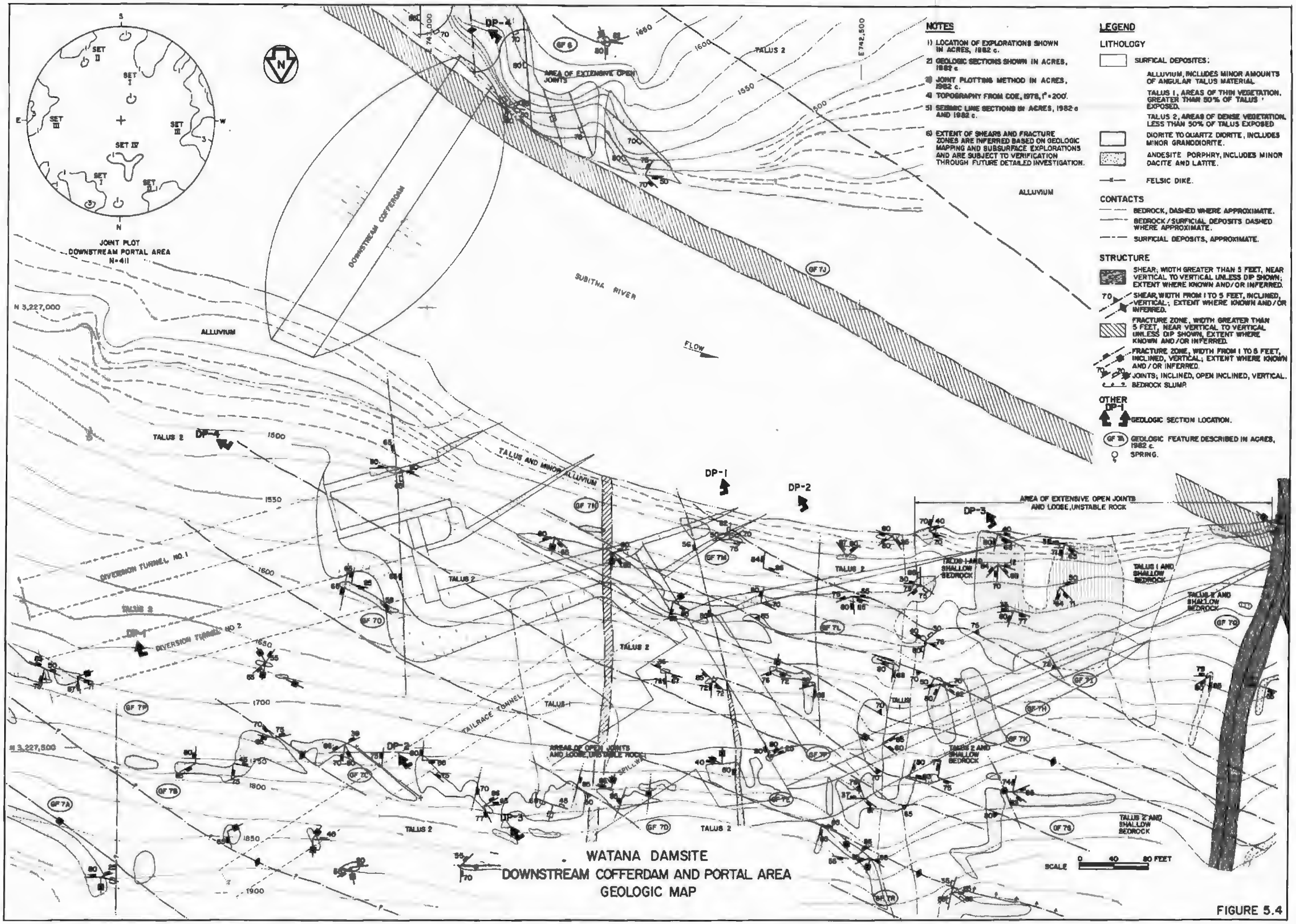
WATANA DAMSITE
GEOLOGIC MAP

FIGURE 5.2



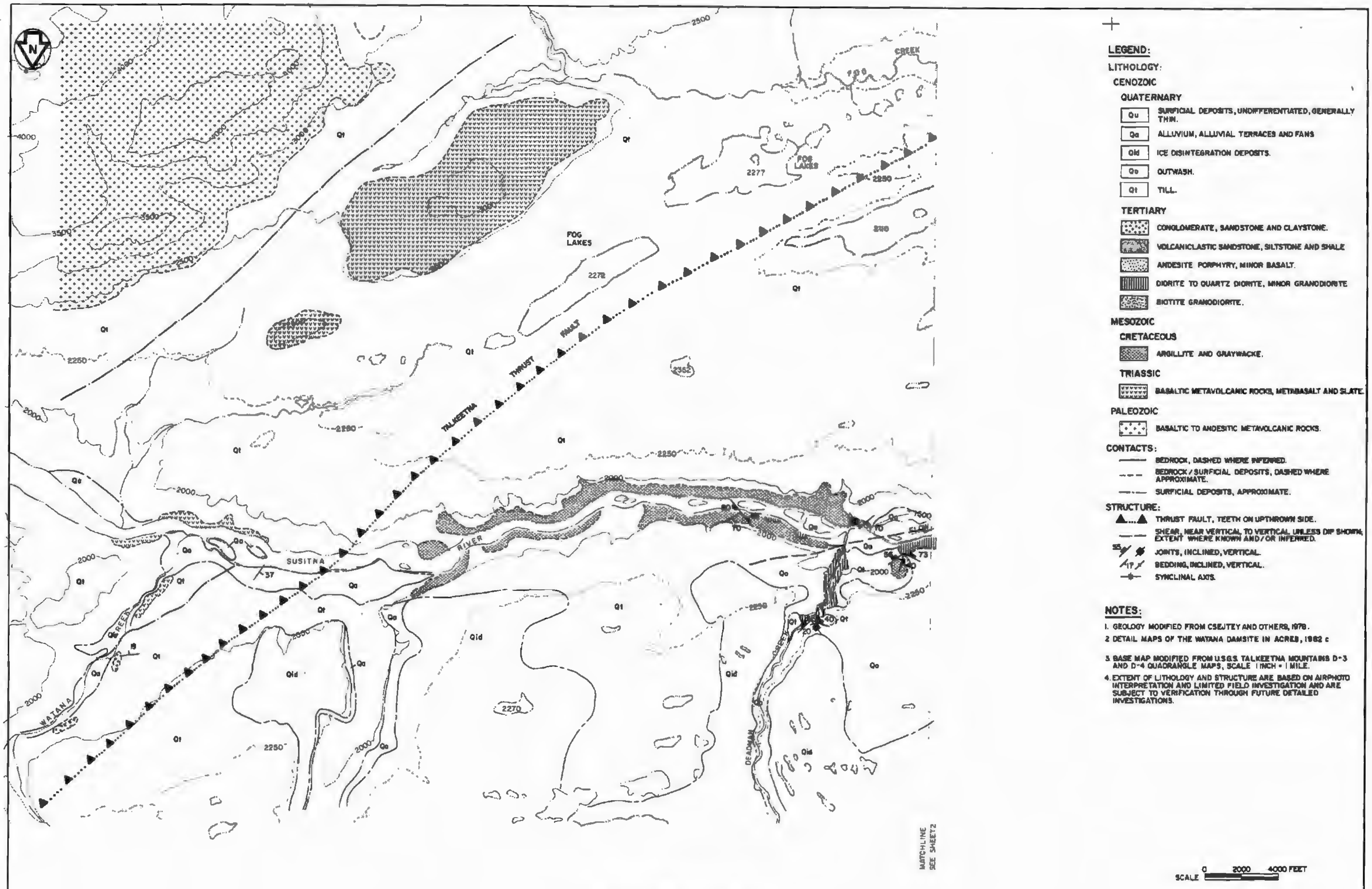
WATANA DAMSITE
UPSTREAM COFFERDAM AND PORTAL AREA
GEOLOGIC MAP

FIGURE 5.3



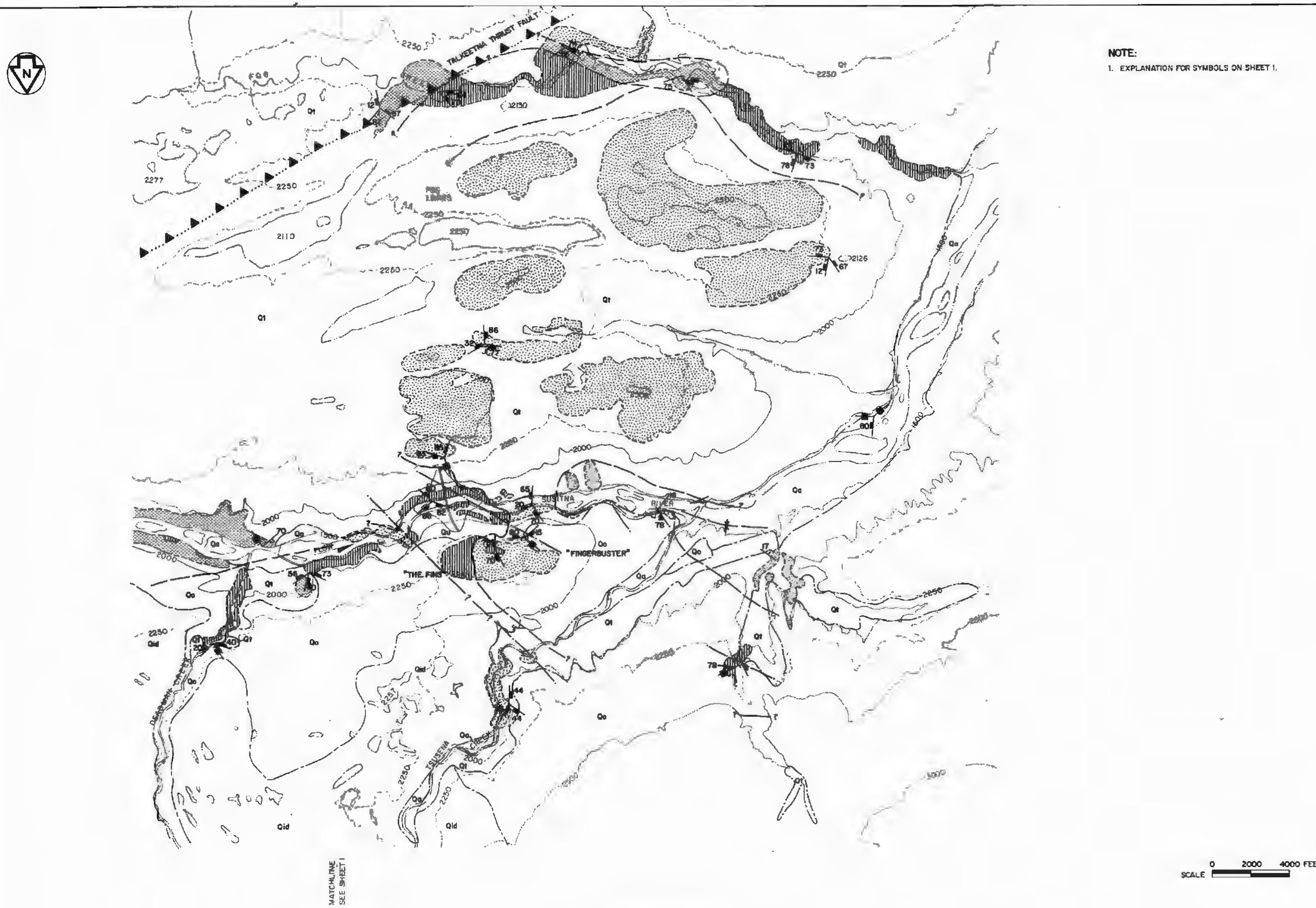
WATANA DAMSITE
DOWNSTREAM COFFERDAM AND PORTAL AREA
GEOLOGIC MAP

FIGURE 5.4



WATANA DAMSITE AREA
GEOLOGIC MAP
SHEET 1 OF 2

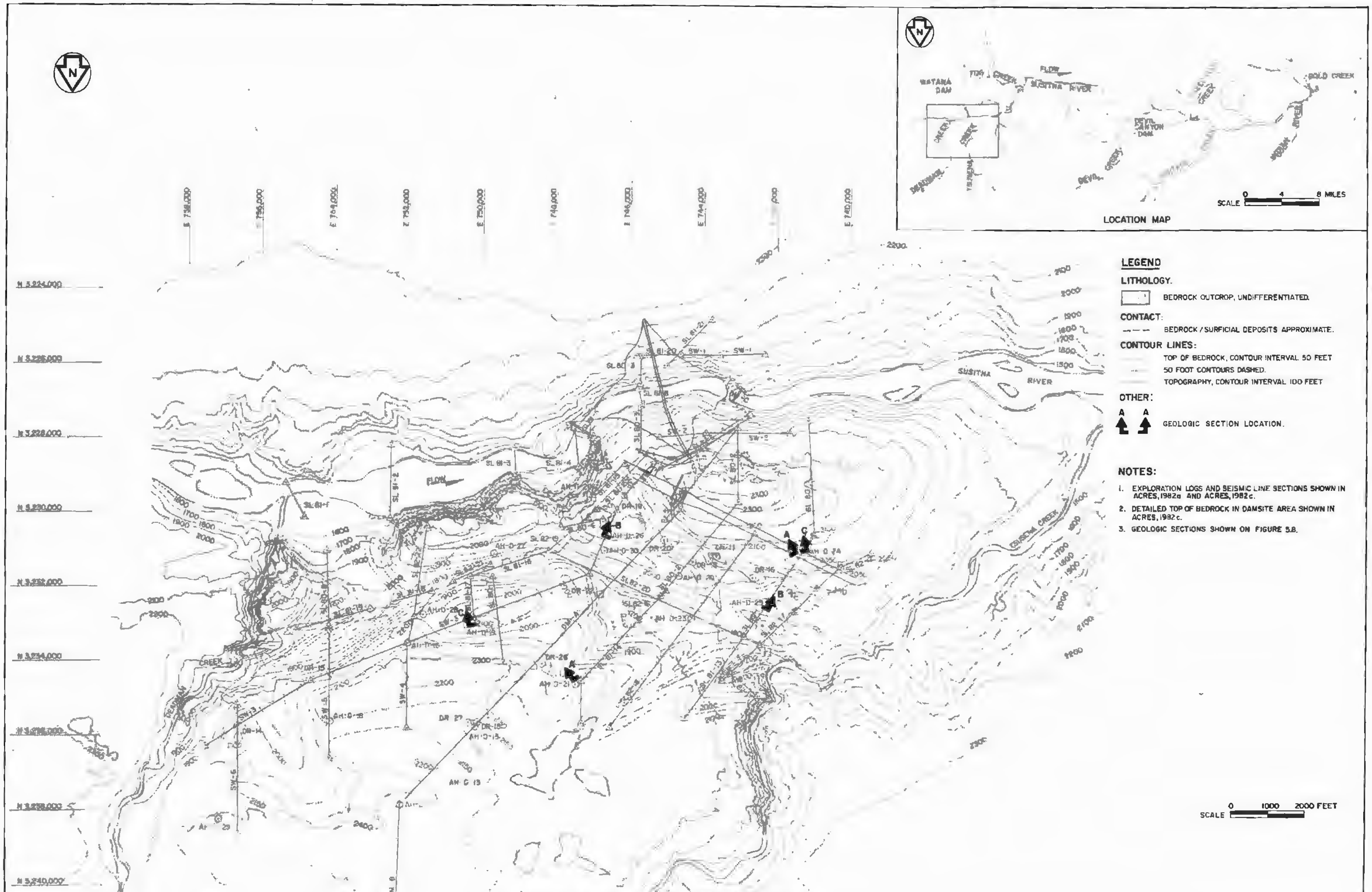
FIGURE 5.5



NOTE:
1. EXPLANATION FOR SYMBOLS ON SHEET 1.

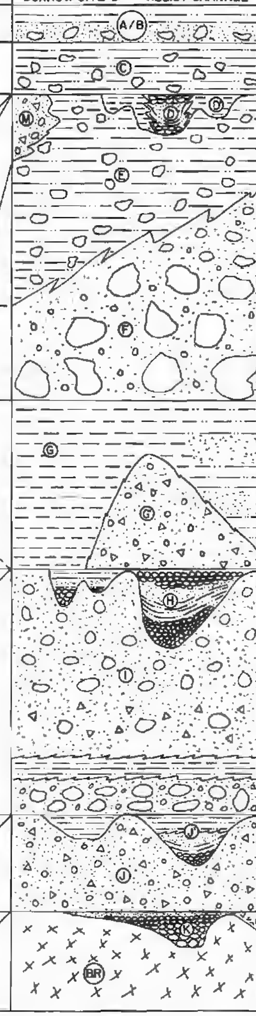
WATANA DAMSITE AREA
GEOLOGIC MAP
SHEET 2 OF 2

FIGURE 5.5



WATANA RELICT CHANNEL / BORROW SITE D
TOP OF BEDROCK MAP

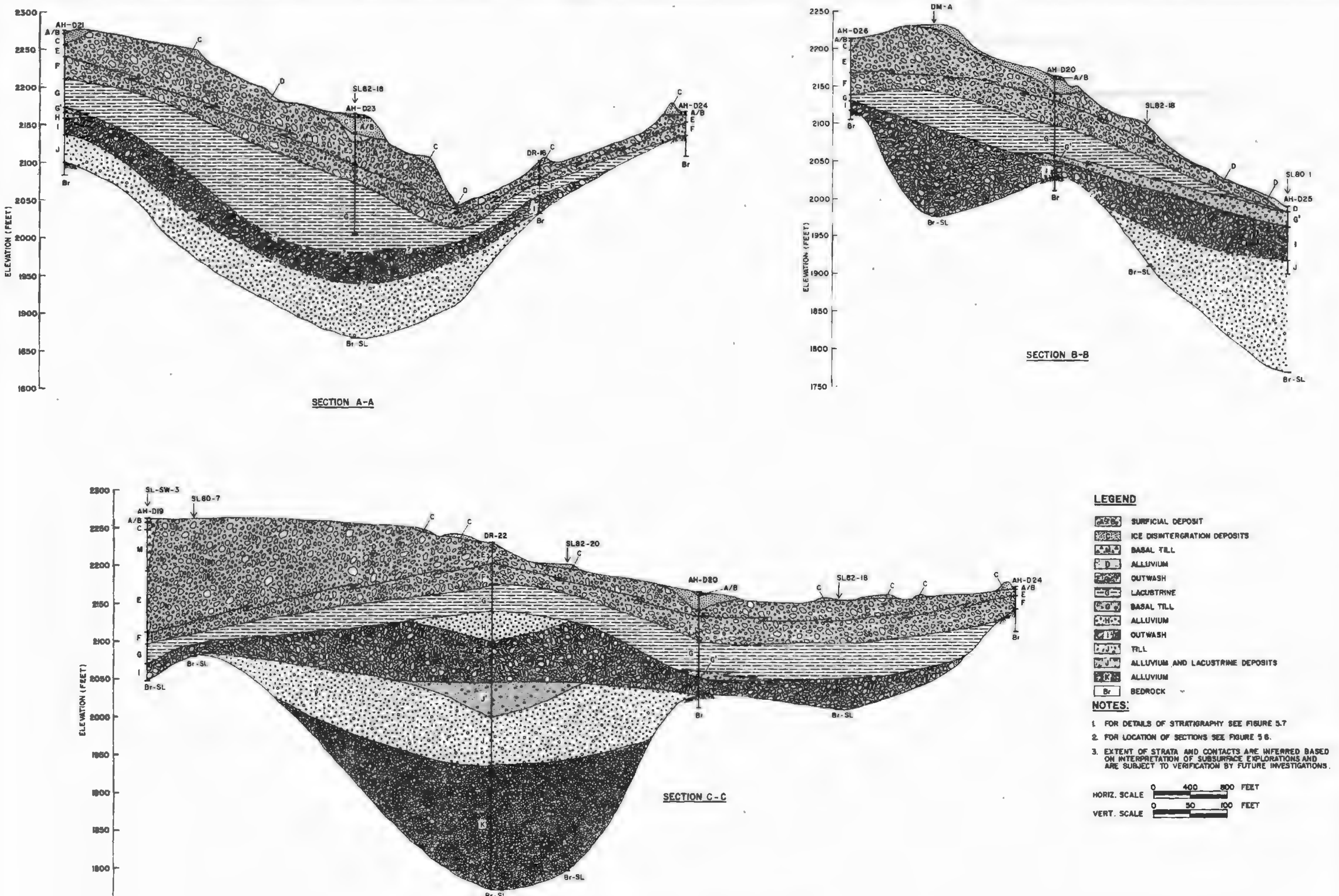
FIGURE 5.6

UNIT	TYPE OF DEPOSIT	GEOLOGIC EVENT	STRATIGRAPHIC COLUMN BORROW SITE D RELICT CHANNEL	THICKNESS	DESCRIPTION	REMARKS
A/B	SURFICIAL DEPOSITS	POST GLACIAL EROSION & FROST HEAVING.		RANGE 0.7 FT. AVG. 3 FT.	ORGANICS, PEAT, SILT & BOULDERS RAISED BY FROST ACTION.	SURFICIAL BOULDER FIELDS, SWAMPS & BOGS.
C	ICE DISINTEGRATION	ABLATION OF LAST GLACIAL ADVANCE & MELTING OF ICE LENSES.		RANGE 0-38 FT. AVG. 9 FT.	TAN-BROWN SAND WITH SOME COBBLES & GRAVEL. LOOSE TO DENSE, CONTAINS LESS SILT THAN OUTWASH UNITS E & F.	HUMMOCKY TOPOGRAPHY, KNOB & KETTLE FEATURES, NO OVERCONSOLIDATION.
		MAJOR GLACIAL ADVANCE				UPPER LIMIT OF OVERCONSOLIDATION
D	ALLUVIUM	INTERGLACIAL, ICE FRONT A LONG DISTANCE FROM DEPOSITIONAL AREA.		RANGE 0-40 FT.	GRAY STRATIFIED SAND, GRAVEL & COBBLES, VERY DENSE.	CONFINED TO TOPOGRAPHIC LOW AREAS ON TOP OF UNIT "E" & RELATED FLOW CHANNELS.
D'	LACUSTRINE	LOCALIZED PONDING OF LAKES DURING INTERGLACIAL.		RANGE 0-21 FT.	GRAY / BROWN LAMINATED CLAY & SILT, VERY DENSE.	LIMITED EXTENT, NOT FOUND IN ALL BORINGS. LAMINATIONS PRESENT. GENERALLY THIN.
		RETREAT OF GLACIATION "M"				
M	BASAL TILL	VALLEY TYPE GLACIAL ADVANCE CONFINED TO FORMER SUSITNA VALLEY.		RANGE 0-79 FT.	GRAY CLAY WITH ANGULAR TO SUBANGULAR GRAVEL & COBBLE, VERY DENSE. COARSE FRACTION MAINLY PHYLLITE & ARGILLITE.	FOUND NEAR SUSITNA VALLEY. PEBBLES & COBBLES SUBANGULAR & STRIATED. APPEARANCE SIMILAR TO "G" BUT MUCH HIGHER PERCENTAGE OF PHYLLITE & ARGILLITE FRAGMENTS.
E	OUTWASH	GLACIAL MELTING & RETREAT; ICE FRONT AT A DISTANCE FROM SITE.			BROWN TO GRAY-BROWN SILTY SAND WITH GRAVEL & COBBLES. PARTICLES SUBANGULAR TO SUBROUNDED.	SUBANGULAR TO SUBROUNDED PARTICLES. FEWER COBBLES & BOULDERS THAN UNIT "F" BELOW. PARTIALLY SORTED.
F	OUTWASH	GLACIAL RETREAT; ICE FRONT NEAR SITE.		RANGE E/F 0-131 FT. AVG. 37 FT.	BROWN SILTY SAND WITH GRAVEL & MANY COBBLES & BOULDERS, POORLY SORTED. SIZE OF COARSE FRACTION INCREASES WITH DEPTH. OFTEN CONTAINS A ZONE OF COBBLES & BOULDERS AT BASE OF UNIT.	LARGE COBBLES & BOULDERS INDICATES HIGH ENERGY ENVIRONMENT WITH ICE FRONT NEARBY. LARGE BOULDER ZONE AT BASE GRADING TO SMALLER FRAGMENTS TOWARD THE TOP OF UNIT INDICATES RECEDING ICE.
		DRAINING OF LAKE "G" / GLACIAL RETREAT BEGINS				
G	GLACIOLACUSTRINE & WATERLAIN TILL	LAKES & FLOATING ICE. ICE MASS PARTIALLY DETACHED (FLOATING).		RANGE 0-74 FT.	GRAY CLAY, LAMINATED, VERY DENSE. CONTAINS SILTY OR SANDY INTERLAMINATIONS WHICH ARE MORE PREVALENT IN RELICT CHANNEL AREA. OCCASIONALLY VARVED.	ORGANICS FOUND IN LAMINATIONS OF UNIT "G". WOOD FOUND IN UPPER HORIZONS OF UNIT "G". LACUSTRINE LAMINATIONS & VARVES PRESENT TOGETHER WITH STRIATED PEBBLES & SAND AS WELL.
		BASAL MELTING, ICE THICKENING				
G'	BASAL TILL	MAJOR GLACIAL ADVANCE.		RANGE 0-231 FT.	GRAY CLAY WITH ANGULAR & SUBANGULAR GRAVEL & COBBLES. UNSORTED, VERY DENSE.	STRIATIONS ON COARSE FRACTION, LITTLE OXIDATION, BASAL TILL STRUCTURE INCLUDING POOR SORTING, HIGH DENSITY & IMBRICATION OF ELONGATED FRAGMENTS.
H	ALLUVIUM	INTERGLACIAL, ICE FRONT REMOVED FROM SITE.		RANGE 0-41 FT.	BROWN GRAVEL, SAND & SILT, STRATIFIED, SORTED, VERY DENSE. CONFINED TO VALLEY AREAS IN THE AT-THE-TIME TOPOGRAPHY OF THE UPPER SURFACE OF UNIT "I".	ROUNDED PARTICLES, SORTED. ORGANICS FOUND IN UNIT "H".
I	OUTWASH (TILL ?)	GLACIAL MELTING & RETREAT, ICE FRONT NEARBY PARAGLACIAL ENVIRONMENT. MINOR GLACIAL RE-ADVANCE. GLACIAL MELTING & RETREAT CONTINUES.		RANGE 0-77 FT.	BROWN TO RED-BROWN SAND & SILT WITH GRAVEL & COBBLES. OXIDATION ON SURFACES OF PARTICLES. VERY ROCKY, OVERCONSOLIDATED. MAY BE AN OUTWASH RE-WORKED BY A MINOR READVANCE. OF ICE.	ORGANICS FOUND IN UPPER HORIZON OF UNIT "I", INCLUDING WOOD. OXIDATION (LIMONITE & HEMATITE) INDICATES WEATHERING & OLDER AGE. OCCASIONALLY DISPLAYS SOME CHARACTERISTICS OF A TILL INCLUDING REMNANT STRIATIONS ON PEBBLES & ANGULAR FRAGMENTS. LACUSTRINE SAND, SILT OR CLAY OFTEN FOUND IN MIDDLE OF UNIT.
		RETREAT OF GLACIATION "J"				
J'	LACUSTRINE & / OR STRATIFIED DEPOSITS	BASAL MELTING & PONDING; FLOWING WATER.		RANGE 0-48 FT.	BROWN SAND, SILT, GRAVEL & CLAY, LAMINATED & / OR STRATIFIED. SAND OCCASIONALLY OXIDIZED.	LIMITED EXTENT, OFTEN APPEARS SORTED, FRAGMENTS ROUNDED.
J	TILL	MAJOR GLACIAL ADVANCE.		RANGE 0-62 FT.	BROWN SILT WITH MANY COBBLES & MUCH GRAVEL. VERY DENSE, OXIDIZED. PARTICLES ANGULAR & SUBANGULAR.	STRIATED PEBBLES, SUBANGULAR PARTICLES, HIGH DEGREE OF OVERCONSOLIDATION.
K	ALLUVIUM	OLDEST UNCONSOLIDATED DEPOSITS FOUND IN WATANA RELICT CHANNEL AREA.		RANGE 0-161 FT.	BOULDERS, COBBLES, SAND & GRAVEL, ROUNDED.	FOUND ONLY LOCALLY ALONG CHANNEL COURSES (THALWEGS) CUT INTO BEDROCK.
BR	BEDROCK				PRIMARILY DIORITE & GRANODIORITE WITH OCCASIONAL INCLUSIONS OF ARGILLITE. ANDESITE FOUND IN WESTERN PORTION OF AREA.	DRILLED > 10' INTO BEDROCK TO VERIFY.

NOTE: STRATIGRAPHIC COLUMN DIAGRAMMATIC & NOT TO SCALE.

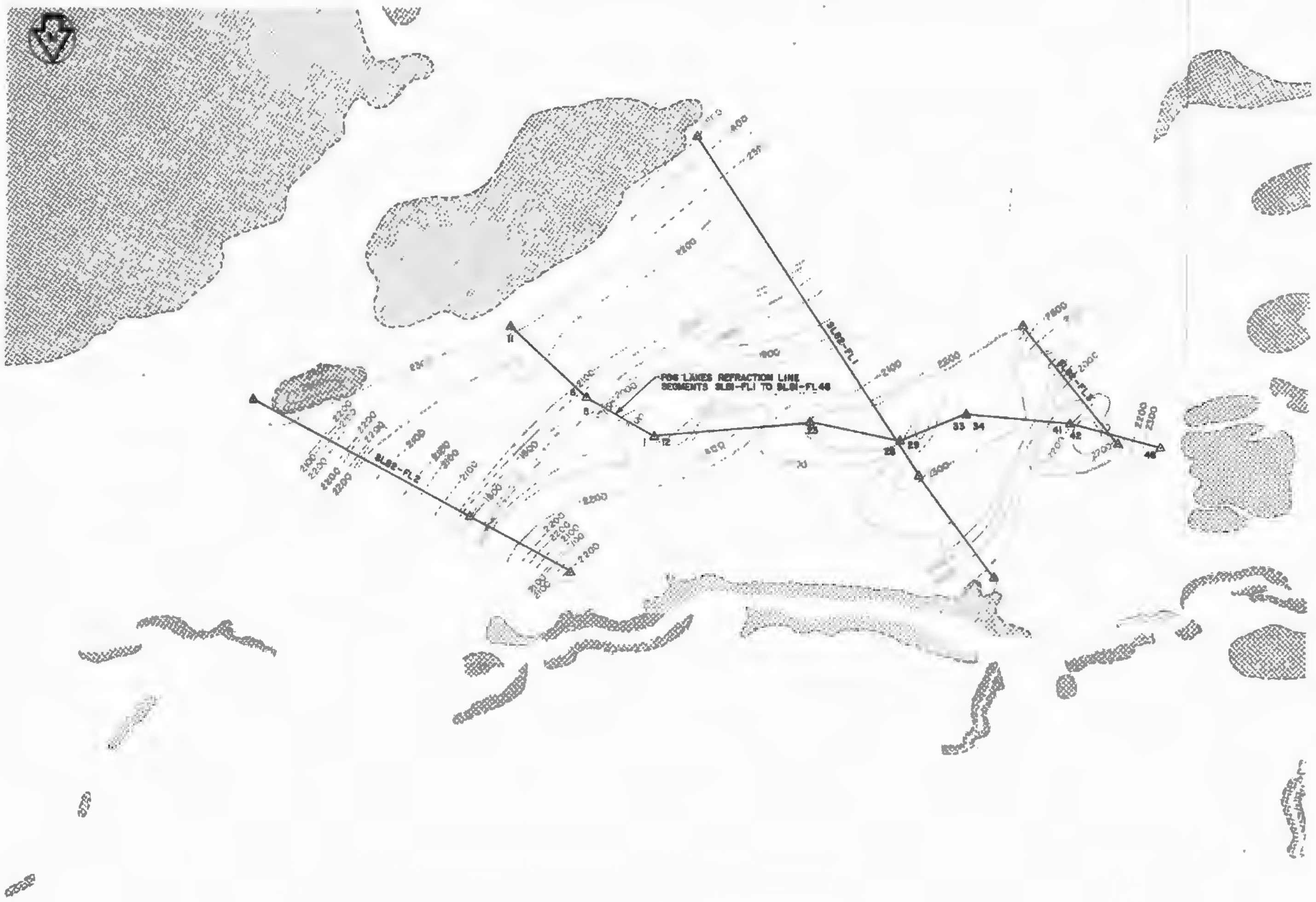
WATANA RELICT CHANNEL / BORROW SITE D
GENERALIZED STRATIGRAPHIC COLUMN

FIGURE 5.7



WATANA RELICT CHANNEL / BORROW SITE D
GEOLOGIC SECTIONS

FIGURE 5.8



LEGEND:

LITHOLOGY:

BEDROCK OUTCROP OR SHALLOW BEDROCK, UNDIFFERENTIATED.

CONTACT:

BEDROCK/SURFICIAL DEPOSITS, APPROXIMATE

CONTOUR LINES:

TOP OF BEDROCK, CONTOUR INTERVAL 100 FEET.
TOPOGRAPHY, CONTOUR INTERVAL 500 FEET.
TOPOGRAPHY, EL 2250 CONTOUR DASHED.

NOTES:

1. BASE MAP MODIFIED FROM U.S.G.S. TALKEETNA MOUTAINS D-3 AND D-4 QUADRANGLE MAPS, SCALE 1IN.=1MI.
2. SEISMIC LINE SECTIONS SHOWN IN ACRES, 1982c

SCALE 0 2000 4000 FEET

WATANA
FOG LAKES RELICT CHANNEL
TOP OF BEDROCK MAP

FIGURE 5.9

6 - TRANSMISSION FACILITIES

6.1 - Introduction

This section describes the development of transmission facilities from the original Acres American Incorporated POS of February 1980 through to the filing of the FERC License Application in February 1983.

The major topics covered in the transmission studies include:

- Electrical system studies;
- Transmission corridor selection;
- Transmission route selection;
- Transmission towers, foundations and conductors;
- Substations; and
- Dispatch center and communications.

The main body of this section is concerned with the transmission studies that have taken place subsequent to the issuance of the Susitna Hydroelectric Project Feasibility Report in March 1982 (Acres 1982a). These studies included a reassessment of the transmission line corridor within the Central Study Area, and a land acquisition analysis in the northern, southern and central study areas; the purpose of which was to fine-tune the alignment and determine the legal descriptions of the rights-of-way. The ways in which these studies have affected each of the six major topics mentioned above are discussed in the following sections.

6.2 - Previous Studies

The two previously published reports which contain the most information relevant to the transmission line studies are:

- The Upper Susitna River Basin Interim Feasibility Report, prepared by the COE (1975).

- The Economic Feasibility Study for the Anchorage-Fairbanks Intertie, prepared by International Engineering Company, Inc., and Robert Retherford Associates. (IECO/RWRA 1979).

The COE report consisted primarily of an evaluation of alternative corridor locations to aid in the selection of those which maximized reliability and minimized costs. Utilizing aerial photographs and existing maps, general corridors connecting the project site with Anchorage and Fairbanks were selected. This study was general in nature and was intended only to demonstrate project feasibility.

The IECO/RWRA report utilized the COE report as background information for both economic feasibility determination and route selection. The corridor selected by IECO/RWRA was very similar to that selected by the COE with further definition. The route selected was based on shortest length, accessibility, and environmental compatibility. The report also presented a detailed economic feasibility study for the Anchorage-Fairbanks transmission intertie.

These two reports, together with the various subtask reports published by Acres since the POS February 1980, served as the data base for the Susitna Hydroelectric Project Feasibility Report (Acres 1982a), to which this report is a supplement.

6.3 - Electric Systems Studies

Subsequent to the publication of the Feasibility Report (Acres 1982a) the route of the Intertie between Willow and Healy has been finalized. As a result of this, the transmission system has undergone the following changes:

At the time the Feasibility Report was published, the intertie interconnected with the Susitna transmission system at Devil Canyon. Since then the intertie has been rerouted to the extent that it now passes approximately eight miles to the west of the Devil Canyon damsite. Studies indicated that the optimum arrangement for connecting to the intertie was to construct a switching station on the south bank terraces of the Susitna River at approximately river mile (RM) 142. The location of this station, referred to as the Gold Creek Switching Station, together with the location of the intertie and other project features, is shown in Figure 6.1. A single-line diagram and plan of the switchyard is presented in Figure 6.2.

Following a land acquisition analysis conducted in the latter half of 1982, the transmission line routing was finalized and the lengths of the various line sections recalculated. Thus Table 14.3 of the Acres Feasibility Report (Acres 1982a) summarizing the transmission system characteristics has been revised to include these updated mileages and the additional switching station at Gold Creek. These revisions are presented in Table 6.1.

Figure 14.1 of the Feasibility Report, showing the configuration of the recommended system, was also changed accordingly and is presented as Figure 6.3.

6.4 - Corridor Identification and Selection

Development of the proposed Susitna project requires a transmission system to deliver electric power to the Railbelt area. The preconstruction of the intertie system will result in a corridor and route for the Susitna transmission lines between Willow and Healy. Therefore three areas were identified as needing further study:

- Northern study area, to connect Healy with Fairbanks;
- Central study area, to connect the Watana and Devil Canyon damsites with the intertie;
- Southern study area, to connect Willow with Anchorage.

The identification of candidate corridors was based on the consideration of previous studies, existing data, aerial reconnaissance, and limited field studies. Corridors 3 to 5 miles wide, which met the criteria discussed in paragraph (a) below, were then selected in each of the three study areas.

(a) Selection Criteria

The objective of the corridor selection conducted by Acres was to select feasible transmission line corridors in each of the three study areas, i.e., northern, central, and southern. Technical, economic, and environmental criteria were developed to select potential corridors within each of the three areas. These criteria are listed in Table 6.2.

Environmental inventory tables were then compiled for each corridor selected, listing length, number of road crossings, number of river and creek crossings, topography, soils, land ownership/status, existing and proposed development, existing rights-of-way, scenic quality/recreation, cultural resources, vegetation, fish, birds, furbearers, and big game. These tables and a more thorough discussion of the technical, economic, and environmental criteria in Table 6.2 above, are included in the Transmission Line Corridor Screening Closeout Report of September 1981 (Acres 1981).

Based on this analysis, 22 corridors were selected: 3 in the southern study area, 15 in the central area, and 4 in the northern study area. Three of the corridors in the southern study area run in a north-south direction, while one runs northeast to Palmer, then northwest to Willow. Corridors in the central area are in two general categories: those running from the Watana damsite west to the intertie, and those running north to the Denali Highway and the Chulitna River. Corridors in the northern study area run either west or east to bypass the Alaskan Range, then proceed north to Fairbanks. The location of these corridors is shown in the Feasibility Report (Acres 1982a).

(b) Screening Criteria

The selected corridors were then subjected to a further evaluation to determine which ones met the more specific technical, economic, and environmental criteria described in Table 6.3. The rationale for the selection of these criteria is explained in the Closeout Report of September 1981 (Acres 1981).

In addition to these criteria, each corridor was screened for reliability. Six basic factors were considered:

- Elevation: Lines located at elevations below 4000 feet will be less exposed to severe wind and ice conditions which can interrupt service.

- Aircraft: Avoidance of areas near aircraft landing and takeoff operations will minimize the risk of power failures.

- Stability: Avoidance of areas susceptible to land, ice, and snow slides will reduce the chance of power failures.

- Topography: Lines located in areas with gentle relief will be easier to construct, repair, and maintain in operation.

- Access: Lines located in reasonable proximity to transportation corridors will be more quickly accessible and, therefore, more quickly repaired if any failures occur.

The screening criteria and reliability factors for each corridor were evaluated utilizing topographic maps, aerial photos, aerial overflights, and published materials. Each corridor was then assigned four ratings (one each for technical, economic, and environmental considerations, and one overall summary rating). Ratings were defined as follows:

A - recommended
C - acceptable but not preferred
F - unacceptable

From the technical point of view, reliability was the main objective. An environmentally and economically sound corridor was rejected if it would be unreliable. Thus, any line which received an F technical rating was assigned a summary rating of F and eliminated from further consideration.

Similarly, because of the critical importance of environmental considerations, any corridor which received an F rating for environmental impacts was assigned a summary rating of F, and eliminated from consideration.

(c) Selected Corridors

In the Feasibility Report (Acres 1982a) the selected transmission corridor consisted of the following segments:

- Southern Study Area	Corridor (2)	ADFC
- Central Study Area	Corridor (1)	ABCD
- Northern Study Area	Corridor (1)	ABC

Descriptions of these corridors and reasons for the rejection of the other corridors are presented in Section 2 of Exhibit B, FERC License Application (Acres 1983a). More detail on the screening process and the specific technical, economic, and environmental ratings of each alternative is included in Chapter 10, Exhibit E of the FERC License Application (Acres 1983).

However, at the time the Feasibility Report was published, the routing of the proposed access road between the damsites was undecided. The location of the access road is of major importance in relation to the transmission line within the central study area, both in terms of economics and environmental impact. Therefore, following the selection of the Denali-North Plan as the proposed access route in September 1982, the transmission line corridor alternatives in the central study area were reassessed.

Of the 15 corridors originally considered in the central study area, 11 were found to be unacceptable, since they had an overall rating of "F." The 4 remaining corridors were then subjected to a more detailed evaluation and comparison to determine which corridor most closely satisfied the screening criteria.

6.5 - Corridor Reassessment: Central Study Area

The four corridors identified as being acceptable in terms of the technical, economic, and environmental criteria described in the Feasibility Report (Acres 1982a) are corridors 1, 3, 13, and 14. The 4 corridors comprise the following segments:

- Corridor One	ABCD
- Corridor Three	AJCF
- Corridor Thirteen	ABCF
- Corridor Fourteen	AJCD

Segments ABC and AJC link Watana with Devil Canyon and, similarly, Segments CD and CF link Devil Canyon with the intertie.

In order to compare the four corridors more directly, a preliminary route was selected in each of the segments. These routes are shown in Figure 6.4. On closer examination of the two routes between Devil Canyon and the intertie, the route in Segment CD was found to be superior to the route in Segment CF for the following reasons:

(a) Economic

A four-wheel-drive trail is already in existence on the south side of the Susitna River between Gold Creek and the proposed location of the railhead facility at Devil Canyon. Therefore the need for new roads along Segment CD, both for construction and operation and maintenance, is significantly less than for Segment CF, which requires the construction of a pioneer road. In addition, the proposed Gold Creek to Devil Canyon railroad extension will also run parallel to Segment CD. Another primary economic aspect considered was the length of the corridors. However, since the lengths of Segments CD and CF are 8.8 miles and 8.7 miles, respectively, this was not a significant factor. Amongst the secondary economic considerations is that of topography. Segment CF crosses more rugged terrain at a higher elevation than Segment CD and would, therefore, prove more difficult and costly to construct and maintain. Hence, Segment CD was considered to have a higher overall economic rating.

(b) Technical

Although both segments are routed below 3000 feet in elevation, Segment CF crosses more rugged, exposed terrain with a maximum elevation of 2600 feet. Segment CD, on the other hand, traverses flatter terrain and has a maximum elevation of 1800 feet. The disadvantages of Segment CF are somewhat offset, however, by the Susitna River crossing that will be needed at RM 150 for Segment CD. Overall, the technical difficulties associated with the two segments may be regarded as being similar.

(d) Environmental

One of the main concerns of the various environmental groups and agencies is to keep any form of access away from sensitive ecological areas previously inaccessible other than by foot. Creating a pioneer road to construct and maintain a transmission line along Segment CF would open that area to all terrain vehicle and public use, and thereby increase the potential for adverse impacts to the environment. The potential for environmental impacts along Segment CD would be present regardless of where the transmission line was built, since there is an existing four-wheel-drive trail, together with the proposed railroad extension, in that area. It is clearly desirable to restrict environmental impacts to a single common corridor; for that reason, Segment CD is preferable to Segment CF.

Because of potential environmental impacts and economic ratings, Segment CF was dropped in favor of Segment CD. Consequently, Corridors 3 (AJCF) and 13 (ABCF) were eliminated from further consideration.

The two corridors remaining are, therefore, Corridors 1 (ABCD) and 14 (AJCD). This reduces to a comparison of alternative routes in Segment ABC on the south side of the Susitna River and Segment AJC on the north side. These routes were then screened in accordance with the criteria set out in the Transmission Line Corridor Screening Closeout Report of September 1981 (Acres 1981). The key points of this evaluation are outlined below:

(d) Economic

For the Watana development, two 345-kv transmission lines will be constructed from Watana through to the intertie. When comparing the relative lengths of transmission line, it was found that the southern route utilizing segment ABC was 33.6 miles in total length compared to 36.4 miles for the northern route using Segment AJC. Although a difference in length of 2.8 miles (equivalent to 12 towers at a spacing of 1200 feet) seems significant, other factors were taken into account. Segment ABC contains mostly woodland black spruce in Segment AB. Segment BC contains open and woodland spruce forests, low shrub, and open and closed mixed forest in about equal amounts. Segment AJC, on the other hand, contains significantly less vegetation and is composed predominantly of low shrub, and tundra in Segment AJ and tall shrub, low shrub and open mixed forest in Segment JC. Consequently, the amount of clearing associated with Segment AJC is considerably less than with Segment ABC, resulting in savings not only during construction but also during periodic recutting. Additional costs would also be incurred with Segment ABC because of the increased spans needed to cross the Susitna River (at RM 165.3) and two other major creek crossings. In summary, the cost differential between the two segments would probably be marginal.

(e) Technical

The route along Segment AJC traverses generally moderately sloping terrain ranging in height from 2000 feet to 3500 feet, with 9 miles of the route being at an elevation in excess of 3000 feet. Route ABC traverses more rugged terrain, crossing several deep ravines, and ranges in elevation from 1800 feet to 2800 feet. In general, there are advantages of reliability and cost associated with transmission lines routed under 3000 feet. The nine miles of Route AJC at elevations in excess of 3000 feet will be subject to more severe wind and ice loadings than Route ABC, and the towers will have to be designed accordingly. However, these additional costs will be offset by the construction and maintenance problems with the more rugged topography and major river and creek crossings of Route ABC. The technical difficulties associated with the two segments are therefore considered similar.

(f) Environmental

From the previous analysis, it is evident that there are no significant differences between the two routes in terms of technical difficulty and economics. The deciding factor, therefore, reduces to the environmental impacts. The access road routing between Watana and Devil Canyon was selected because it has the least potential for creating adverse impacts to wildlife, wildlife habitat, and fisheries. Similarly, Segment AJC, within which the access road is located, is environmentally less sensitive than Segment ABC, for it traverses or approaches fewer areas of productive habitat and zones of species concentration or movement. The most important consideration, however, is that for ground access during operation and maintenance, it will be necessary to have some form of trail along the transmission line route. This trail would permit human entry into an area which is relatively inaccessible at present, causing both direct and indirect impacts. By placing the transmission and access road within the same general corridor as in Segment AJC, impacts will be confined to that one corridor. If access route and transmission line are placed in separate corridors, as in Segment ABC, environmental impacts would be far greater.

Segment AJC is thus considered superior to segment ABC. Consequently, corridor 1 (ABCD) was eliminated and Corridor 14 (AJCD) selected as the proposed route.

6.6 - Final Corridor Selection

Table 14.6 of the Feasibility Report (Acres 1982a), which gives the summary of ratings for each of the three corridors, was revised following the change to the proposed transmission line corridor in the central study area. The revised table is presented as Table 6.4.

The transmission line corridor presented in the FERC License Application thus changed to:

- Southern Study Area	Corridor 2	ADFC
- Central Study Area	Corridor 14	AJCD
- Northern Study Area	Corridor 1	ABC

A more detailed explanation of the screening and final selection process, with particular reference to environmental constraints, is given in Chapter 10 of Exhibit E, of the FERC License Application (Acres 1983).

6.7 - Route Selection

(a) Studies Prior to Publication of Feasibility Report

The route selection methodology followed in Section 14.3 of the Feasibility Report (Acres 1982a) resulted in the development of recommended routes for each of the three study areas. The data base used in this analysis was obtained from:

- An up-to-date land status study;
- Existing aerial photographs;
- New aerial photographs produced for selected sections of the previously recommended transmission line corridors;
- Environmental studies including aesthetic considerations;
- Climatological studies;
- Geotechnical exploration;
- Additional field studies; and
- Public opinions.

Many specific routing constraints were identified during the preliminary screening, and others were determined during the 1981 field investigations. These constraints were collated, placed on a base map, and a route of least impact selected.

(b) Studies Subsequent to Publication of Feasibility Report

The original corridors which were three to five miles in width were narrowed to a half mile and, after final adjustment, to a finalized route with a defined right-of-way.

As discussed earlier, the routing of the transmission line corridor in the central study area was changed so that it shares the same general corridor as the access road between the dams and the railroad extension between Devil Canyon and Gold Creek. The final alignment within this section was chosen to parallel the access road and railroad extension to the maximum extent possible so as to minimize the mileage of new access trail development. It is also desirable to minimize the number of bends in the corridor to keep the number of special structures and, therefore, the cost to a minimum. With both these objectives in mind, the selected alignment, as shown in Figure 6.1, represents the optimum alignment of the transmission line based on existing data.

In the latter half of 1982, a land acquisition analysis was conducted along the length of the transmission line corridor, the purpose of which was to identify areas where land acquisition would present a problem. Additional environmental studies identifying environmentally sensitive areas were also undertaken. These studies have resulted in the alignment being refined along the northern and southern corridor stubs to the extent that most of the land acquisition problems and environmentally sensitive zones have been avoided.

The selected transmission line route for the three study areas is presented in Exhibit G of the FERC License Application (Acres 1983b). This route will be subject to some minor revision during the final design phase once the detailed soils investigations and engineering design are completed.

(c) Right-of-way

Preliminary studies have indicated that for a hinged-guyed x-configuration tower the following right-of-way widths should be sufficient.

1 tower	190 feet
2 towers	300 feet
3 towers	400 feet
4 towers	510 feet

These right-of-way widths were developed assuming the following parameters:

- Height from tower cross arm to ground 85 feet;
- Horizontal phase spacing, 33 feet; and
- Level terrain (less than 10° slope).

During final design, these right-of-way widths may vary slightly where difficult terrain is encountered or the need for special tower structures dictates.

6.8 - Towers, Foundations, and Conductors

The types of towers, foundations, and conductors to be utilized in the transmission system have not changed since the publication of the Feasibility Report. In general, hinged-guyed, x-configuration towers, of the type selected for the intertie, will be used. Guyed pole-type structures will be used on larger angle and dead end structures; and a similar arrangement used in especially heavy loading zones. A span of 1200 to 1300 feet is expected with final spans varying to greater and lesser values in specific cases depending upon span ratio and loading zone. Typical tower and foundation details are given in Figures 14.6 and 14.7 of the Feasibility Report. (Acres 1982a).

6.9 - Substations

As discussed earlier, the intertie has been re-routed since the Feasibility Report was issued; and the Gold Creek switching station added to the transmission system. The switching station will be located in a wooded area on the south bank terraces of the river at approximately RM 142. The location of the switching station is shown in Figure 6.1. A single-line diagram and plan of the switchyard is presented in Figure 6.2.

6.10 - Dispatch Center and Communications

The operation of the transmission facility and the dispatch of power to the load centers will be controlled from a central dispatch and Energy Management System (EMS) center. It is recommended that the center be located at Willow since a suitable site could be developed at the Willow Switching Station site. The center will operate in conjunction with northern and southern area control systems in Fairbanks and Anchorage. The generation at the Susitna Hydroelectric sites would be controlled at the Watana power facility. The Energy Management Center would orchestrate the overall operation of the system by request to the three local generation-control centers for action and direct operation of the Gold Creek Switching Station and the four 345-kv switching and substations along the transmission system.

As recommended in the Feasibility Report (Acres 1982a), the system communications requirements will be provided by means of a microwave system. The system will be an enlargement of the facility being provided for the operation of the intertie between Willow and Healy. Communications into the hydroelectric plants will be via a microwave extension from the Gold Creek Switching Station.

REFERENCES

Acres American Incorporated. 1981. Susitna Hydroelectric Project Transmission Line Corridor Screening Closeout Report. Prepared for the Alaska Power Authority.

______. 1982a. Susitna Hydroelectric Project Feasibility Report. Prepared for the Alaska Power Authority.

______. 1983. Susitna Hydroelectric Project FERC License Application-Exhibit E. Prepared for the Alaska Power Authority.

______. 1983a. Susitna Hydroelectric Project FERC License Application-Exhibit B. Prepared for the Alaska Power Authority.

______. 1983b. Susitna Hydroelectric Project FERC License Application-Exhibit G. Prepared for the Alaska Power Authority.

International Engineering Company, Inc./Robert W. Retherford Associates. 1979. Economic Feasibility Study. Prepared for the Alaska Power Authority.

TABLE 6.1: TRANSMISSION SYSTEM CHARACTERISTICS

Line Section	Length (mi)	Number of Circuits	Voltage (kV)
Watana to Gold Creek	37	2	345
Devil Canyon to Gold Creek	8	2	345
Gold Creek to Willow	79	3	345
Willow to Knik Arm	44	3	345
Knik Arm Crossing*	3	3	345
Knik Arm to University Substation (Anchorage)	19	2	345
Gold Creek to Ester Substation (Fairbanks)	185	2	345

TABLE 6.2: TECHNICAL, ECONOMIC, AND ENVIRONMENTAL CRITERIA USED IN CORRIDOR SELECTION

Type	Criteria	Selection
1. Technical		
- Primary	General Location	Connect with Intertie near Gold Creek, Willow, and Healy. Connect Healy to Fairbanks. Connect Willow to Anchorage.
	Elevation	Avoid mountainous areas.
	Relief	Select gentle relief.
	Access	Locate in proximity to existing transportation corridors to facilitate maintenance and repairs.
- Secondary	River Crossings	Minimize wide crossings.
2. Economical		
- Primary	Elevation	Avoid mountainous areas.
	Access	Locate in proximity to existing transportation corridors to reduce construction costs.
- Secondary	River Crossings	Minimize wide crossings.
	Timbered Areas	Minimize such areas to reduce clearing costs.
	Wetlands	Minimize crossings which require special designs.
3. Environmental		
- Primary	Development	Avoid existing or proposed developed areas.
	Existing Transmission Right-of-Way	Parallel.
	Land Status	Avoid private lands, wildlife refuges, parks.
	Topography	Select gentle relief.
- Secondary	Vegetation	Avoid heavily timbered areas.

TABLE 6.3: TECHNICAL, ECONOMIC, AND ENVIRONMENTAL CRITERIA USED IN CORRIDOR SCREENING

TECHNICAL

Primary

- Topography
- Climate and Elevation
- Soils
- Length

Secondary

- Vegetation and Clearing
- Highway and River Crossings

ECONOMIC

Primary

- Length
- Presence of Right-of-Way
- Presence of Access Roads

Secondary

- Topography
- Stream Crossings
- Highway Railroad Crossings

ENVIRONMENTAL

Primary

- Aesthetic and Visual
- Land Use
- Presence of Existing Right-of-Way
- Existing and Proposed Development

Secondary

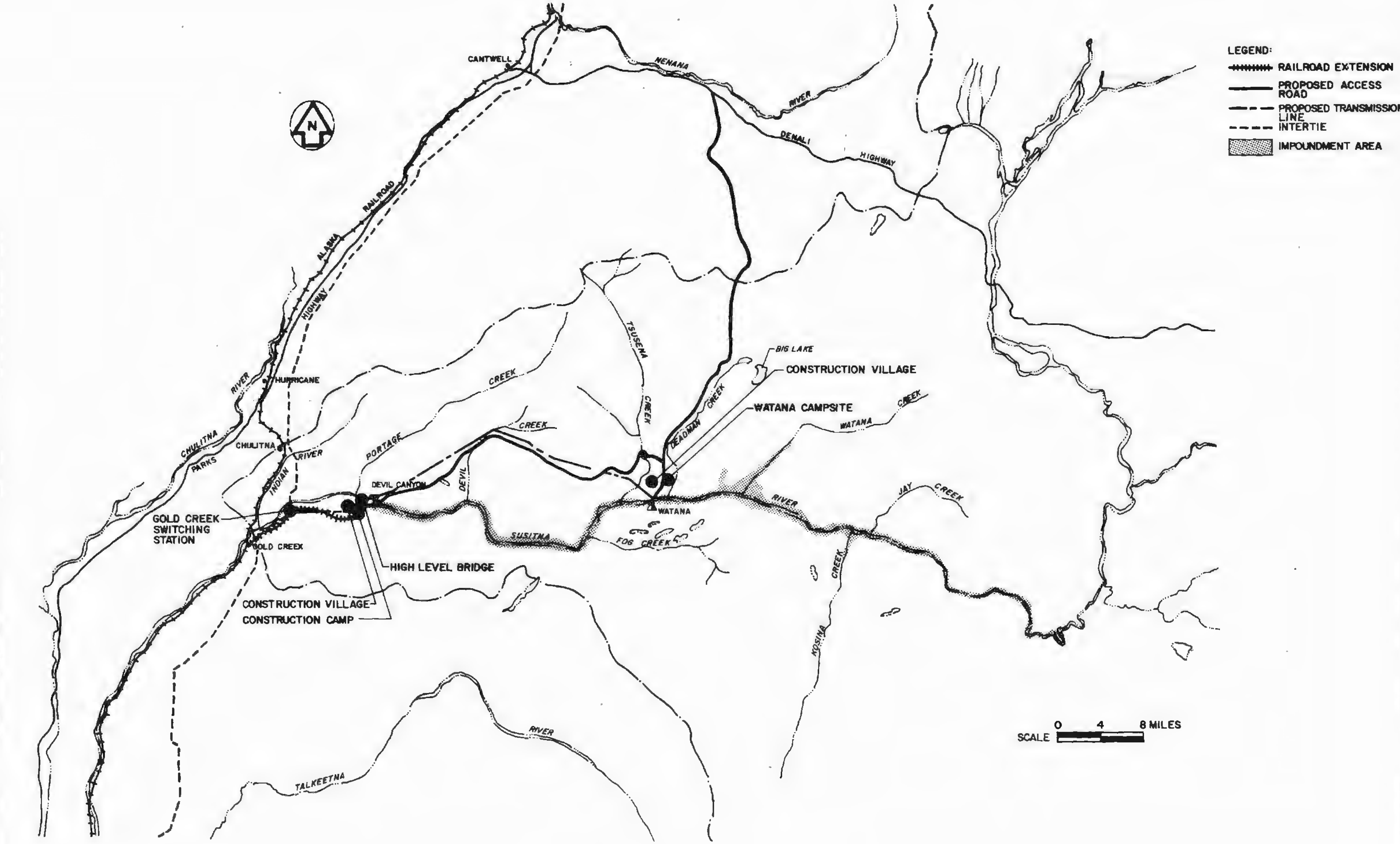
- Length
- Topography
- Soils
- Cultural Resources
- Vegetation
- Fishery Resources
- Wildlife Resources

TABLE 6.4: SUMMARY OF SCREENING RESULTS

Corridor		Ratings			
		Environmental	Economic	Technical	Summary
- Southern Study Area					
(1)	ABC'	C	C	C	C
(2)	ADFC*	A	A	A	A
(3)	AEFC	F	C	A	F
- Central Study Area					
(1)	ABCD	C	C	A	C
(2)	ABECD	F	C	C	F
(3)	AJCF	C	C	C	C
(4)	ABCJHI	F	F	F	F
(5)	ABECJHI	F	F	F	F
(6)	CBAHI	F	C	F	F
(7)	CEBAHI	F	F	C	F
(8)	CBAG	F	F	C	F
(9)	CEBAG	F	F	C	F
(10)	CJAG	F	F	C	F
(11)	CJAHI	F	C	C	F
(12)	JACJHI	F	F	C	F
(13)	ABCF	C	C	C	C
(14)	AJCD*	A	A	A	A
(15)	ABECF	F	C	C	F
- Northern Study Area					
(1)	ABC*	A	A	A	A
(2)	ABDC	C	A	C	C
(3)	AEDC	F	C	F	F
(4)	AEF	F	C	F	F

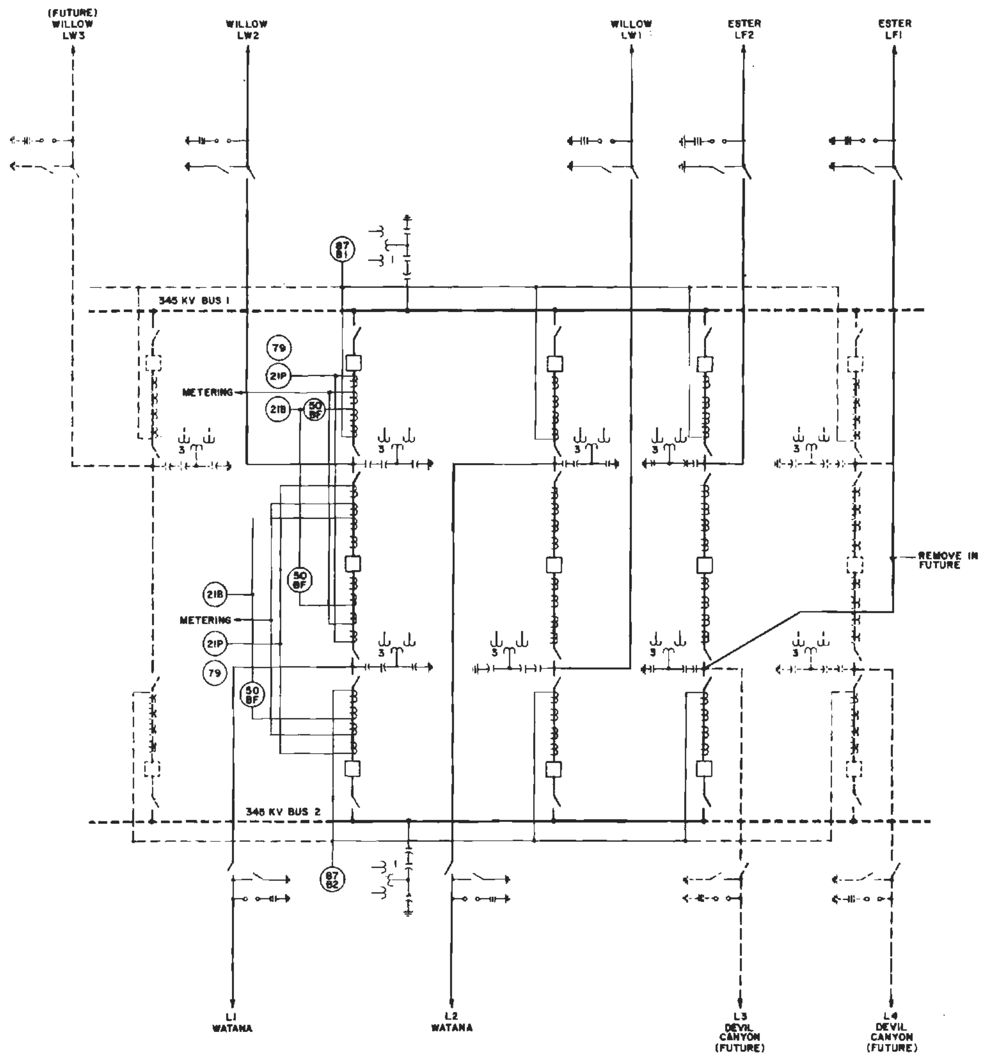
A = recommended
C = acceptable but not preferred
F = unacceptable

* Indicates selected corridor.

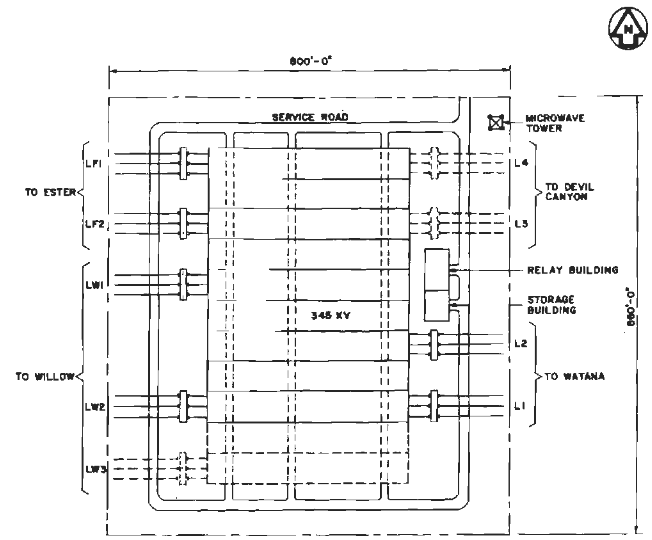


PROPOSED PROJECT FEATURES

FIGURE 6.1



SINGLE LINE DIAGRAM

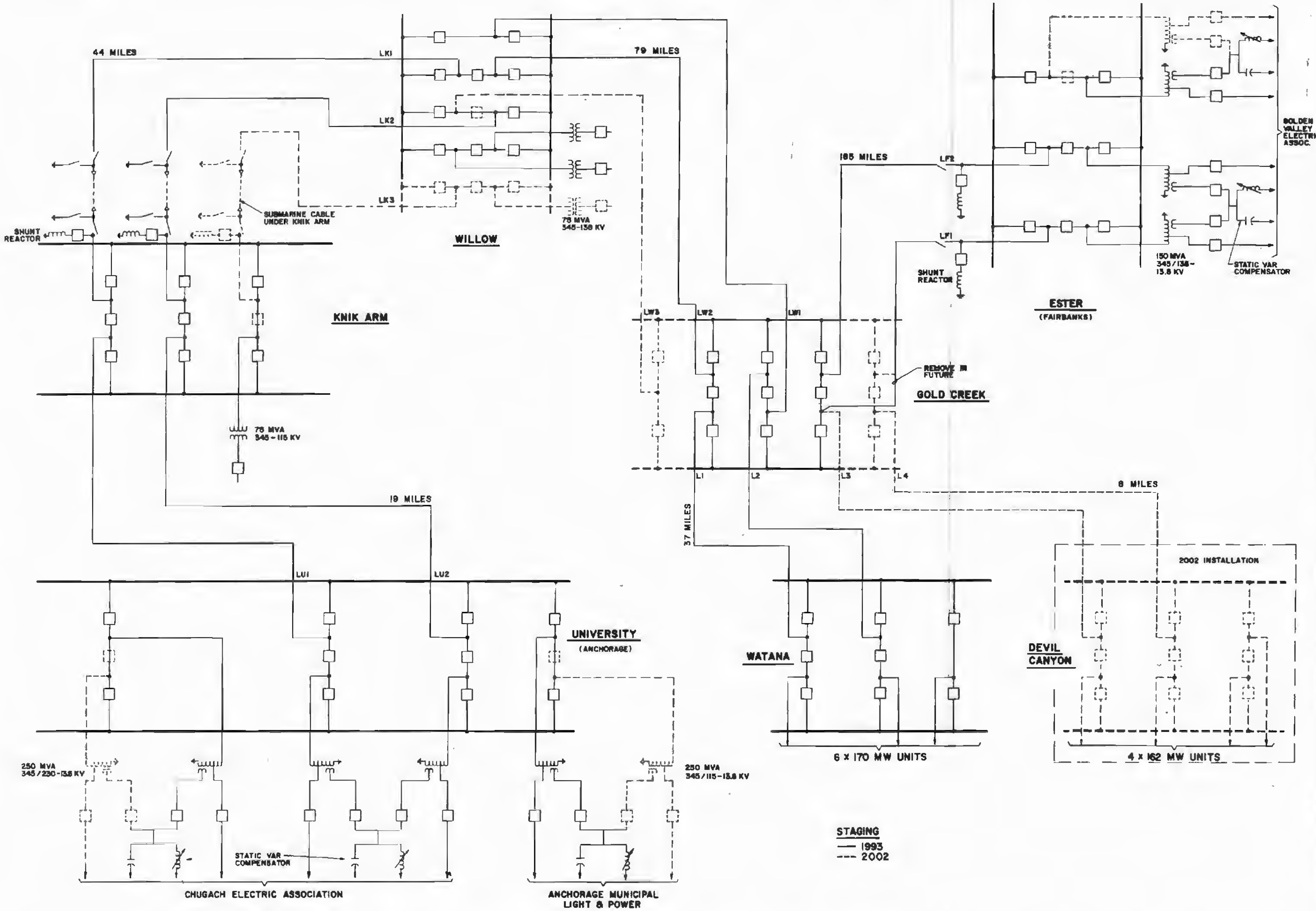


SWITCHYARD PLAN
SCALE A

SCALE A 0 100 200 FEET (1 INCH = 100 FEET)

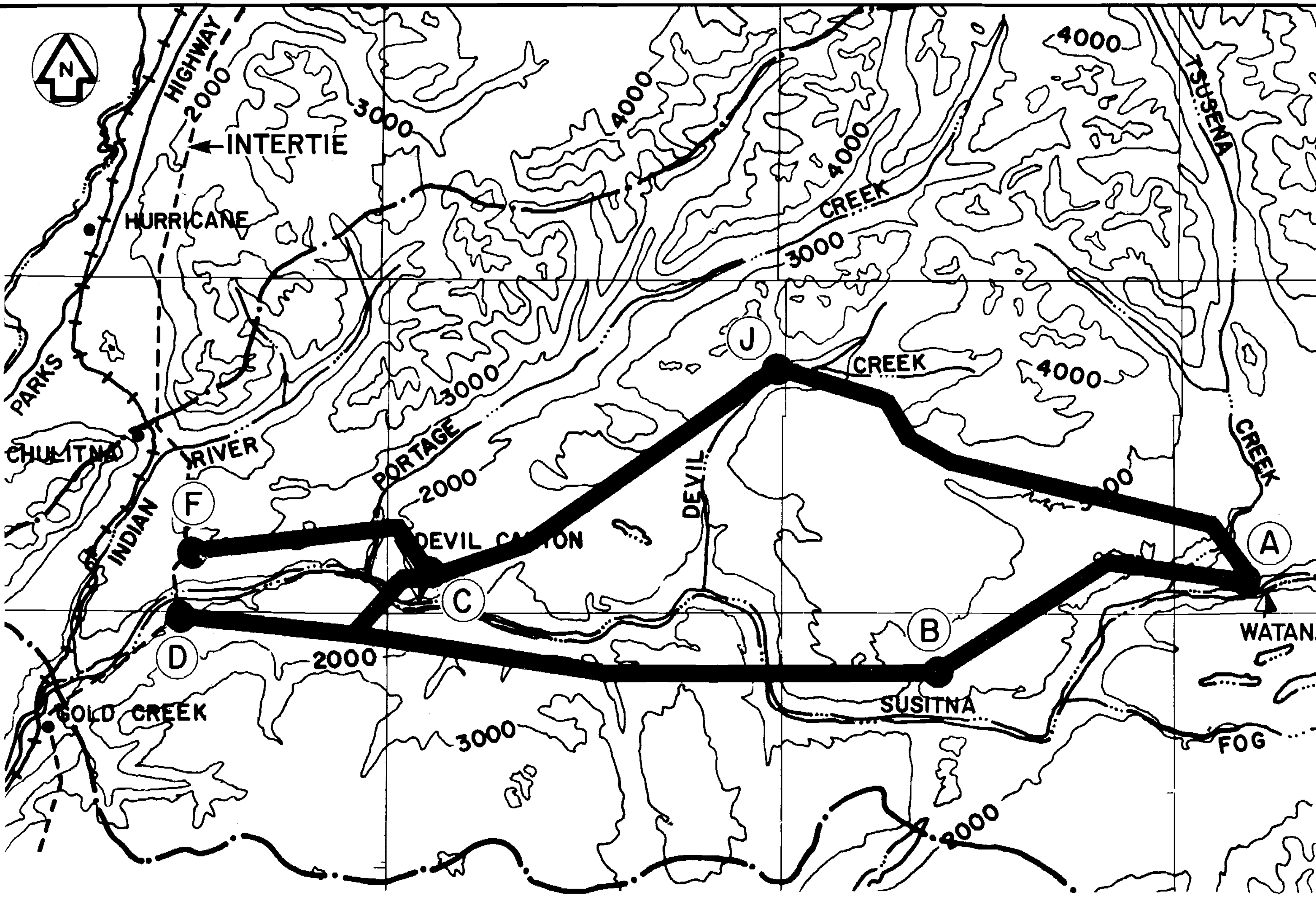
GOLD CREEK SWITCHYARD
SINGLE LINE DIAGRAM AND PLAN

FIGURE 6.2



RAILBELT 345 KV TRANSMISSION SYSTEM SINGLE LINE DIAGRAM

FIGURE 6.3



CENTRAL STUDY AREA ALTERNATIVE TRANSMISSION ROUTES

FIGURE 6.4

7 - PROJECT OPERATION

7.1 - Introduction

The energy potential of the Susitna Hydroelectric Project was assessed using a monthly energy simulation model developed specifically for the project. Studies made to determine optimum height, drawdown, and impact of downstream flow requirements are reported in Appendix A, Hydrological Studies of the Susitna Hydroelectric Project, Feasibility Report (Acres 1982a). Extension of these studies was made in 1982 to include refinements to operating rule curves, downstream flow, and energy demand. Downstream flow requirements were refined during the fishery mitigation plan development and particularly affected flow timing to ensure coincidence with critical spawning periods. Further details of the mitigation plan are given in the Susitna Hydroelectric Project, License Application, Exhibit E (Acres 1983).

Complete output for the selected operations is given in Attachment A of this report for Watana operation and Watana/Devil Canyon operation.

7.2 - Simulation Model

A multi-reservoir energy simulation model was used to evaluate the optimum method of operating the Susitna Hydroelectric Project for a range of post-project flows at the Gold Creek gaging station 15 miles downstream from the Devil Canyon damsite.

The simulation model incorporates several features which are satisfied according to the following hierarchy:

- Minimum downstream flow requirement;
- Minimum energy demand;
- Reservoir operation rule; and
- Maximum usable energy (demand).

Input to the model includes the reservoir storage-elevation relationships, powerhouse characteristics, streamflow at the damsites and at the reference downstream location, system demand for a given year, system demand pattern, and reservoir operating rules, plus other minor operating and program specific values.

Weekly and monthly energy simulation programs were developed. However, their only difference is in the basic time step. Both programs have the following solution path:

- Meet minimum energy demand;
- Check reservoir levels against rule curve;
- Check energy production against energy demand; and
- Meet downstream flow requirement.

The minimum energy demand was determined as a fraction of the monthly energy demand. This fraction was iteratively derived so that the minimum energy is produced at all times and all available reservoir storage is used. The monthly energy is based on the energy pattern developed by ISER/Woodward Clyde (ISER/Woodward Clyde 1980).

During periods of above average runoff, the reservoir levels remain substantially higher than average. This results, during periods of back-to-back wet years, in spillage during summer months. To reduce this spillage and waste of energy, it is worthwhile to draw the reservoir down during the winter months of wetter periods. This is achieved by the rule curve. The rule curve check will compare reservoir levels after minimum energy production with the rule curve. If reservoir levels are above the rule curve level, more water is released through the powerhouse. The amount of the release is the quantity of water in storage over the rule curve level times a fraction. This fraction is usually equal to one and is used to maintain additional storage in the reservoirs, particularly in early summer months.

To ensure that the above release does not result in energy production in excess of system needs, a check is made against system energy demand. This demand is for a given year and is equal to the forecast for that year (Battelle 1982). The period demand pattern is based on studies by Acres American (Acres 1983a). If overproduction occurs, powerhouse flows are reduced and the water is saved in storage.

Energy requirements are met within a given percentage (generally one percent) whenever the minimum or maximum energy routines are evoked. This, however, can be negated by downstream flow requirements which could cause excessive powerhouse flows. In this situation, flows are shifted to the spillways in a specified manner so that Watana powerhouse flow is reduced first, or the majority of the spillage is at Watana. Since the downstream flow requirement is applied last, it takes precedent over the energy production requirements. Downstream flow requirements are met by releasing as much flow from Devil Canyon as possible, given drawdown limits. Releases from Watana to meet downstream flow requirements occur only when Devil Canyon is at its lowest permissible water level.

7.3 - Project Reservoirs

(a) Watana Reservoir Characteristics

The Watana reservoir will be operated at a normal maximum operating level of El 2183 above mean sea level but will be allowed to surcharge to El 2190 in late August during wet years. Average annual drawdown will be to El 2093 with Watana operation and El 2080 with Watana/Devil Canyon operation. The maximum drawdown for either operation scenario will be to El 2065. During extreme flood events, the reservoir will rise to El 2193.3 for the 1:10,000 year flood and El 2200.5 for the probable maximum flood.

At El 2185, the reservoir will have a surface area of 38,000 acres and a total volume of 9.47 million acre-feet as indicated in the area-capacity curves in Figure 7.1. Maximum depth will be 735 feet, the mean depth will be 250 feet, and the shoreline length will be 183 miles. The reservoir will have a retention time of 1.65 years.

Within the Watana reservoir area, the substrate classification varies greatly. It consists predominantly of glacial, colluvial, and fluvial unconsolidated sediments and several bedrock lithologies. Many of these deposits are frozen.

(b) Devil Canyon Reservoir Characteristics

Devil Canyon reservoir will be operated at a normal maximum operating level of El 1455 above mean sea level. Average annual drawdown will be 28 feet with the maximum drawdown equaling 50 feet. At El 1455, the reservoir will have a surface area of 7800 acres and a volume of 1.09 million acre-feet. Figure 7.2 illustrates the area capacity curve of the reservoir. The maximum depth will be 565 feet, the mean depth will be 140 feet, and the shoreline length will total 76 miles. The reservoir will have a retention time of two months.

Materials forming the walls and floors of the reservoir area are composed predominantly of bedrock and glacial, colluvial, and fluvial materials.

7.4 - Flow Range

(a) Pre-Project Flows

The 32-year discharge record at Gold Creek was combined with regional analysis of streamflow records to develop a 32-year record for the Cantwell gage near Vee Canyon at the upper end of the proposed Watana reservoir. The flow at Watana and Devil Canyon was then calculated using the Cantwell flow as the base and adding an incremental flow proportional to the additional drainage area between the Cantwell gage and the damsites (Acres 1982a).

The available 32-year record was considered adequate for determining a statistical distribution of annual energies for each annual demand scenario considered; thus, it was not considered necessary to synthesize additional years of record.

The 32 years of record contained a low flow event (water year [WY] 1969) with a recurrence interval of approximately 1000 years, as illustrated in Figure 7.3. This WY was adjusted to reflect a low flow frequency of 1:30 years, since a 1:30-year event represents a more reasonable return period for firm energy used in system reliability tests.

Although the frequency of the adjusted or modified year is a 1:30-year occurrence, the two-year, low-flow frequency of the modified WY 1969 and the succeeding low flow, WY 1970, is approximately 1:100 years. The unmodified two-year, low-flow frequency is approximately 1:250 years. This two-year, low-flow event is important in that, if the reservoir is drawn down to its minimum level after the first dry year, the volume of water in storage in the reservoir at the start of the winter season of the second year of the two-year sequence will be insufficient to satisfy the minimum energy requirements. Hence, the modified record was adopted for use in the energy simulation studies.

The 1:30-year annual water volume was proportioned on a monthly basis according to the long-term, average monthly distribution. This increased the WY 1969 average annual discharge at Gold Creek 1600 cfs, from 5600 cfs to 7200 cfs, and the average annual discharge at Gold Creek for the 32 years of record by 0.5 percent. The resulting monthly flows at Watana, Devil Canyon, and Gold Creek are presented in Tables 7.1, 7.2, and 7.3, respectively.

Weekly flows at the damsites were determined from daily records at Gold Creek prorated in proportion to drainage basin area at the damsites and Gold Creek.

(b) Project Flows

A range of project operational target flows from 6000 to 19,000 cfs at Gold Creek was analyzed. The flow at Gold Creek was selected because it was judged to be representative of the Devil Canyon-to-Talkeetna reach where downstream impacts will be the greatest. Additionally, the flows can be directly compared with the 32 years of discharge records at Gold Creek.

The range of project flows analyzed included the operational flow that would produce the maximum amount of usable energy from the project neglecting downstream flow considerations (referred to as Case A) and the operational flow which would result in essentially no impact on the downstream fishery during the anadromous fish spawning period (referred to as Case D). Between these two end points, five additional flow scenarios were analyzed.

In Case A, the minimum target flow at Gold Creek for the month of August and the first half of September was established at 6000 cfs. Flow was increased in increments of 2000 cfs for the August-September time period, thereby establishing the target flow for Cases A1, A2, C, C1, and C2. The August-September flow for Case D was established at 19,000 cfs. The resulting seven flow scenarios were adequate to define the change in project economics resulting from a change in project flow requirements. The monthly minimum target flows for all seven flow scenarios are presented in Table 7.4 and Figure 7.4.

In the reach of the Susitna River between Talkeetna and Devil Canyon, an important aspect of maintaining natural sockeye and chum salmon reproduction is the provision of access to the slough spawning areas hydraulically connected to the mainstem of the river. Access to these slough spawning areas is primarily a function of flow (water level) in the main channel of the river during the period when the salmon must gain access to the spawning areas. Field studies during 1981 and 1982 have shown that the most critical period for access is August and early September. Thus, the project operational flow has been scheduled to satisfy this requirement; i.e., the flow will be increased the last week of July, held constant during August and the first two weeks of September, and then decreased to a level specified by energy demand in mid-September.

7.5 - Energy Production and Net Benefits

(a) Energy Production

The reservoir simulation model was run assuming 120 feet of drawdown at Watana and 50 feet at Devil Canyon for the seven flow cases given in Section 7.4(a). Additional runs were made for Watana drawdowns of 80, 100, and 140 feet for Cases A and C. Monthly average and firm energies for the seven flow cases for Watana and Watana/Devil Canyon operation are given in Tables 7.5 through 7.11. Case A and Case C energies for 80, 100, and 140 feet drawdown are given in Tables 7.5 and 7.8, respectively. These tables show the variation in average and firm monthly energies.

(b) Net Benefits

The energies given in Tables 7.5 to 7.11 were used as input to the generation planning model which determines the long-term, present-worth cost of producing energy for the Railbelt. The present-worth cost is determined by using the Optimized Generation Planning Model, Version 5, (OGP5) (General Electric 1979). This model determines, in 1982 dollars, the present-worth cost of supplying the Railbelt energy needs by various means of generation (thermal or thermal and hydroelectric). The best all-thermal option has a present-worth cost of $8,238 million (1982 dollars), and this value is used to measure the net benefit of the Susitna Hydroelectric Project. The present-worth cost of each of the seven flow cases is given in Table 7.12 and the net benefit in Figure 7.5. Variation in present-worth cost with Watana downstream is given in Tables 7.13 and the net benefit variation in Figure 7.6.

In the OGP analysis, no change in construction costs has been assumed for the various drawdown scenarios. This provides, therefore, a comparison of net benefit from energy production only and does not reflect the actual net benefit from the scheme. The project cost is based on the scheme given in the Feasibility

Report (Acres 1982) which had an intake structure providing facility to draw to 140 feet. Consequently, for drawdowns less than 140 feet, an additional benefit would result due to savings in intake construction. It has been estimated that intake cost difference between 80- and 160-foot intakes is about $0.5 million per foot of intake. Above 160 feet drawdown, substantial costs are incurred due to excessive excavation and rock support.

Another adjustment to net benefit results from the analysis made in OGP with respect to loss-of-load probability (LOLP). This quantity determines the reliability of the system and, consequently, the need for additional capacity.

In the OGP analysis for the 140-foot drawdown (Case C), the LOLP for the year 2010 is 0.0954 days/year. In the 120-foot drawdown case, the LOLP is 0.0527 days/year in 2010. This large difference is due to the addition of a gas turbine in February 2010 in the 120-foot drawdown case. Since OGP assumes system costs are constant from year 2010 to 2040, the difference in cost (due to number of gas turbine units) is significant. Therefore, assuming a gas turbine is added in January 2011, this would result in an additional cost in the 140-foot drawdown case of about $41 million or a reduction of the net benefit to $1,227 million. Adjusted drawdown/net benefit relation is given in Figure 7.6. Present-worth cost and net benefit for the two flow cases with drawdowns assumed are given in Table 7.13.

The incremental difference between Watana drawdowns of 120 and 140 feet is approximately $60 million. This value represents about 5 percent of the net benefit and about one percent of the present worth cost. The uncertainties associated with rock support costs and the increase in environmental impact with increased drawdown result in the selection of 120-foot drawdown at Watana. Further analyses into environmental impacts, primarily with respect to outflow temperatures, power studies, and geotechnical investigations, may result in modification to this drawdown.

The OGP analysis for the seven flow cases (Table 7.12 and Figure 7.5) shows an impact on the net benefit between Case A and Case C. This is due to August powerhouse flows being generally below the usable energy limit for that month. Between Case A and D, however, the net benefit is reduced by about $550 million, or 45 percent. This is mainly due to the loss in average annual energy as a result of spillage in August to meet downstream flow requirements. The spillage associated with the higher flow cases prevents storage of water in August-September for release during winter months. Also, flows are generally in exceedance of power requirements.

The impacts of the various flow scenarios on fisheries, tributary, downstream water rights, and other downsteam use are discussed in detail in Exhibit E of the Susitna License Application (Acres 1983). Based on the environmental impacts (Acres 1983) and the economic analysis discussed above, it was judged that while Cases A, A1, and A2 flows produced essentially the same net benefit, the loss in net benefits for Case C is of acceptable magnitude. The loss associated with Case C1 is on the borderline between acceptable and unacceptable. However, as fishery and instream flow impacts (and hence mitigation costs associated with the various flow scenarios) are refined (Acres 1983), the potential decrease in mitigation costs associated with higher flows will not offset the loss in net benefits. Thus, selecting a higher flow case such as C1 cannot be justified by savings in mitigation costs. The loss in net benefits associated with Cases C2 and D is considered unacceptable, since the mitigation cost reduction associated with these higher flows will not bring them into the acceptable range. Therefore, the Case C flow scenario has been selected.

REFERENCES

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General Electric Company. 1979. Optimized Generation Planning Program (OGP). Electric Utility Systems Engineering Department. Schenectady, New York.

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TABLE 7.1: WATANA PRE-PROJECT MONTHLY FLOW (CFS) MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	4720.	2084.	1169.	815.	642.	569.	680.	8656.	16432.	19193.	16914.	7320.	6648.1
2	3299.	1107.	906.	808.	673.	620.	1302.	11650.	18518.	19787.	16478.	17206.	7733.7
3	4593.	2170.	1501.	1275.	841.	735.	804.	4217.	25773.	22111.	17356.	11571.	7776.7
4	6286.	2757.	1281.	819.	612.	671.	1382.	15037.	21470.	17355.	16682.	11514.	8035.2
5	4219.	1600.	1184.	1088.	803.	638.	943.	11697.	19477.	16984.	20421.	9166.	7400.4
6	3859.	2051.	1550.	1388.	1051.	886.	941.	6718.	24881.	23788.	23537.	13448.	8719.3
7	4102.	1588.	1039.	817.	755.	694.	718.	12953.	27172.	25831.	19153.	13194.	9051.0
8	4208.	2277.	1707.	1373.	1189.	935.	945.	10176.	25275.	19949.	17318.	14841.	8381.0
9	6035.	2936.	2259.	1481.	1042.	974.	1265.	9958.	22098.	19753.	18843.	5979.	7769.4
10	3668.	1730.	1115.	1081.	949.	694.	886.	10141.	18330.	20493.	23940.	12467.	8011.0
11	5166.	2214.	1672.	1400.	1139.	961.	1070.	13044.	13233.	19506.	19323.	16086.	7954.0
12	6049.	2328.	1973.	1780.	1305.	1331.	1965.	13638.	22784.	19840.	19480.	10146.	8602.9
13	4638.	2263.	1760.	1609.	1257.	1177.	1457.	11334.	36017.	23444.	19887.	12746.	9832.9
14	5560.	2509.	1709.	1309.	1185.	884.	777.	15299.	20663.	28767.	21011.	10800.	9277.7
15	5187.	1789.	1195.	852.	782.	575.	609.	3579.	42842.	20083.	14048.	7524.	8262.7
16	4759.	2368.	1070.	863.	773.	807.	1232.	10966.	21213.	23236.	17394.	16226.	8451.5
17	5221.	1565.	1204.	1060.	985.	985.	1338.	7094.	25940.	16154.	17391.	9214.	7374.4
18	3270.	1202.	1122.	1102.	1031.	890.	850.	12556.	24712.	21987.	26105.	13673.	9095.7
19	4019.	1934.	1704.	1618.	1560.	1560.	1577.	12827.	25704.	22083.	14148.	7164.	8032.2
20	3447.	1567.	1073.	884.	748.	686.	850.	7942.	17509.	15871.	14078.	8150.	6100.4
21	2403.	1021.	709.	636.	602.	624.	986.	9536.	14399.	18410.	16264.	7224.	6114.6
22	3768.	2496.	1687.	1097.	777.	717.	814.	2857.	27613.	21126.	27447.	12189.	8588.5
23	4979.	2587.	1957.	1671.	1491.	1366.	1305.	15973.	27429.	19820.	17510.	10956.	8963.4
24	4301.	1978.	1247.	1032.	1000.	874.	914.	7287.	23859.	16351.	18017.	8100.	7112.0
25	3057.	1355.	932.	786.	690.	627.	872.	12889.	14781.	15972.	13524.	9786.	6313.7
26	3089.	1474.	1277.	1216.	1110.	1041.	1211.	11672.	26689.	23430.	15127.	13075.	8402.7
27	5679.	1601.	876.	758.	743.	691.	1060.	8939.	19994.	17015.	18394.	5712.	6834.8
28	2974.	1927.	1688.	1349.	1203.	1111.	1203.	8569.	31353.	19707.	16807.	10613.	8232.6
29	5794.	2645.	1980.	1578.	1268.	1257.	1408.	11232.	17277.	18385.	13412.	7133.	6992.2
30	3774.	1945.	1313.	1137.	1055.	1101.	1318.	12369.	22905.	24912.	16671.	9097.	8183.7
31	6150.	3525.	2032.	1470.	1233.	1177.	1404.	10140.	23400.	26740.	18000.	11000.	8907.9
32	6458.	3297.	1385.	1147.	971.	889.	1103.	10406.	17017.	27840.	31435.	12026.	9580.4
MAX	6458.	3525.	2259.	1780.	1560.	1560.	1965.	15973.	42842.	28767.	31435.	17206.	9832.9
MIN	2403.	1021.	709.	636.	602.	569.	609.	2857.	13233.	15871.	13412.	5712.	6100.4
MEAN	4523.	2059.	1415.	1166.	983.	898.	1100.	10355.	23024.	20810.	18629.	10792.	8023.0

TABLE 7.2: DEVIL CANYON PRE-PROJECT MONTHLY FLOW (CFS) MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	5758.	2405.	1343.	951.	736.	670.	802.	10491.	18469.	21383.	18821.	7951.	7537.8
2	3652.	1231.	1031.	906.	768.	697.	1505.	13219.	19979.	21576.	18530.	19799.	8615.9
3	5222.	2539.	1758.	1484.	943.	828.	879.	4990.	30014.	24862.	19647.	13441.	8918.0
4	7518.	3233.	1550.	1000.	746.	767.	1532.	17758.	25231.	19184.	19207.	13928.	9356.4
5	5109.	1921.	1387.	1224.	930.	729.	1131.	15286.	23188.	19154.	24072.	11579.	8866.9
6	4830.	2507.	1868.	1649.	1275.	1024.	1107.	8390.	28082.	26213.	24960.	13989.	9707.4
7	4648.	1789.	1207.	922.	893.	852.	867.	15979.	31137.	29212.	22610.	16496.	10608.2
8	5235.	2774.	1987.	1583.	1389.	1105.	1109.	12474.	28415.	22110.	19389.	18029.	9668.7
9	7435.	3590.	2905.	1792.	1212.	1086.	1437.	11849.	24414.	21763.	21220.	6989.	8866.8
10	4403.	2000.	1371.	1317.	1179.	878.	1120.	13901.	21538.	23390.	28594.	15330.	9649.6
11	6061.	2623.	2012.	1686.	1340.	1113.	1218.	14803.	14710.	21739.	22066.	18930.	9084.4
12	7171.	2760.	2437.	2212.	1594.	1639.	2405.	16031.	27069.	22881.	21164.	12219.	10021.3
13	5459.	2544.	1979.	1796.	1413.	1320.	1613.	12141.	40680.	24991.	22242.	14767.	10946.5
14	6308.	2696.	1896.	1496.	1387.	958.	811.	17698.	24094.	32388.	22721.	11777.	10431.8
15	5998.	2085.	1387.	978.	900.	664.	697.	4047.	47816.	21926.	15586.	8840.	9250.7
16	5744.	2645.	1161.	925.	829.	867.	1314.	12267.	24110.	26196.	19789.	18234.	9555.5
17	6497.	1908.	1478.	1279.	1187.	1187.	1619.	8734.	30446.	18536.	20245.	10844.	8697.0
18	3844.	1458.	1365.	1358.	1268.	1089.	1054.	14436.	27796.	25081.	30293.	15728.	10460.4
19	4585.	2204.	1930.	1851.	1779.	1779.	1791.	14982.	29462.	24871.	16091.	8226.	9175.4
20	3976.	1783.	1237.	1012.	859.	780.	959.	9154.	19421.	17291.	15500.	9188.	6800.1
21	2867.	1146.	810.	757.	709.	722.	1047.	10722.	17119.	21142.	18653.	8444.	7063.9
22	4745.	3082.	2075.	1319.	944.	867.	986.	3428.	31031.	22942.	30316.	13636.	9657.2
23	5537.	2912.	2313.	2036.	1836.	1660.	1566.	19777.	31930.	21717.	18654.	11884.	10199.0
24	4639.	2155.	1387.	1140.	1129.	955.	987.	7896.	26393.	17572.	19478.	8726.	7738.3
25	3491.	1463.	997.	843.	746.	690.	949.	15005.	16767.	17790.	15257.	11370.	7160.5
26	3507.	1619.	1487.	1409.	1342.	1272.	1457.	14037.	30303.	26188.	17032.	15155.	9606.6
27	7003.	1853.	1008.	897.	876.	825.	1261.	11305.	22814.	18253.	19298.	6463.	7705.5
28	3552.	2392.	2148.	1657.	1470.	1361.	1510.	11212.	35607.	21741.	18371.	11916.	9438.8
29	6936.	3211.	2371.	1868.	1525.	1481.	1597.	11693.	18417.	20079.	15327.	8080.	7765.1
30	4502.	2324.	1549.	1304.	1204.	1165.	1403.	13334.	24052.	27463.	19107.	10172.	9023.0
31	6900.	3955.	2279.	1649.	1383.	1321.	1575.	11377.	26255.	30002.	20196.	12342.	9994.5
32	7246.	3699.	1554.	1287.	1089.	997.	1238.	11676.	17741.	31236.	35270.	12762.	10577.9
MAX	7518.	3955.	2905.	2212.	1836.	1779.	2405.	19777.	47816.	32388.	35270.	19799.	10946.5
MIN	2867.	1146.	810.	757.	709.	664.	697.	3428.	14710.	17291.	15257.	6463.	6800.1
MEAN	5324.	2391.	1664.	1362.	1152.	1042.	1267.	12190.	26078.	23152.	20928.	12414.	9129.7

TABLE 7.3: GOLD CREEK PRE-PROJECT MONTHLY FLOW (CFS) MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	6335.	2583.	1439.	1027.	788.	726.	870.	11510.	19600.	22600.	19880.	8301.	8032.1
2	3848.	1300.	1100.	960.	820.	740.	1617.	14090.	20790.	22570.	19670.	21240.	9106.0
3	5571.	2744.	1900.	1600.	1000.	880.	920.	5419.	32370.	26390.	20920.	14480.	9552.1
4	8202.	3497.	1700.	1100.	820.	820.	1615.	19270.	27320.	20200.	20610.	15270.	10090.4
5	5604.	2100.	1500.	1300.	1000.	780.	1235.	17280.	25250.	20360.	26100.	12920.	9681.6
6	5370.	2760.	2045.	1794.	1400.	1100.	1200.	9319.	29860.	27560.	25750.	14290.	10256.4
7	4951.	1900.	1300.	980.	970.	940.	950.	17660.	33340.	31090.	24530.	18330.	11473.3
8	5806.	3050.	2142.	1700.	1500.	1200.	1200.	13750.	30160.	23310.	20540.	19800.	10384.1
9	8212.	3954.	3264.	1965.	1307.	1148.	1533.	12900.	25700.	22880.	22540.	7550.	9476.4
10	4811.	2150.	1513.	1448.	1307.	980.	1250.	15990.	23320.	25000.	31180.	16920.	10559.9
11	6558.	2850.	2200.	1845.	1452.	1197.	1300.	15780.	15530.	22980.	23590.	20510.	9712.3
12	7794.	3000.	2694.	2452.	1754.	1810.	2650.	17360.	29450.	24570.	22100.	13370.	10809.3
13	5916.	2700.	2100.	1900.	1500.	1400.	1700.	12590.	43270.	25850.	23550.	15890.	11565.2
14	6723.	2800.	2000.	1600.	1500.	1000.	830.	19030.	26000.	34400.	23670.	12320.	11072.9
15	6449.	2250.	1494.	1048.	966.	713.	745.	4307.	50580.	22950.	16440.	9571.	9799.6
16	6291.	2799.	1211.	960.	860.	900.	1360.	12990.	25720.	27840.	21120.	19350.	10168.8
17	7205.	2098.	1631.	1400.	1300.	1300.	1775.	9645.	32950.	19860.	21830.	11750.	9431.8
18	4163.	1600.	1500.	1500.	1400.	1200.	1167.	15480.	29510.	26800.	32620.	16870.	11218.5
19	4900.	2353.	2055.	1981.	1900.	1900.	1910.	16180.	31550.	26420.	17170.	8816.	9810.6
20	4272.	1906.	1330.	1086.	922.	833.	1022.	9852.	20523.	18093.	16322.	9776.	7200.1
21	3124.	1215.	866.	824.	768.	776.	1080.	11380.	18630.	22660.	19980.	9121.	7591.2
22	5288.	3407.	2290.	1442.	1036.	950.	1082.	3745.	32930.	23950.	31910.	14440.	10251.0
23	5847.	3093.	2510.	2239.	2028.	1823.	1710.	21890.	34430.	22770.	19290.	12400.	10885.5
24	4826.	2253.	1465.	1200.	1200.	1000.	1027.	8235.	27800.	18250.	20290.	9074.	8086.2
25	3733.	1523.	1034.	874.	777.	724.	992.	16180.	17870.	18800.	16220.	12250.	7631.0
26	3739.	1700.	1603.	1516.	1471.	1400.	1593.	15350.	32310.	27720.	18090.	16310.	10275.4
27	7739.	1993.	1081.	974.	950.	900.	1373.	12620.	24380.	18940.	19800.	6881.	8189.3
28	3874.	2650.	2403.	1829.	1618.	1500.	1680.	12680.	37970.	22870.	19240.	12640.	10109.0
29	7571.	3525.	2589.	2029.	1668.	1605.	1702.	11950.	19050.	21020.	16390.	8607.	8194.5
30	4907.	2535.	1681.	1397.	1286.	1200.	1450.	13870.	24690.	28880.	20460.	10770.	9489.3
31	7311.	4192.	2416.	1748.	1466.	1400.	1670.	12060.	29080.	32660.	20960.	13280.	10747.7
32	7725.	3986.	1773.	1454.	1236.	1114.	1368.	13317.	18143.	32000.	38538.	13171.	11255.3
MAX	8212.	4192.	3264.	2452.	2028.	1900.	2650.	21890.	50580.	34400.	38538.	21240.	11565.2
MIN	3124.	1215.	866.	824.	768.	713.	745.	3745.	15530.	18093.	16220.	6881.	7200.1
MEAN	5771.	2577.	1807.	1474.	1249.	1124.	1362.	13240.	27815.	24445.	22228.	13321.	9753.3

TABLE 7.4: MONTHLY FLOW REQUIREMENTS AT GOLD CREEK (CFS)

MONTH	A	A1	A2	C	C1	C2	D
Oct	5000	5000	5000	5000	5000	5000	5000
Nov	5000	5000	5000	5000	5000	5000	5000
Dec	5000	5000	5000	5000	5000	5000	5000
Jan	5000	5000	5000	5000	5000	5000	5000
Feb	5000	5000	5000	5000	5000	5000	5000
Mar	5000	5000	5000	5000	5000	5000	5000
Apr	5000	5000	5000	5000	5000	5000	5000
May	4000	5000	5000	6000	6000	6000	6000
Jun	4000	5000	5000	6000	6000	6000	6000
Jul[1]	4000	5100	5320	6480	6530	6920	7260
Aug	6000	8000	10000	12000	14000	16000	19000
Sep[1]	5000	6500	7670	9300	10450	11620	13170

NOTE:

1. Derivation of transitional flows.

DATE		CASE						
Jul	Sep	A	A1	A2	C	C2	C2	D
25	7	4000	5000	5000	6000	6000	6000	6000
26	6	4000	5000	5000	6000	7000	7000	7500
27	5	4000	5000	5000	7000	8000	8500	9000
28	4	4000	5000	6000	8000	9000	10000	10500
29	3	4000	5000	7000	9000	10000	11500	12000
30	2	4000	6000	8000	10000	11000	13000	14000
31	1	5000	7000	9000	11000	12500	14500	16000

TABLE 7.5: MONTHLY ENERGY PRODUCTION: CASE A, VARIABLE DRAWDOWN

	ENERGY (GWH)															
	80' DRAWDOWN				100' DRAWDOWN				120' DRAWDOWN				140' DRAWDOWN			
	Watana Alone		Watana/Devil Canyon		Watana Alone		Watana/Devil Canyon		Watana Alone		Watana/Devil Canyon		Watana Alone		Watana/Devil Canyon	
MONTH	Firm	Average	Firm	Average	Firm	Average	Firm	Average	Firm	Average	Firm	Average	Firm	Average	Firm	Average
Oct	215	279	459	557	238	290	459	551	244	296	482	548	259	294	505	553
Nov	234	291	503	568	263	334	503	683	269	340	528	678	285	332	553	672
Dec	277	383	588	710	307	379	587	809	315	407	617	801	334	378	647	797
Jan	287	357	537	657	281	357	537	746	288	356	564	742	305	355	591	744
Feb	295	307	417	575	218	279	417	640	224	291	438	637	237	278	459	631
Mar	238	248	467	480	244	279	467	619	250	290	490	627	265	279	514	623
Apr	184	186	392	391	204	260	392	396	209	253	409	515	222	257	430	511
May	233	276	499	499	196	248	451	451	200	266	423	484	212	250	417	480
Jun	161	277	345	509	179	245	345	475	183	236	363	440	194	249	381	447
Jul	164	311	353	470	182	216	353	434	187	216	371	424	198	224	390	430
Aug	173	365	370	520	192	317	371	469	196	286	390	454	208	305	408	441
Sep	175	250	375	520	195	307	375	485	200	239	394	461	212	298	413	473
Annual	2636	3530	5305	6456	2699	3511	5257	6758	2765	3476	5469	6811	2931	3499	5708	6802

TABLE 7.6: MONTHLY ENERGY PRODUCTION: CASE A1, 120' DRAWDOWN

	ENERGY (GWH)			
Month	Watana Alone Firm	Watana Alone Average	Watana/Devil Canyon Firm	Watana/Devil Canyon Average
Oct	232	265	520	561
Nov	256	350	538	661
Dec	300	440	629	801
Jan	274	382	575	737
Feb	213	330	447	606
Mar	238	307	500	608
Apr	199	249	418	448
May	191	222	406	492
Jun	174	241	370	488
Jul	178	197	378	454
Aug	187	240	397	464
Sep	190	218	401	477
Annual	2632	3441	5579	6797

TABLE 7.7: MONTHLY ENERGY PRODUCTION: CASE A2, 120' DRAWDOWN

	ENERGY (GWH)			
Month	Watana Alone		Watana/Devil Canyon	
	Firm	Average	Firm	Average
Oct	223	252	592	592
Nov	246	338	507	674
Dec	288	431	593	787
Jan	264	379	542	738
Feb	205	324	421	625
Mar	229	303	471	624
Apr	191	248	396	451
May	184	218	399	479
Jun	168	239	349	446
Jul	171	191	357	421
Aug	229	288	435	491
Sep	210	229	400	469
Annual	2608	3440	5462	6797

TABLE 7.8: MONTHLY ENERGY PRODUCTION: CASE C, VARIABLE DRAWDOWN

MONTH	ENERGY (GWH) 80' DRAWDOWN Watana Alone Firm	80' Watana Alone Average	80' Watana/Devil Canyon Firm	80' Watana/Devil Canyon Average	100' DRAWDOWN Watana Alone Firm	100' Watana Alone Average	100' Watana/Devil Canyon Firm	100' Watana/Devil Canyon Average	120' DRAWDOWN Watana Alone Firm	120' Watana Alone Average	120' Watana/Devil Canyon Firm	120' Watana/Devil Canyon Average	140' DRAWDOWN Watana Alone Firm	140' Watana Alone Average	140' Watana/Devil Canyon Firm	140' Watana/Devil Canyon Average
Oct	218	266	594	594	215	258	593	593	221	263	610	610	233	263	640	640
Nov	238	335	441	685	237	328	431	612	243	322	472	635	256	320	497	650
Dec	281	332	516	718	277	375	504	761	285	388	551	769	300	387	581	791
Jan	257	310	471	627	253	337	461	708	260	346	504	716	274	345	531	732
Feb	199	216	367	477	197	257	358	589	202	283	392	615	213	283	413	599
Mar	223	232	410	507	220	273	400	615	226	286	438	613	238	285	462	569
Apr	186	189	344	413	184	256	336	447	189	250	366	507	199	248	386	497
May	179	200	382	382	177	250	479	479	182	258	401	445	192	256	376	425
Jun	163	357	303	458	161	240	296	480	165	227	324	429	174	229	339	471
Jul	167	324	310	477	164	246	303	434	169	205	332	406	185	209	347	416
Aug	316	482	468	538	309	397	462	513	303	373	479	520	333	370	502	512
Sep	276	308	492	545	270	283	489	523	266	274	469	508	197	273	396	489
Annual	2703	3551	5099	6421	2664	3500	5112	6754	2711	3475	5338	6773	2794	3468	5470	6791

TABLE 7.9: MONTHLY ENERGY PRODUCTION: CASE C1, 120' DRAWDOWN

	ENERGY (GWH)			
Month	Watana Alone Firm	Watana Alone Average	Watana/Devil Canyon Firm	Watana/Devil Canyon Average
Oct	209	237	603	603
Nov	230	303	447	572
Dec	270	377	522	753
Jan	246	337	477	699
Feb	191	279	370	610
Mar	214	283	415	598
Apr	179	249	346	499
May	172	255	334	460
Jun	157	223	340	418
Jul	160	201	316	396
Aug	377	434	543	542
Sep	304	295	569	553
Annual	2709	3473	5282	6703

TABLE 7.10: MONTHLY ENERGY PRODUCTION: CASE C2, 120' DRAWDOWN

	ENERGY (GWH)			
Month	Watana Alone Firm	Watana Alone Average	Watana/Devil Canyon Firm	Watana/Devil Canyon Average
Oct	200	218	590	590
Nov	221	272	421	518
Dec	258	361	492	719
Jan	236	330	450	683
Feb	183	274	350	600
Mar	205	279	391	584
Apr	171	248	327	487
May	165	253	318	453
Jun	150	220	322	413
Jul	153	198	311	389
Aug	448	496	543	543
Sep	323	321	567	567
Annual	2713	3470	5082	6546

TABLE 7.11: MONTHLY ENERGY PRODUCTION: CASE D, 120' DRAWDOWN

	ENERGY (GWH)			
Month	Watana Alone		Watana/Devil Canyon	
	Firm	Average	Firm	Average
Oct	188	193	587	587
Nov	208	236	410	473
Dec	243	321	480	645
Jan	222	314	439	646
Feb	172	265	341	513
Mar	193	274	381	527
Apr	161	245	319	483
May	156	250	338	425
Jun	141	214	282	441
Jul	144	197	288	398
Aug	556	597	543	543
Sep	321	359	569	569
Annual	2705	3465	4977	6250

TABLE 7.12: NET BENEFIT VARIATION WITH DOWNSTREAM FLOW REQUIREMENT

CASE	$1982 x 10^6	
	PWC	NET BENEFIT
Thermal	8238	---
A	7023	1215
A1	6998	1240
A2	7012	1226
C	7097	1141
C1	7189	1048
C2	7357	881
D	7569	669

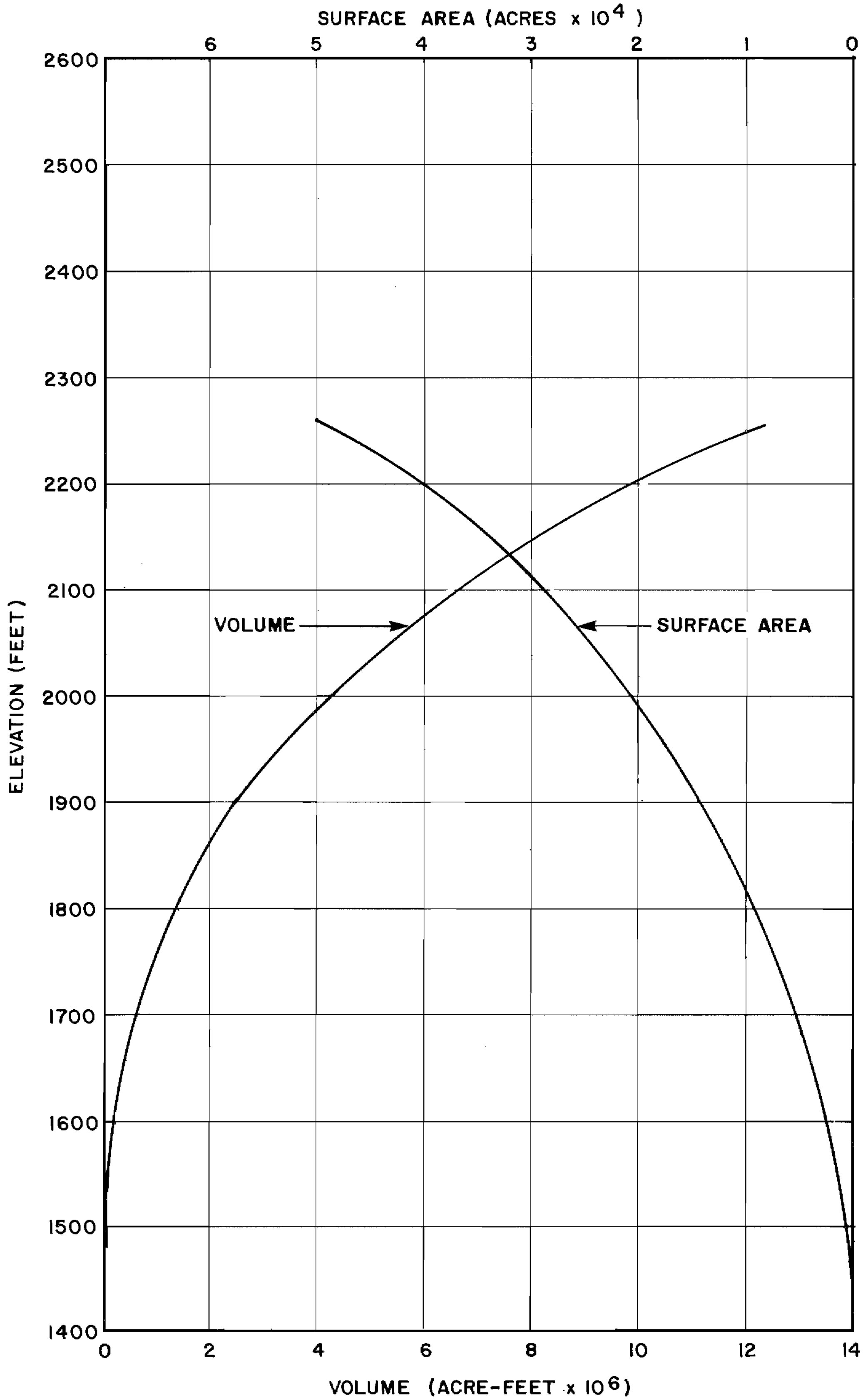
Note: Assuming 120' drawdown at Watana.

TABLE 7.13: NET BENEFIT VARIATION WITH WATANA DRAWDOWN (CASE A AND CASE C)

CASE	$1982 x 10^6		
	DRAWDOWN	PWC[1]	NET BENEFIT
A	80	7197	1041
	120	7023	1215
	140	6944	1294
C	80	7380	858
	100	7148	1040
	120	7097	1141
	140	6970	1268
	160	7035	1203

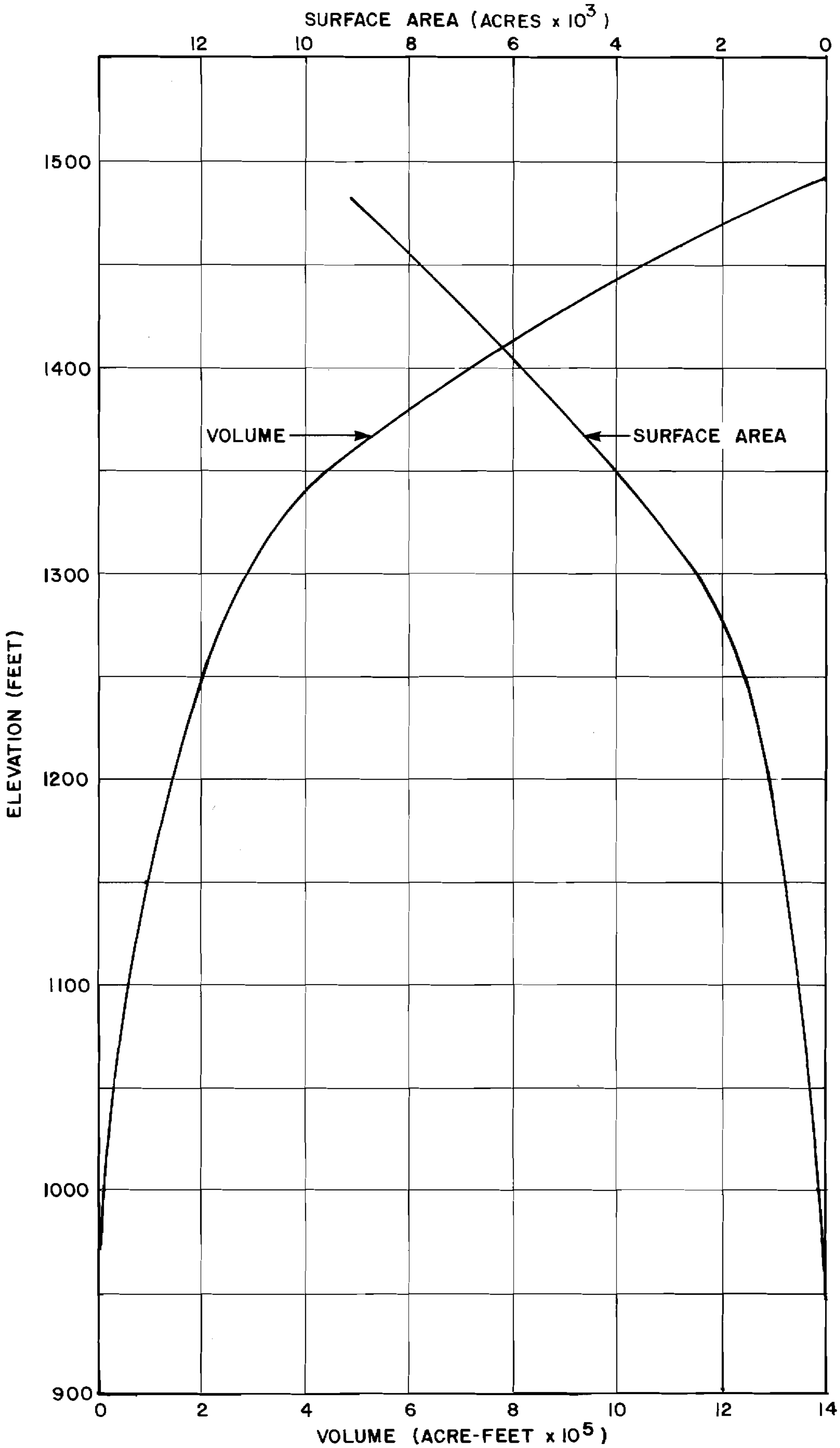
NOTE:

1. OGP Analysis assumes no change in project costs.



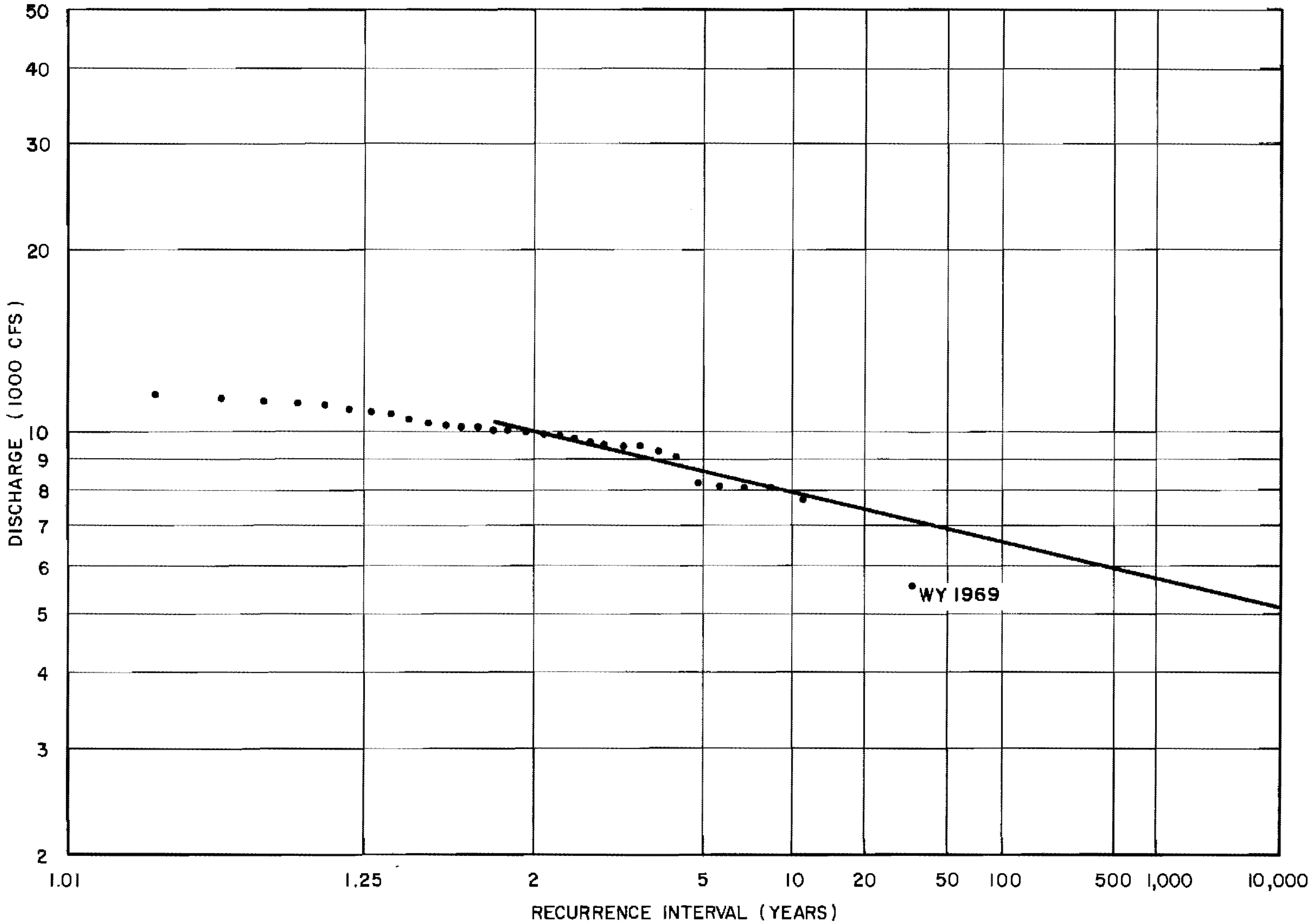
WATANA RESERVOIR VOLUME AND SURFACE AREA

FIGURE 7.1



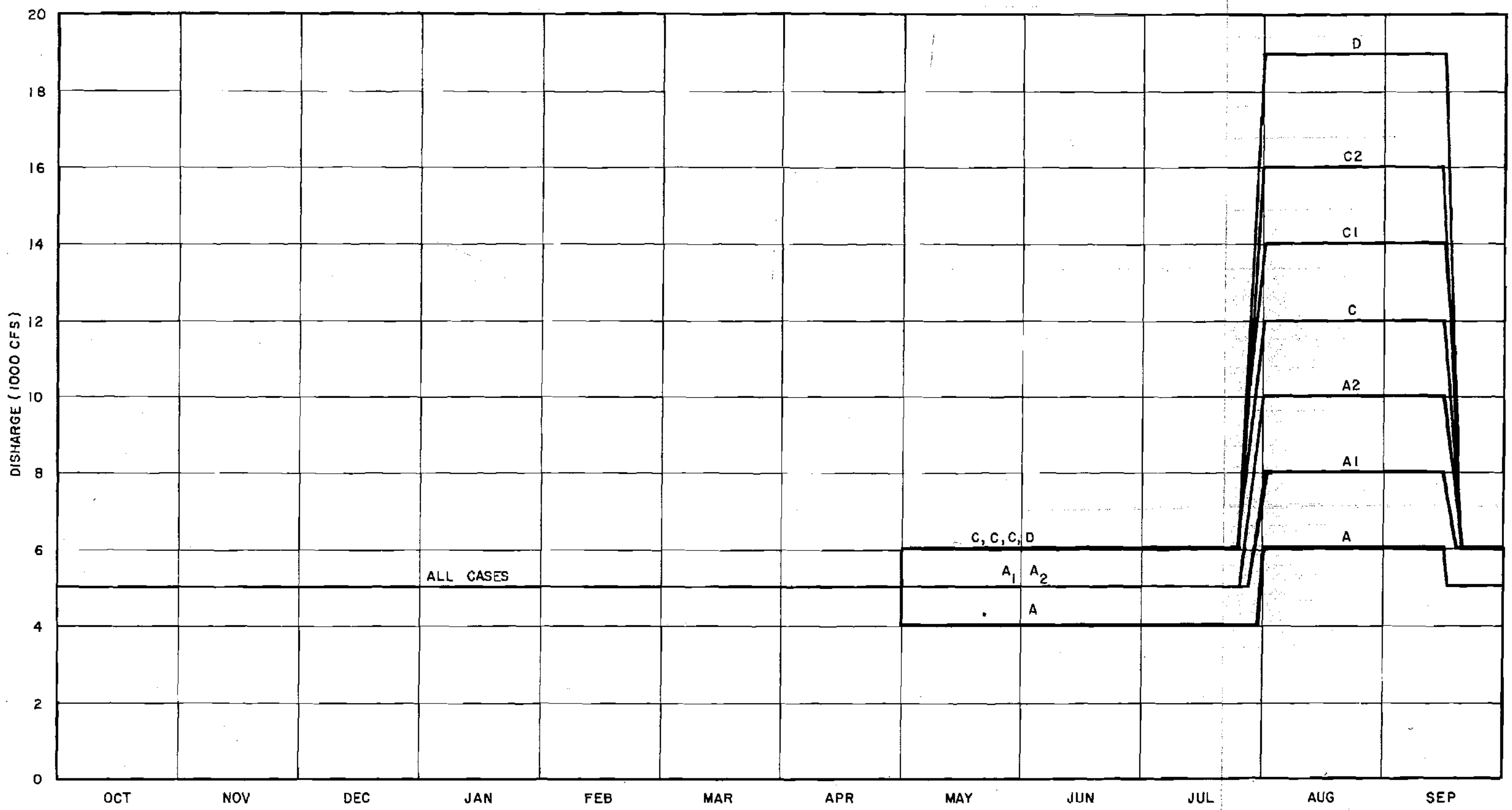
DEVIL CANYON RESERVOIR VOLUME AND SURFACE AREA

FIGURE 7.2



LOW-FLOW FREQUENCY ANALYSIS
OF MEAN ANNUAL FLOW
AT GOLD CREEK

FIGURE 7.3



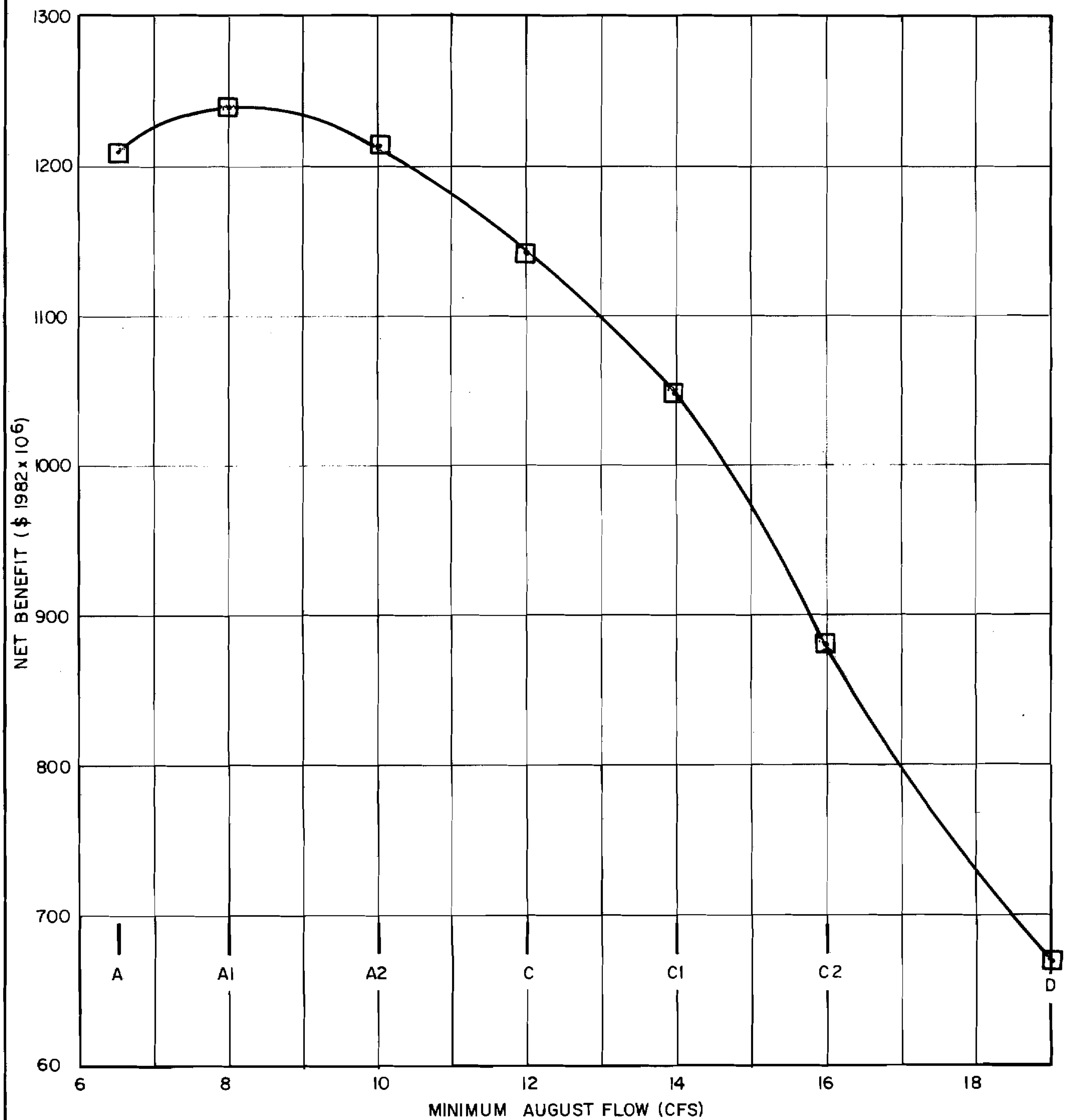
NOTES:

1) LETTERS DESIGNATE THE VARIOUS SCENARIOS CONSIDERED (ie. A=CASE A).

2) FLOW REPRESENTS GOLD CREEK FLOWS.

MINIMUM OPERATIONAL TARGET FLOWS FOR ALTERNATIVE FLOW SCENARIOS

FIGURE 7.4

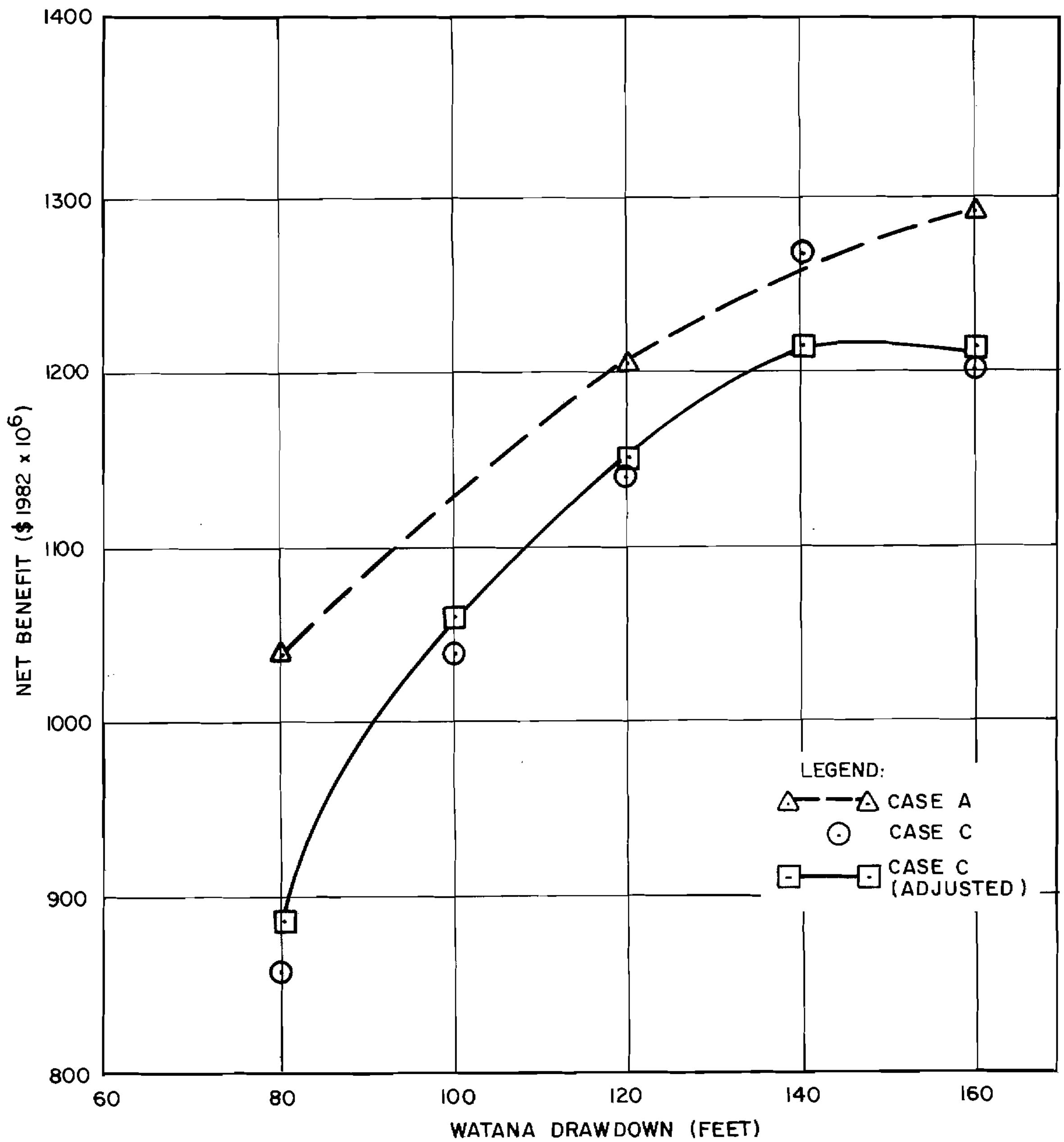


NOTE:

1. NET BENEFIT BASED ON THERMAL OPTION COST OF $ 8238 x 10^6.
2. MINIMUM FLOW AT GOLD CREEK.

VARIATION IN NET BENEFIT WITH DOWNSTREAM FLOW REQUIREMENT

FIGURE 7.5



VARIATION IN NET BENEFIT WITH
WITH WATANA DRAWDOWN (CASE A AND CASE C)

FIGURE 7.6

ATTACHMENT A

DETAILED OUTPUT
WATANA OPERATION
WATANA/DEVIL CANYON OPERATION

SUSITNA HEP
WATANA 2185
CASE C 120' :mh:R4:

EL	STORAGE
1900.0	2550000.0
1950.0	3330000.0
2000.0	4250000.0
2050.0	5340000.0
2100.0	6650000.0
2150.0	8189999.5
2200.0	10020000.0
2250.0	12210000.0

MINIMUM STORAGE= 5733000.0 MAXIMUM STORAGE 9654000.0

MAXIMUM P.H.Q = 19391.0 START WSEL=2185.0 TWEL=1455.0 PMAX=.10200E+07

MONTHLY BASELOAD DEMAND

0.297968E+06	0.337748E+06	0.382500E+06	0.349605E+06	0.300645E+06	0.304088E+06
0.262395E+06	0.244418E+06	0.229500E+06	0.226823E+06	0.238298E+06	0.250537E+06

MONTHLY DISCHARGE REQUIREMENT

2000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	6000.0	6000.0	6484.0	12000.0	9300.0

MONTHLY WATER LEVEL

2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.0	2135.0	2165.0	2180.0	2190.0

MONTHLY FLOW DISTRIBUTION

1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.7

MONTHLY L.F. = 0.375

NO. YEARS OF SIMULATION = 32

PDS= 0 NSEC= 318 NDEF= 66 NDFF1= 0 NDSFL= 0

YEAR	TOTE	TOTSEC	TOTDEF
1	0.33717E+10	0.87162E+09	0.24103E+06
2	0.27670E+10	0.26989E+09	0.31644E+07
3	0.34132E+10	0.91294E+09	0.22797E+05
4	0.36156E+10	0.11153E+10	0.00000E+00
5	0.31830E+10	0.68311E+09	0.37742E+06
6	0.36494E+10	0.11511E+10	0.19579E+07
7	0.39460E+10	0.14457E+10	0.00000E+00
8	0.36573E+10	0.11570E+10	0.00000E+00
9	0.36947E+10	0.11944E+10	0.00000E+00
10	0.31765E+10	0.67861E+09	0.24329E+07
11	0.35648E+10	0.10645E+10	0.00000E+00
12	0.37044E+10	0.12041E+10	0.00000E+00
13	0.41957E+10	0.16954E+10	0.00000E+00
14	0.41354E+10	0.16351E+10	0.00000E+00
15	0.38732E+10	0.13729E+10	0.24889E+05
16	0.32976E+10	0.79900E+09	0.17246E+07
17	0.34867E+10	0.98778E+09	0.13662E+07
18	0.36868E+10	0.11893E+10	0.27825E+07
19	0.38596E+10	0.13593E+10	0.00000E+00
20	0.30244E+10	0.52784E+09	0.37512E+07
21	0.27114E+10	0.21258E+09	0.14333E+07
22	0.27529E+10	0.25585E+09	0.31947E+07
23	0.40703E+10	0.15700E+10	0.00000E+00
24	0.33210E+10	0.82235E+09	0.16606E+07
25	0.30157E+10	0.51844E+09	0.30284E+07
26	0.29076E+10	0.40827E+09	0.98166E+06
27	0.34785E+10	0.97820E+09	0.00000E+00
28	0.31772E+10	0.67993E+09	0.30018E+07
29	0.35385E+10	0.10382E+10	0.00000E+00
30	0.29781E+10	0.48066E+09	0.28034E+07
31	0.37669E+10	0.12666E+10	0.00000E+00
32	0.41730E+10	0.16728E+10	0.00000E+00

AVERAGE MONTHLY ENERGY AND POWER

MONTH	TOTAL POWER MW	PEAK POWER MW	OFFPEAK POWER MW	TOTAL ENERGY GWH	OFFPEAK ENERGY GWH	PEAK ENERGY GWH	DEFICIT MW	SEC MW
OCT	352.793	352.793	352.793	262.478	262.478	0.000	0.360	55.186
NOV	447.625	447.625	447.625	322.290	322.290	0.000	0.804	110.681
DEC	522.002	522.002	522.002	388.369	388.369	0.000	0.017	139.519
JAN	465.451	465.451	465.451	346.296	346.296	0.000	0.015	115.861
FEB	420.705	420.705	420.705	282.713	282.713	0.000	0.009	120.068
MAR	383.747	383.747	383.747	285.507	285.507	0.000	0.009	79.668
APR	346.805	346.805	346.805	249.700	249.700	0.000	0.007	84.417
MAY	346.974	346.974	346.974	258.149	258.149	0.000	0.232	102.788
JUN	315.152	315.152	315.152	226.910	226.910	0.000	0.000	85.652
JUL	276.054	276.054	276.054	205.384	205.384	0.000	0.000	49.232
AUG	501.703	501.703	501.703	373.267	373.267	0.000	0.000	263.406
SEP	380.197	380.197	380.197	273.742	273.742	0.000	0.000	129.660

AVERAGE MONTHLY DISCHARGES AND HEAD

MONTH	INFLOW	P.H.FLOW	PEAK	OFFPEAK	HEAD	SPILL	HLOSS
OCT	4522.81	6766.07	6766.07	6766.07	722.36	0.00	0.00
NOV	2059.05	8667.67	8667.67	8667.67	715.01	0.00	0.00
DEC	1414.81	10300.94	10300.94	10300.94	701.89	0.00	0.00
JAN	1165.55	9399.18	9399.18	9399.18	686.28	0.00	0.00
FEB	983.27	8685.35	8685.35	8685.35	671.40	0.00	0.00
MAR	898.33	8098.33	8098.33	8098.33	657.18	0.00	0.00
APR	1099.71	7478.08	7478.08	7478.08	643.20	0.00	0.00
MAY	10354.69	7519.61	7519.61	7519.61	639.76	0.00	0.00
JUN	23023.72	6628.34	6628.34	6628.34	659.07	0.00	0.00
JUL	20810.12	5549.63	5549.63	5549.63	689.41	0.00	0.00
AUG	18628.52	9778.77	9778.77	9778.77	711.24	0.00	0.00
SEP	10791.97	7310.72	7310.72	7310.72	721.58	0.00	0.00

AVERAGE ANNUAL ENERGY = 0.347480E+10 KWH

DELMASS = 0.18298725E+06
STOREND = 0.96540000E+07
STORSTART = 0.96540000E+07
INFLOW MASS = 0.18591853E+09
OUTFL. MASS = 0.18573549E+09

INFLOW CFS

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	4719.9	2083.6	1168.9	815.1	641.7	569.1	680.1	8655.9	16432.1	19193.4	16913.6	7320.4
2	3299.1	1107.3	906.2	808.0	673.0	619.8	1302.2	11649.8	18517.9	19786.6	16478.0	17205.5
3	4592.9	2170.1	1501.0	1274.5	841.0	735.0	803.9	4216.5	25773.4	22110.9	17356.3	11571.0
4	6285.7	2756.8	1281.2	818.9	611.7	670.7	1382.0	15037.2	21469.8	17355.3	16481.6	11513.5
5	4218.9	1599.6	1183.8	1087.8	803.1	638.2	942.6	11696.8	19476.7	16983.6	20420.6	9165.5
6	3859.2	2051.1	1549.5	1388.3	1050.5	886.1	940.8	6718.1	24881.4	23787.9	23537.0	13447.8
7	4102.3	1588.1	1038.6	816.9	754.8	694.4	718.3	12953.3	27171.8	25831.3	19153.4	13194.4
8	4208.0	2276.6	1707.0	1373.0	1189.0	935.0	945.1	10176.2	25275.0	19948.9	17317.7	14841.1
9	6034.9	2935.9	2258.5	1180.6	1041.7	973.5	1245.4	9957.8	22097.8	19752.7	18843.4	5978.7
10	3668.0	1729.5	1115.1	1081.0	949.0	694.0	885.7	10140.6	18329.6	20493.1	23940.4	12466.9
11	5165.5	2217.5	1672.3	1400.4	1138.9	961.1	1069.9	13044.2	13233.4	19506.1	19323.1	16085.6
12	6049.3	2327.8	1973.2	1779.9	1304.8	1331.0	1965.0	13637.9	22784.1	19839.8	19480.2	10146.2
13	4637.6	2263.4	1760.4	1608.9	1257.4	1176.8	1457.4	11333.5	36017.1	23443.7	19887.1	12746.2
14	5560.1	2508.9	1708.9	1308.9	1184.7	883.6	776.6	15299.2	20663.4	28767.4	21011.4	10800.0
15	5187.1	1789.1	1194.7	852.0	781.6	575.2	609.2	3578.8	42841.9	20082.8	14048.2	7524.2
16	4759.4	2368.2	1070.3	863.0	772.7	807.3	1232.4	10966.0	21213.0	23235.9	17394.1	16225.6
17	5221.2	1565.3	1203.6	1060.4	984.7	984.7	1338.4	7094.1	25939.6	16153.5	17390.9	9214.1
18	3269.8	1202.2	1121.6	1102.2	1031.3	889.5	849.7	12555.5	24711.9	21987.3	26104.5	13672.9
19	4019.0	1934.3	1704.2	1617.6	1560.4	1560.4	1576.7	12826.7	25704.0	22082.8	14147.5	7163.6
20	3447.0	1567.0	1073.0	884.0	748.0	686.0	850.0	7942.0	17509.0	15871.0	14078.0	8150.0
21	2403.1	1020.9	709.3	636.2	602.1	624.1	986.4	9536.4	14399.0	18410.1	16263.8	7224.1
22	3768.0	2496.4	1687.4	1097.1	777.4	717.1	813.7	2857.2	27612.8	21126.4	27446.6	12188.9
23	4979.1	2587.0	1957.4	1670.9	1491.1	1366.0	1305.4	15973.1	27429.3	19820.3	17509.5	10955.7
24	4301.2	1977.9	1246.5	1031.5	1000.2	873.9	914.1	7287.0	23859.3	16351.1	18016.7	8099.7
25	3056.5	1354.7	931.6	786.4	689.9	627.3	871.9	12889.0	14780.6	15971.9	13523.7	9786.2
26	3088.8	1474.4	1276.7	1215.8	1110.3	1041.4	1211.2	11672.2	26689.2	23430.4	15126.6	13075.3
27	5679.1	1601.1	876.2	757.8	743.2	690.7	1059.8	8938.8	19994.0	17015.3	18393.5	5711.5
28	2973.5	1926.7	1687.5	1348.7	1202.9	1110.8	1203.4	8569.4	31352.8	19707.3	16807.3	10613.1
29	5793.9	2645.3	1979.7	1577.9	1267.7	1256.7	1408.4	11231.5	17277.2	18385.2	13412.1	7132.6
30	3773.9	1944.9	1312.6	1136.8	1055.4	1101.2	1317.9	17369.3	22904.8	24911.7	16670.7	9096.7
31	6150.0	3525.0	2032.0	1470.0	1233.0	1177.0	1404.0	10140.0	23400.0	26740.0	18000.0	11000.0
32	6458.0	3297.0	1385.0	1147.0	971.0	889.0	1103.0	10406.0	17017.0	27840.0	31435.0	12026.0

POWERHOUSE FLOW CFS

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	5664.6	9716.3	11285.3	9705.6	8958.2	8080.8	7383.7	5632.5	4853.9	4617.4	9033.6	8301.0
2	5840.9	6640.7	7716.0	7189.9	6290.0	6468.3	5674.3	7874.1	4835.5	4778.1	8808.0	5265.5
3	7082.9	10164.1	11617.4	10165.0	9157.5	8246.7	7507.5	5326.8	5002.3	4797.2	8436.3	6391.0
4	8269.3	10750.7	11397.6	9709.4	8928.2	8182.4	8085.6	11375.6	4959.6	4560.9	8071.6	5543.5
5	5691.2	6591.6	11300.2	9978.3	9119.6	8149.9	7646.2	8369.3	4962.2	4590.8	6320.6	5545.5
6	5684.0	7246.1	11665.9	10278.8	9367.0	8397.8	7644.4	5258.9	5174.6	6849.6	14063.1	8457.8
7	7620.0	9582.1	11155.0	9707.4	9071.3	8206.1	7421.9	9500.1	9088.6	8818.7	10055.4	8275.0
8	7778.5	10270.5	11823.4	10263.5	9505.5	8446.7	7648.7	7000.7	7123.4	4748.4	8777.7	7254.1
9	9605.4	10929.9	12374.9	10371.1	9358.2	8485.2	7969.0	6804.2	4963.6	4755.7	8303.4	7550.0
10	5731.9	6512.7	7772.5	9971.5	9265.5	8205.7	7589.3	6968.7	4838.2	4780.9	8969.2	7390.3
11	8736.0	10207.4	11788.7	10290.9	9455.4	8472.8	7773.5	9581.9	4870.4	4812.9	7733.1	4875.6
12	6482.7	10321.7	12089.6	10670.4	9621.3	8842.7	8668.6	10116.3	5203.3	4747.4	9380.2	6076.2
13	6050.3	10257.3	11876.8	10499.4	9573.9	8688.5	8161.0	8042.3	16898.9	7579.4	11004.0	7286.0
14	9130.6	10502.9	11825.3	10199.4	9501.2	8395.3	7480.2	11611.4	4959.4	9515.9	12488.0	7780.0
15	6516.0	9783.1	11311.1	9742.5	9098.1	8086.9	7312.8	5333.1	18353.5	5020.1	9608.2	7253.2
16	5759.3	6535.8	7538.2	9560.5	9089.2	8319.0	7936.0	7711.6	4962.8	5167.4	8274.1	10381.7
17	8791.7	9559.3	11320.0	9950.9	9301.2	8496.4	8042.0	5258.9	6476.3	4555.1	7560.9	6764.1
18	5722.3	6504.8	7606.3	9992.7	9347.8	8401.2	7553.3	9142.1	6837.7	5550.2	16188.9	8753.5
19	7589.5	9928.2	11820.6	10508.1	9876.9	9072.1	8280.3	9386.2	7755.8	5705.5	8977.5	7647.6
20	5756.8	6543.1	7573.0	7636.5	9064.5	8197.7	7553.6	5259.9	4851.7	4629.7	9756.0	7674.0
21	5907.9	6809.4	7856.2	7330.4	6420.2	6619.0	5826.2	5428.1	4982.6	4747.2	8283.8	7403.1
22	5971.4	6790.2	7879.0	7336.3	6419.1	6614.8	5823.1	5501.8	5166.8	4938.7	8685.6	7048.9
23	7860.2	10580.9	12073.8	10561.4	9807.9	8877.7	8009.0	12218.0	9601.0	4742.3	10219.5	7855.7
24	5697.0	6589.5	11362.9	9922.0	9316.7	8385.6	7617.7	5258.9	4973.6	4585.1	9726.7	8325.7
25	5780.5	6573.2	7622.2	7091.7	6638.2	8139.0	7575.5	9442.3	4859.5	4654.8	9303.7	6836.2
26	5901.1	6782.7	7811.4	7274.2	6358.6	6537.0	5739.0	5346.7	7869.7	6791.1	9036.6	6065.3
27	7736.1	9595.1	10992.6	9448.3	9059.7	8202.4	7763.4	5887.1	4964.3	4587.9	10593.5	6881.0
28	5827.7	6628.1	7677.0	7135.9	6231.4	7593.1	7907.0	5554.6	12444.1	4745.4	9567.3	7273.1
29	5692.1	9188.0	12096.1	10468.4	9584.2	8768.4	8112.0	7950.5	4844.1	4608.4	9022.1	7825.6
30	5881.8	6683.9	7750.7	7215.6	6306.8	6477.9	5679.0	8309.9	5122.8	7742.0	8210.7	7626.7
31	5681.2	11303.1	12148.4	10360.5	9549.3	8688.7	8107.6	6968.2	5432.6	9231.9	9070.3	7020.0
32	9053.3	11290.9	11501.4	10037.5	9287.5	8400.7	7806.6	7207.6	4874.0	5632.0	19391.0	9316.0

SPILL, CFS

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
10	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
11	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
12	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
14	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
15	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
16	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
17	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
18	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
19	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
20	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
21	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
22	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
23	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
24	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
25	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
26	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
27	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
28	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
29	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
30	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
31	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
32	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

PRE-PROJECT FLOW @ D/S LOCATION

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	6335.0	2583.0	1439.0	1027.0	788.0	726.0	870.0	11510.0	19600.0	22600.0	19880.0	8301.0
	3848.0	1300.0	1100.0	960.0	820.0	740.0	1617.0	14090.0	20790.0	22570.0	19670.0	21240.0
	5571.0	2744.0	1900.0	1600.0	1000.0	880.0	920.0	5419.0	32370.1	26390.0	20920.0	14480.0
	8202.0	3497.0	1700.0	1100.0	820.0	820.0	1615.0	19270.0	27320.1	20200.0	20610.0	15270.0
	5604.0	2100.0	1500.0	1300.0	1000.0	780.0	1235.0	17280.0	25250.0	20360.0	26100.0	12920.0
	5370.0	2760.0	2045.0	1794.0	1400.0	1100.0	1200.0	9319.0	29860.0	27560.0	25750.0	14290.0
	4951.0	1900.0	1300.0	980.0	970.0	940.0	950.0	17660.0	33340.0	31090.1	24530.0	18330.0
	5806.0	3050.0	2142.0	1700.0	1500.0	1200.0	1200.0	13750.0	30160.0	23310.0	20540.0	19800.0
	8212.0	3954.0	3264.0	1965.0	1307.0	1148.0	1533.0	12900.0	25700.0	22880.0	22540.0	7550.0
	4811.0	2150.0	1513.0	1448.0	1307.0	980.0	1250.0	15990.0	23320.0	25000.0	31180.0	16920.0
	6558.0	2850.0	2200.0	1845.0	1452.0	1197.0	1300.0	15780.0	15530.0	22980.0	23590.0	20510.0
	7794.0	3000.0	2694.0	2452.0	1754.0	1810.0	2650.0	17360.0	29450.0	24570.0	22100.0	13370.0
	5916.0	2700.0	2100.0	1900.0	1500.0	1400.0	1700.0	12590.0	43270.0	25850.0	23550.0	15890.0
	6723.0	2800.0	2000.0	1600.0	1500.0	1000.0	830.0	19030.0	26000.0	34400.0	23670.0	12320.0
	6449.0	2250.0	1494.0	1018.0	966.0	713.0	745.0	4307.0	50580.0	22950.0	16440.0	9571.0
	6291.0	2799.0	1211.0	960.0	860.0	900.0	1360.0	12990.0	25720.0	27840.0	21120.0	19350.0
	7205.0	2098.0	1631.0	1400.0	1300.0	1300.0	1775.0	9645.0	32950.0	19860.0	21830.0	11750.0
	4163.0	1600.0	1500.0	1500.0	1400.0	1200.0	1167.0	15480.0	29510.0	26800.0	32620.0	16870.0
	4900.0	2333.0	2055.0	1981.0	1900.0	1900.0	1910.0	16180.0	31550.0	26420.0	17170.0	8816.0
	4272.0	1906.0	1330.0	1086.0	922.0	833.0	1022.0	9852.0	20523.0	18093.0	16322.0	9776.0
	3124.0	1215.0	866.0	824.0	768.0	776.0	1080.0	11380.0	18630.0	22660.0	19980.0	9121.0
	5288.0	3407.0	2290.0	1442.0	1036.0	950.0	1082.0	3745.0	32930.0	23950.0	31910.0	14440.0
	5847.0	3093.0	2510.0	2239.0	2028.0	1823.0	1710.0	21890.0	34430.0	22770.0	19290.0	12400.0
	4826.0	2253.0	1465.0	1200.0	1200.0	1000.0	1027.0	8235.0	27800.0	18250.0	20290.0	9074.0
	3733.0	1523.0	1034.0	874.0	777.0	724.0	992.0	16180.0	17870.0	18800.0	16220.0	12250.0
	3739.0	1700.0	1603.0	1516.0	1471.0	1400.0	1593.0	15350.0	32310.0	27720.0	18090.0	16310.0
	7739.0	1993.0	1081.0	974.0	950.0	900.0	1373.0	12620.0	24380.0	18940.0	19800.0	6881.0
	3874.0	2650.0	2403.0	1829.0	1618.0	1500.0	1680.0	12680.0	37970.0	22870.0	19240.0	12640.0
	7571.0	3525.0	2589.0	2029.0	1668.0	1605.0	1702.0	11950.0	19050.0	21020.0	16390.0	8607.0
	4907.0	2535.0	1681.0	1397.0	1286.0	1200.0	1450.0	13870.0	24690.0	28880.1	20460.0	10770.0
	7311.0	4192.0	2416.0	1748.0	1466.0	1400.0	1670.0	12060.0	29080.0	32660.0	20960.0	13280.0
	7725.0	3986.0	1773.1	1453.6	1235.6	1114.3	1367.5	13316.7	18143.0	32000.0	38538.0	13171.1

POST-PROJECT FLOW @ D/S LOCATION CFS

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	7279.7	10215.7	11555.4	9917.5	9104.5	8237.7	7573.6	8486.6	8021.8	8024.0	12000.0	9281.6
2	6389.8	6833.4	7909.8	7341.9	6437.0	6588.5	5989.1	10314.3	7107.6	7561.5	12000.0	9300.0
3	8061.0	10738.0	12016.4	10490.5	9316.5	8391.7	7623.6	6529.3	11599.0	9076.3	12000.0	9300.0
4	10185.6	11490.9	11816.4	9990.5	9136.5	8331.7	8318.6	15608.4	10809.9	7405.6	12000.0	9300.0
5	7076.3	7092.0	11616.4	10190.5	9316.5	8291.7	7938.6	13952.5	10735.5	7967.2	12000.0	9300.0
6	7194.8	7955.0	12161.4	10684.5	9716.5	8611.7	7903.6	7859.8	10153.2	10621.7	16276.1	9300.0
7	8468.7	9894.0	11416.4	9870.5	9286.5	8451.7	7653.6	14206.8	15256.8	14077.5	15432.0	13410.6
8	9376.5	11044.0	12258.4	10590.5	9816.5	8711.7	7903.6	10574.5	12008.4	8109.5	12000.0	12213.0
9	11782.5	11948.0	13380.4	10855.5	9623.5	8659.7	8236.6	9746.4	8565.8	7883.0	12000.0	9121.3
10	6874.9	6933.2	8170.4	10338.5	9623.5	8491.7	7953.6	12818.1	9828.6	9287.8	16208.8	11843.4
11	10128.5	10843.9	12316.4	10735.5	9768.5	8708.7	8003.6	12317.7	7167.0	8286.8	12000.0	9300.0
12	8227.4	10993.9	12810.4	11342.5	10070.5	9321.7	9353.6	13838.4	11869.2	9477.6	12000.0	9300.0
13	7328.7	10694.0	12216.4	10790.5	9816.5	8911.7	8403.6	9298.8	24151.8	9985.7	14666.9	10429.8
14	10293.5	10794.0	12116.4	10490.5	9816.5	8511.7	7533.6	15342.2	10296.0	15148.5	15146.6	9300.0
15	7777.9	10244.0	11610.4	9938.5	9282.5	8224.7	7448.6	6061.3	26091.6	7887.3	12000.0	9300.0
16	7290.9	6966.6	7678.9	9657.5	9176.5	8411.7	8063.6	9735.6	9469.8	9771.5	12000.0	13506.1
17	10775.5	10092.0	11747.4	10290.5	9616.5	8811.7	8478.6	7809.8	13486.7	8261.6	12000.0	9300.0
18	6615.5	6902.6	7984.7	10390.5	9716.5	8711.7	7870.6	12066.6	11635.8	10362.9	22704.4	11950.6
19	8470.5	10346.9	12171.4	10871.5	10216.5	9411.7	8613.6	12739.5	13601.8	10042.6	12000.0	9300.0
20	6581.8	6892.1	7830.0	7838.5	9238.5	8344.7	7725.6	7169.9	7865.7	6851.7	12000.0	9300.0
21	6628.8	7003.5	8012.9	7518.2	6586.1	6770.9	5919.8	7271.7	9213.6	8997.1	12000.0	9300.0
22	7491.4	7700.8	8481.6	7681.2	6677.7	6847.7	6091.4	6389.6	10484.0	7762.3	13149.0	9300.0
23	8728.1	11086.9	12626.4	11129.5	10344.5	9334.7	8413.6	18134.9	16601.7	7692.0	12000.0	9300.0
24	6221.8	6864.6	11581.4	10090.5	9516.5	8511.7	7730.6	6206.9	8914.3	6484.0	12000.0	9300.0
25	6457.0	6741.5	7724.6	7179.3	6725.3	8235.7	7695.6	12733.3	7948.9	7482.9	12000.0	9300.0
26	6551.3	7008.3	8137.7	7574.4	6719.3	6895.6	6120.8	9024.5	13490.5	11080.7	12000.0	9300.0
27	9816.0	9987.0	11197.4	9864.5	9266.5	8411.7	8076.6	9568.3	9350.3	6512.6	12000.0	8050.5
28	6728.2	7351.4	8392.5	7616.2	6646.5	7982.3	8383.6	9665.2	19061.3	7908.1	12000.0	9300.0
29	7169.2	10067.7	12705.4	10919.5	9984.5	9116.7	8405.6	8669.0	6616.9	7243.2	12000.0	9300.0
30	7014.9	7274.0	8119.1	7475.8	6537.4	6576.7	5811.1	9810.6	6908.0	11710.4	12000.0	9300.0
31	6842.2	11972.1	12532.4	10638.5	9782.5	8911.7	8373.6	8888.2	11112.6	15151.9	12030.3	9300.0
32	10320.3	11979.9	11889.5	10344.1	9552.1	8626.0	8071.1	10118.3	6000.0	9792.0	26494.0	10461.1

AVERAGE HEAD FT

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	729.2	722.2	707.5	690.5	674.5	659.5	645.0	641.5	656.3	681.9	702.9	708.8
2	705.8	699.2	687.8	674.7	663.2	652.3	641.6	641.2	658.8	686.4	707.3	723.5
3	731.1	722.5	707.5	690.5	674.5	659.5	645.0	636.7	656.2	692.9	716.4	728.1
4	730.7	722.5	707.5	690.5	674.5	659.5	645.0	642.2	662.3	690.3	709.6	721.7
5	725.4	720.1	707.5	690.5	674.5	659.5	645.0	641.8	659.7	685.8	709.8	724.6
6	726.0	720.2	707.5	690.5	674.5	659.5	645.0	639.7	660.7	695.5	718.8	730.9
7	732.0	722.5	707.5	690.5	674.5	659.5	645.0	642.0	663.4	696.3	719.4	731.0
8	732.0	722.5	707.5	690.5	674.5	659.5	645.0	641.7	662.9	694.4	715.5	728.8
9	732.0	722.5	707.5	690.5	674.5	659.5	645.0	641.7	661.9	692.4	715.1	722.7
10	719.7	714.1	704.6	690.5	674.5	659.5	645.0	641.7	658.4	686.5	714.2	730.9
11	732.0	722.5	707.5	690.5	674.5	659.5	645.0	642.0	654.0	676.8	701.5	720.6
12	729.4	722.5	707.5	690.5	674.5	659.5	645.0	642.0	663.1	693.9	716.3	728.1
13	730.2	722.5	707.5	690.5	674.5	659.5	645.0	641.8	664.1	696.9	718.7	730.6
14	732.0	722.5	707.5	690.5	674.5	659.5	645.0	642.2	661.6	694.4	719.2	728.8
15	730.1	722.5	707.5	690.5	674.5	659.5	645.0	635.9	658.4	696.5	713.8	717.8
16	717.2	712.9	704.1	690.3	674.5	659.5	645.0	641.8	661.2	693.6	717.8	730.2
17	732.0	722.5	707.5	690.5	674.5	659.5	645.0	640.2	661.3	691.2	710.4	720.6
18	720.6	714.2	704.4	690.5	674.5	659.5	645.0	641.9	663.1	695.4	718.7	731.0
19	732.0	722.5	707.5	690.5	674.5	659.5	645.0	642.0	663.3	695.5	714.7	718.7
20	716.4	710.4	700.9	688.7	674.5	659.5	645.0	641.1	656.6	680.1	695.2	699.5
21	696.9	688.3	675.5	661.7	649.8	637.4	624.9	624.2	639.3	663.3	684.9	692.7
22	690.3	683.9	673.6	661.2	649.9	637.8	625.2	616.4	637.4	677.6	709.6	729.7
23	731.4	722.5	707.5	690.5	674.5	659.5	645.0	642.3	663.8	694.8	714.7	723.3
24	724.7	719.7	707.5	690.5	674.5	659.5	645.0	640.4	661.2	690.7	708.8	715.6
25	713.1	706.5	696.3	684.0	672.4	659.5	645.0	642.0	655.5	676.4	691.8	698.3
26	698.4	691.0	679.4	666.9	656.1	645.4	634.4	636.7	662.4	695.7	716.0	726.8
27	730.7	722.5	707.5	690.5	674.5	659.5	645.0	641.6	659.7	686.3	704.9	710.5
28	707.2	701.0	691.4	679.8	669.5	658.5	645.0	641.5	663.3	695.2	715.0	723.8
29	726.6	721.3	707.5	690.5	674.5	659.5	645.0	641.8	657.6	683.2	700.5	703.6
30	701.3	695.3	684.8	672.3	661.5	651.4	641.1	641.0	662.9	695.6	718.4	726.7
31	728.3	722.3	707.5	690.5	674.5	659.5	645.0	641.7	662.7	696.0	719.4	730.1
32	731.2	722.5	707.5	690.5	674.5	659.5	645.0	641.7	657.2	689.6	720.5	732.8

TOTAL ENERGY GWH

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	221.4	364.1	428.0	359.3	292.6	285.7	247.1	193.7	165.3	168.8	340.4	305.2
2	221.0	240.9	284.5	260.1	202.0	226.2	188.9	270.7	165.3	175.8	334.0	197.6
3	277.6	381.0	440.6	376.3	299.1	291.6	251.2	181.8	170.3	178.2	324.0	241.4
4	323.9	403.0	432.3	359.4	291.6	289.3	270.6	391.6	170.4	168.8	307.1	207.6
5	221.3	246.2	428.6	369.4	297.9	288.1	255.9	288.0	169.8	168.8	240.5	208.5
6	221.2	270.8	442.5	380.5	305.9	296.9	255.8	180.4	177.4	255.4	542.0	320.7
7	299.0	359.2	423.1	359.3	296.3	290.1	248.4	327.0	312.8	329.2	387.8	313.8
8	305.3	385.0	448.5	379.9	310.5	298.6	256.0	240.8	245.0	176.8	336.7	274.3
9	376.9	409.7	469.4	383.9	305.6	300.0	266.7	234.1	170.4	176.5	318.3	283.1
10	221.2	241.3	293.6	369.1	302.6	290.1	254.0	239.7	165.3	176.0	343.4	280.2
11	342.8	382.6	447.1	380.9	308.8	299.6	260.1	329.8	165.3	174.6	290.8	182.3
12	253.5	386.9	458.6	395.0	314.2	312.6	290.1	348.2	179.0	176.6	360.2	229.5
13	236.8	384.5	450.5	388.7	312.7	307.2	273.1	276.7	582.2	283.2	424.0	276.2
14	358.3	393.7	448.5	377.6	310.3	296.8	250.3	399.8	170.2	354.2	481.5	294.2
15	255.0	366.7	429.0	360.6	297.2	285.9	244.7	181.8	626.9	187.4	367.7	270.1
16	221.4	241.7	284.5	353.8	296.9	294.1	265.6	265.3	170.3	192.1	318.4	393.3
17	345.0	358.3	429.4	368.4	303.8	300.4	249.1	180.5	222.2	168.8	288.0	252.9
18	221.1	241.0	287.3	369.9	305.3	297.0	252.8	314.6	235.2	206.9	623.7	332.0
19	297.8	372.2	418.3	389.0	322.6	320.8	277.1	323.0	266.9	212.7	344.0	285.2
20	221.1	241.1	284.5	282.0	296.1	289.8	252.8	180.8	165.3	168.8	363.6	278.5
21	220.7	243.1	284.5	260.0	202.0	226.2	188.9	181.7	165.3	168.8	304.2	266.0
22	221.0	240.9	284.5	260.1	202.0	226.2	188.9	181.8	170.9	179.4	330.4	266.8
23	308.2	396.6	458.0	391.0	320.3	313.9	268.0	420.7	330.6	176.6	391.6	294.8
24	221.3	246.1	431.0	367.3	304.3	296.5	254.9	180.5	170.6	169.8	369.6	309.1
25	221.0	241.0	284.5	260.1	216.1	287.8	253.5	325.0	165.3	168.8	345.1	247.7
26	220.9	243.2	284.5	260.1	202.0	226.2	188.9	182.5	270.4	253.3	346.9	228.7
27	303.8	339.7	416.9	357.2	295.9	290.0	259.8	202.5	169.9	168.8	400.3	253.7
28	220.9	241.0	284.5	260.1	202.0	268.0	264.6	191.0	428.3	176.9	366.7	273.1
29	221.7	343.8	458.8	387.5	313.0	310.0	271.5	273.6	165.3	168.8	338.8	285.7
30	221.1	241.1	284.5	260.1	202.0	226.2	188.9	285.5	176.2	288.7	316.2	287.5
31	221.8	423.7	460.8	383.5	311.9	307.2	271.3	239.7	186.8	344.5	349.8	265.9
32	354.9	423.2	436.2	371.6	303.3	297.0	261.2	248.0	166.2	208.2	749.0	354.2

WSEL (MONTH END) FT

YR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2183.4	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.1	2122.5	2151.3	2164.6	2163.0
2	2158.7	2149.6	2136.0	2123.3	2113.2	2101.5	2091.8	2100.6	2127.0	2155.9	2168.8	2188.2
3	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2090.4	2132.0	2163.9	2178.9	2187.3
4	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2101.4	2133.3	2157.4	2171.9	2181.6
5	2179.1	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.7	2128.7	2152.9	2176.6	2182.5
6	2179.4	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2096.4	2135.0	2165.9	2181.8	2189.9
7	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.9	2135.9	2166.7	2182.0	2190.0
8	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.4	2135.5	2163.3	2177.7	2190.0
9	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.3	2133.5	2161.3	2179.0	2176.4
10	2173.0	2165.2	2154.0	2137.0	2122.0	2107.0	2093.0	2100.4	2126.5	2156.6	2181.7	2190.0
11	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2101.0	2117.1	2146.5	2166.5	2184.7
12	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2101.1	2135.1	2162.8	2179.8	2186.4
13	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.6	2137.6	2166.2	2181.1	2190.0
14	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2101.4	2131.8	2167.0	2181.3	2186.2
15	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2088.9	2137.9	2165.1	2172.6	2173.0
16	2171.3	2164.5	2153.7	2137.0	2122.0	2107.0	2093.0	2100.5	2131.9	2165.2	2180.5	2190.0
17	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2097.3	2135.3	2157.1	2173.7	2177.6
18	2173.5	2164.9	2154.0	2137.0	2122.0	2107.0	2093.0	2100.9	2135.4	2165.3	2182.0	2190.0
19	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.9	2135.6	2165.4	2174.1	2173.3
20	2169.4	2161.3	2150.4	2137.0	2122.0	2107.0	2093.0	2099.3	2123.9	2146.3	2154.2	2154.9
21	2148.9	2137.7	2123.4	2110.0	2099.5	2085.4	2074.4	2084.0	2104.6	2131.9	2147.8	2147.5
22	2143.1	2134.8	2122.4	2110.0	2099.8	2085.9	2074.5	2068.3	2116.4	2148.8	2180.5	2188.8
23	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2101.5	2136.0	2163.6	2175.8	2180.8
24	2178.5	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2097.8	2134.6	2156.8	2170.7	2170.4
25	2165.8	2157.3	2145.3	2132.7	2122.0	2107.0	2093.0	2100.9	2120.1	2142.7	2150.9	2155.7
26	2151.0	2141.0	2127.9	2115.8	2106.3	2094.6	2084.3	2099.1	2135.6	2165.9	2176.1	2187.5
27	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.1	2129.2	2153.4	2166.5	2164.6
28	2159.8	2152.1	2140.6	2129.0	2119.9	2107.0	2093.0	2100.1	2136.6	2163.9	2176.0	2181.5
29	2181.6	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.6	2124.6	2151.8	2159.2	2158.0
30	2154.5	2146.2	2133.3	2121.2	2111.7	2101.0	2091.3	2100.7	2135.0	2166.3	2180.5	2182.9
31	2183.7	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.4	2135.1	2166.9	2181.9	2188.4
32	2184.0	2171.0	2154.0	2137.0	2122.0	2107.0	2093.0	2100.4	2123.9	2165.4	2185.6	2190.0

SUSITNA HEP
WATANA 2190 DC 1455
CASE C 120':mh!R2!aprt!

EL	STORAGE	EL	STORAGE
1900.0	2550000.0	925.0	0.0
1950.0	3330000.0	1000.0	7500.0
2000.0	4250000.0	1050.0	25000.0
2050.0	5340000.0	1150.0	85000.0
2100.0	6650000.0	1200.0	132000.0
2150.0	8189999.5	1250.0	195000.0
2200.0	10020000.0	1300.0	292000.0
2250.0	12210000.0	1350.0	456000.0
-1.0	-1000000.0	1400.0	707000.0
-1.0	-1000000.0	1450.0	1048000.0
-1.0	-1000000.0	1500.0	1484000.0

MAX. STORAGE = 9654000.0 1092000.0
MIN. STORAGE = 5733000.0 741000.0

MAXIMUM P.H.Q = 19391.0 START WSEL=2185.0 TWEL=1455.0 PMAX=.10200E+07
MAXIMUM P.H.Q = 13763.2 START WSEL=1455.0 TWEL= 850.0 PMAX=.60000E+06

MONTHLY WATER LEVEL

2185.0	2170.0	2150.0	2130.0	2112.0	2095.0	2080.0	2092.0	2125.0	2160.0	2180.0	2190.0
1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0

MONTHLY FLOW DISTRIBUTION

1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.7
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0

MONTHLY FLOW REQD

2000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	6000.0	6000.0	6484.0	12000.0	9300.0

YEARS OF SIMULATION = 32 TER = 0.0100

DEMAND FACTOR 0.460

MONTHLY POWER DEMAND

0.580511E+06	0.658012E+06	0.745200E+06	0.681113E+06	0.585727E+06	0.592434E+06
0.511207E+06	0.476183E+06	0.447120E+06	0.441904E+06	0.464260E+06	0.488106E+06

MTH	UPPER RESERVOIR P.H.FLOW CFS	HEAD FT	POWER MW	ENERGY GWH	LOWER RESERVOIR P.H.FLOW CFS	HEAD FT	POWER MW	ENERGY GWH	TOTAL ENERGY (GWH) PROD	USED
OCT	9764.4	723.5	507.8	377.8	7318.4	590.8	312.2	232.3	610.1	610.1
NOV	9112.6	713.2	469.8	338.2	9444.5	605.0	411.7	296.5	634.7	634.6
DEC	10881.2	699.1	549.7	409.0	11128.2	605.0	485.1	361.0	769.9	769.3
JAN	10287.5	681.9	506.6	376.9	10484.6	605.0	457.1	340.1	717.0	716.4
FEB	9924.6	664.8	476.3	320.1	10094.3	605.0	440.1	295.7	615.8	615.3
MAR	9059.2	648.2	423.6	315.1	9204.0	605.0	401.3	298.5	613.7	613.2
APR	7793.9	632.1	355.3	255.8	8005.7	604.8	348.9	251.2	507.0	507.0
MAY	5826.6	629.8	264.6	196.9	7656.6	604.7	333.7	248.2	445.1	445.0
JUN	5123.6	653.2	241.5	173.9	8146.1	604.9	355.1	255.6	429.5	429.4
JUL	4736.1	686.4	234.9	174.8	7094.4	604.9	309.2	230.1	404.8	404.7
AUG	5947.5	712.5	304.6	228.1	11128.1	591.5	474.5	353.0	581.1	519.9
SEP	7838.4	725.7	410.6	295.7	9424.8	577.4	393.9	283.6	579.3	508.0
ANN	8024.6	680.9	395.6	288.5	9094.2	600.3	393.6	287.2	6908.1	6772.7

	ENERGY (GWH) OCT-APR	MAY-SEP	ANNUAL
AVERAGE	4465.8	2306.9	6772.7
FIRM (YEAR 22)	3375.0	2152.6	5527.6

ENERGY (GWH)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
AVER	610.1	634.6	769.3	716.4	615.3	613.2	507.0	445.0	429.4	404.7	519.9	508.0	6772.7
FIRM YR 22	649.9	472.3	551.8	504.3	391.9	438.4	366.4	352.9	358.9	328.8	543.1	568.8	5527.6

PRESENT WORTH COST BASED ON REGRESSION ANALYSIS

R1 = -0.8151050 R2 = -0.1259790 R3 = 13274.9

PRESENT WORTH COST ($*10**6) = 7056.1

INFLOW MASS (AC-FT) 0.211562720E+09
OUTFLOW MASS (AC-FT) 0.211379344E+09
DELTA STOR. 1 (AC-FT) 0.183000000E+06
DELTA STOR. 2 (AC-FT) 0.400000000E+03

RESERVOIR 1

INFLOW (CFS)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	4719.9	2083.6	1168.9	815.1	641.7	569.1	680.1	8655.9	16432.1	19193.4	16913.6	7320.4
2	3299.1	1107.3	906.2	808.0	673.0	619.8	1302.2	11649.8	18517.9	19786.6	16478.0	17205.5
3	4592.9	2170.1	1501.0	1274.5	841.0	735.0	803.9	4216.5	25773.4	22110.9	17356.3	11571.0
4	6285.7	2756.8	1281.2	818.9	611.7	670.7	1382.0	15037.2	21469.8	17355.3	16681.6	11513.5
5	4218.9	1599.6	1183.8	1087.8	803.1	638.2	942.6	11696.8	19476.7	16983.6	20420.6	9165.5
6	3859.2	2051.1	1549.5	1388.3	1050.5	886.1	940.8	6718.1	24881.4	23787.9	23537.0	13447.8
7	4102.3	1588.1	1038.6	816.9	754.8	694.4	718.3	12953.3	27171.8	25831.3	19153.4	13194.4
8	4208.0	2276.6	1707.0	1373.0	1189.0	935.0	945.1	10176.2	25275.0	19948.9	17317.7	14841.1
9	6034.9	2935.9	2258.5	1480.6	1041.7	973.5	1265.4	9957.8	22097.8	19752.7	18843.4	5978.7
10	3668.0	1729.5	1115.1	1081.0	949.0	694.0	885.7	10140.6	18329.6	20493.1	23940.4	12466.9
11	5165.5	2213.5	1672.3	1400.4	1138.9	961.1	1069.9	13044.2	13233.4	19506.1	19323.1	16085.6
12	6049.3	2327.8	1973.2	1779.9	1304.8	1331.0	1965.0	13637.9	22784.1	19839.8	19480.2	10146.2
13	4637.6	2263.4	1760.4	1608.9	1257.4	1176.8	1457.4	11333.5	36017.1	23443.7	19887.1	12746.2
14	5560.1	2508.9	1708.9	1308.9	1184.7	883.6	776.6	15299.2	20663.4	28767.4	21011.4	10800.0
15	5187.1	1789.1	1194.7	852.0	781.6	575.2	609.2	3578.8	42841.9	20082.8	14048.2	7524.2
16	4759.4	2368.2	1070.3	663.0	772.7	807.3	1232.4	10966.0	21213.0	23235.9	17394.1	16225.6
17	5221.2	1545.3	1203.6	1060.4	984.7	984.7	1338.4	7094.1	25939.6	16153.5	17390.9	9214.1
18	3269.8	1202.2	1121.6	1102.2	1031.3	889.5	849.7	12555.5	24711.9	21987.3	26104.5	13672.9
19	4019.0	1934.3	1704.2	1617.6	1560.4	1560.4	1576.7	12826.7	25704.0	22082.8	14147.5	7163.6
20	3447.0	1567.0	1073.0	884.0	748.0	686.0	850.0	7942.0	17509.0	15871.0	14078.0	8150.0
21	2403.1	1020.9	709.3	636.2	602.1	624.1	986.4	9536.4	14399.0	18410.1	16263.8	7224.1
22	3768.0	2496.4	1687.4	1097.1	777.4	717.1	813.7	2857.2	27612.8	21126.4	27446.6	12188.9
23	4979.1	2587.0	1957.4	1670.9	1491.4	1366.0	1305.4	15973.1	27429.3	19820.3	17509.5	10955.7
24	4301.2	1977.9	1246.5	1031.5	1000.2	873.9	914.1	7287.0	23859.3	16351.1	18016.7	8099.7
25	3056.5	1354.7	931.6	786.4	689.9	627.3	871.9	12889.0	14780.6	15971.9	13523.7	9786.2
26	3088.8	1474.4	1276.7	1215.8	1110.3	1041.4	1211.2	11672.2	26689.2	23430.4	15126.6	13075.3
27	5679.1	1601.1	876.2	757.8	743.2	690.7	1059.8	8938.8	19994.0	17015.3	18393.5	5711.5
28	2973.5	1926.7	1687.5	1348.7	1202.9	1110.8	1203.4	8569.4	31352.8	19707.3	16807.3	10613.1
29	3796.9	2645.3	1979.7	1577.9	1267.7	1256.7	1408.4	11231.5	17277.2	18385.2	13412.1	7132.6
30	3773.9	1944.9	1312.6	1136.8	1055.4	1101.2	1317.9	12369.3	22904.8	24911.7	16670.7	9096.7
31	6150.0	3525.0	2032.0	1470.0	1233.0	1177.0	1404.0	10140.0	23100.0	26740.0	18000.0	11000.0
32	6458.0	3297.0	1385.0	1147.0	971.0	889.0	1103.0	10406.0	17017.0	27840.0	31435.0	12026.0
AVE	4522.8	2059.1	1414.8	1165.5	983.3	898.3	1099.7	10354.7	23023.7	20810.1	18628.5	10792.0

POWERHOUSE FLOW (CFS)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	5564.1	10435.0	12314.6	11438.4	10785.8	8708.4	7282.9	4470.2	4011.0	3799.5	4080.9	7546.7
2	11900.0	6948.4	7941.1	7345.6	6377.0	6511.7	6823.8	6344.3	4283.0	3925.0	3994.0	6939.1
3	9061.9	9850.5	12276.3	11401.4	11021.6	9708.1	7406.7	4992.5	3198.6	3628.9	5170.1	5760.3
4	9261.1	10916.8	12249.2	11408.5	11003.3	9827.2	7984.8	7029.0	6219.4	3931.4	3767.8	4192.5
5	11477.9	6740.6	11580.1	11103.4	10782.9	8777.5	7545.4	6287.2	3312.1	3779.9	3263.4	4123.9
6	10208.6	6683.3	12250.4	11376.7	10961.5	10315.6	7543.6	4550.3	5182.4	5128.7	7015.6	12466.0
7	7077.7	10811.9	12317.2	11435.6	10734.6	8833.7	7321.1	6881.3	6114.0	5829.8	8243.3	13194.4
8	7183.4	10907.1	12248.1	11394.9	10967.3	10193.6	8572.1	4982.2	6537.0	3771.0	5121.8	8991.7
9	8805.9	10830.7	12128.6	11312.9	10942.6	10208.1	9197.8	6059.5	5625.0	3854.8	4418.0	5853.2
10	11673.8	6809.6	7783.9	9626.1	10928.8	8833.3	7488.5	4878.2	3432.3	3442.5	5550.2	10149.9
11	8140.9	10947.2	12222.0	11340.3	10967.0	10203.4	8619.3	7501.6	4273.2	3790.8	3700.2	4009.2
12	10336.7	10068.4	12172.4	11373.7	11003.6	10125.2	9074.4	7178.1	5969.3	4106.5	6898.7	4894.6
13	9420.4	9619.6	12347.8	11410.3	10991.6	10209.5	8945.7	6097.0	5751.8	6625.6	13868.6	12746.2
14	8535.5	11048.4	12289.7	11405.4	10966.2	10239.9	8272.6	7186.8	6377.5	5757.0	8597.1	10800.0
15	8162.5	11012.9	12305.9	11442.9	10999.7	8714.5	7212.0	5142.5	5707.4	6499.0	6927.4	5163.5
16	10477.4	8758.0	12353.0	11497.6	10752.5	8946.6	7835.2	5742.0	4736.9	4587.1	5402.3	10487.7
17	8196.6	10789.1	12267.8	11399.3	10978.1	9625.9	7941.2	4566.1	5895.8	3674.0	3623.9	4935.2
18	11738.4	6814.9	7793.1	9300.0	11011.1	9028.8	7452.5	7144.1	6562.7	5028.6	8676.3	13672.9
19	6994.4	11011.0	12386.3	11388.2	10961.3	10170.4	9185.3	7298.8	6230.0	6134.6	4013.0	6880.4
20	11765.1	6839.6	7834.0	8575.6	10727.8	8825.3	7452.8	4776.5	4079.7	4168.0	4335.2	7482.2
21	11900.7	7018.2	8039.4	7419.3	6448.0	6591.5	5100.4	6241.5	3729.0	3592.5	3913.5	6028.6
22	11695.6	6814.1	7897.6	7352.2	6397.3	6537.0	5682.1	4624.2	4462.9	3926.8	6383.9	8999.6
23	7954.5	10985.4	12209.5	11299.8	10869.5	10123.9	9154.2	6463.1	5819.1	6512.3	7118.4	9213.6
24	7715.4	10748.3	12329.9	11451.0	11014.3	9396.7	7516.9	5072.9	4338.0	4230.3	4381.1	8325.7
25	11841.4	6935.6	7938.1	7336.3	6370.2	8005.1	7474.7	7327.0	4024.9	3978.8	4185.4	6234.6
26	11900.1	6974.5	7942.4	7334.7	6337.0	6459.8	5607.7	5809.6	6308.3	6148.0	5613.0	7336.6
27	8651.5	10824.9	12333.9	11217.3	10723.0	8830.0	7662.6	4208.7	3625.2	4225.9	5226.4	8130.5
28	11801.3	6792.3	7775.9	7227.3	6272.0	8825.4	7806.2	4072.9	5981.5	6465.8	6985.7	5188.5
29	10178.6	10412.9	12205.4	11359.5	10940.1	10167.2	9199.9	6261.4	4439.9	4027.5	4074.8	7047.3
30	11758.0	6849.0	7903.9	7321.9	6356.0	6519.3	7233.4	7021.5	6458.3	6041.3	5072.9	4971.9
31	11642.2	8475.1	12272.0	11411.6	10992.6	10207.8	9084.8	5001.7	6626.9	5932.7	6652.7	7034.9
32	9433.4	10950.5	12289.0	11452.9	11003.6	10223.1	8723.2	5239.5	4642.9	5011.1	14043.2	12026.0
AVE	9764.4	9112.6	10881.2	10287.5	9924.6	9059.2	7793.9	5826.6	5123.6	4736.1	5947.5	7838.4

SPILLS (CFS)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AVE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HEAD (FT)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	729.3	721.8	705.6	685.8	666.1	648.5	632.5	629.9	647.6	675.7	702.2	713.1
2	705.7	693.1	680.8	667.2	655.6	644.0	631.3	631.2	651.8	681.7	707.8	726.7
3	731.2	721.2	705.9	687.0	667.8	649.3	632.5	624.1	646.6	687.6	715.3	730.3
4	732.5	723.4	707.5	688.0	668.4	649.5	632.5	634.4	658.6	686.4	710.3	727.1
5	726.9	716.7	703.7	685.0	666.0	648.5	632.5	631.3	653.9	683.1	710.6	729.1
6	727.9	718.8	706.0	687.2	668.5	649.8	632.5	627.5	650.2	688.0	719.5	734.2
7	732.5	722.5	705.5	685.5	666.0	648.5	632.5	632.1	660.0	698.7	725.8	735.0
8	732.5	723.0	707.1	688.6	670.0	651.8	633.7	631.1	655.9	689.8	715.2	730.2
9	732.7	723.9	709.2	691.7	673.5	655.3	637.2	632.8	653.9	685.7	713.1	725.3
10	718.7	707.9	697.9	683.5	666.0	648.5	632.5	631.2	652.3	683.8	715.8	733.1
11	732.5	722.9	706.9	688.1	669.9	651.6	633.6	631.5	647.2	672.1	701.5	725.0
12	731.2	721.3	706.4	688.6	670.5	652.9	636.0	635.5	659.5	690.6	715.9	730.7
13	731.0	721.0	706.1	687.6	669.3	651.3	633.5	631.1	667.0	710.8	729.9	735.0
14	732.5	723.1	707.2	688.6	670.0	651.6	633.5	634.5	657.9	693.0	724.6	735.0
15	732.5	722.5	705.7	685.9	666.2	648.5	632.5	623.2	658.8	707.8	725.2	733.1
16	730.2	720.2	705.5	685.5	666.0	648.5	632.5	631.1	653.8	687.9	715.6	730.3
17	732.5	722.5	705.7	686.2	667.0	649.0	632.5	628.0	651.4	684.1	708.0	723.0
18	719.4	707.7	697.3	683.2	666.0	648.5	632.5	631.4	655.8	689.8	720.4	735.0
19	732.5	722.6	706.3	687.7	669.7	652.6	635.3	633.1	658.8	692.8	716.0	724.8
20	718.0	706.7	696.4	682.7	666.0	648.5	632.5	628.7	646.3	671.9	692.7	702.3
21	694.1	679.6	666.5	652.1	639.5	626.4	614.7	613.9	629.9	657.0	684.2	697.4
22	690.8	679.0	668.6	656.2	644.4	632.0	619.7	612.1	635.0	677.1	712.1	732.4
23	732.5	723.2	707.7	689.9	672.2	655.0	637.5	639.4	671.0	703.3	723.4	733.6
24	732.1	722.1	705.7	686.1	666.8	648.9	632.5	627.6	650.2	682.2	705.8	717.2
25	709.6	697.5	685.8	672.3	660.6	647.7	632.5	631.5	649.0	671.9	692.6	704.2
26	699.4	686.4	674.5	661.7	650.9	639.9	628.6	630.5	657.7	693.8	717.7	730.3
27	732.5	722.5	705.4	685.4	666.0	648.5	632.5	630.6	652.6	681.8	705.7	714.8
28	705.4	693.6	683.1	671.2	660.7	648.1	632.5	630.3	660.8	697.8	717.9	730.6
29	731.3	721.3	706.4	688.3	670.1	652.3	634.5	631.5	650.3	677.6	700.0	708.2
30	701.5	690.0	678.7	666.0	655.0	644.3	631.7	631.3	654.0	688.2	715.8	728.9
31	727.6	719.0	706.1	688.1	669.7	651.7	633.7	631.0	653.9	690.1	719.0	731.8
32	732.5	723.8	708.4	689.3	670.4	651.8	633.7	631.1	649.7	684.0	720.4	735.0
AVE	723.5	713.2	699.1	681.9	664.8	648.2	632.1	629.8	653.2	686.4	712.5	725.7

WATER SURFACE AT START OF MONTH (FT)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2185.0	2183.6	2170.0	2151.3	2130.3	2112.0	2095.0	2080.0	2089.8	2115.3	2146.1	2168.3
2	2167.9	2153.5	2142.8	2128.8	2115.7	2105.4	2092.5	2080.0	2092.5	2121.1	2152.3	2173.3
3	2190.0	2182.5	2170.0	2151.9	2132.0	2113.7	2095.0	2080.0	2078.2	2125.1	2160.1	2180.6
4	2190.0	2185.0	2171.7	2153.3	2132.8	2114.0	2095.0	2080.0	2098.8	2128.4	2154.4	2176.1
5	2188.0	2175.8	2167.5	2150.0	2130.0	2112.0	2095.0	2080.0	2092.7	2125.0	2151.2	2180.0
6	2188.2	2177.5	2170.0	2152.0	2132.5	2114.6	2095.0	2080.0	2085.1	2125.4	2160.6	2188.4
7	2190.0	2185.0	2170.0	2151.0	2130.0	2112.0	2095.0	2080.0	2094.3	2135.8	2171.7	2190.0
8	2190.0	2185.0	2171.0	2153.3	2133.9	2116.2	2097.3	2080.0	2092.2	2129.6	2160.0	2180.5
9	2190.0	2185.3	2172.5	2155.9	2137.4	2119.5	2101.1	2083.3	2092.4	2125.4	2156.0	2180.2
10	2180.4	2167.0	2158.7	2147.1	2130.0	2112.0	2095.0	2080.0	2092.4	2122.3	2155.3	2186.2
11	2190.0	2185.0	2170.8	2153.1	2133.8	2116.0	2097.2	2080.0	2093.0	2111.4	2142.8	2170.2
12	2189.8	2182.6	2170.0	2152.9	2134.2	2116.7	2099.0	2082.9	2098.1	2130.8	2160.3	2181.5
13	2190.0	2182.0	2170.0	2152.2	2133.1	2115.5	2097.0	2080.0	2092.3	2151.6	2179.9	2190.0
14	2190.0	2185.0	2171.1	2153.3	2133.8	2116.2	2097.0	2080.0	2099.0	2126.8	2169.1	2190.0
15	2190.0	2185.0	2170.0	2151.3	2130.4	2112.0	2095.0	2080.0	2076.3	2151.4	2174.2	2186.2
16	2190.0	2180.4	2170.0	2151.0	2130.0	2112.0	2095.0	2080.0	2092.3	2125.3	2160.5	2180.7
17	2190.0	2185.0	2170.0	2151.4	2131.0	2113.0	2095.0	2080.0	2085.9	2126.8	2151.4	2174.6
18	2181.5	2167.3	2158.2	2146.4	2130.0	2112.0	2095.0	2080.0	2092.7	2128.9	2160.7	2190.0
19	2190.0	2185.0	2170.2	2152.3	2133.2	2116.3	2098.9	2081.6	2094.6	2133.0	2162.5	2179.5
20	2180.0	2166.0	2157.5	2145.4	2130.0	2112.0	2095.0	2080.0	2087.4	2115.3	2138.6	2156.8
21	2157.9	2140.4	2128.8	2114.2	2100.6	2088.4	2074.3	2065.0	2072.7	2097.0	2127.0	2151.4
22	2153.4	2138.2	2129.8	2117.4	2104.9	2093.9	2080.2	2069.1	2065.0	2115.0	2149.3	2184.8
23	2190.0	2185.0	2171.3	2154.1	2135.7	2118.7	2101.3	2083.6	2105.1	2146.8	2169.7	2187.2
24	2190.0	2184.3	2170.0	2151.4	2130.8	2112.8	2095.0	2080.0	2085.2	2125.1	2149.3	2172.4
25	2172.0	2157.2	2147.8	2133.8	2120.7	2110.5	2095.0	2080.0	2093.1	2114.9	2138.8	2156.3
26	2162.1	2146.7	2136.1	2122.8	2110.6	2101.2	2088.6	2078.7	2092.4	2132.9	2164.7	2180.7
27	2190.0	2185.0	2170.0	2150.7	2130.0	2112.0	2095.0	2080.0	2091.1	2124.1	2149.6	2171.8
28	2167.9	2153.0	2144.2	2132.0	2120.3	2111.2	2095.0	2080.0	2090.6	2141.0	2164.7	2181.2
29	2190.0	2182.6	2170.0	2152.8	2133.8	2116.4	2098.3	2080.6	2092.3	2118.3	2146.9	2163.1
30	2163.2	2149.8	2140.3	2127.1	2114.8	2105.2	2093.4	2080.0	2092.6	2125.4	2161.0	2180.5
31	2187.2	2178.0	2170.0	2152.8	2133.5	2115.9	2097.4	2080.0	2092.1	2125.7	2164.5	2183.6
32	2190.0	2185.0	2172.6	2154.2	2134.4	2116.4	2097.3	2080.0	2092.1	2117.2	2160.8	2190.0
AVE	2183.0	2174.0	2162.3	2145.9	2127.9	2111.7	2094.7	2079.5	2090.1	2126.2	2156.7	2178.3

ENERGY FROM RESERVOIR 1 (GWH)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1	217.5	390.8	465.9	420.5	347.9	302.8	239.0	151.0	134.8	137.6	153.6	279.2	3240.5
2	450.2	249.9	289.8	262.8	202.4	224.8	223.5	214.7	144.8	143.4	151.6	261.6	2819.5
3	355.2	368.6	464.6	419.9	356.4	337.9	243.1	167.0	107.3	133.8	198.3	218.2	3370.4
4	363.7	409.7	464.6	420.8	356.1	342.2	262.0	239.1	212.5	144.7	143.5	158.1	3517.0
5	447.3	250.6	436.9	407.8	347.7	305.2	247.6	212.8	112.4	138.4	124.3	156.0	3187.0
6	398.4	249.2	463.7	419.1	354.8	359.3	247.5	153.1	174.8	189.2	270.6	474.8	3754.7
7	277.9	405.3	465.9	421.0	346.2	307.1	240.2	233.2	209.4	218.4	320.8	503.1	3948.5
8	282.1	409.1	464.3	420.6	355.8	356.2	281.8	168.6	222.4	139.4	196.4	340.7	3637.5
9	345.9	406.8	461.1	419.5	356.9	358.6	304.1	205.6	190.8	141.7	168.9	220.3	3580.1
10	449.8	250.1	291.2	352.7	352.4	307.1	245.7	165.1	116.2	126.2	213.0	386.1	3255.6
11	319.7	410.6	463.2	419.3	355.7	356.4	283.3	254.0	143.5	136.6	139.1	150.8	3432.2
12	405.2	376.8	461.0	419.8	357.3	354.4	299.4	244.5	204.2	152.0	264.8	185.6	3725.0
13	369.2	359.8	467.1	420.6	356.2	356.5	294.0	206.3	199.0	252.5	542.7	486.0	4310.3
14	335.2	414.5	466.0	421.0	355.8	357.7	271.9	244.5	217.7	213.9	333.9	411.8	4043.8
15	320.5	412.8	465.5	420.8	354.8	303.0	236.7	171.8	195.1	246.6	269.3	196.4	3593.3
16	410.1	327.2	467.2	422.5	346.8	311.0	257.1	194.3	160.7	169.2	207.2	397.4	3670.8
17	321.9	404.4	464.1	419.4	354.6	334.9	260.6	153.7	199.2	134.7	137.5	185.1	3370.2
18	452.7	250.2	291.3	340.6	355.1	313.9	244.6	241.8	223.3	186.0	335.1	521.4	3755.9
19	274.7	412.8	469.0	419.9	355.5	355.8	302.7	247.7	212.9	227.8	154.0	258.7	3691.6
20	452.9	250.8	292.5	313.9	346.0	306.8	244.6	161.0	136.8	150.1	161.0	272.6	3088.9
21	442.9	247.5	287.3	259.5	199.7	221.3	162.7	205.4	121.9	126.5	143.6	218.1	2636.2
22	433.1	240.0	283.1	258.6	199.6	221.5	182.7	151.7	147.0	142.5	243.7	342.0	2845.6
23	312.4	412.2	463.2	417.9	353.8	355.5	302.7	221.5	202.6	245.5	276.1	350.7	3914.1
24	302.8	402.7	466.5	421.2	355.6	326.9	246.7	170.7	146.3	154.7	165.8	309.8	3469.6
25	450.6	251.0	291.9	261.4	203.8	278.0	245.3	248.1	135.5	143.3	155.4	227.8	2894.9
26	446.2	248.4	287.2	260.2	199.7	221.6	182.9	196.4	215.2	228.7	216.0	278.0	2980.4
27	339.9	405.8	466.4	412.2	345.8	307.0	251.4	142.3	122.7	154.5	197.7	301.5	3447.2
28	446.3	244.4	284.8	260.0	200.7	306.6	256.2	137.6	205.1	241.9	268.9	196.7	3049.1
29	399.1	389.7	462.2	419.2	355.0	355.6	302.8	212.0	149.8	116.3	152.9	258.9	3603.4
30	442.2	245.2	287.6	261.4	201.6	225.2	237.1	237.6	219.1	222.9	194.7	188.0	2962.6
31	454.1	315.4	464.7	421.0	356.5	356.6	298.7	169.2	224.8	219.5	256.4	267.1	3804.0
32	370.4	411.2	466.7	423.3	357.2	357.2	286.8	177.3	156.5	183.8	542.4	458.6	4191.3
AVE	377.8	338.2	409.0	374.9	320.1	315.1	255.8	196.9	173.9	174.8	228.1	295.7	3462.2

RESERVOIR 2

INFLOW (CFS)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	6602.4	10756.1	12488.2	11574.6	10879.8	8809.3	7405.0	6305.0	6047.5	5989.5	5987.9	8177.1
2	12252.9	7072.3	8065.7	7443.3	6471.5	6589.0	7026.2	7913.0	5743.6	5714.3	6046.0	9532.7
3	9690.7	10219.4	12532.8	11610.6	11123.8	9801.3	7181.3	5765.5	7439.4	6379.7	7461.0	7630.4
4	10493.0	11392.6	12518.4	11589.2	11137.2	9923.2	8134.6	9750.1	9980.3	5760.1	6293.2	6607.4
5	12368.3	7062.3	11783.4	11239.8	10909.5	8868.7	7733.4	9876.4	7023.5	5950.5	6914.4	6537.5
6	11179.8	7139.0	12568.9	11637.5	11186.2	10453.1	7710.2	6222.3	8382.9	7553.6	8438.2	13007.4
7	7623.3	11012.4	12485.2	11560.4	10872.9	8991.6	7470.1	9907.0	10079.3	9210.5	11699.7	16495.8
8	8210.7	11404.3	12527.7	11605.1	11167.2	10364.0	8736.0	7279.6	9677.4	5931.7	7193.3	12179.6
9	10205.5	11483.2	12775.0	11624.3	11113.1	10320.3	9369.8	7950.9	7940.7	5865.2	6794.4	6863.3
10	12408.6	7079.9	8039.7	9862.0	11158.9	9017.2	7722.7	8638.5	6640.4	6339.8	10204.2	13012.6
11	9036.1	11356.4	12561.2	11646.1	11168.3	10355.1	8767.2	9260.3	5749.6	6024.0	6443.2	6853.5
12	11458.3	10500.5	12635.8	11805.8	11292.4	10433.1	9514.8	9570.9	10254.5	7147.3	8582.9	6967.0
13	10242.2	9900.3	12566.1	11597.4	11147.6	10353.0	9101.7	6904.7	10414.4	8172.5	16223.3	14767.2
14	9283.1	11235.5	12476.8	11592.5	11168.9	10314.7	8306.9	9585.2	9808.2	9378.0	10306.2	11777.2
15	8973.7	11309.2	12498.3	11568.9	11118.3	8803.1	7299.3	5610.6	10681.9	8342.2	8465.0	6479.3
16	11462.0	9034.9	12443.5	11559.9	10808.6	9006.2	7917.2	7043.1	7634.2	7546.9	7797.5	12496.3
17	9471.9	11131.6	12542.6	11617.6	11180.8	9828.6	8221.9	6206.0	10402.5	6056.7	6477.6	6565.4
18	12312.6	7070.6	8036.4	9555.7	11248.1	9228.4	7656.5	9024.1	9647.2	8122.5	12864.8	15728.2
19	7560.7	11280.2	12611.8	11621.8	11179.6	10388.7	9399.6	9454.5	9988.1	8922.8	5956.0	7942.7
20	12294.1	7055.6	7998.0	8703.6	10838.8	8919.3	7561.8	5988.5	5991.7	5588.0	5757.2	8520.2
21	12361.1	7143.0	8140.1	7540.0	6554.6	6689.2	5160.6	7426.7	6448.9	6324.6	6302.5	7248.0
22	12672.8	7399.5	8285.0	7573.9	6563.5	6686.7	5854.6	5194.9	7881.1	5742.0	9253.2	10446.7
23	8512.4	11310.7	12564.7	11665.0	11214.5	10417.7	9414.3	10266.8	10319.6	8408.5	8263.0	10142.1
24	8052.8	10925.2	12470.4	11559.3	11142.7	9477.8	7589.5	5682.3	6871.3	5451.0	5842.5	8952.0
25	12279.3	7043.8	8003.9	7392.6	6426.2	8067.3	7551.9	9442.6	6011.0	5796.9	5918.7	7818.5
26	12318.1	7119.5	8152.2	7527.7	6568.9	6690.3	5853.2	8173.9	9921.7	8905.6	7518.0	9416.0
27	9978.7	11076.8	12465.6	11356.3	10856.0	8944.5	7864.0	6575.2	6444.8	5463.2	6130.6	8882.3
28	12380.2	7257.3	8235.9	7536.0	6538.8	9075.6	8112.6	6715.4	10235.4	8499.0	8549.6	6491.5
29	11321.0	10978.4	12597.1	11649.5	11197.4	10391.1	9388.6	6723.3	5579.5	5721.3	5989.2	7995.1
30	12486.4	7228.4	8140.7	7489.2	6504.2	6582.8	7318.3	7986.2	7605.9	8592.4	7508.9	6047.6
31	12392.2	8885.1	12519.0	11590.6	11142.6	10351.8	9255.8	6238.7	9481.9	9194.7	8848.7	8376.9
32	10221.4	11352.5	12458.0	11592.9	11121.6	10331.1	8858.2	6509.5	5366.9	8407.1	17878.2	12762.0
AVE	10565.9	9144.3	11130.9	10484.0	10093.8	9202.9	7961.2	7662.2	8178.0	7078.2	8247.1	9460.0

POWERHOUSE FLOW (CFS)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	6602.4	10736.1	12481.7	11574.6	10887.0	8809.3	7405.0	6305.0	6047.5	5989.5	10940.6	8949.8
2	6552.5	7072.3	8065.7	7443.3	6471.5	6589.0	7026.2	7913.0	5743.6	5714.3	10860.0	7859.1
3	6489.8	10226.1	12526.3	11610.6	11123.8	9807.8	7481.3	5765.5	7439.4	6373.2	10727.2	8261.1
4	6623.0	11385.9	12518.4	11589.2	11137.2	9929.7	8134.6	9743.6	9980.3	5760.1	10597.0	7958.4
5	6757.0	7049.0	11783.4	11239.8	10909.3	8868.7	7733.4	9876.4	7023.5	5950.5	9971.6	7959.1
6	6746.9	7139.0	12562.4	11637.5	11186.2	10459.6	7710.2	6222.3	8382.9	7547.1	11209.6	10143.6
7	7629.8	11012.4	12478.7	11566.9	10872.9	8991.6	7470.1	9900.5	10079.3	9210.5	11699.7	13763.2
8	8217.2	11397.6	12527.7	11605.1	11167.2	10364.0	8742.8	7279.6	9670.7	5931.7	10849.2	8401.8
9	10205.5	11485.2	12775.0	11624.3	11113.1	10320.3	9369.8	7957.4	7940.7	5865.2	10679.8	8738.8
10	6708.1	7079.9	8039.7	9862.0	11158.9	9017.2	7722.7	8638.5	6640.4	6339.8	10197.7	13012.6
11	9042.6	11349.7	12561.2	11616.1	11168.3	10355.1	8774.0	9253.8	5756.3	6024.0	10476.1	7719.9
12	6580.5	10507.2	12629.3	11805.8	11292.4	10433.1	9514.8	9570.9	10254.5	7147.3	11064.4	8148.6
13	6617.2	9907.0	12559.6	11597.4	11147.6	10353.0	9108.4	6904.7	10407.7	8172.5	13763.2	13763.2
14	9289.6	11228.8	12476.8	11592.5	11168.9	10314.7	8313.6	9578.7	9808.2	9378.0	11050.5	11008.1
15	8980.2	11309.2	12491.8	11568.9	11125.5	8803.1	7299.3	5739.9	10541.6	8342.2	11145.8	8569.0
16	6758.8	9041.7	12437.0	11566.4	10808.6	9006.2	7917.2	7043.1	7634.2	7540.4	10669.3	9528.7
17	9478.4	11131.6	12536.1	11617.6	11180.8	9835.1	8221.9	6206.0	10395.8	6056.7	10414.6	8394.3
18	6612.1	7070.6	8036.4	9555.7	11248.1	9228.4	7656.5	9024.1	9640.5	8122.5	12864.8	13763.2
19	7567.2	11273.5	12611.8	11621.8	11179.6	10388.7	9399.6	9454.5	9988.1	8922.8	10920.5	8709.9
20	6593.6	7055.6	7998.0	8703.6	10838.8	8919.3	7561.8	5988.5	5991.7	5682.0	11178.0	8712.0
21	6663.6	7143.0	8140.1	7540.0	6554.6	6689.2	6544.4	6087.6	6418.9	6324.6	10672.8	8622.5
22	6972.3	7399.5	8285.0	7573.9	6563.5	6686.7	5854.6	6244.8	6796.2	5742.0	10405.9	9248.8
23	8518.9	11304.0	12564.7	11665.0	11214.5	10417.7	9414.3	10266.8	10319.6	8408.5	11364.1	8784.2
24	6265.8	10931.9	12463.9	11559.3	11142.7	9484.3	7589.5	5682.3	6871.3	5805.8	11188.1	8952.0
25	6578.8	7043.8	8003.9	7392.6	6426.2	8067.3	7551.9	9436.1	6017.8	5796.9	11037.0	8420.1
26	6617.7	7119.5	8152.2	7527.7	6568.9	6690.3	5853.2	8173.9	9915.0	8905.6	10941.6	8144.7
27	7791.9	11076.8	12459.1	11362.8	10856.0	8964.5	7864.0	6575.2	6444.8	5796.6	11497.7	8882.3
28	6679.8	7257.3	8235.9	7536.0	6538.8	9075.6	8112.6	6715.4	10228.7	8499.0	11131.2	8576.1
29	6722.0	10985.1	12590.6	11649.5	11197.4	10391.1	9388.6	6729.8	5579.5	5721.3	10936.5	8773.4
30	6785.9	7228.4	8140.7	7489.2	6504.2	6582.8	7318.3	7986.2	7605.9	8585.9	10646.7	8702.4
31	6685.2	8891.8	12512.5	11590.6	11142.6	10351.8	9262.5	6238.7	9481.9	9188.2	11236.0	8362.0
32	7855.0	11345.7	12458.0	11592.9	11121.6	10331.1	8864.9	6509.5	5598.0	8176.9	13763.2	12762.0
AVE	7318.4	9444.5	11128.2	10484.6	10094.3	9204.0	8005.7	7656.6	8146.1	7094.4	11128.1	9424.8

SPILLS (CFS)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2732.6
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2460.1	1004.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1965.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4115.0	0.0
AVE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	205.5	178.2

HEAD (FT)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	583.4	558.4
2	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	584.0	570.3
3	591.3	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	591.0	574.2
4	588.2	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	586.3	561.7
5	580.4	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	591.9	572.6
6	585.7	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	593.3	593.3
7	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0
8	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	589.3	589.3
9	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	588.2	563.2
10	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0
11	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	587.5	566.2
12	583.8	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	594.6	578.9
13	589.4	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0
14	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	602.4	602.4
15	605.0	605.0	605.0	605.0	605.0	605.0	605.0	604.5	604.6	605.0	593.7	573.2
16	584.5	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	592.8	592.8
17	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	588.0	563.0
18	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0
19	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	583.4	558.3
20	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	604.7	580.5	555.8
21	580.0	605.0	605.0	605.0	605.0	605.0	599.7	599.7	605.0	605.0	586.0	561.0
22	580.0	605.0	605.0	605.0	605.0	605.0	605.0	601.0	601.0	605.0	600.5	600.5
23	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	591.8	584.4
24	597.7	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	603.7	578.7	555.0
25	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	582.6	557.6
26	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	590.3	581.1
27	595.8	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	603.8	578.8	555.0
28	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	594.1	574.1
29	585.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	583.4	558.4
30	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	591.6	566.6
31	580.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	595.0	585.0
32	595.0	605.0	605.0	605.0	605.0	605.0	605.0	605.0	604.2	604.2	605.0	605.0
AVE	590.8	605.0	605.0	605.0	605.0	605.0	604.8	604.7	604.9	604.9	591.5	577.4

WATER SURFACE AT START OF MONTH (FT)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1411.7
2	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1413.0
3	1427.6	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1427.0
4	1421.5	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1417.6
5	1405.8	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1428.8
6	1416.4	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1431.5
7	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0
8	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1423.5
9	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1421.4
10	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0
11	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1420.0
12	1412.5	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1434.1
13	1423.8	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0
14	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1449.7
15	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1454.1	1455.0	1455.0	1432.3
16	1414.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1430.6
17	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1420.9
18	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0
19	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1411.7
20	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1454.3	1406.7
21	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1444.3	1455.0	1455.0	1455.0	1417.0
22	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1446.9	1455.0	1455.0	1446.0
23	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1428.5
24	1440.3	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1452.5	1405.0
25	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1410.2
26	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1425.6
27	1436.7	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1452.6	1405.0
28	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1433.2
29	1415.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1411.8
30	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1428.2
31	1405.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1434.9
32	1435.1	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1453.4	1455.0	1455.0
AVE	1426.7	1455.0	1455.0	1455.0	1455.0	1455.0	1455.0	1454.7	1454.7	1455.0	1454.9	1428.2

ENFRGY FROM RESERVOIR 2 (GWH)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1	214.1	337.6	404.9	375.4	319.0	285.7	232.4	204.5	199.8	194.3	342.2	259.3	3359.2
2	203.7	222.0	261.6	241.4	189.6	213.7	220.5	256.7	180.3	185.3	340.0	232.5	2747.4
3	205.7	321.0	404.3	376.6	325.9	318.1	234.8	187.0	233.5	206.7	339.9	246.1	3401.7
4	208.9	357.4	406.1	375.9	326.3	322.1	255.3	316.0	313.3	186.8	333.1	231.9	3633.1
5	210.3	221.9	382.2	364.6	319.6	287.7	242.7	320.3	220.5	193.0	316.4	236.4	3315.5
6	211.9	224.1	407.5	377.5	327.7	339.3	242.0	201.8	263.1	244.8	356.5	312.2	3508.3
7	247.5	345.7	404.8	375.2	318.5	291.6	234.5	321.1	316.4	298.8	379.5	432.0	3945.5
8	266.5	357.8	406.4	376.4	327.2	336.2	274.4	236.1	303.6	192.4	342.7	256.9	3676.5
9	331.0	360.5	414.4	377.1	325.6	334.8	294.1	258.1	249.2	190.2	336.8	255.3	3727.1
10	208.6	222.2	260.8	319.9	376.9	292.5	242.4	280.2	208.4	205.6	330.8	408.5	3306.7
11	293.3	356.3	407.4	377.8	327.2	335.9	275.4	300.2	180.7	195.4	330.0	226.8	3606.2
12	205.9	329.8	409.6	382.9	330.8	338.4	298.7	310.4	321.9	231.8	352.7	244.7	3757.9
13	209.1	311.0	407.4	376.2	326.6	335.8	285.9	223.9	326.7	265.1	446.4	432.0	3946.1
14	301.3	352.5	404.7	376.0	327.2	334.6	261.0	310.7	307.9	304.2	356.9	344.0	3980.9
15	291.3	355.0	405.2	375.3	325.9	285.5	229.1	186.0	330.6	270.6	354.7	254.8	3664.1
16	211.8	283.8	403.4	375.2	316.6	292.1	248.5	228.4	239.6	244.6	339.1	293.1	3476.2
17	307.4	349.4	406.6	376.8	327.6	319.0	258.1	201.3	326.3	196.5	328.3	245.2	3642.5
18	205.6	221.9	260.7	309.9	329.5	299.3	240.3	292.7	302.6	263.5	417.3	432.0	3575.4
19	245.1	353.9	409.1	377.0	327.5	337.0	295.1	306.7	313.5	289.4	341.5	252.3	3848.4
20	205.0	221.5	259.4	282.3	317.5	289.3	237.4	194.2	188.1	184.2	347.9	251.2	2977.9
21	207.2	224.2	264.0	244.6	192.0	217.0	203.6	195.7	202.4	205.1	335.3	251.0	2742.1
22	216.8	232.3	268.7	245.7	192.3	216.9	183.8	201.2	211.9	186.2	335.0	288.2	2778.8
23	276.3	354.8	407.6	378.4	328.6	337.9	295.5	333.0	323.9	272.7	360.5	266.3	3935.6
24	200.8	343.1	404.3	374.9	326.5	307.6	238.2	184.3	215.7	187.9	347.1	257.8	3388.2
25	204.6	221.1	259.6	239.8	188.3	261.7	237.0	306.1	188.9	188.0	344.7	243.6	2883.3
26	205.8	223.5	264.4	244.2	192.4	217.0	183.7	265.1	311.2	288.9	346.3	245.6	2988.0
27	248.9	347.7	404.1	368.6	318.0	290.8	246.8	213.3	202.3	187.6	356.8	255.8	3440.6
28	207.7	227.8	267.1	244.4	191.6	294.4	254.6	217.8	321.1	275.7	354.5	255.4	3112.1
29	210.8	344.8	408.4	377.9	328.1	337.1	294.7	218.3	175.1	185.6	342.0	254.2	3476.9
30	211.0	226.9	264.0	242.9	190.5	213.5	229.7	259.0	238.7	278.5	337.7	255.8	2948.3
31	207.9	279.1	405.8	376.0	326.5	335.8	290.7	202.3	297.6	298.0	358.4	253.8	3631.9
32	250.6	356.1	404.1	376.0	325.8	335.1	278.3	211.1	175.5	264.9	446.4	400.6	3824.6
AVE	232.3	296.5	361.0	340.1	295.7	298.5	251.2	248.2	255.6	230.1	353.0	283.6	3445.9

TOTAL ENERGY PRODUCED (GWH)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1	431.7	728.4	870.7	794.0	666.9	588.5	471.4	355.5	324.6	331.9	495.8	538.5	6599.7
2	653.9	471.9	551.4	504.2	392.0	438.5	444.0	471.3	325.1	328.8	491.6	494.1	5566.9
3	561.0	689.6	870.9	796.5	682.3	656.1	477.9	354.0	340.8	340.5	538.2	464.4	6772.1
4	572.5	767.1	870.7	796.7	682.4	664.3	517.4	555.1	525.8	331.5	476.6	390.1	7150.2
5	657.6	472.5	819.1	772.3	667.3	592.8	490.3	533.1	332.8	331.4	440.7	392.4	6502.5
6	610.2	473.3	871.1	796.6	682.6	698.6	489.6	354.9	438.0	434.0	627.1	787.0	7263.0
7	525.4	750.9	870.6	796.2	664.7	598.8	474.7	554.3	525.8	517.1	700.3	935.2	7914.0
8	548.6	766.9	870.7	797.1	683.0	692.4	556.2	404.7	526.0	331.9	539.1	597.5	7314.0
9	676.9	767.3	875.5	796.5	682.4	693.4	598.2	463.7	440.1	331.9	505.7	475.6	7307.3
10	658.4	472.3	552.0	672.6	679.4	599.6	488.1	445.2	324.6	331.8	543.7	794.5	6562.3
11	613.0	766.8	870.6	797.0	683.0	692.3	558.7	554.1	324.2	332.0	469.1	377.6	7038.4
12	611.1	706.6	870.6	802.8	688.1	692.8	598.1	555.0	526.1	383.9	617.4	430.3	7482.9
13	578.3	670.8	874.8	796.8	682.8	692.3	579.9	430.2	525.7	517.6	989.1	918.1	8256.4
14	636.5	766.9	870.7	797.0	683.0	692.3	532.9	555.2	525.6	518.1	690.8	755.9	8024.7
15	611.8	767.8	870.7	794.0	680.8	588.5	465.8	357.8	525.7	517.2	624.0	451.2	7257.4
16	622.0	611.1	870.6	797.7	663.4	603.2	505.6	422.7	400.3	413.7	546.3	690.4	7147.0
17	629.3	733.8	870.7	796.2	682.1	653.9	518.7	355.0	525.6	331.2	465.8	430.3	7012.7
18	658.3	472.2	552.0	650.6	684.6	613.2	484.9	534.5	525.9	449.4	752.4	953.4	7331.3
19	520.1	766.7	878.1	796.9	683.0	692.8	597.8	554.4	526.5	517.3	495.6	511.0	7540.0
20	657.9	472.2	551.9	596.2	663.5	596.1	481.9	355.2	324.9	334.3	508.9	523.9	6066.9
21	650.1	471.7	551.3	504.1	391.7	438.3	366.3	401.1	324.3	331.7	478.8	469.1	5378.3
22	649.9	472.3	551.8	504.3	391.9	438.4	366.4	352.9	358.9	328.8	578.7	630.1	5624.4
23	588.7	767.0	870.8	796.3	682.4	693.4	598.3	554.6	526.5	518.3	636.6	617.0	7849.8
24	503.6	745.8	870.7	796.1	682.1	634.5	484.9	355.0	362.0	342.6	512.9	567.5	6857.9
25	655.1	472.1	551.5	504.2	392.0	539.6	482.3	554.1	324.4	331.3	500.1	471.4	5778.2
26	652.0	471.8	551.6	504.3	392.2	438.6	366.6	461.5	526.5	517.5	562.2	523.5	5968.4
27	588.8	753.1	870.5	780.7	663.8	597.7	498.3	355.5	325.0	342.1	554.5	557.3	6887.8
28	654.0	472.2	551.9	504.5	392.2	601.0	510.8	355.4	526.1	517.6	673.4	452.1	6161.2
29	609.9	734.5	870.6	797.0	683.0	692.6	597.5	430.3	324.9	331.9	495.0	513.1	7080.3
30	653.2	472.1	551.6	504.3	392.1	438.7	466.8	496.7	457.9	501.4	532.3	443.8	5910.9
31	662.0	594.5	870.6	796.9	682.9	692.4	589.4	371.6	522.4	517.5	614.8	520.9	7436.0
32	621.0	767.3	870.8	799.3	683.0	692.4	565.0	388.4	332.0	448.6	988.8	859.2	8015.8
AVE	610.1	634.7	769.9	717.0	615.8	613.7	507.0	445.1	429.5	404.8	581.1	579.3	6908.1

TOTAL USABLE ENERGY (GWH)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1	431.7	728.4	870.5	796.0	666.9	588.5	471.4	355.5	324.6	331.9	495.8	538.5	6599.5
2	653.9	471.9	551.4	504.2	392.0	438.5	444.0	471.3	325.1	328.8	491.6	494.1	5566.9
3	561.0	689.6	870.5	796.1	682.1	656.1	477.9	354.0	340.8	340.5	538.2	464.4	6771.0
4	572.5	766.8	870.5	796.1	682.1	664.3	517.4	554.3	525.6	331.5	476.6	390.1	7147.7
5	657.6	472.5	819.1	772.3	667.3	592.8	490.3	533.1	332.8	331.4	440.7	392.4	6502.5
6	610.2	473.3	870.5	796.1	682.1	691.9	489.6	354.9	438.0	434.0	543.1	568.8	6952.4
7	525.4	750.9	870.5	796.1	664.7	598.8	474.7	554.3	525.6	517.1	543.1	568.8	7390.0
8	548.6	766.8	870.5	796.1	682.1	691.9	556.2	404.7	525.6	331.9	539.1	568.8	7282.3
9	676.9	766.8	870.5	796.1	682.1	691.9	597.6	463.7	440.1	331.9	505.7	475.6	7298.8
10	658.4	472.3	552.0	672.6	679.4	599.6	488.1	445.2	324.6	331.8	543.1	568.8	6335.9
11	613.0	766.8	870.5	796.1	682.1	691.9	558.7	554.1	324.2	332.0	469.1	377.6	7036.0
12	611.1	706.6	870.5	796.1	682.1	691.9	597.6	554.3	525.6	383.9	543.1	430.3	7393.1
13	578.3	670.8	870.5	796.1	682.1	691.9	579.9	430.2	525.6	517.1	543.1	568.8	7454.4
14	636.5	766.8	870.5	796.1	682.1	691.9	532.9	554.3	525.6	517.1	543.1	568.8	7685.6
15	611.8	766.8	870.5	796.0	680.8	588.5	465.8	357.8	525.6	517.1	543.1	451.2	7175.0
16	622.0	611.1	870.5	796.1	663.4	603.2	505.6	422.7	400.3	413.7	543.1	568.8	7020.4
17	629.3	753.8	870.5	796.1	682.1	653.9	518.7	355.0	525.6	331.2	465.8	430.3	7012.3
18	658.3	472.2	552.0	650.6	682.1	613.2	484.9	534.5	525.6	449.4	543.1	568.8	6734.6
19	520.1	766.7	870.5	796.1	682.1	691.9	597.6	554.3	525.6	517.1	495.6	511.0	7528.5
20	657.9	472.2	551.9	596.2	663.5	596.1	481.9	355.2	324.9	334.3	508.9	523.9	6066.9
21	650.1	471.7	551.3	504.1	391.7	438.3	366.3	401.1	324.3	331.7	478.8	469.1	5378.3
22	649.9	472.3	551.8	504.3	391.9	438.4	366.4	352.9	358.9	328.8	543.1	568.8	5527.6
23	588.7	766.8	870.5	796.1	482.1	691.9	597.6	554.3	525.6	517.1	543.1	568.8	7702.5
24	503.6	745.8	870.5	796.1	682.1	634.5	484.9	355.0	362.0	342.6	512.9	567.5	6857.5
25	655.1	472.1	551.5	504.2	392.0	539.6	482.3	554.1	324.4	331.3	500.1	471.4	5778.2
26	652.0	471.8	551.6	504.3	392.2	438.6	366.6	461.5	525.6	517.1	543.1	523.5	5948.0
27	588.8	753.4	870.5	780.7	663.8	597.7	498.3	355.5	325.0	342.1	543.1	557.3	6876.3
28	654.0	472.2	551.9	504.5	392.2	601.0	510.8	355.4	525.6	517.1	543.1	452.1	6079.9
29	609.9	734.5	870.5	796.1	682.1	691.9	597.5	430.3	324.9	331.9	495.0	513.1	7077.6
30	653.2	472.1	551.6	504.3	392.1	438.7	466.8	496.7	457.9	501.4	532.3	443.8	5910.9
31	662.0	594.5	870.5	796.1	682.1	691.9	589.4	371.6	522.4	517.1	543.1	520.9	7361.6
32	621.0	766.8	870.5	796.1	682.1	691.9	565.0	388.4	332.0	448.6	543.1	568.8	7274.3
AVE	610.1	634.6	769.3	716.4	615.3	613.2	507.0	445.0	429.4	404.7	519.9	508.0	6772.7

FORECAST DEMAND ENERGY (GWH)

OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
677.0	766.8	870.5	796.1	682.1	691.9	597.6	554.3	525.6	517.1	543.1	568.8	7790.9

PRE-PROJECT FLOW AT GOLD CREEK (CFS)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	6335.0	2583.0	1439.0	1027.0	788.0	726.0	870.0	11510.0	19600.0	22600.0	19880.0	8301.0
2	3848.0	1300.0	1100.0	960.0	820.0	740.0	1617.0	14090.0	20790.0	22570.0	19670.0	21240.0
3	5571.0	2744.0	1900.0	1600.0	1000.0	880.0	920.0	5419.0	32370.1	26390.0	20920.0	14480.0
4	8202.0	3497.0	1700.0	1100.0	820.0	820.0	1615.0	19270.0	27320.1	20200.0	20610.0	15270.0
5	5604.0	2100.0	1500.0	1300.0	1000.0	780.0	1235.0	17280.0	25250.0	20360.0	26100.0	12920.0
6	5370.0	2760.0	2045.0	1794.0	1400.0	1100.0	1200.0	9319.0	29860.0	27560.0	25750.0	14290.0
7	4951.0	1900.0	1300.0	980.0	970.0	940.0	950.0	17660.0	33340.0	31090.1	24530.0	18330.0
8	5806.0	3050.0	2142.0	1700.0	1500.0	1200.0	1200.0	13750.0	30160.0	23310.0	20540.0	19800.0
9	8212.0	3954.0	3264.0	1965.0	1307.0	1148.0	1533.0	12900.0	25700.0	22880.0	22540.0	7550.0
10	4811.0	2150.0	1513.0	1448.0	1307.0	980.0	1259.0	15990.0	23320.0	25000.0	31180.0	16920.0
11	6558.0	2850.0	2200.0	1845.0	1452.0	1197.0	1300.0	15780.0	15530.0	22980.0	23590.0	20510.0
12	7794.0	3000.0	2694.0	2452.0	1754.0	1810.0	2650.0	17360.0	29450.0	24570.0	22100.0	13370.0
13	5916.0	2700.0	2100.0	1900.0	1500.0	1400.0	1700.0	12590.0	43270.0	25850.0	23550.0	15890.0
14	6723.0	2800.0	2000.0	1600.0	1500.0	1000.0	830.0	19030.0	26000.0	34400.0	23670.0	12320.0
15	6449.0	2250.0	1494.0	1048.0	966.0	713.0	745.0	4307.0	50580.0	22950.0	16440.0	9571.0
16	6291.0	2799.0	1211.0	960.0	860.0	900.0	1360.0	12990.0	25720.0	27840.0	21120.0	19350.0
17	7205.0	2098.0	1631.0	1400.0	1300.0	1300.0	1775.0	9645.0	32950.0	19860.0	21830.0	11750.0
18	4163.0	1600.0	1500.0	1500.0	1400.0	1200.0	1167.0	15480.0	29510.0	26800.0	32620.0	16870.0
19	4900.0	2353.0	2055.0	1981.0	1900.0	1900.0	1910.0	16180.0	31550.0	26420.0	17170.0	8816.0
20	4272.0	1906.0	1330.0	1086.0	922.0	833.0	1022.0	9852.0	20523.0	18093.0	16322.0	9776.0
21	3124.0	1215.0	866.0	824.0	768.0	776.0	1080.0	11380.0	18630.0	22660.0	19980.0	9121.0
22	5288.0	3407.0	2290.0	1442.0	1036.0	950.0	1082.0	3745.0	32930.0	23950.0	31910.0	14440.0
23	5847.0	3093.0	2510.0	2239.0	2028.0	1823.0	1710.0	21890.0	34130.0	22770.0	19290.0	12400.0
24	4826.0	2253.0	1465.0	1200.0	1200.0	1000.0	1027.0	8235.0	27800.0	18250.0	20290.0	9074.0
25	3733.0	1523.0	1034.0	874.0	777.0	724.0	992.0	16180.0	17870.0	18800.0	16220.0	12250.0
26	3739.0	1700.0	1603.0	1516.0	1471.0	1400.0	1593.0	15350.0	32310.0	27720.0	18090.0	16310.0
27	7739.0	1993.0	1081.0	974.0	950.0	900.0	1373.0	12620.0	24380.0	18940.0	19800.0	6881.0
28	3874.0	2650.0	2403.0	1829.0	1618.0	1500.0	1680.0	12680.0	37970.0	22870.0	19240.0	12640.0
29	7571.0	3525.0	2589.0	2029.0	1668.0	1605.0	1702.0	11950.0	19050.0	21020.0	16390.0	8607.0
30	4907.0	2535.0	1681.0	1397.0	1286.0	1200.0	1450.0	13870.0	24690.0	28880.1	20460.0	10770.0
31	7311.0	4192.0	2416.0	1748.0	1466.0	1400.0	1670.0	12040.0	29080.0	32660.0	20960.0	13280.0
32	7725.0	3986.0	1773.1	1453.6	1235.6	1114.3	1367.5	13316.7	18143.0	32000.0	38538.0	13171.1
AVE	5770.8	2577.1	1807.2	1474.1	1249.1	1123.7	1361.7	13240.0	27814.9	24445.1	22228.1	13320.9

POST-PROJECT FLOWS AT GOLD CREEK (CFS)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	7179.2	10934.4	12578.2	11650.3	10939.3	8865.3	7472.8	7324.3	7178.9	7206.1	12000.0	9300.0
2	6748.5	7141.1	8134.9	7497.6	6524.0	6631.9	7138.6	8784.5	6555.1	6708.4	12000.0	9300.0
3	6839.1	10431.1	12668.8	11726.9	11180.6	9859.6	7522.8	6195.0	9795.3	7901.5	12000.0	9300.0
4	7307.4	11650.3	12668.0	11689.6	11211.6	9983.0	8217.8	11255.3	12069.7	6776.1	12000.0	9300.0
5	7251.7	7247.7	11896.3	11315.6	10979.8	8919.3	7837.8	11870.1	9085.4	7156.4	12000.0	9300.0
6	7286.5	7392.2	12739.4	11782.4	11311.0	10536.0	7802.8	7151.2	10161.0	8894.3	12000.0	10444.4
7	7932.9	11123.8	12572.1	11625.2	10949.8	9079.3	7552.8	11581.5	12282.2	11088.6	13619.9	18330.0
8	8787.9	11673.8	12683.1	11721.9	11278.3	10458.6	8833.8	8556.0	11415.3	7132.1	12000.0	10172.8
9	10983.0	11848.8	13134.1	11797.3	11207.9	10382.6	9465.4	9008.2	9227.2	6982.1	12000.0	9300.0
10	7116.3	7230.1	8181.8	9993.1	11286.8	9119.3	7852.8	10727.6	8422.7	7949.4	12783.3	14603.0
11	9539.9	11577.0	12749.7	11804.9	11280.1	10439.3	8856.2	10230.9	6576.5	7264.7	12000.0	9300.0
12	7203.6	10747.3	12886.7	12045.8	11452.8	10604.2	9759.4	10900.2	12635.2	8836.7	12000.0	9300.0
13	7073.8	10062.9	12680.9	11701.4	11234.2	10432.7	9195.0	7353.5	12998.0	9031.9	17531.5	15890.0
14	9704.9	11332.8	12580.8	11696.5	11281.5	10356.3	8332.7	10911.1	11714.1	11389.6	12000.0	11550.9
15	9430.9	11473.8	12598.7	11638.9	11191.3	8852.3	7347.8	6000.0	13305.2	9366.2	12000.0	9300.0
16	7305.8	9195.6	12487.2	11601.1	10839.8	9039.3	7962.8	7766.0	9243.9	9184.7	12000.0	10644.5
17	10186.9	11321.8	12688.7	11738.9	11293.4	9947.7	8377.8	7117.0	12899.5	7380.5	12000.0	9300.0
18	6931.1	7212.7	8171.5	9697.8	11379.8	9339.3	7769.8	10068.6	11354.1	9841.3	15191.8	16870.0
19	7881.9	11423.0	12737.1	11751.6	11300.9	10510.0	9518.6	10652.1	12076.0	10471.8	12000.0	9300.0
20	6889.6	7178.6	8091.0	8777.6	10901.8	8972.3	7624.8	6686.5	7093.7	6484.0	12000.0	9300.0
21	6921.1	7212.3	8196.1	7607.1	6613.9	6743.4	6577.8	6746.0	7960.0	7842.4	12000.0	9300.0
22	7515.1	7724.7	8500.2	7697.1	6655.9	6769.9	5950.4	6561.9	8695.2	6750.4	12000.0	10052.8
23	8828.9	11484.7	12762.1	11867.9	11406.1	10580.9	9558.8	12380.0	12819.8	9162.0	12000.0	9300.0
24	6453.2	11030.1	12541.9	11619.5	11214.1	9529.3	7629.8	6020.9	8278.7	6484.0	12000.0	9300.0
25	6820.4	7103.9	8040.5	7423.9	6457.3	8101.8	7594.8	10611.5	7121.1	6806.9	12000.0	9300.0
26	6849.9	7200.1	8268.7	7634.9	6697.7	6818.4	5989.5	9487.4	11922.4	10437.6	12000.0	9300.0
27	8527.6	11216.8	12532.2	11440.0	10929.8	9039.3	7975.8	7889.9	8011.2	6484.0	12000.0	9300.0
28	7001.4	7515.6	8491.4	7707.6	6687.1	9214.6	8282.8	8183.5	12592.0	9628.5	12000.0	9300.0
29	7356.7	11299.3	12808.2	11810.6	11340.4	10515.5	9493.5	6986.4	6212.7	6662.3	12000.0	9300.0
30	7190.6	7439.1	8272.3	7582.1	6586.6	6618.1	7365.5	8522.2	8243.5	10003.2	12000.0	9300.0
31	7096.2	9128.8	12649.5	11689.6	11225.6	10430.8	9357.5	6921.7	12306.9	11846.2	12000.0	9300.0
32	8334.0	11632.7	12677.1	11759.5	11268.2	10448.4	8994.4	8150.2	6000.0	8940.9	21146.2	13171.1
AVE	7764.9	9630.8	11270.9	10596.7	10190.9	9285.6	8100.4	8706.3	9882.9	8387.3	12633.5	10510.3

8 - RESERVOIR AND RIVER TEMPERATURE STUDIES

8.1 - Introduction

The objective of the reservoir temperature studies was to determine the impact of project operation on water temperatures immediately downstream from the damsites. Companion studies were made to extend these outflow temperatures to critical locations between the damsites and Talkeetna.

The results of these studies are used to determine the best outlet works and power intake configuration to achieve downstream water temperatures consistent with the fishery mitigation plan and, when possible, to maintain acceptable ice cover growth and stability.

Two models were used in the reservoir temperature study. Early studies had used the Reservoir Temperature Stratification Program developed by the U.S. Army Corps of Engineers (1972). Results from this study are given in Acres (1982). Review of these findings resulted in the recommendation to the Alaska Power Authority to continue reservoir temperature modeling with a more detailed model and to verify this model with collection of temperature profiles and other data at an existing Alaskan lake or reservoir.

Several models were reviewed for availability and suitability for Alaskan conditions. Of importance was the requirement to model reservoir temperatures under ice-covered conditions and the ability to model selective withdrawal intakes. The program Dynamic Reservoir Simulation Model (DYRESM), by Imberger and Patterson (1978, 1980), was selected as a suitable model due to its general acceptance in the field of temperature modeling and its application to lakes and reservoirs in Canada. An ice-cover subroutine was developed by Dr. J.C. Patterson and Acres to model winter conditions.

Two programs developed in-house were used to predict water temperatures in the downstream reach between the damsites and Talkeetna and to establish ice cover formation and growth. Reservoir temperature modeling, in conjunction with the project operation model, provided the necessary upstream boundary condition of temperature and discharge required for the downstream temperature model (HEATSM). This in turn provided the upstream boundary condition (ice generation section) for the ice model (ICESM). Together, the three programs provide a complete model of the reservoir and river reach thermal condition.

8.2 - Early Studies

The conclusion drawn from temperature studies finalized in 1981 (Acres 1982) was that single power intakes capable of drawing water to the lowest operating level would not be able to provide the downstream temperatures required for fisheries. Consequently, intake structures with the capability of withdrawing at variable levels were found to provide acceptable temperatures during the summer months. However, winter temperatures were not as acceptable because of delay of ice-cover formation and subsequent uncertainties of ice-cover stability.

The operational philosophy of the power intake was to draw off water as close to the surface as possible, given the intake layout and hydraulic submergence criteria. This operation was assumed for three weather conditions of wet, average, and dry, and for two downstream flow conditions. Downstream conditions assumed were Case A (best power operation, August minimum flow of 6000 cfs) and Case D (least environmental impact, August minimum flow of 19,000 cfs).

Results of the temperature modeling for Case A for the reach from Devil Canyon dam to Talkeetna with Watana/Devil Canyon operation are summarized in Tables 8.1 to 8.3 for average, wet, and dry weather conditions. Cross-section locations are given in Figure 8.1. Generally, summer (July and August) water temperatures at Gold Creek are about 10°C for all weather conditions assumed. June and September temperatures at Gold Creek are about 8°C. Winter (October to May) temperatures at Gold Creek never fall below 3°C for the three weather conditions assumed. Similarly, at Talkeetna summer water temperatures are about 12°C, June temperatures are about 10°c, and September temperatures are about 8°C. Winter temperatures are such as to prevent the establishment of a significant ice cover above the Susitna/Chulitna confluence at Talkeetna.

Further details of the models and the results can be found in Appendix A4 of Acres (1982).

8.3 - 1982 Studies

(a) Introduction

During 1982, studies of reservoir temperatures were extended to include recorded meteorological data at Watana and elaboration of modeling techniques. Previous studies based on a monthly time step were unable to provide the necessary details on possible daily temperature fluctuations to the fishery mitigation plan. The extended studies required the selection of a reservoir temperature model which could provide daily temperature results and be able to accurately model meteorological forcing, wind mixing, inflow dynamics, and outflow dynamics on the same daily time step. After review of several models with the above qualifications, the program DYRESM was selected.

The selection of DYRESM was based on a general review of the model's analogues of the physical system, the availability of the model and of one of the authors (Dr. J.C. Patterson) for consultation, and the verification or use of the model on deep, glacial-fed lakes in British Columbia, notably Kootenay Lake. A brief general description of the model is given below in Section 8.3(b). Detailed discussion of the model and its analogues is given in Imberger and Patterson (1980). Modifications to the basic program are discussed in subsequent sections of this section.

Verification of DYRESM was accomplished by modeling the dynamics of Eklutna Lake, Alaska, and by comparison of the results with measured data. Details of this verification and of modifications made to DYRESM to better model the temperature regime are given in Section 8.4. Reservoir temperature results for Watana and for Watana/Devil Canyon are given in Sections 8.5 and 8.6, respectively.

(b) DYRESM Model

Predictions of reservoir temperatures stratification and outflow temperatures have been made using a one-dimensional numerical model developed by Imberger et al. (1980). The DYRESM model has been modified to include ice-cover formation and outflow hydraulics associated with multiple intake structures.

DYRESM approaches the problem of reservoir temperature (and salinity) modeling by parameterization of the physical process rather than numerical solution of the appropriate differential equations. The reservoir is modeled by a system of horizontal layers with uniform properties which move up and down, in accordance with the volume-depth relationship, as inflow and withdrawal increase and decrease the reservoir volume. Each model layer has dimensions suited to the function or condition it is required to represent. For example, the reservoirs mixed layer may be modeled by a combination of several layers starting with a reasonably coarse layer structure in the epilimnion and graduating down to a very narrow fine layer in the transition zone.

The construction of the model DYRESM consists of a main program with subroutines which separately model each of the physical processes of inflow, withdrawal, mixed layer dynamics, and vertical transport in the hypolimnion. Other subroutines provide support for handling frequently required data such as volumes, density, etc.

The physical processes involved in the modeling require definition of the time step over which they act. Inflow and outflow dynamics generally change relatively slowly from day to day, whereas the mixed layer dynamics require a much finer time step. In DYRESM, the base time step is set at one day for calls to subroutines which deal with inflow and outflow. Calls to other subroutines are based on the dynamics of the situation and range from fifteen minutes to twelve hours.

Meteorological data are generally assumed to be input as daily averages, except for wind speed which is also given as six-hour resultant wind speeds. Allowance is built into the program for short wave radiation absorption between day and night. DYRESM requires comprehensive data on wind speed, short- and long-wave radiation, temperature, vapor pressure, and precipitation in addition to physical characteristics of the reservoir and inflow and outflow quantities.

Detailed discussion of DYRESM is provided in Imberger et al. (1978), Imberger and Patterson (1980) and Fischer (1979).

8.4 - Eklutna Lake Temperature Modeling

The program DYRESM has been extensively used in Canada and Australia to predict thermal and salinity profiles within lakes and reservoirs. To aid in assessing the acceptability of DYRESM for Alaskan conditions, a data collection program was established in 1982 to obtain information on the thermal structure of Eklutna Lake and to collect meteorological data.

Eklutna Lake is located approximately 30 miles north of Anchorage (Figure 8.2). It is a natural glacial lake formed by blockage of the valley by moraine. In 1965, a hydroelectric project was developed at the lake to utilize the flow and storage capacity.

Powerhouse facilities are connected to the lake via a single tunnel with an intake located in the northern end of the lake (Figures 8.2 and 8.3). Elevation-area storage curves were developed by R&M Consultants from the hydroelectric project construction drawings and topographical maps (R&M 1982).

(a) Data Collection Program

The reservoir temperature model DYRESM requires detailed daily meteorological data. These data include on a daily basis:

- Mean temperature (°C);
- Mean wind speed (m/s);
- Air vapor pressure (mb);
- Total short-wave radiation (kj/m^2);
- Precipitation (mm); and
- Long-wave radiation (kj/m^2) or, as an alternative, cloud cover as percent of sky.

In addition, the version of DYRESM used requires resultant wind speed for six-hour increments. These variables were collected at a weather station located near the southern end of the lake (Figure 8.2). A "Weather Wizard" similar to those used in the Susitna Basin was established.

In addition to climate data, information on the quantity and temperature of inflow to the lake as well as powerhouse and overflow quantities are required. The inflow data requirement was met by establishing two gaging stations on the major tributaries which measured temperature and stage; station locations are shown on Figure 8.3. Periodic measurements were made at these stations to determine the stage-discharge relationship so that daily flows could be estimated. Temperatures were measured on a continuous basis at the two locations. Powerhouse and overflow quantities were obtained from records kept at the Eklutna powerhouse.

Approximately at two-week intervals, measurements of lake temperature profiles were made at up to seven stations. In addition, measurements of turbidity and conductivity were made at selected locations.

The above information was collected by R&M Consultants and was reduced to the form required by DYRESM. Their report (R&M 1982) contains a summary of this information.

On those occasions when either weather data or streamflow information was missing or not reliable, estimates were made based on other sources. The periods covered by estimation are given in R&M (1982).

(b) Eklutna Lake Modeling Results

Before modeling commenced for Eklutna Lake, a review of DYRESM was made to ensure that any site-specific parameters were accurately represented. This review resulted mainly in adjustments to meteorological variables, particularly wind speed.

In DYRESM, the wind speed is assumed to be measured at a height of 6 m and is adjusted within the program to provide an estimate of the wind speed at the water surface. This adjustment is required to correct for the velocity distribution within the turbulent boundary layer usually existing at an air/water interface. The Weather Wizard instrument, however, measures wind speed at about 2 m above surrounding scrub vegetation, so an underestimation of wind speeds would occur if no correction was applied. Based on boundary layer theory, the wind speeds measured were adjusted by the ratio given below.

$$WS_d = \left(\frac{h_d}{h_g}\right)^{1/7} \cdot WS_g$$

Where: WS_d = wind speed used in DYRESM;
WS_g = measured wind speed;
h_g = gage height above ground and vegetation (2 m); and;
h_d = DYRESM assumed height (6 m).

This produces an increase of 17 percent in measured wind speeds. Other key site-specific parameters used in DYRESM are given in Table 8.4. These are based on measurements at the site and recommended values (Patterson 1982 Personal communication; Imberger and Patterson 1980).

The initial run of DYRESM for Eklutna Lake was made for the periods June 1 to June 18 and August 25 to October 13. These periods were selected for calibration of the model because of the uncertainties associated with July and August meteorological data (R&M 1982). The comparisons of measured and estimated profiles within Eklutna Lake are given in Figures 8.4 to 8.6 for June 18, September 9, and September 21. These results show acceptable agreement between estimated and measured profiles for June 18 and September 9. However, on September 21 the measured profile shows substantial mixing to depth indicated by the warmer hypolimnion, whereas the estimated profile remains substantially stratified.

Review of the meteorological data indicates that two periods of high winds occurred between September 9 and September 21. These events would explain the mixing to depth of warmer surface water with cooler hypolimnion water and could produce the profile measured. In DYRESM, however, these wind events have only caused deepening to about 50 feet. Consequently, the base version of DYRESM would appear to be not strictly applicable during high wind shear events. Fortunately adjustments can be made to the model to provide adequate representation of the mixing process during high wind shear. This is discussed below.

DYRESM has three conditions under which the assumption of one-dimensionality is valid (Imberger 1980). The most important condition for Eklutna is given by the Wedderburn number:

$$W = \frac{g'h}{U^{*2}} \cdot \frac{h}{L}$$

Where: W = Wedderburn number;
g' = effective reduced gravity across the thermocline;
h = depth of the mixed layer;
L = basin scale; and
U^* = surface shear velocity.

Spigel and Imberger (1980) have shown that for $W>1$, the departure from one-dimensionality can be assumed minimal. For $0<W<1$, the departure is severe but can be parameterized, and for $W<0$, the lake overturns. To determine whether these criteria for one-dimensionality were violated, the Wedderburn number for Eklutna Lake was determined for selected days from meteorological data and the simulated temperature profile; these values are given in Table 8.5. This shows that for September 15 and 21 (periods of high winds), the Wedderburn number is less than or close to one. Consequently, the one-dimensionality of DYRESM is not strictly valid during these periods. Fortunately, the problem can be resolved by modification of the vertical diffusion coefficient, which is a scale of the efficiency of transport of mass and momentum.

The global vertical diffusion coefficient E_z is a measure of the mixing caused by wind and inflows for a given stratification and forcing history. E_z is computed as follows:

$$E_z = k_1 \frac{H^2 (P_w + P_s)}{ES}$$

Where: E_z = global vertical diffusion coefficient;
K_1 = a function depending upon the basin shape, the stratification, and the forcing history;
H = reservoir depth;
P_w = power introduced by wind at the surface;
P_s = power introduced by the inflowing streams;
E = potential energy of the stratification in the whole lake; and
S = stability parameter.

Imberger and Patterson (1980) recommend a value of K_1 of 0.048. However, Patterson (Personal communication 1982) proposed values of K_1 of 0.096, 0.24, and 0.48 during periods when the Wedderburn number is less than one. Analyses were made with these values, and it was found that K_1 equal to 0.096 provided the best fit of simulated profiles measured. Comparisons with measured profiles for September 9 and September 21 are given in Figures 8.7 and 8.8, respectively.

The parameterization affects only those periods of weak stratification or high winds. Periods with moderate-to-strong stratification or moderate wind speeds would result in DYRESM using the recommended value of K_1 = 0.048. Obviously, this method requires much more refinement and justification, but it is believed the present method is adequate.

With the above parameterization of the mixing process during periods of low Wedderburn numbers, a simulation was made of Eklutna Lake temperature for the period June 1 to December 31. This was broken into two periods of June 1 to August 25 and August 25 to December 31 to model the system accurately. This breakdown isolated the estimated Eklutna meteorological data of July and August and permitted better analysis of the August 25 to December 31 period. In addition, a reevaluation of meteorological and other input was made to ensure accuracy. This review resulted in changes in some meteorological variables in September through December.

Simulated and measured profiles at the station in the approximate center of the lake are given in Figures 8.9 to 8.19. In general, most profiles are modeled to within 0.5°C. This is generally within the observed variations of temperatures between measuring stations (R&M 1982).

Deviations in measured and simulated profiles can be explained through an assessment of the meteorological variables used, the reliability of the measurement of these variables, and the general modeling techniques used in DYRESM. Reduction of the magnitude of deviations could be achieved by a very fine tuning of the model to meet specific conditions and adjustments to input data to produce better results. In most cases, however, the temperature profiles are reasonably estimated; consequently, there appears to be no justification to undertake a major reevaluation of estimated meteorological data or modeling technique.

Outflow temperatures from Eklutna Lake are given in Figures 8.20 and 8.21. In general, the simulated outflow temperature is 1°C below the measured temperature during July to mid-September. From mid-September to December, simulated and measured temperatures match well. In late June and early July, severe deviations between measured and simulated temperatures occur (Figure 8.20). This deviation is believed to be a result of a combination of DYRESM inadequacy in modeling a three-dimensional system and possible underestimation of air temperature and solar radiation and overestimation of wind speed, variables for which data were not available during much of this period.

The configuration of Eklutna is such that the portion of the lake near the intake structure is shallower than the rest of the lake (Figure 8.3). This would result in a greater mixing influence from the intake structure than is modeled by DYRESM. The major portion of the temperature deviation is, however, believed to be caused by uncertainties associated with data collected during this period. The model results for June 18 (Figure 8.10) show a very reasonable match to measured profiles as does that of July 14 (Figure 8.11). This indicates that average meteorological conditions over the entire period, June 18 to July 14, are suitably measured. However, estimates of conditions on a daily basis may be in error. Errors in estimates of wind speed, in particular, can have a major influence, since overestimation would result in too much epilimnion mixing and subsequent deepening, which in turn, would result in cooler outflow temperatures. Errors in outflow temperature measurements may also be present. Temperature isopleths for June 18 and July 14 for the lake are given in Figures 8.22 and 8.23, respectively. These demonstrate the temperature pattern throughout the lake and provide further documentation that DYRESM is modeling the system adequately.

The deviation in temperatures from July to mid-September is believed to be caused by the model approach of assuming an average lake temperature profile. Field measurements indicate that Eklutna Lake is generally warmer in the intake aea than in the mid-lake area. This would explain the higher measured temperatures.

Ice-cover formation on Eklutna Lake began during the latter part of November 1982 with a full ice cover believed to have been formed in mid-December. DYRESM, as the result of a slight daily overestimation of cooling rates during late October and November, estimated ice-cover formation to begin November 17 with a full ice cover on November 29. Measurements made on January 14, 1983, indicated an ice-cover thickness of around 18 inches. This compares favorably with an ice thickness of 21 inches predicted by DYRESM.

The above discussion establishes the adequacy of DYRESM to predict the winter and summer thermal stratification of a glacial lake under Alaskan meteorological conditions. It is, therefore, believed that the program DYRESM can predict an average reservoir temperature profile to within 0.5°C and outflow temperature to within 1°C. It is likely that ice cover formation and ice thickness is predictable to within five days and five inches, respectively.

8.5 - Watana Reservoir Temperature

Detailed daily simulations were made of the temperature structure of Watana reservoir operating under Case C power operation conditions (12,000 cfs minimum August flow). Meteorological data collected at Watana camp for June to December 1981 were used as input to DYRESM.

(a) Reservoir Temperature Profiles

Temperature profiles for the first day of each month of June through December are given in Figures 8.24 to 8.30, respectively. A profile for December 31, 1981 is given in Figure 8.31. The temperature structure at Watana follows the typical pattern for reservoirs and lakes of similar size and climatic conditions. In general, stratification occurs during June, July, and August. Maximum surface temperatures occur in July and August. The maximum surface temperature simulated was 10.9°C on July 3 and August 28.

Depths to the thermocline are variable with strong dependence upon weather conditions, particularly wind speed. In June, typical mixed layer depths are small, about 5 to 15 feet. During July and August, the heat balance is positive into the reservoir and moderate-to-strong stratification occurs. Mixed layer depths during this period can be about 130 feet, with a sharp temperature gradient of approximately 5°C in about 50 feet.

Multiple-mixed layers are estimated in Watana because of periods of warm, calm weather that provide surface warming with little mixing interspersed with windy periods which cause deepening by mixing warm surface waters with cooler water below. The duration and magnitude of the wind dictate the amount or depth of mixing occurring; hence, the step-like appearance of some summer profiles (Figure 8.27).

Cooling in September results in the gradual destruction of summer stratification and the deepening of the epilimnion to depths in excess of 150 feet. This process continues until isothermal conditions occur which are simulated to occur in mid-October. Isothermal conditions continue until water reaches its maximum density, after which reverse stratification takes place.

For the Watana reservoir simulation with 1981 data, a weak reverse stratification (Figures 8.30 and 8.31) occurs in late November and remains relatively stable throughout December. Under other meteorological conditions, the simulated depth to the hypolimnion of about 180 feet could be much less due to less surface mixing or earlier ice cover formation.

Ice-cover formation on Watana reservoir was estimated to occur on November 20 with a full ice cover on November 22. Ice thickness on December 31 was estimated at 31 inches.

(b) Outflow Temperatures

The multiple-level intake at Watana allows the utility to provide variable water temperatures within a range dictated by the thermal structure within the reservoir. The philosophy of operating this structure is to provide water temperatures as close to ambient river temperatures as possible. In general, this results in the intake closest to the surface being used, provided hydraulic submergence criteria are met. However, on a few days, deeper intakes are used to provide water temperatures which are closer to those required.

The outflow temperature immediately downstream from Watana dam is given in Figures 8.32 and 8.33. This temperature series represents the temperature used as input to downstream temperature modeling discussed later. Effects of spillage, when it occurs, have been included in the estimate of outflow temperature.

The comparison of natural (inflow) temperature and simulated outflow temperature shows that during summer months, the outflow temperature follows natural temperature trends but is cooler during July and slightly warmer in August. On most days, however, outflow temperatures in July and August are within 0.5°C of natural temperature. In June, outflow temperatures lag significantly behind natural temperatures because of reservoir filling and the heat required to warm the sizable Watana reservoir. The reverse is true in September, when cooling is insufficient to provide close to 0°C outflow temperature (Figure 8.33).

During September to mid-November, the simulation shows a gradual reduction of outflow temperature from 9.5°C to 2°C (Figures 8.32 and 8.33). Stable outflow temperatures of around 2°C start in mid-November and continue throughout December. Temperatures are expected to remain close to 2°C until spring breakup, which is generally in May.

8.6 - Watana/Devil Canyon Operation

(a) Reservoir Temperature Profiles

The DYRESM program was used to predict reservoir temperature profiles and outflow temperatures at the Watana and Devil Canyon reservoirs. Case C power operation was assumed in both cases. Watana inflow and meteorology were assumed to be the same as for Watana operation. However, Watana outflow is changed as the result of different power operation when Devil Canyon powerhouse is on line.

Watana outflow quantity and temperature plus flow and heat contribution from the area between the damsites is used as input to Devil Canyon reservoir. This provides a much more stable temperature input to Devil Canyon than for Watana, with a delay in warming of water in June and cooling of water in September. However, Devil Canyon will exhibit the general pattern of early summer warming, summer stratification, and fall-to-winter cooling through an isothermal condition to reverse stratification.

Stratification and outflow temperatures at Watana under the assumed Watana/Devil Canyon operation scenario are essentially the same as for Watana operation.

Typical reservoir temperature profiles at Devil Canyon are given in Figures 8.34 through 8.40 for the first of each month from June to December. Figure 8.41 shows the profile for December 31. Devil Canyon reservoir, because it is smaller than Watana reservoir, exhibits responses to meteorological conditions in a manner more similar to Eklutna Lake. This is particularly true for strong wind storms which result in stepped temperature profiles, as shown in Figures 8.35 and 8.36. Generally, reservoir stratification is weak in June but builds during July and August. Typical mixed layer depths are about 50 to 70 feet during the summer months. For 1981 weather data, cooling at Devil Canyon is delayed to late September and early October. This is partly because of the warmer inflows to the Devil Canyon reservoir from Watana.

Isothermal conditions occur in late November with cooling until maximum density water is present throughout the reservoir depth. Reverse stratification begins in mid-December and the reservoir is very weakly stratified on December 31. Mixed layer depth in December is about 30 feet; however, it would be greatly influenced by severe cold weather, mixing events, and the outflow and temperature of Watana.

The maximum Devil Canyon reservoir surface temperature of 8.8°C occurred on August 28. The minimum surface temperature of 2.4°C occurred at the end of the simulation period (December 31, 1981). No ice formation was observed for the simulation of Devil Canyon.

(b) Outflow Temperature

Devil Canyon outflow temperatures, like Watana, are assumed to follow the inflow temperature as close as possible. The two-level intake structure at Devil Canyon provides some flexibility but not as much as at Watana. This problem, however, is not acute, since Devil Canyon operation provides a more stable water surface level. Maximum outflow temperatures occur in late July to mid-August and are about 8°C. Temperatures in June fluctuate because of the tendency for mixing and deepening of the thermocline during this weak stratification period. Outflow temperatures for June to September are given in Figure 8.42 and for October to December in Figure 8.43.

For this simulation period, large summer runoff resulted in power operation under full reservoirs, and spillage occurred at both reservoirs. This is reflected by the depression of temperatures to about 5°C during the maximum spillage period around August 19 (Figure 8.42). This coldest temperature occurs for only one day, with temperatures rising to about 6°C after three days. As spillage reduces, outflow temperatures increase and eventually return to about 7°C by early September.

Devil Canyon outflow temperatures from mid-September to December 31 exhibit a much more gradual fluctuation in temperatures than those observed at Watana. Temperatures during this period fall from a high of 8°C on September 14 to a low of 3.5°C on December 31 (Figures 8.42 and 8.43).

8.7 - Downstream Temperatures

(a) Watana Operation

The outflow temperatures estimated by DYRESM with 1981 meteorological data and Watana operation have been used to determine the water temperatures in the reach between Watana and Talkeetna. The discharge and outflow temperatures from Watana are input to the HEATSM program to make this estimate. Case C (12,000 cfs minimum flow in August) has been assumed.

Results of the HEATSM analysis are presented in Figures 8.44, 8.45, and 8.46 for the period June to December. During June and July, warming of the Watana discharge occurs between the damsite and Talkeetna. For the two days in August, shown in Figure 8.44, the heat balance between the water and atmosphere results in no heating or cooling, and temperatures at Talkeetna are equal to the Watana outflow temperatures.

In September, the heat balance in the reach becomes negative, resulting in cooling, and Talkeetna temperatures are below those of the outflows at Watana. This cooling continues throughout the winter months. Because of the gradual reduction in outflow temperature in September and October, the downstream temperatures exhibit a similar trend, which is clearly demonstrated by the upstream movement of the 0°C front with time (Figure 8.46). Coincident with stable outflow temperatures is the establishment of a stable 0°C water temperature at river mile (RM) 150 (Portage Creek). Hence, this would be the probable upstream limit of ice generation. Table 8.6 summarizes the temperature variation for locations at Watana dam, Sherman, and Talkeetna for June through December.

Because of the sensitivity of ice-cover formation and growth to the mitigation plan selected and to uncertainties associated with climatic conditions, sensitivity analyses have been performed to determine downstream temperature conditions under two other outflow temperature conditions. The first assumes a warm period with selective withdrawal giving 4°C water continuously from October through April. This scenario would result in water temperatures being greater than 0°C above RM 131 (near Sherman) at all times under the assumed average weather conditions. Results are shown in Figures 8.47 and 8.48.

The second scenario assumes a linear reduction from 4°C to 2°C between November 1 and mid-January. This case also shows a trend of upstream movement of the 0°C front. The maximum movement is to RM 150 (Portage Creek). Results are shown in Figures 8.49 and 8.50.

(b) Watana/Devil Canyon Operation

The temperature regime downstream from Devil Canyon dam is different from existing conditions or conditions under the Watana-only operation. Similar studies, therefore, were made to estimate the temperatures in the reach between Devil Canyon damsite and Talkeetna. Three cases of outflow temperatures were assumed in addition to two meteorological conditions.

The first scenario uses the temperature regime for 1981 meteorological records at Watana and Devil Canyon outflow temperatures given by the reservoir temperature model for Watana/Devil Canyon operation. Results of the HEATSM program are given in Figures 8.51 and 8.52 for June to September and October to December, respectively. Generally, outflow temperatures are warmed with distance downstream during June and July; this warming is about 2°C by Talkeetna. In August, climate and water temperatures are in balance with no significant warming or cooling occurring.

Cooling begins slowly in September with a gradual 1°C reduction between Devil Canyon damsite and Talkeetna on September 15. This accelerates as winter progresses, reaching a maximum cooling in January. On December 31, outflow temperatures of 3.5°C are cooled to about 0.5°C at Talkeetna.

During the spill period in August and early September of 1981, the minimum outflow temperature of 4.6°C observed on August 21 has warmed to 4.7°C at Sherman and to 4.9°C at Talkeetna. Temperatures at Devil Canyon, Sherman, and Talkeetna for the days shown in Figures 8.51 and 8.52 are given in Table 8.7.

To assess the impact of other winter outflow temperatures on downstream temperatures, two scenarios were assumed. The first assumes a constant outflow temperature of 4°C throughout the winter (Figures 8.53 and 8.54) and a linear reduction in outflow temperature from 4°C on November 1 to 2°C on January 15 (Figures 8.55 and 8.56). The first case produces temperatures above 0°C for the entire reach between Devil Canyon dam and Talkeetna until January 15. On January 15, 0°C water is estimated to occur at RM 99, just upstream from Talkeetna. During the latter part of January, less cooling occurs and water temperatures for the reach remain above 0°C.

With reduction in outflow temperatures to 2°C on January 15 and the maintenance of this temperature to April 30, 0°C water is estimated to occur at about RM 119 on January 19 (Figure 8.55). This is the most upstream location for this water temperature and, hence, the probable upstream limit of ice production. The 0°C water front moves downstream to about RM 104 in February and below Talkeetna in March.

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TABLE 8.1: STREAM WATER TEMPERATURE FOR AVERAGE YEAR (°F) - "CASE A" OPERATION

Cross Section	January	February	March	April	May	June	July	August	September	October	November	December
LRX 68	39.0	39.0	39.0	39.0	42.3	44.8	49.6	49.3	45.7	39.7	39.0	39.0
LRX 61	38.8	38.8	39.0	39.0	42.4	44.8	49.6	49.5	45.7	39.7	39.0	38.8
LRX 54	37.9	38.3	38.7	39.2	43.0	45.5	50.2	50.2	45.9	39.6	38.3	38.3
LRX 47	37.4	37.8	38.5	39.4	43.2	46.0	50.4	50.5	46.0	39.6	38.1	37.9
LRX 41	37.2	37.8	38.5	39.4	43.3	46.2	50.5	50.7	46.0	39.6	37.9	37.8
LRX 34	36.7	37.2	38.1	39.6	43.7	46.8	50.9	51.3	46.2	39.4	37.4	37.2
LRX 27	35.8	36.5	37.9	39.7	44.2	47.5	51.3	51.8	46.4	39.4	36.9	36.5
LRX 21	35.1	36.1	37.8	39.9	44.6	48.0	51.6	52.3	46.6	39.2	36.5	36.0
LRX 15	34.0	35.2	37.4	40.1	45.1	48.9	52.2	53.2	46.8	39.0	35.8	35.1
LRX 9	32.9	34.5	37.0	40.5	45.9	49.8	52.7	54.0	46.9	38.8	35.1	34.3
LRX 3	32.2	34.0	36.7	40.6	46.2	50.5	53.1	54.7	47.1	38.8	34.5	33.6
Discharge Below Devil Canyon (cfs)	10514.0	8883.0	8072.0	7903.0	9344.0	10288.0	9070.0	8665.0	6972.0	7403.0	9425.0	11864.0

TABLE 8.2: STREAM WATER TEMPERATURE FOR WET YEAR (°F) - "CASE A" OPERATION

Cross Section	January	February	March	April	May	June	July	August	September	October	November	December
LRX 68	39.0	39.0	39.0	39.0	42.3	44.8	50.2	49.5	45.1	39.6	39.6	39.0
LRX 61	38.8	38.8	39.0	39.0	42.4	45.0	50.2	49.6	45.1	39.6	39.0	38.8
LRX 54	37.9	38.3	38.7	39.2	42.8	45.5	50.5	50.0	45.3	39.4	38.3	38.3
LRX 47	37.4	37.9	38.5	39.4	43.2	46.0	50.7	50.4	45.5	39.4	37.9	37.9
LRX 41	37.2	37.8	38.5	39.4	43.2	46.2	50.9	50.4	45.5	39.4	37.9	37.8
LRX 34	36.7	37.2	38.1	39.6	43.5	46.6	51.1	50.7	45.5	39.2	37.6	37.2
LRX 27	35.8	36.7	37.9	39.7	44.1	47.3	51.4	51.3	45.7	39.0	36.9	36.7
LRX 21	35.2	36.1	37.8	39.9	44.4	47.8	51.6	51.6	45.9	39.0	36.5	36.1
LRX 15	34.0	35.4	37.4	40.1	45.0	48.7	52.0	52.2	46.0	38.8	35.8	35.2
LRX 9	33.1	34.7	37.0	40.5	45.5	49.6	52.3	52.9	46.2	38.7	35.1	34.5
LRX 3	32.2	34.2	36.7	40.6	46.0	50.4	52.7	53.2	46.2	38.5	34.7	33.8
Discharge Below Devil Canyon (cfs)	10708.0	9066.0	8004.0	7889.0	10606.0	11052.0	13763.0	14085.0	12783.0	6540.0	9680.0	12436.0

TABLE 8.3: STREAM WATER TEMPERATURE FOR DRY YEAR (°F) - "CASE A" OPERATION

Cross Section	January	February	March	April	May	June	July	August	September	October	November	December
LRX 68	39.0	39.0	39.0	39.0	42.3	44.4	48.9	48.6	45.3	39.7	39.0	39.0
LRX 61	38.8	38.8	39.0	39.0	42.4	44.4	48.9	48.7	45.3	39.7	38.8	38.8
LRX 54	37.8	37.9	38.7	39.4	43.2	45.3	49.5	50.0	45.7	39.6	38.3	38.1
LRX 47	37.0	37.6	38.3	39.6	43.7	45.7	49.8	50.7	45.9	39.4	37.8	37.6
LRX 41	36.9	37.4	38.3	39.6	43.9	45.9	50.0	50.9	45.9	39.4	37.6	37.4
LRX 34	36.1	36.7	38.1	39.7	44.2	46.4	50.4	51.8	46.0	39.4	37.2	36.9
LRX 27	35.1	36.0	37.8	39.9	45.0	47.3	50.9	52.9	46.4	39.2	36.5	36.0
LRX 21	34.3	35.4	37.6	40.1	45.5	47.7	51.3	53.6	46.6	39.0	36.1	35.4
LRX 15	33.1	34.5	37.0	40.5	46.4	48.7	51.8	54.9	46.9	38.8	35.2	34.3
LRX 9	32.0	33.6	36.7	40.6	47.1	49.6	52.3	55.9	47.1	38.7	34.5	33.4
LRX 3	32.0	33.1	36.5	41.0	47.7	50.4	52.9	56.7	47.3	38.7	34.0	32.7
Discharge Below Devil Canyon (cfs)	8353.0	6742.0	6914.0	5842.0	6079.0	10041.0	7988.0	4707.0	4474.0	6914.0	7934.0	9463.0

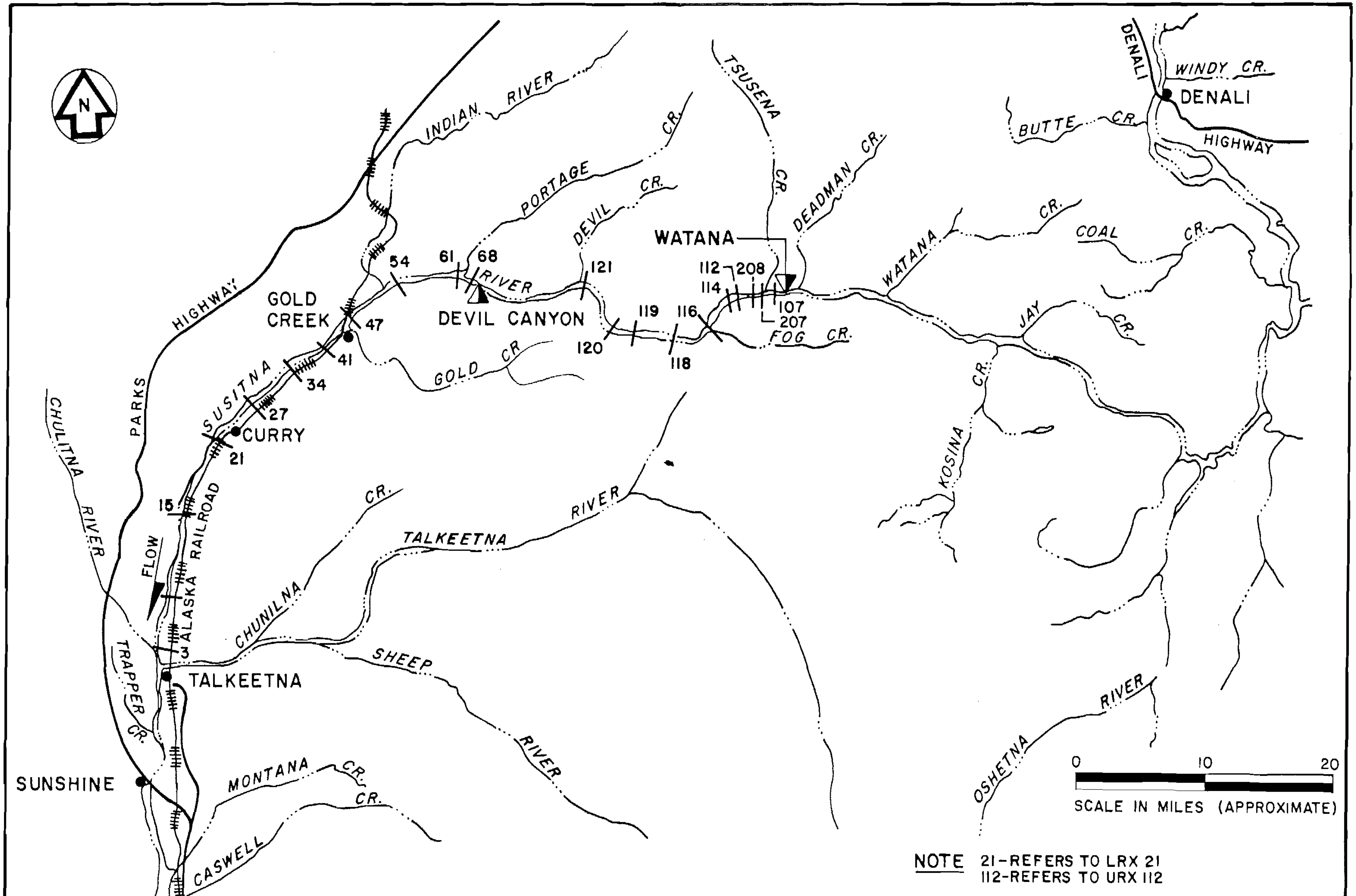
TABLE 8.5: WEDDERBURN NUMBER FOR EKLUTNA LAKE SIMULATION (RUN 1070)

DAY	DENSITY (kg/m^3) CNS	CO	(M)	U* M/S x 10^{-3}	W
Aug 25	999.348	999.958	2.64	0.635	10.6
Sept 1	999.955	999.955	4.51	0.954	10.2
Sept 9	999.645	999.953	5.99	2.098	2.5
Sept 15	999.785	999.952	12.84	8.932	0.3
Sept 21	999.856	999.951	16.40	4.699	1.2
Oct 1	999.909	999.951	22.95	0.992	22.5
Oct 7	999.937	999.952	30.24	1.383	7.2
Oct 14	999.955	999.951	50.01	1.675	-3.5[1]

Note: 1. Lake overturns.

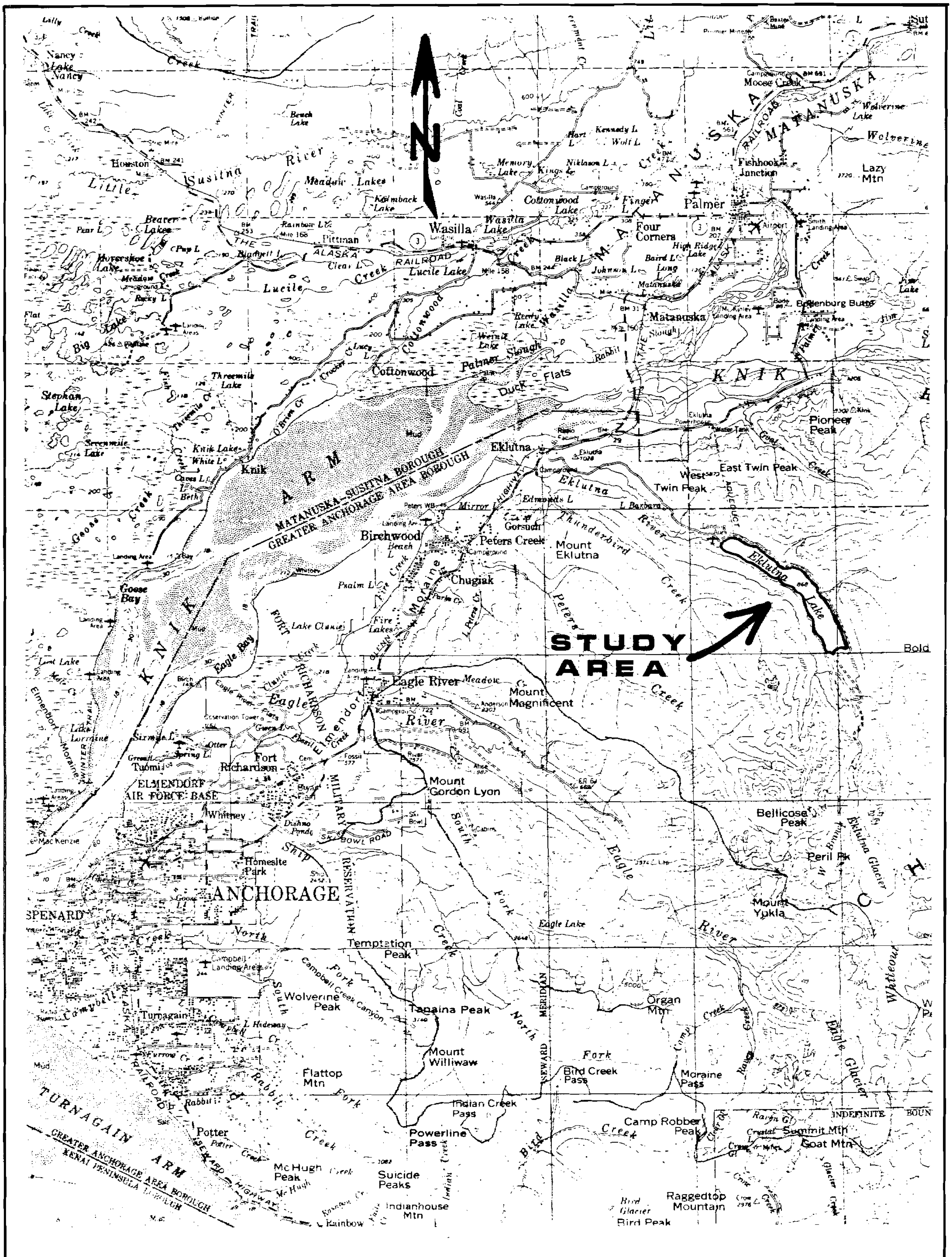
TABLE 8.7: DOWNSTREAM WATER TEMPERATURES (°C)
WATANA/DEVIL CANYON OPERATION

DATE	LOCATION		
	Devil Canyon Dam	Sherman	Talkeetna
June 15	5.0	5.6	6.8
30	5.1	5.7	6.6
July 15	7.3	8.0	9.1
31	7.7	8.0	8.7
Aug 15	7.8	7.8	7.8
31	6.5	6.5	6.7
Sept 15	8.1	8.0	7.7
30	6.9	6.5	5.7
Oct 15	6.8	6.2	5.2
31	6.2	5.3	3.7
Nov 15	5.3	4.4	2.5
30	4.5	3.4	1.4
Dec 15	3.9	2.8	0.8
31	3.4	2.5	0.6



MAP SHOWING RIVER CROSS SECTIONS

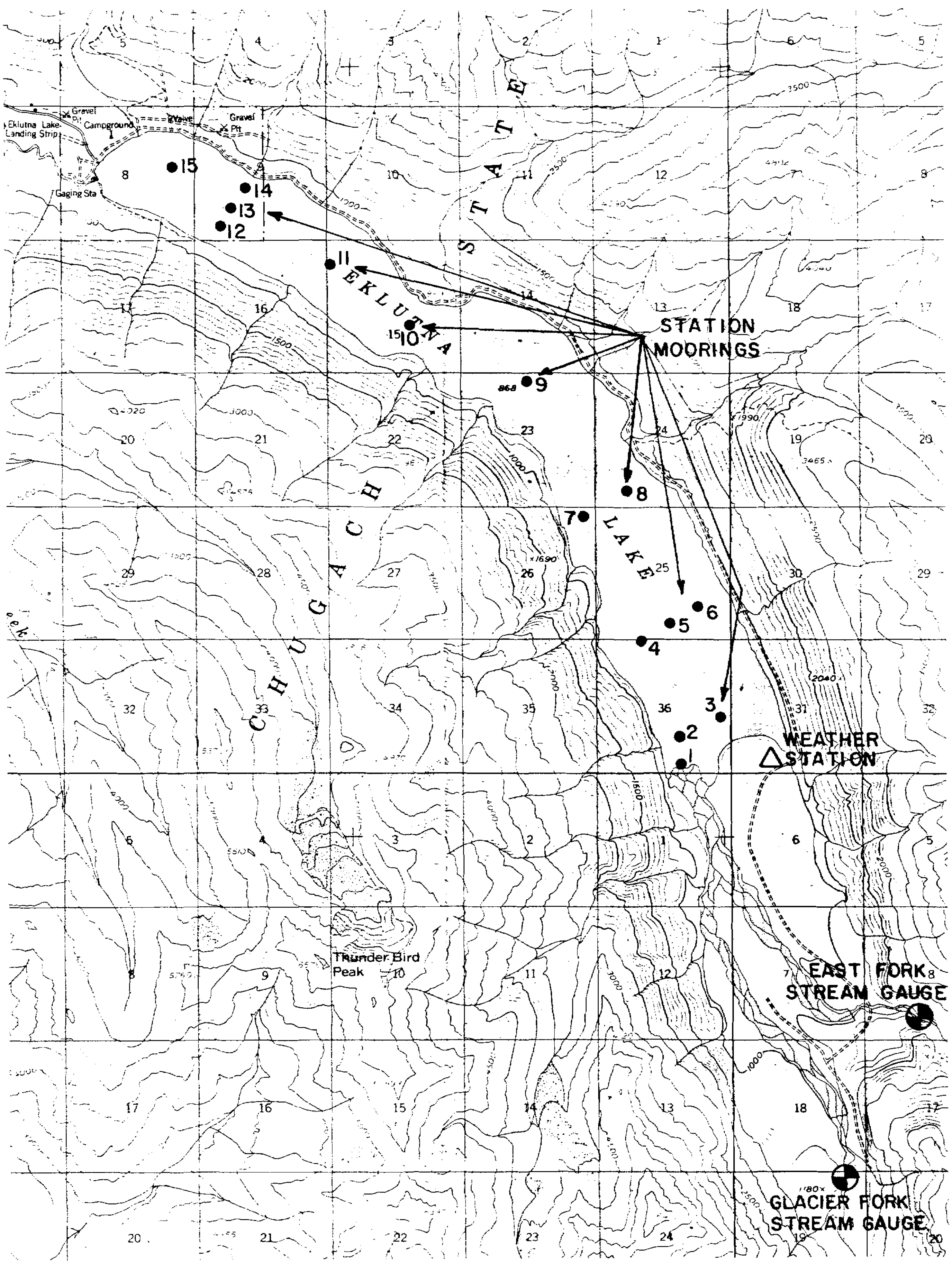
FIGURE 8.1



EKLUTNA LAKE LOCATION MAP

SOURCE: R&M CONSULTANTS INC.

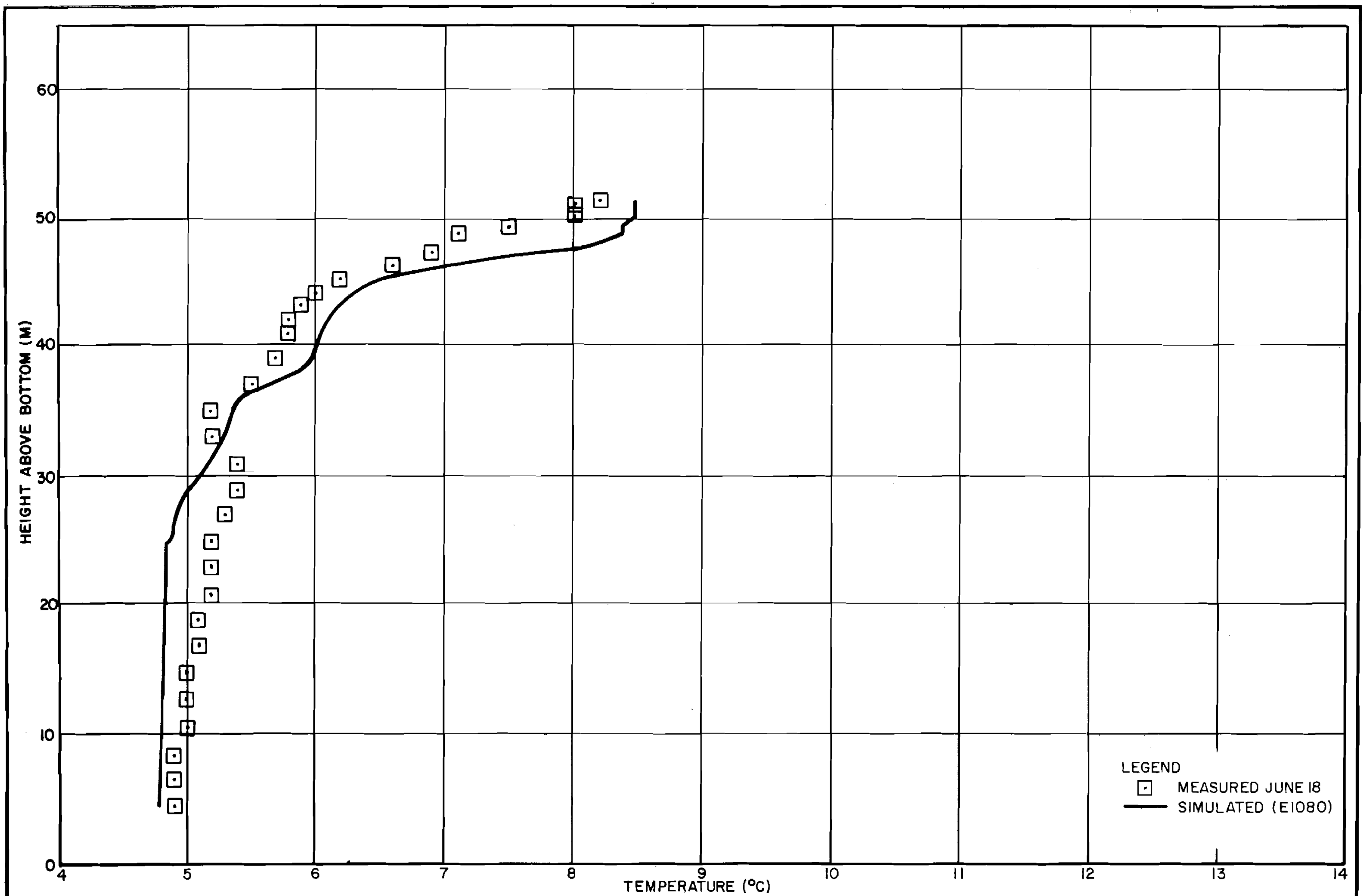
FIGURE 8.2



EKLUTNA LAKE STATION LOCATIONS

SOURCE: R & M CONSULTANTS INC.

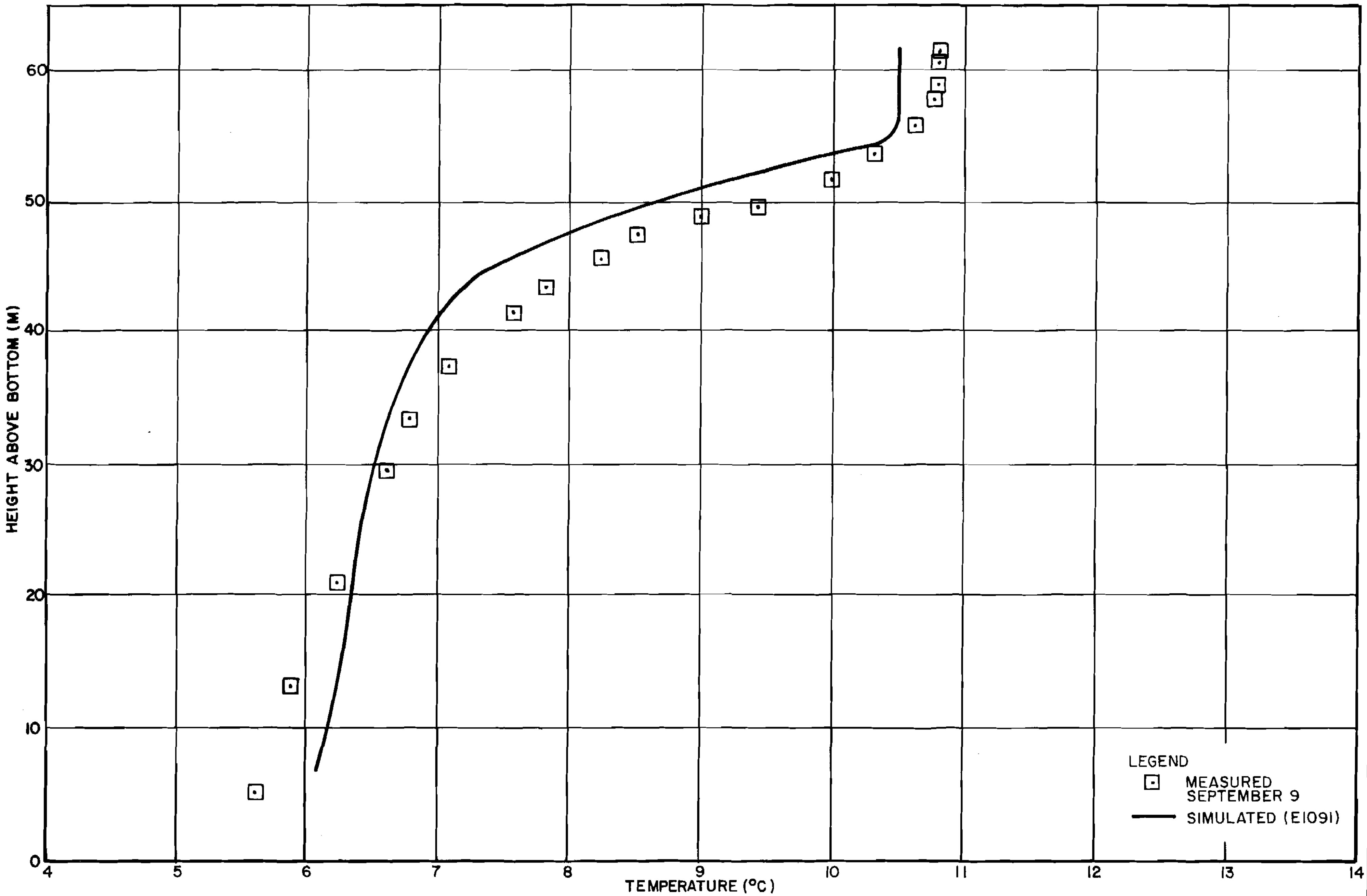
FIGURE 8.3



NOTE: E1080 REFERS TO
RUN CODE

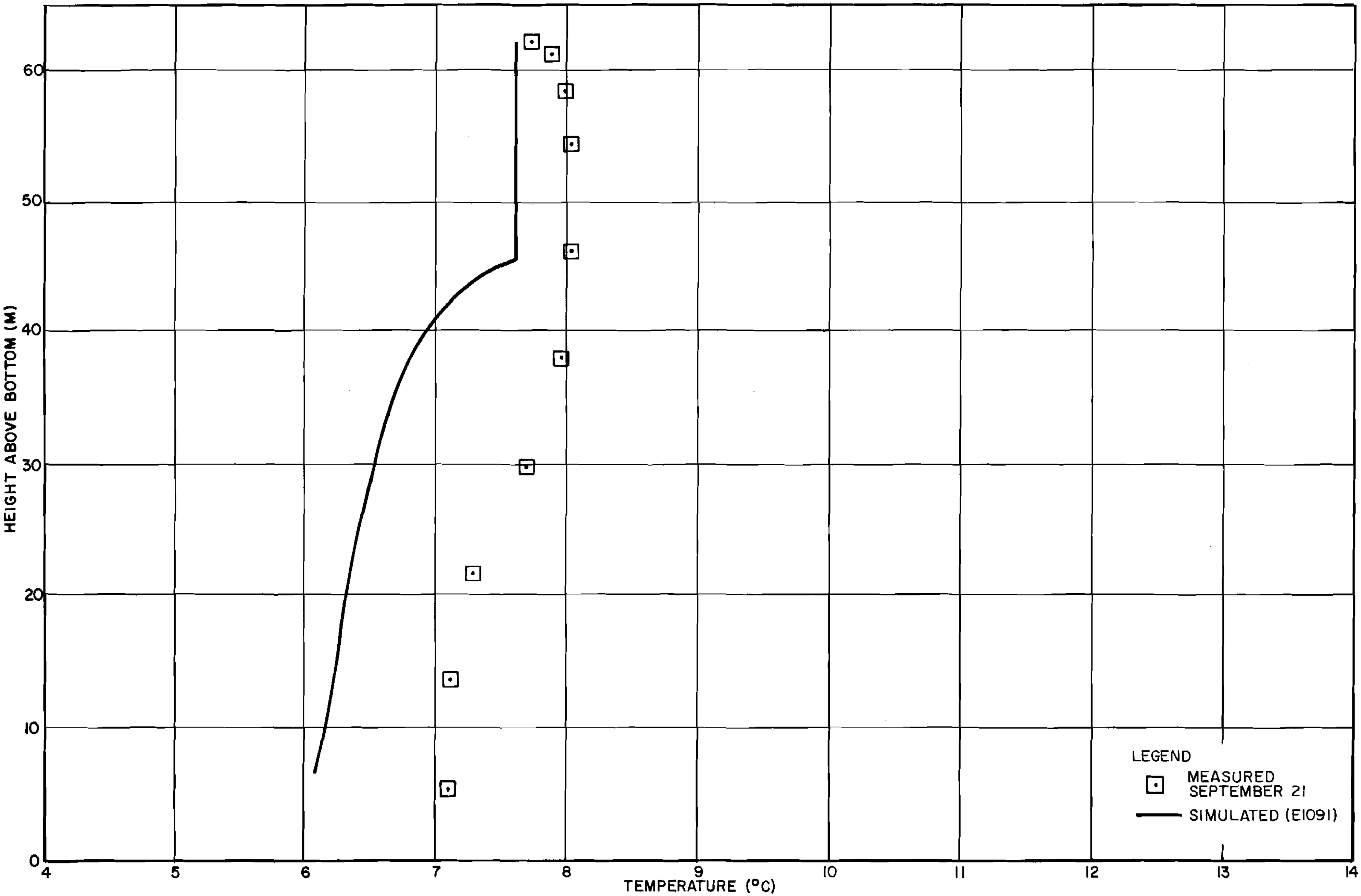
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.4



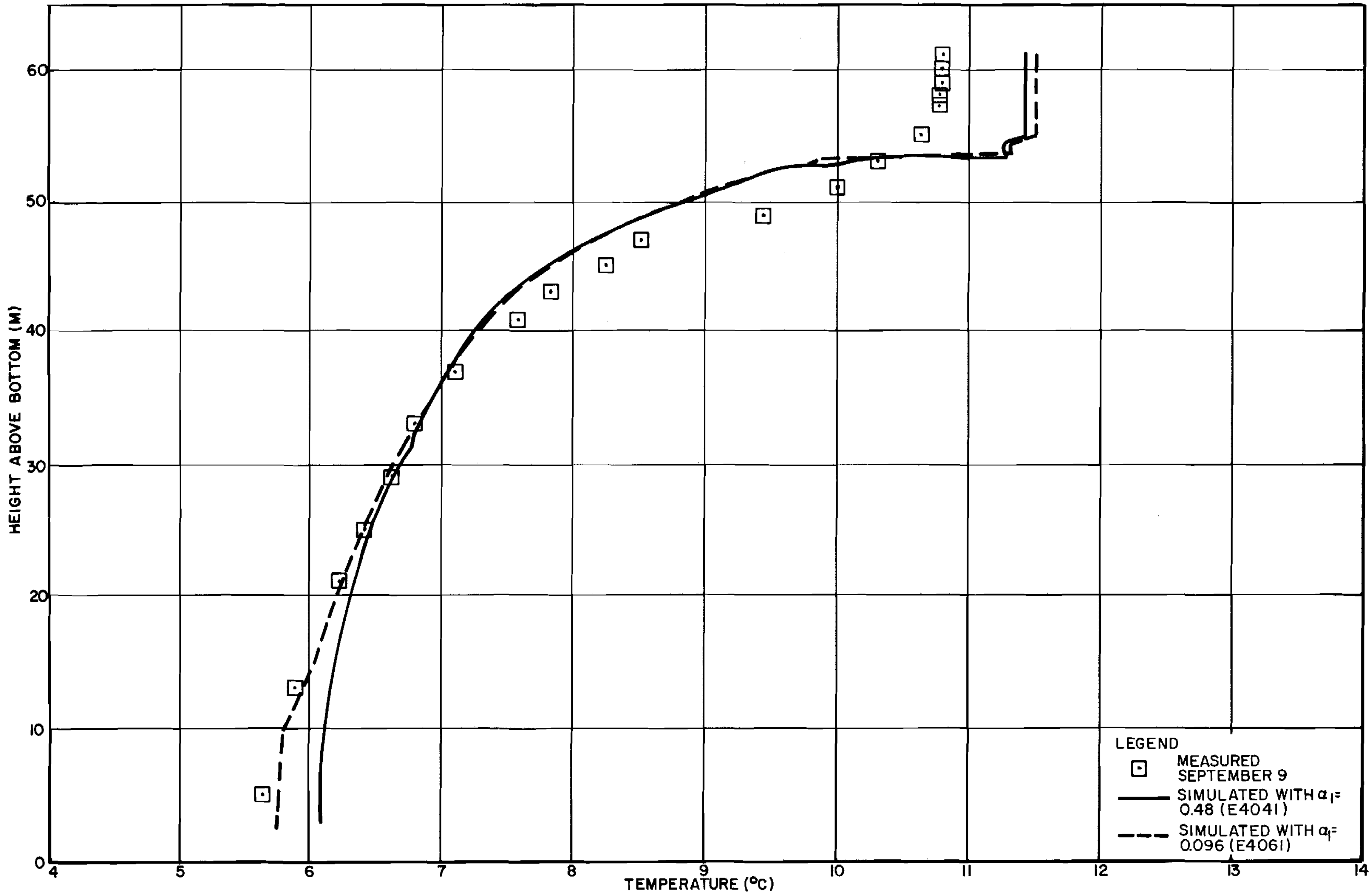
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.5



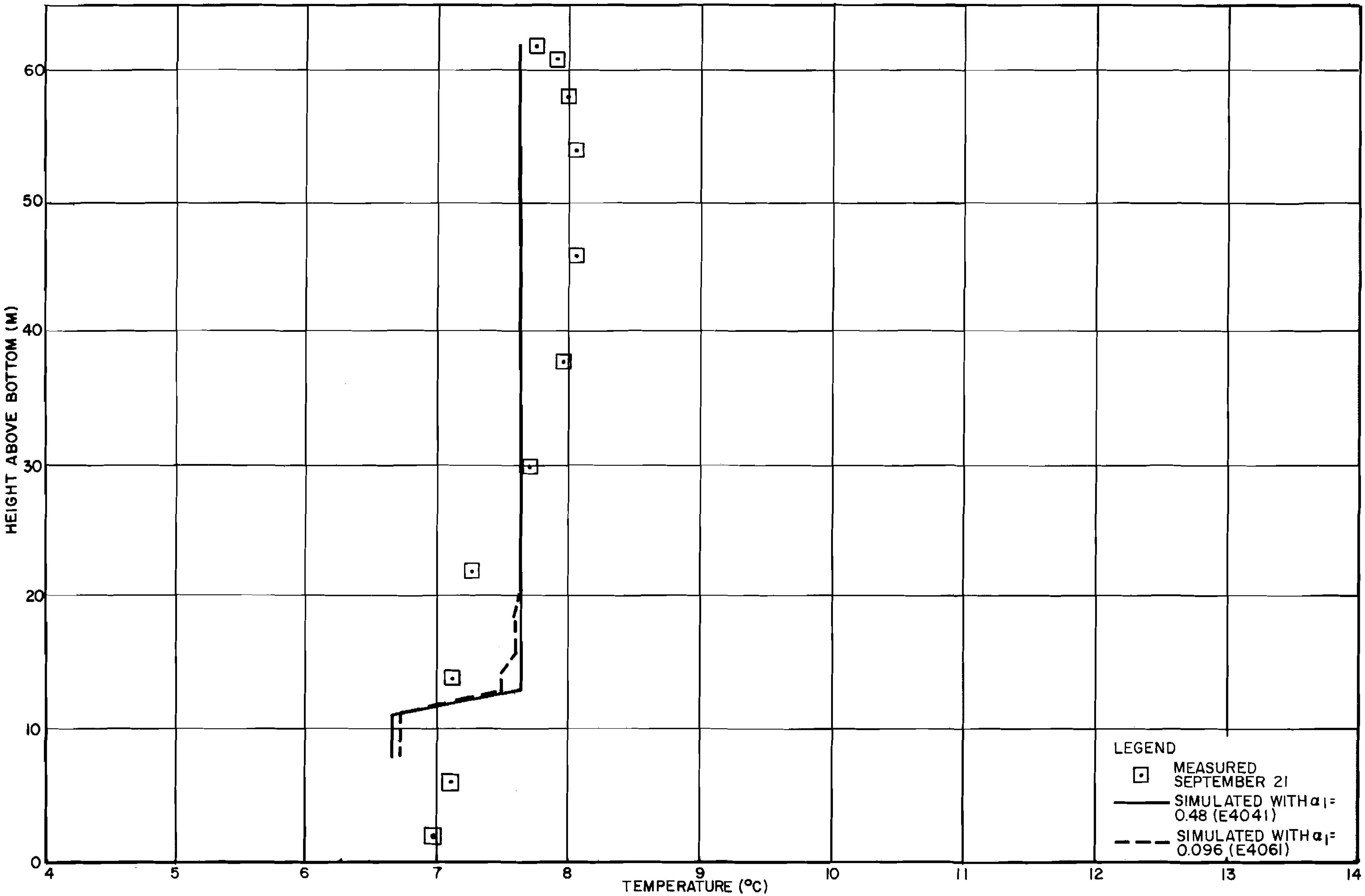
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.6



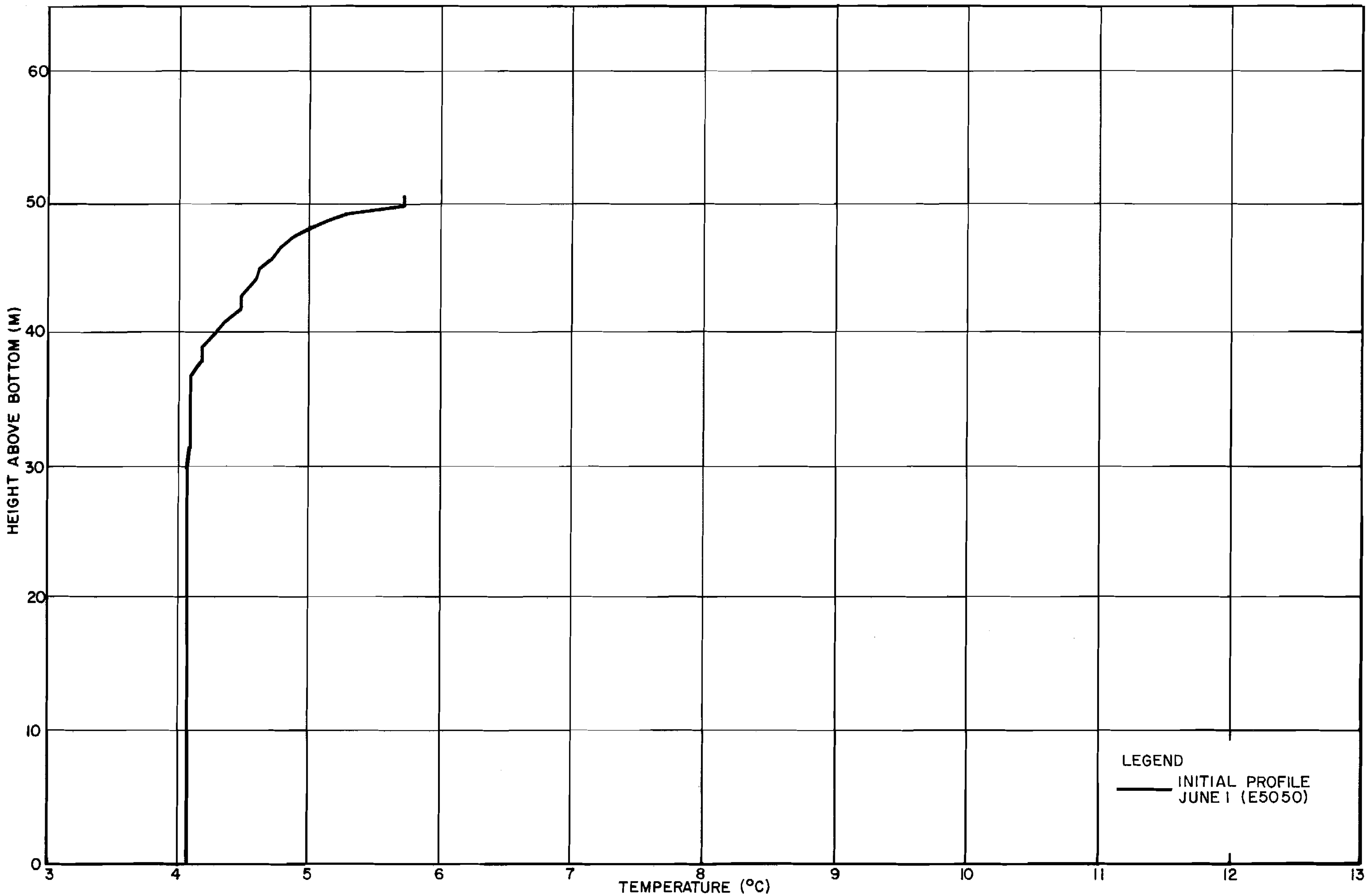
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.7



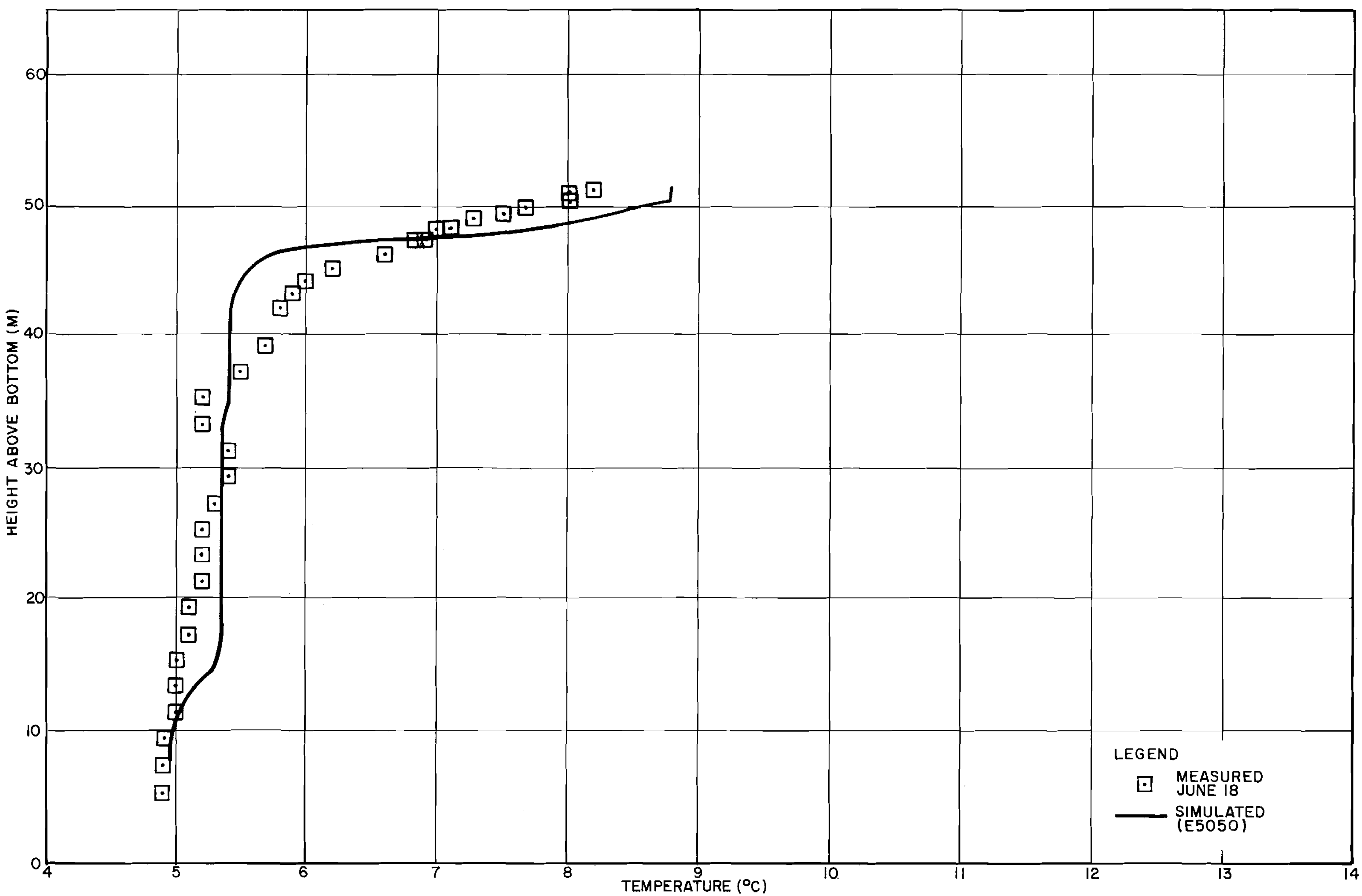
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.8



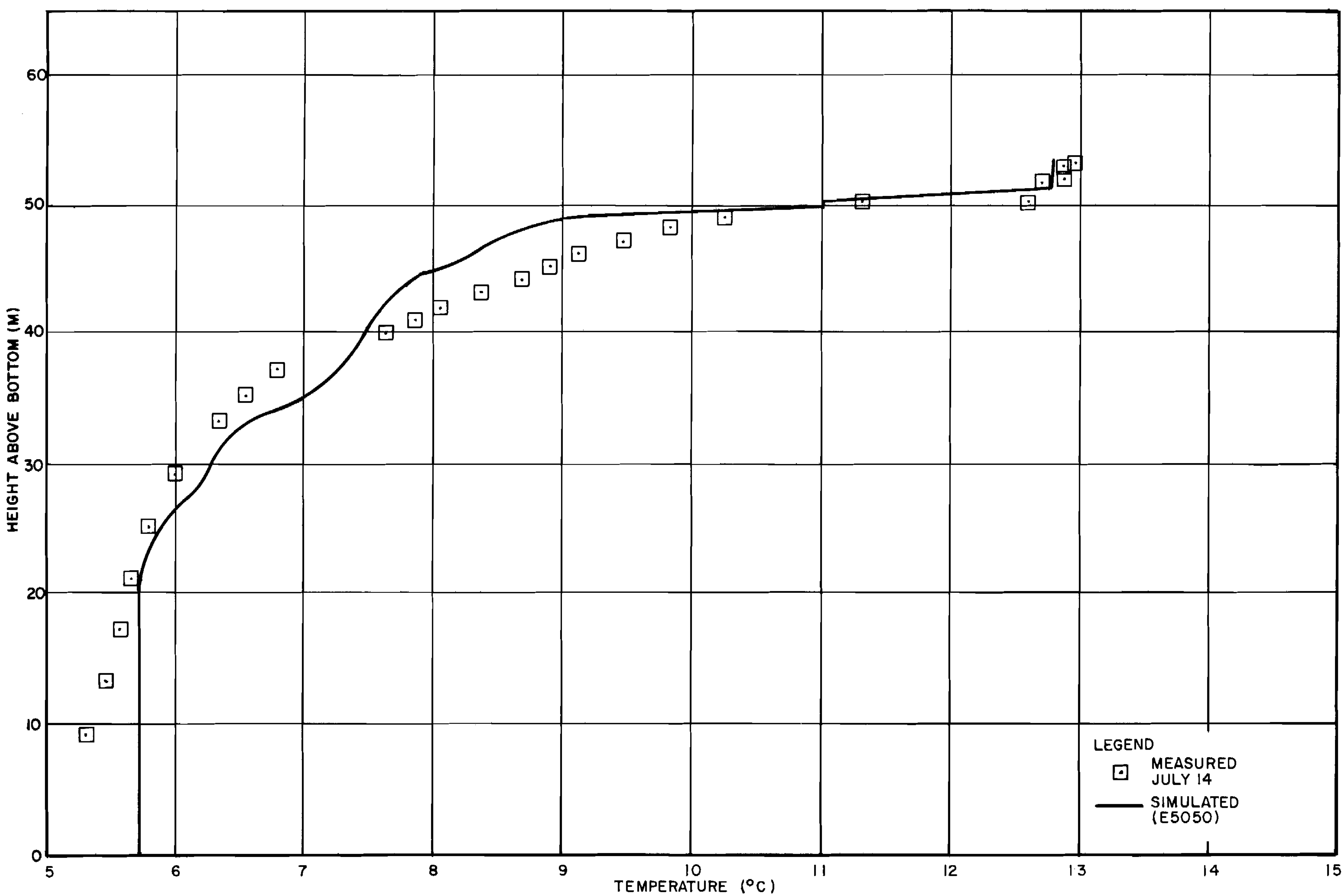
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.9



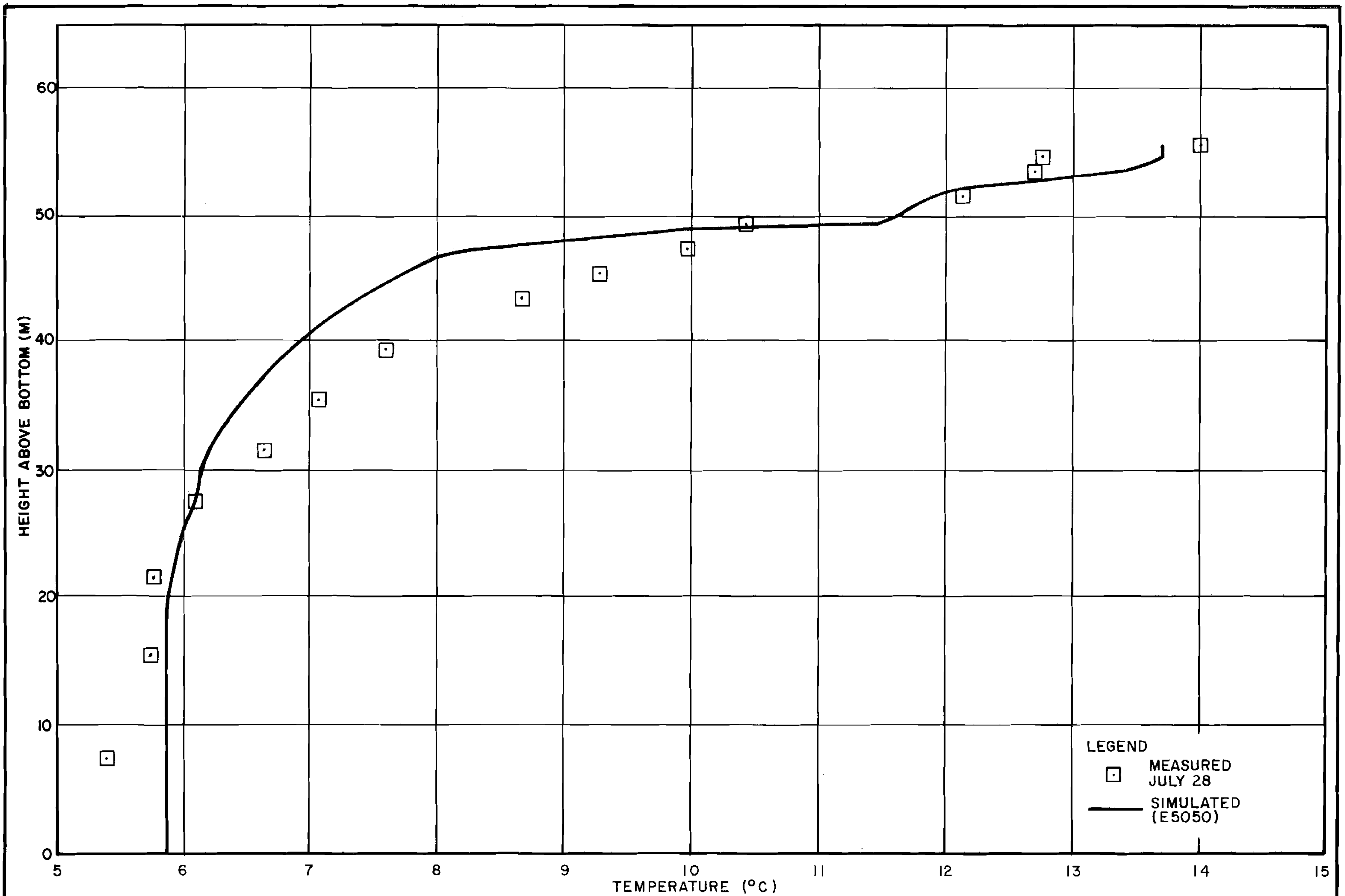
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.10



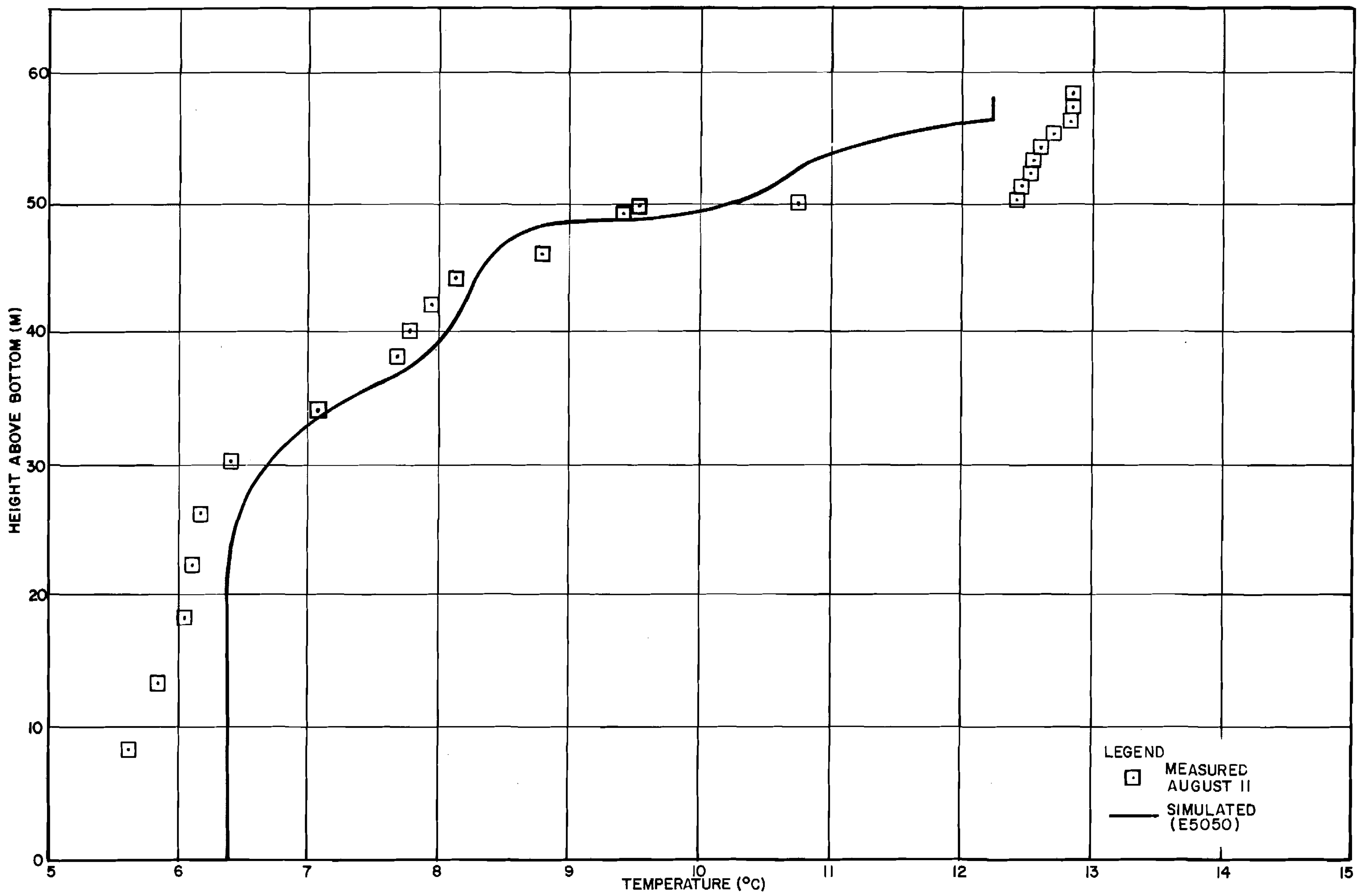
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.11



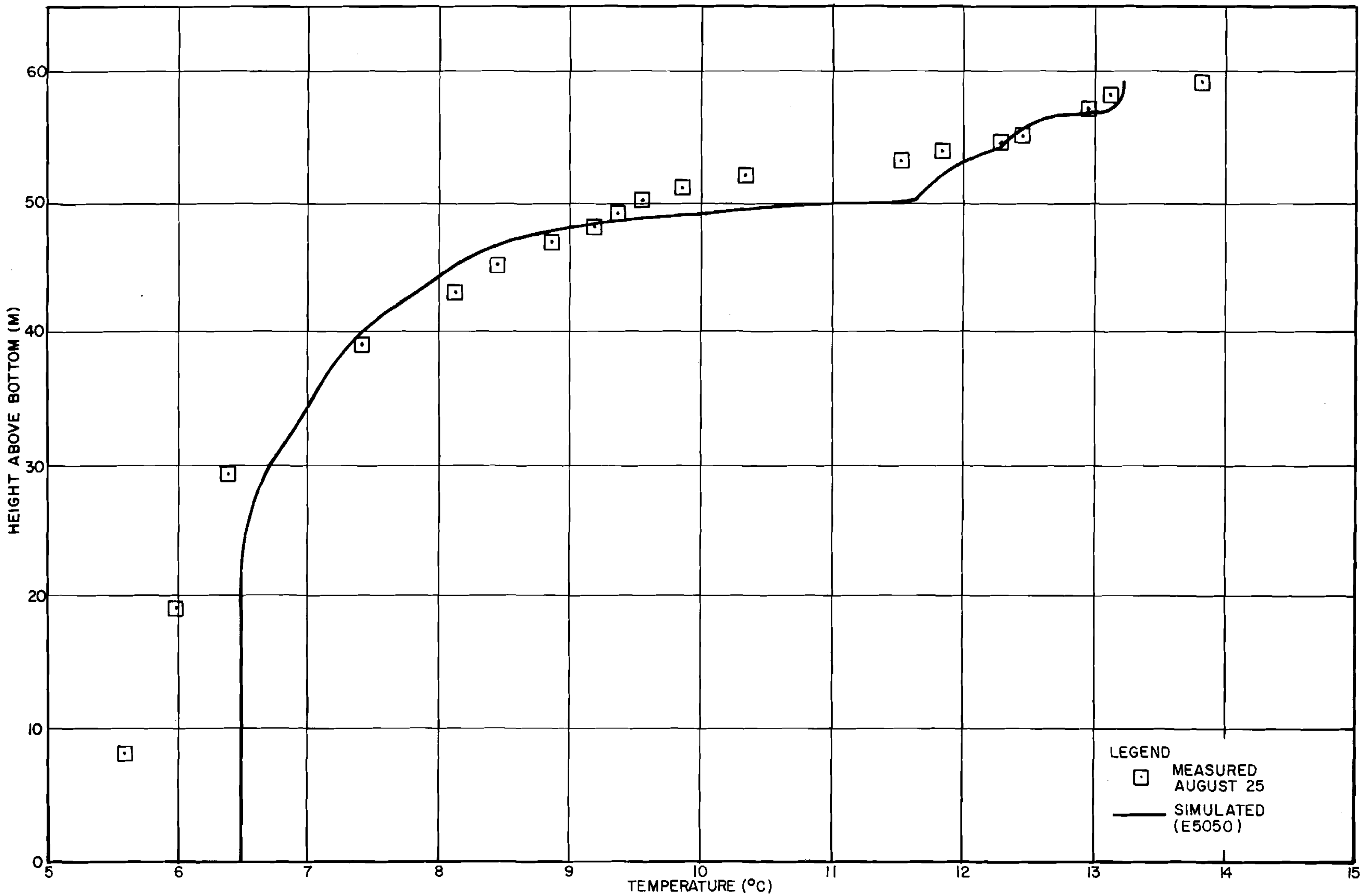
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.12



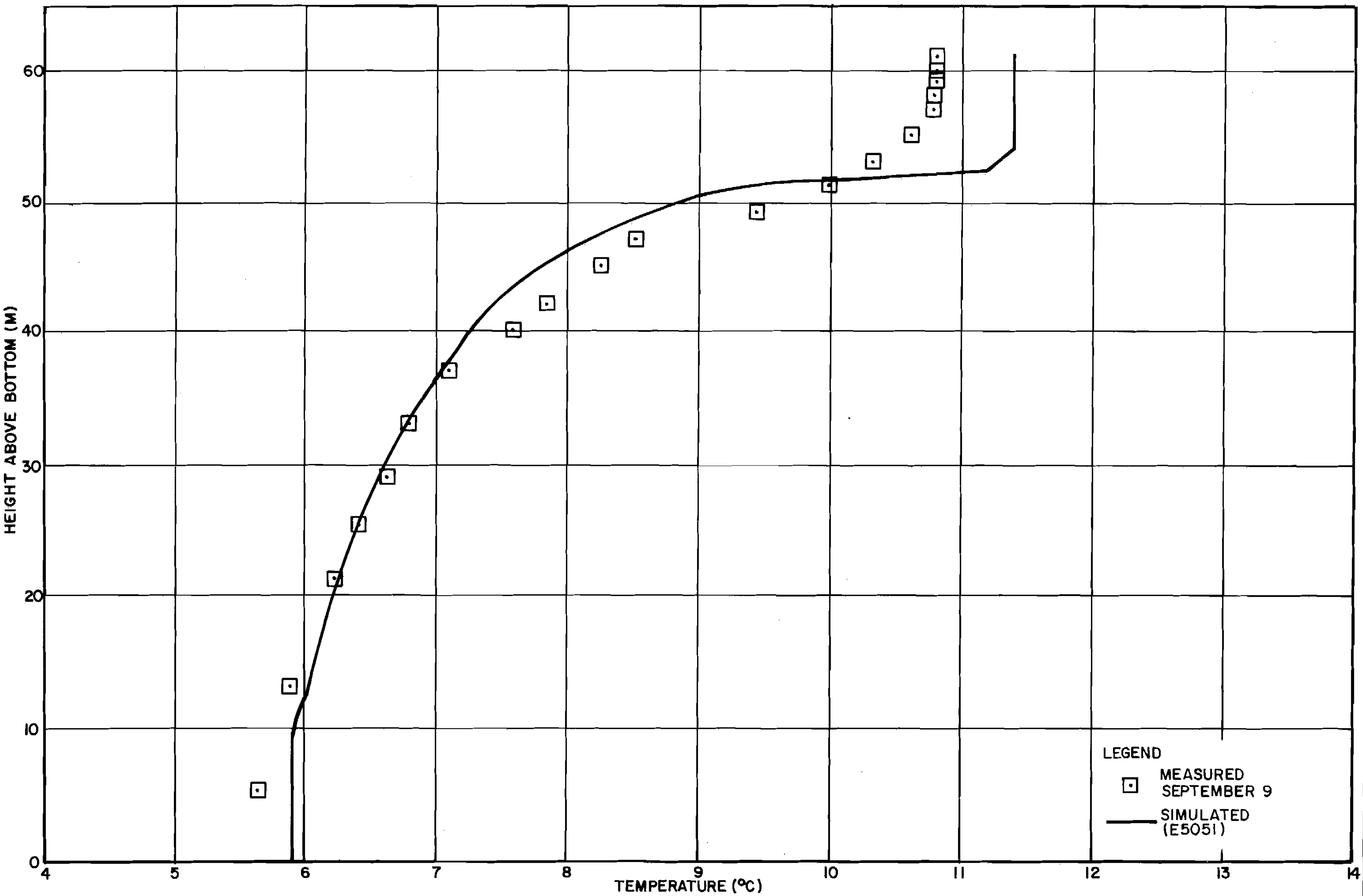
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.13



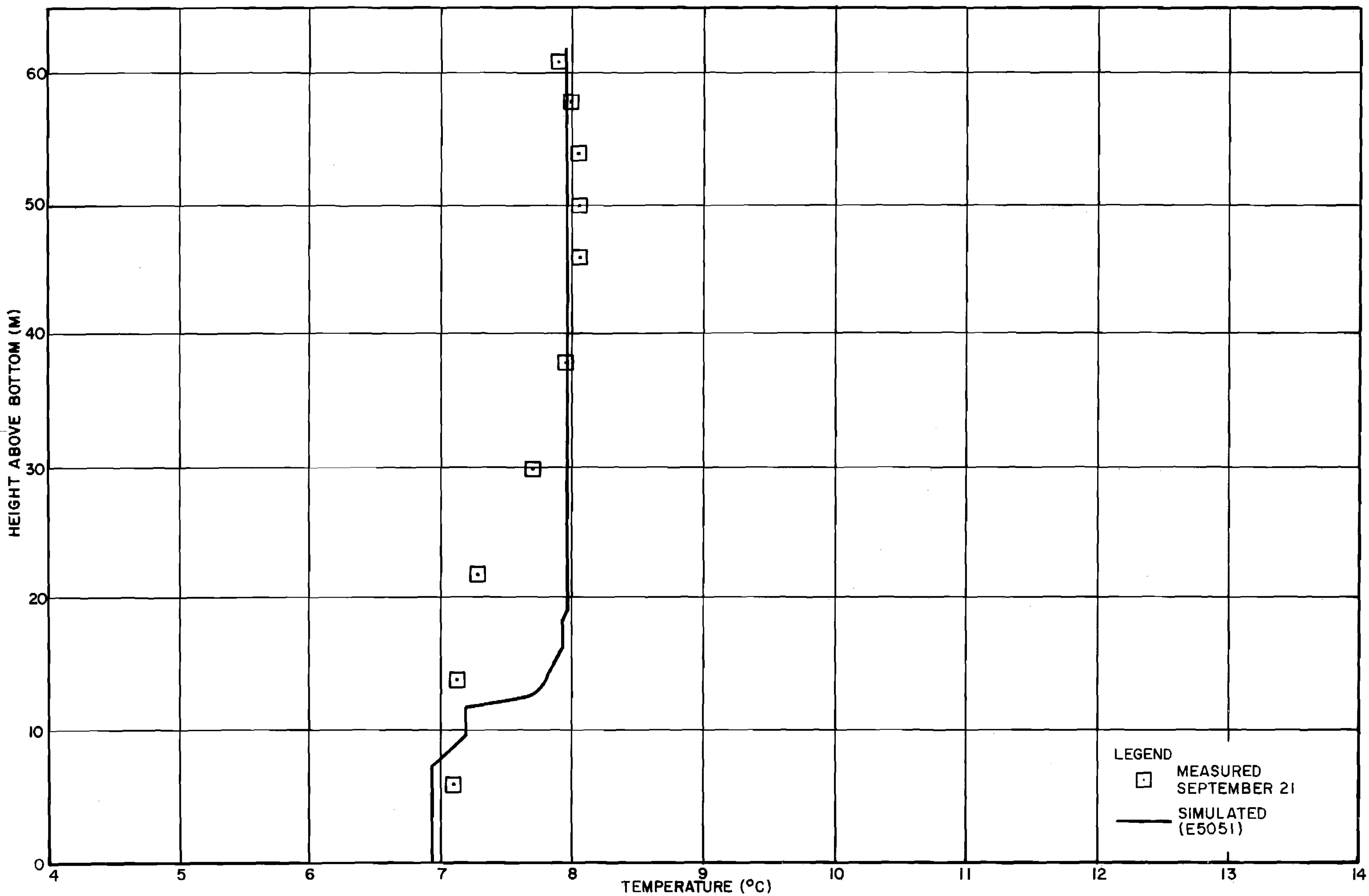
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.14



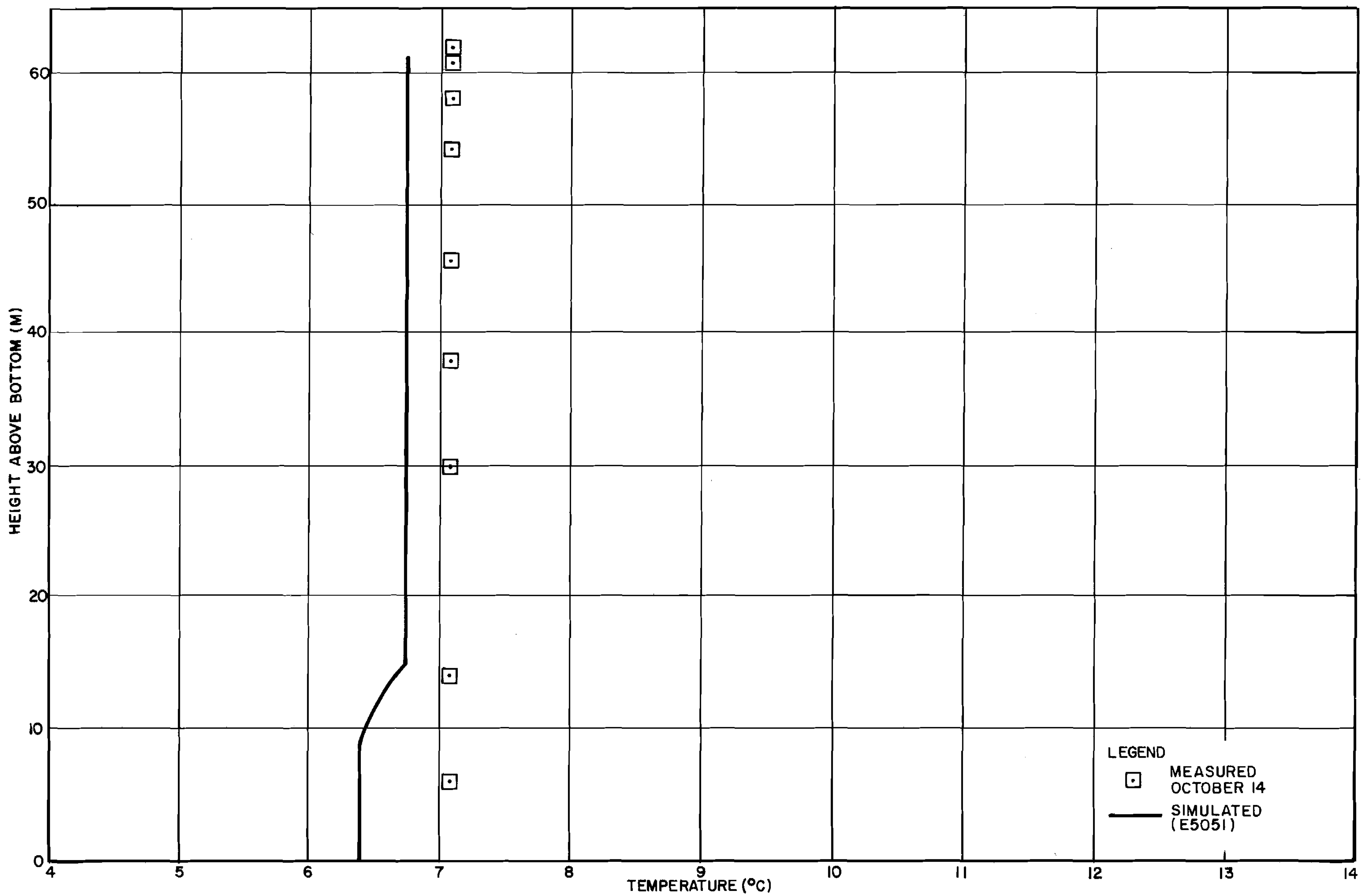
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.15



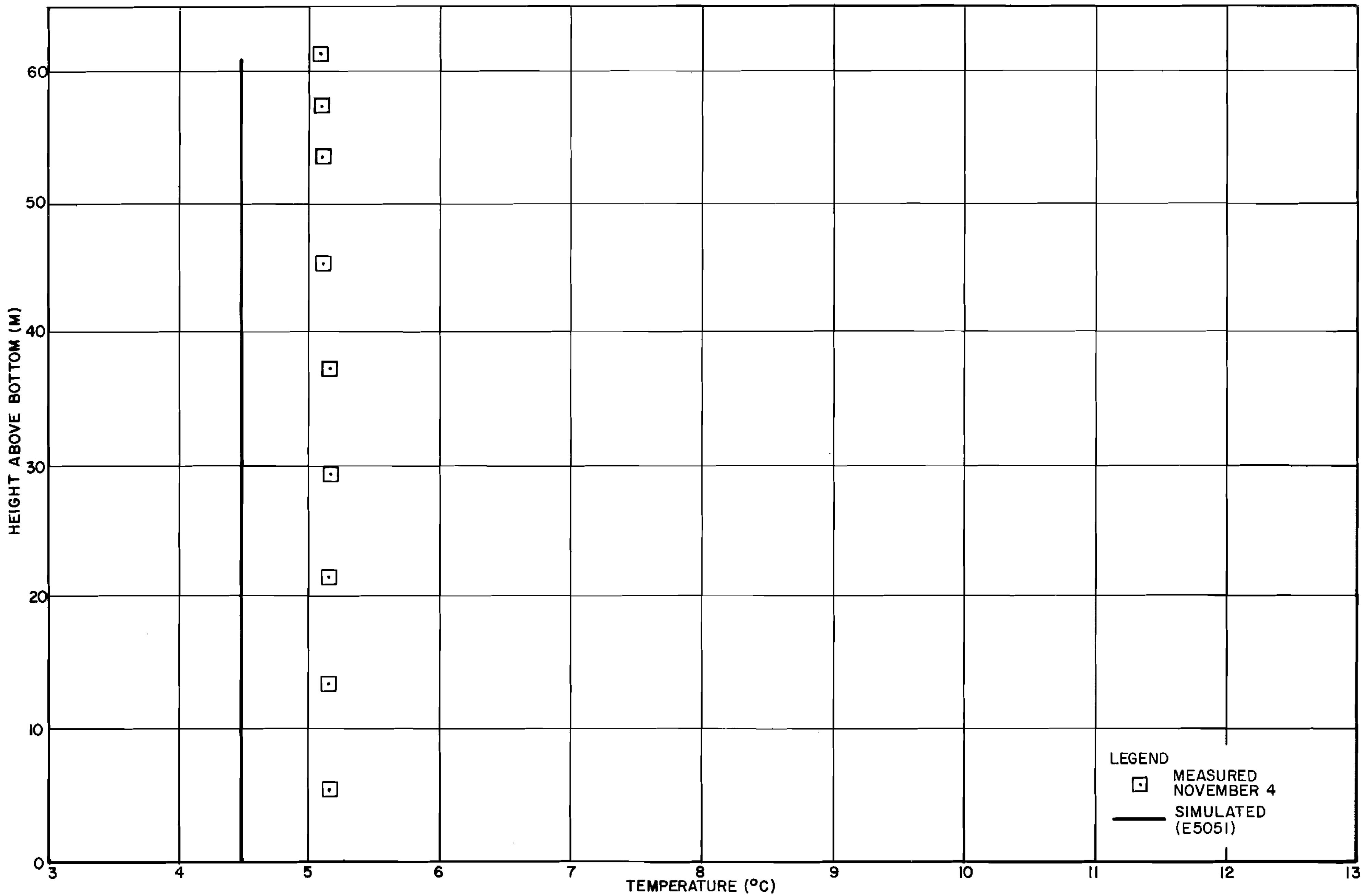
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.16



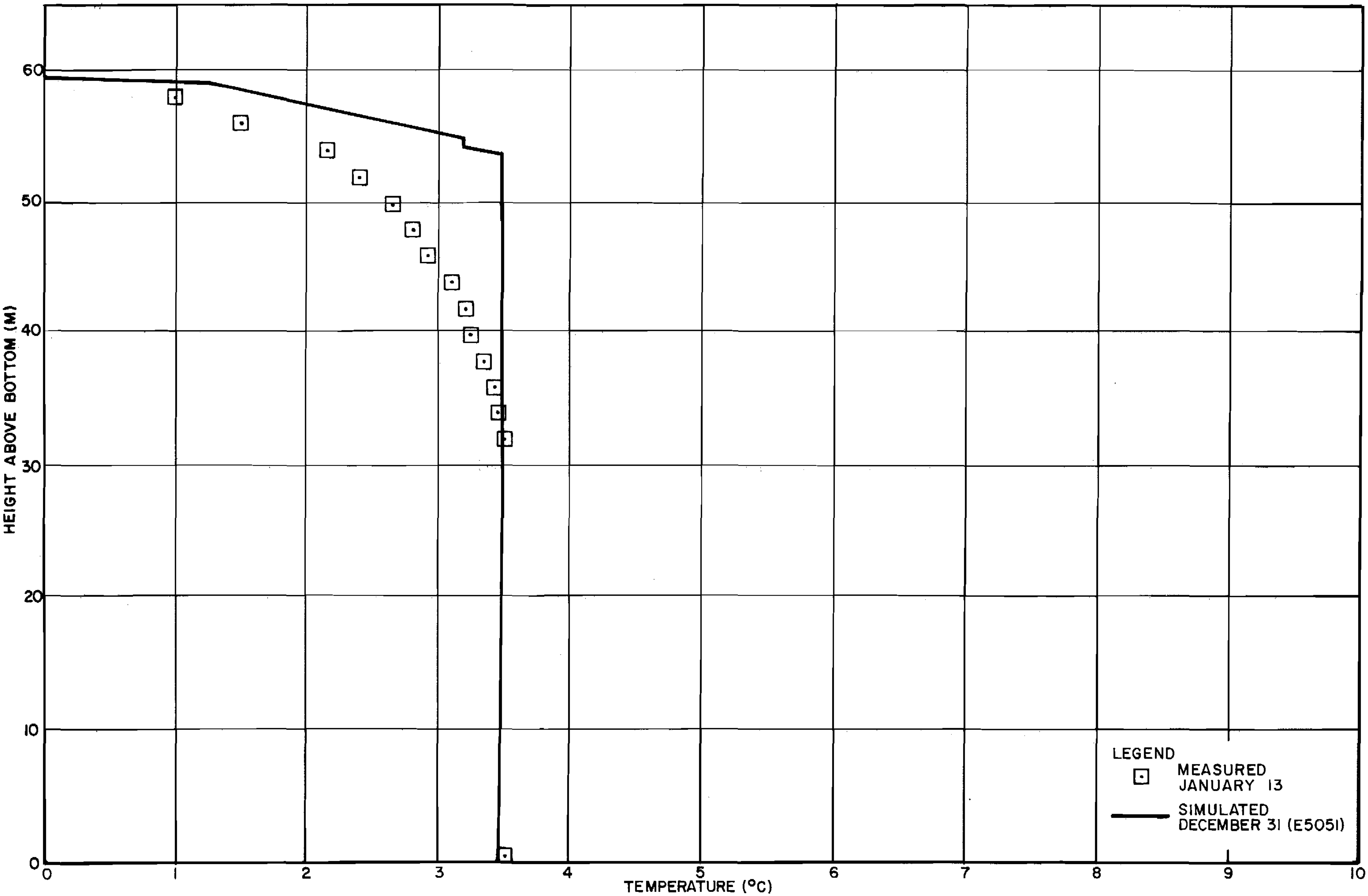
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.17



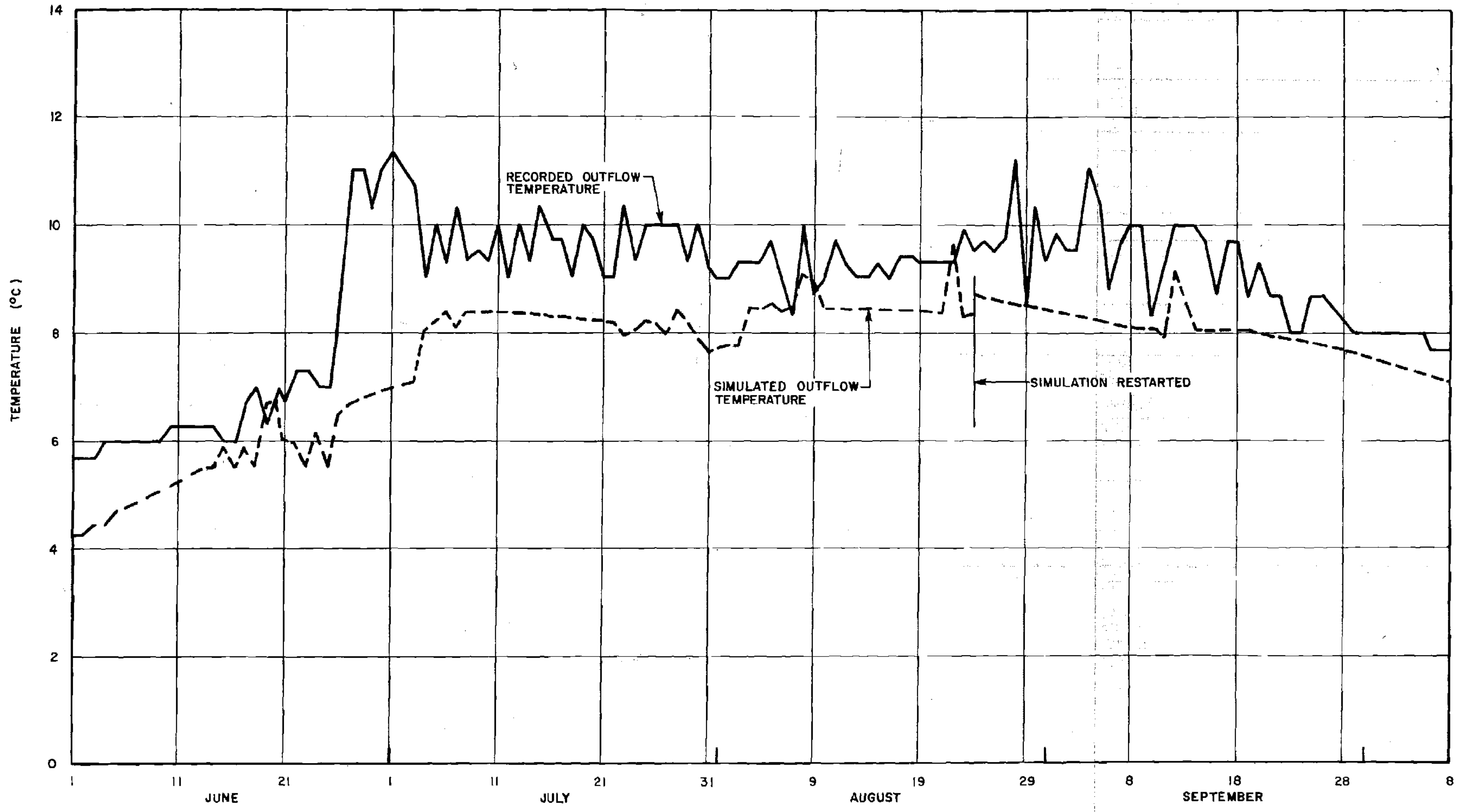
EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.18



EKLUTNA LAKE TEMPERATURE PROFILES

FIGURE 8.19



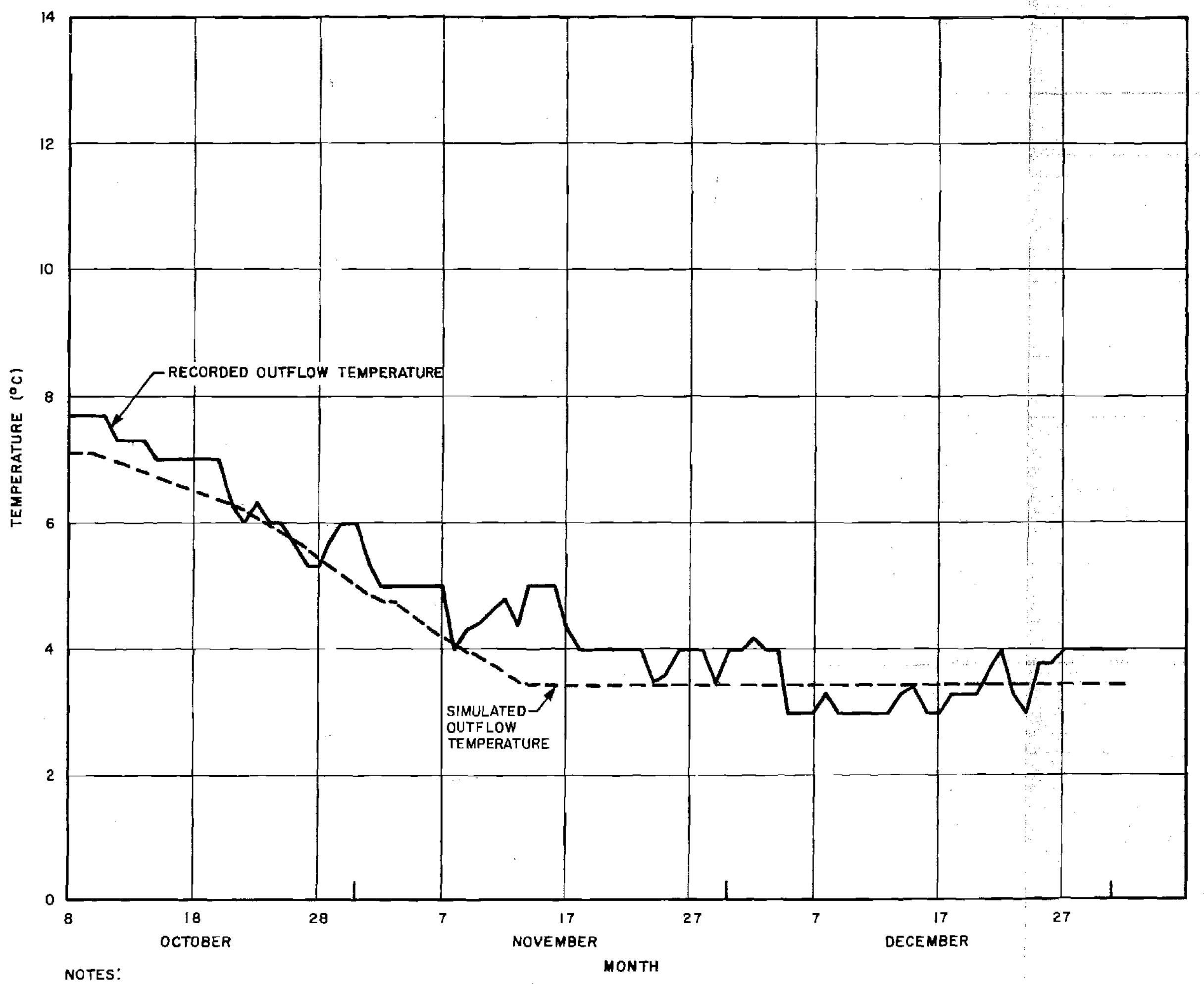
NOTES:

1) TIME SCALE IS IN INCREMENTS OF 10 DAYS.

2) BASED ON 1982 DATA.

EKLUTNA LAKE
RESERVOIR TEMPERATURE SIMULATION
JUN TO SEP

FIGURE 8.20

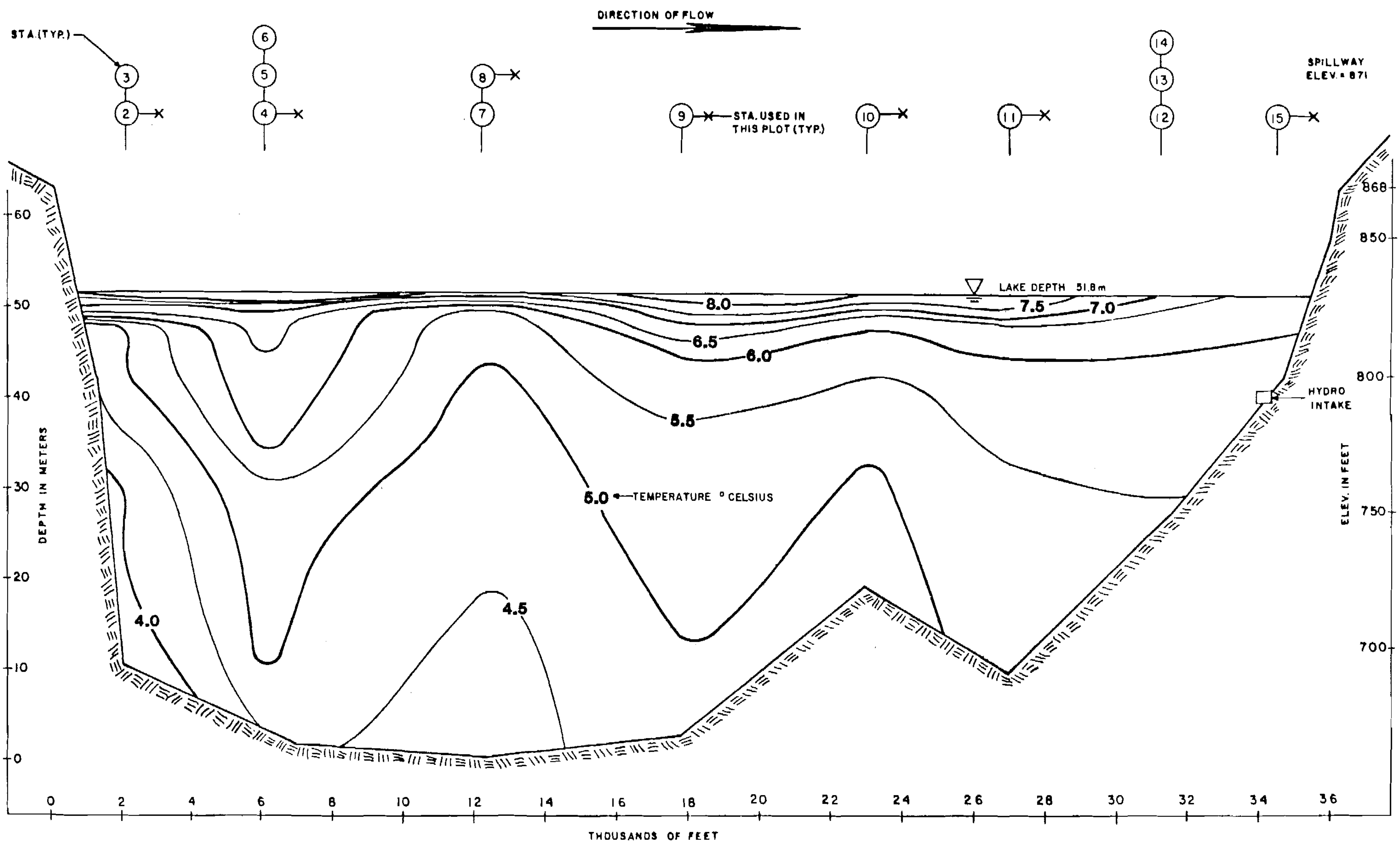


NOTES:

1) TIME SCALE IS IN INCREMENTS OF 10 DAYS.
2) BASED ON 1982 DATA.

EKLUTNA LAKE
RESERVOIR TEMPERATURE SIMULATION
OCT TO DEC

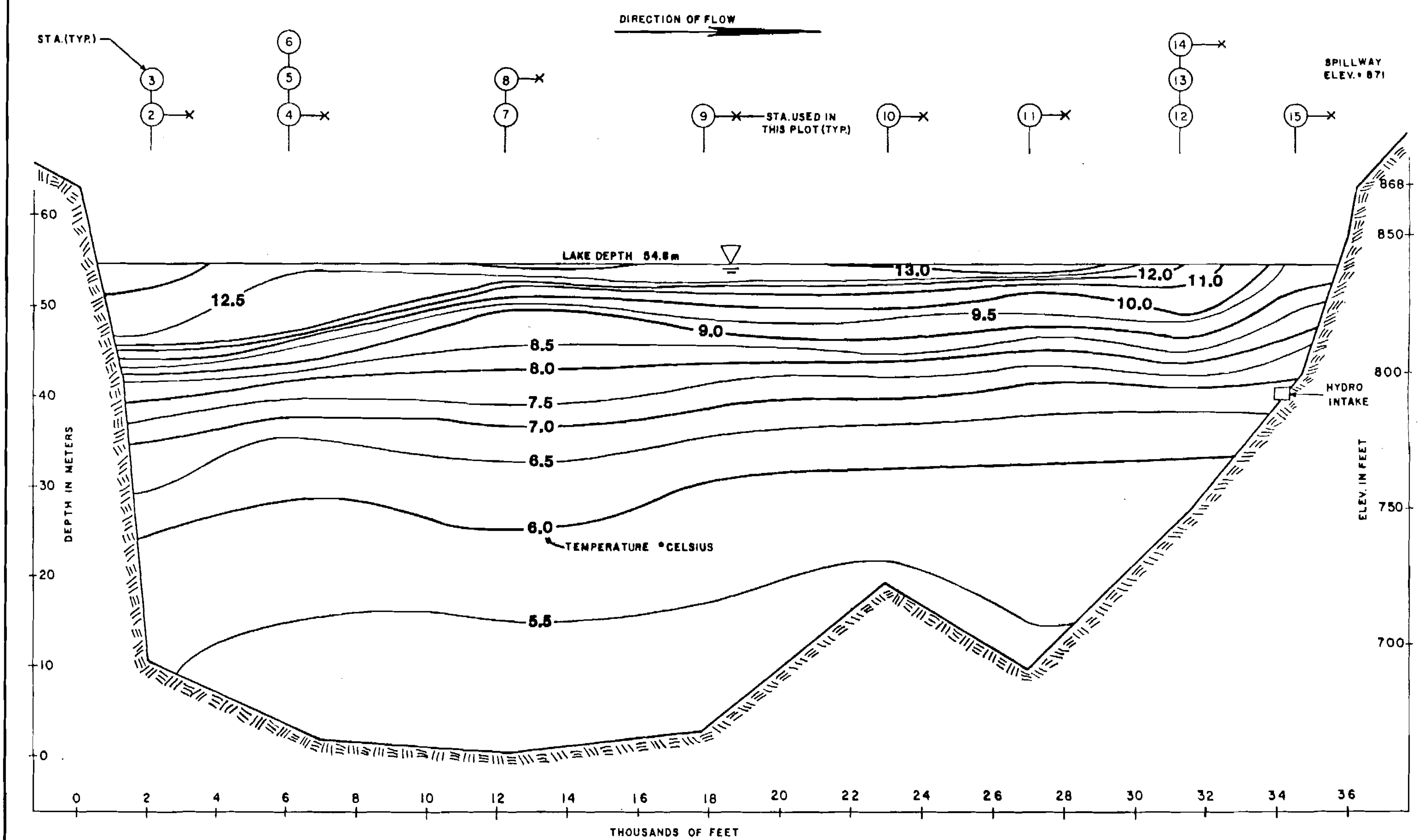
FIGURE 8.21



SOURCE R & M CONSULTANTS INC.

EKLUTNA LAKE PROFILE
TEMPERATURE ISOPLETHS FOR JUNE 17 & 18

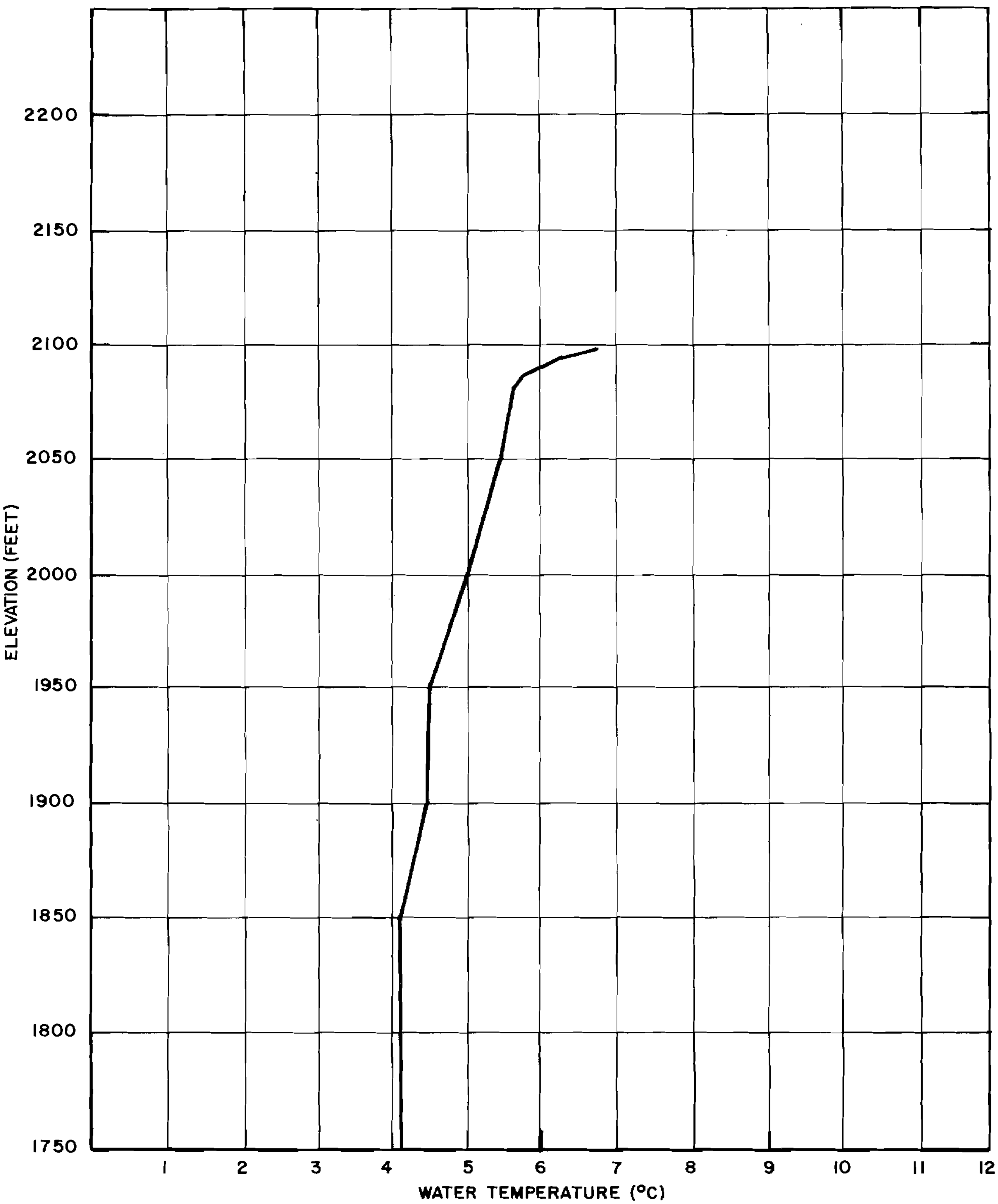
FIGURE 8.22



EKLUTNA LAKE PROFILE
TEMPERATURE ISOPLETHS FOR JULY 14

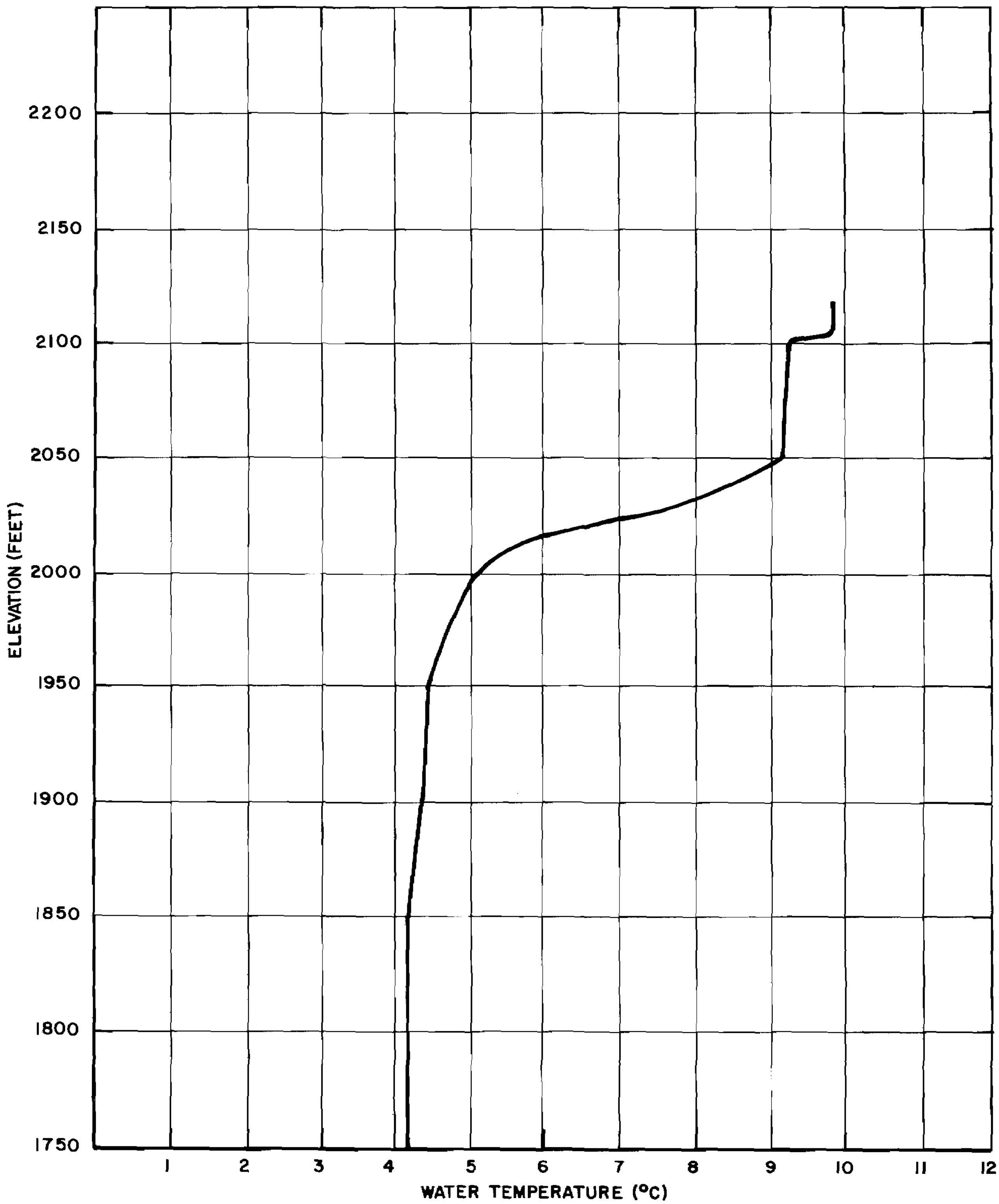
SOURCE R&M CONSULTANTS INC.

FIGURE 8.23



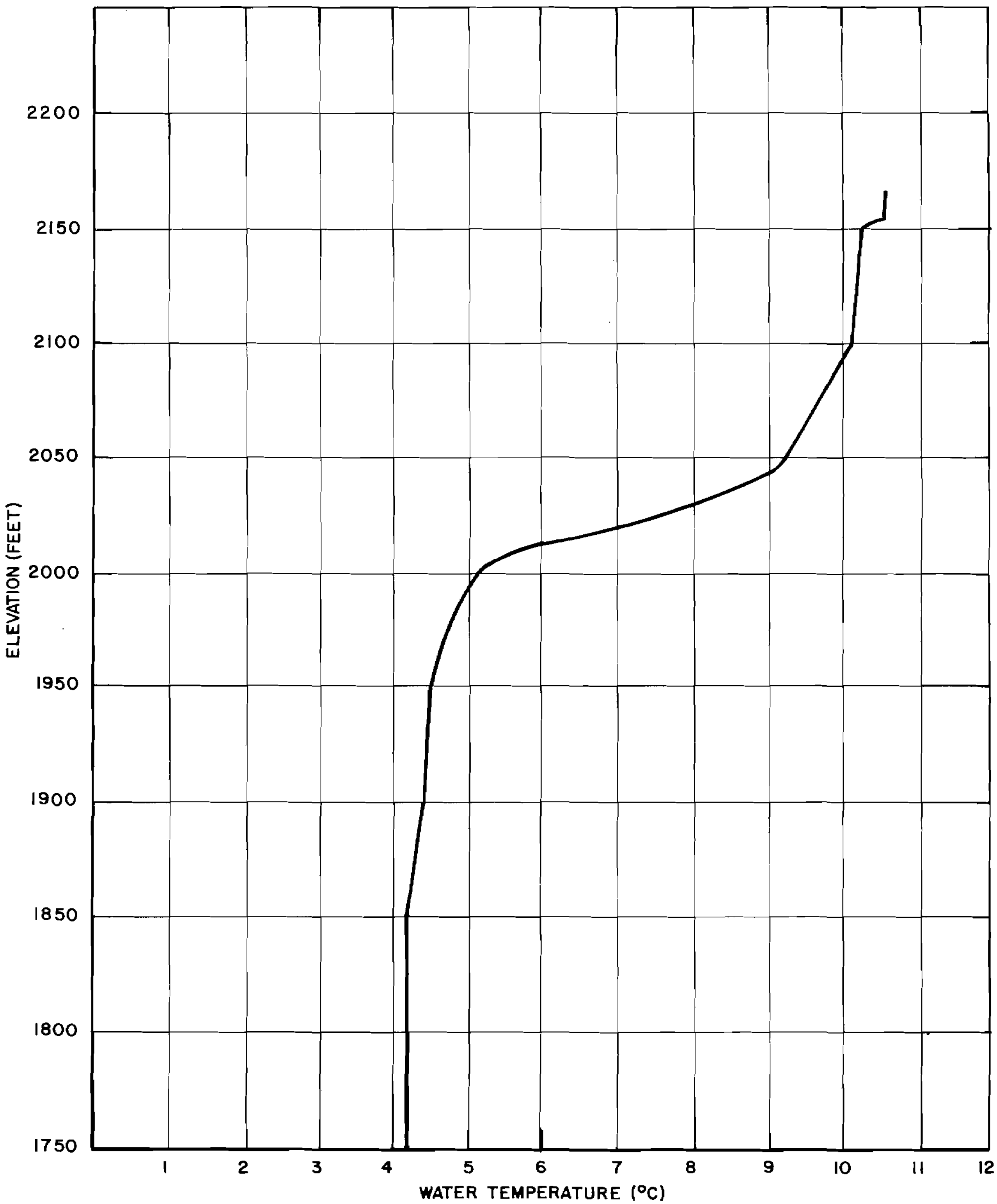
SIMULATED PROFILE IN WATANA
JUNE 1, 1981

FIGURE 8.24



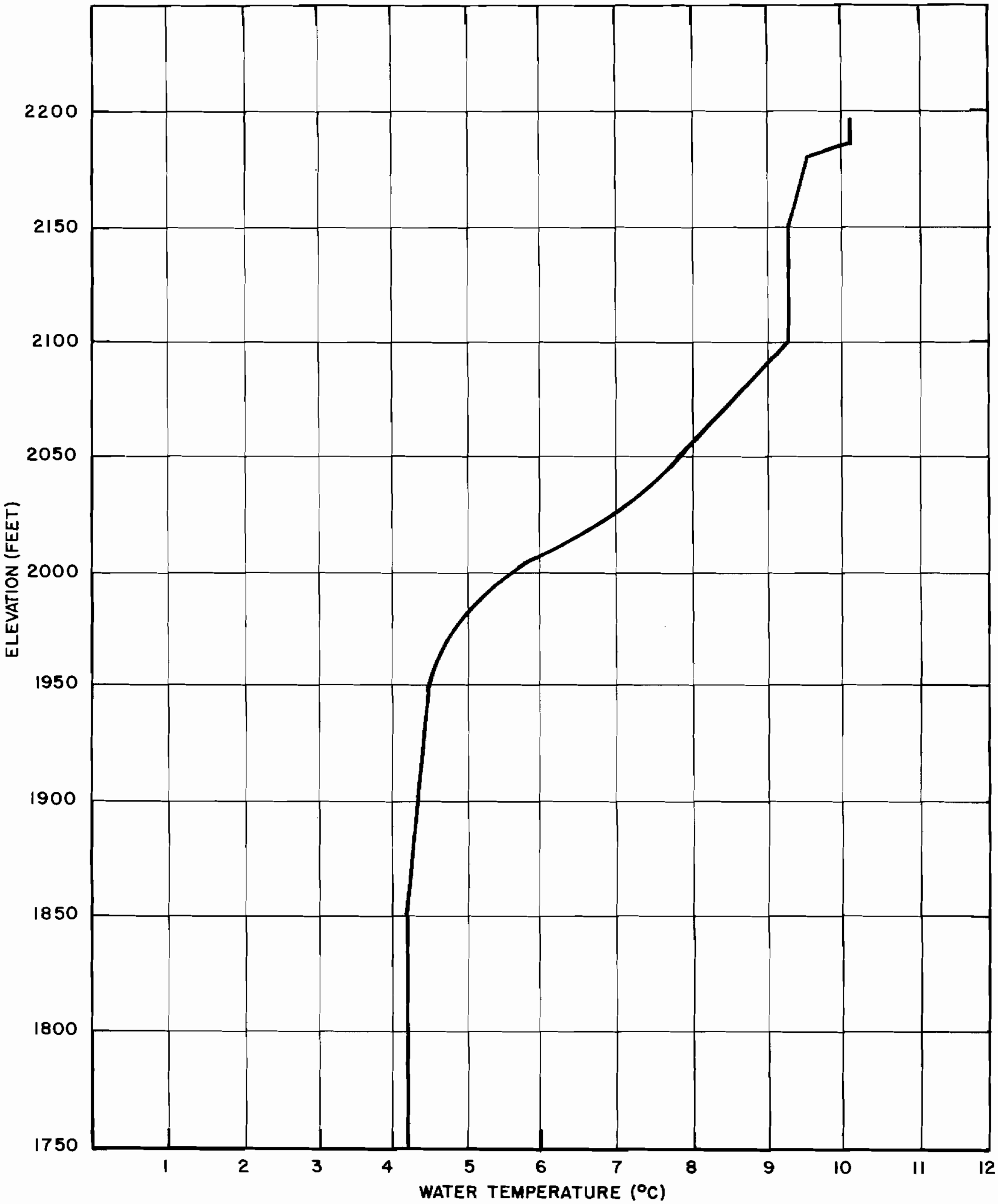
SIMULATED PROFILE IN WATANA
JULY 1, 1981

FIGURE 8.25



SIMULATED PROFILE IN WATANA AUGUST 1, 1981

FIGURE 8.26

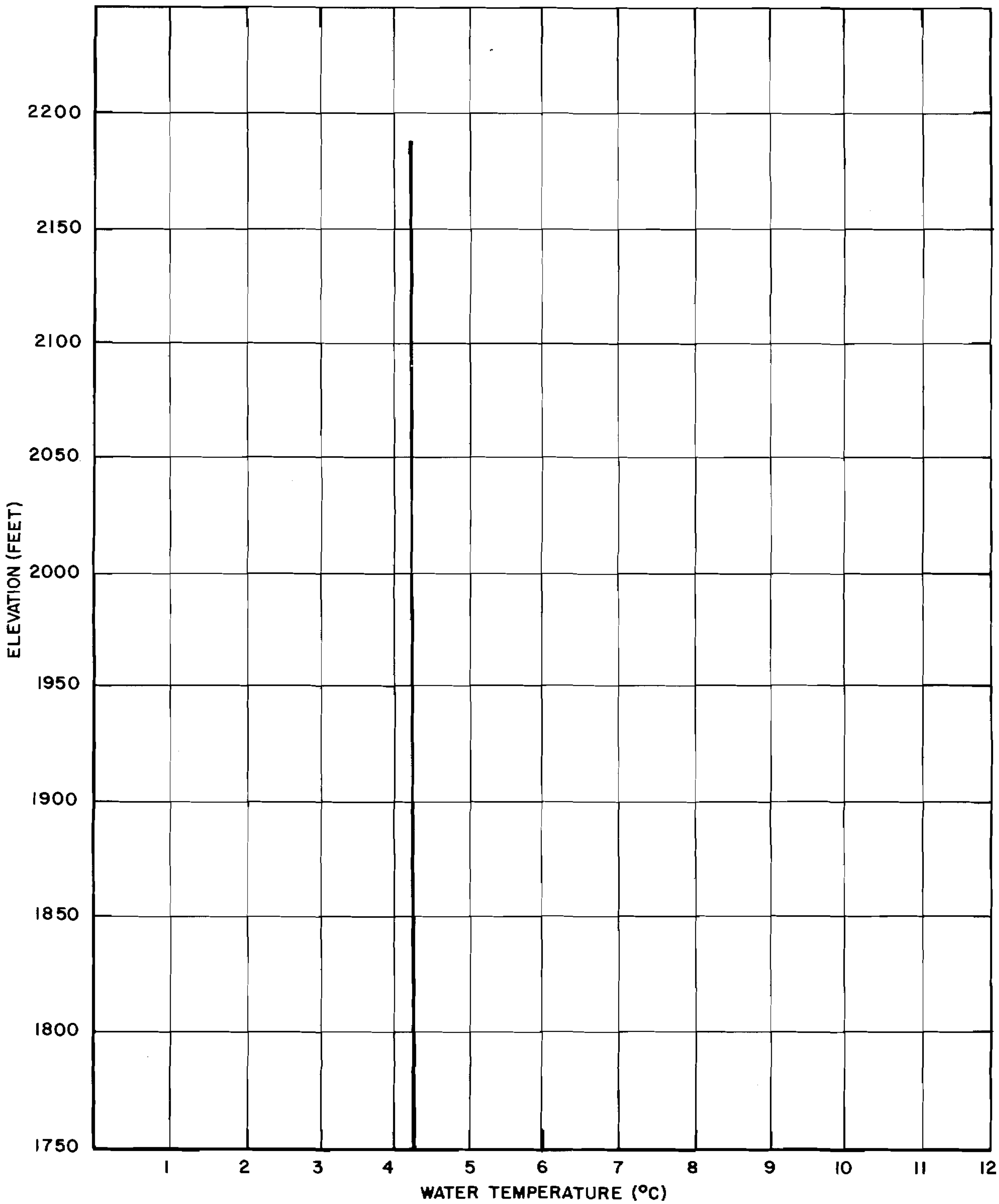


SIMULATED PROFILE IN WATANA
SEPTEMBER 1, 1981

FIGURE 8.27

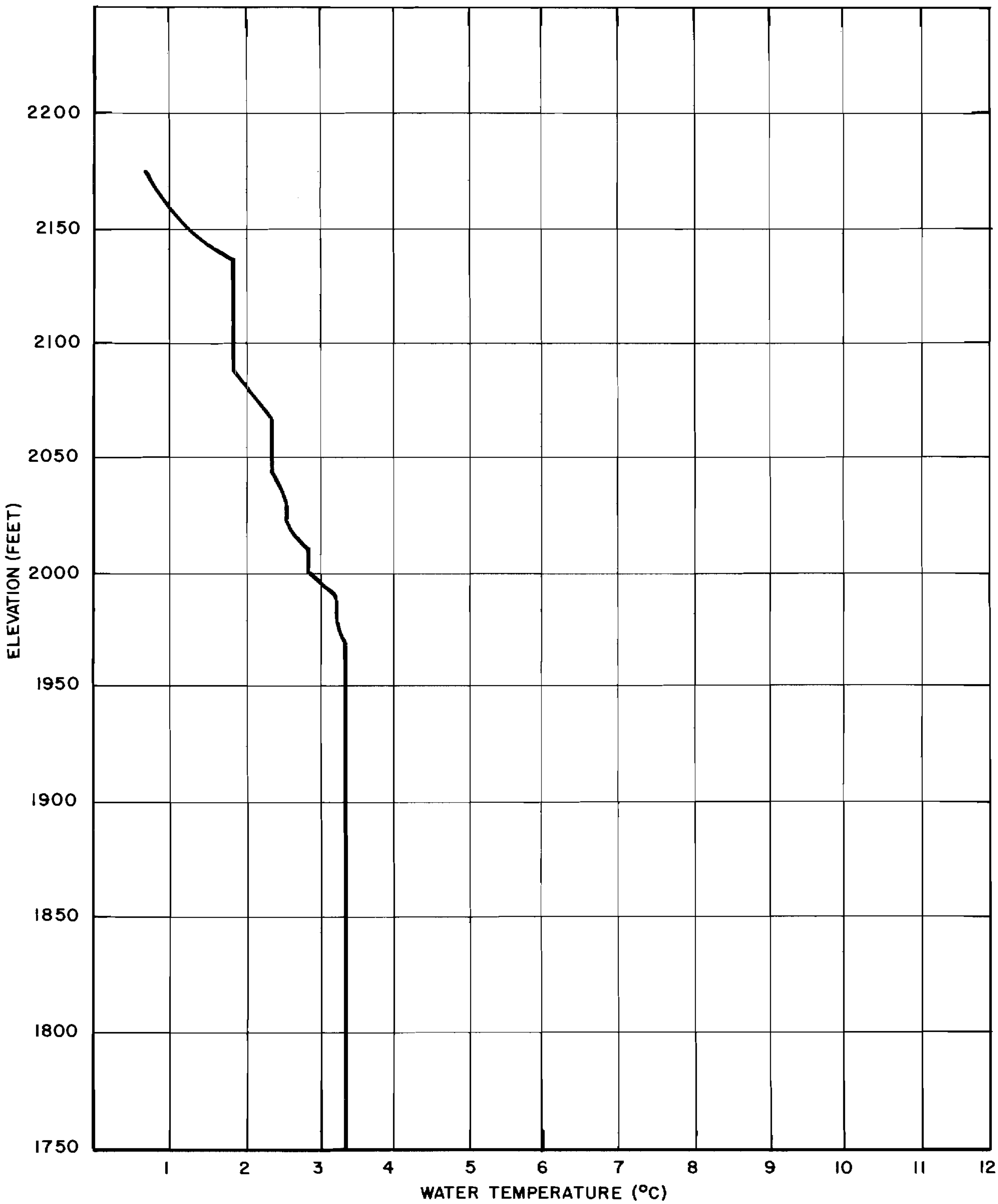
SIMULATED PROFILE IN WATANA
OCTOBER 1, 1981

FIGURE 8.28



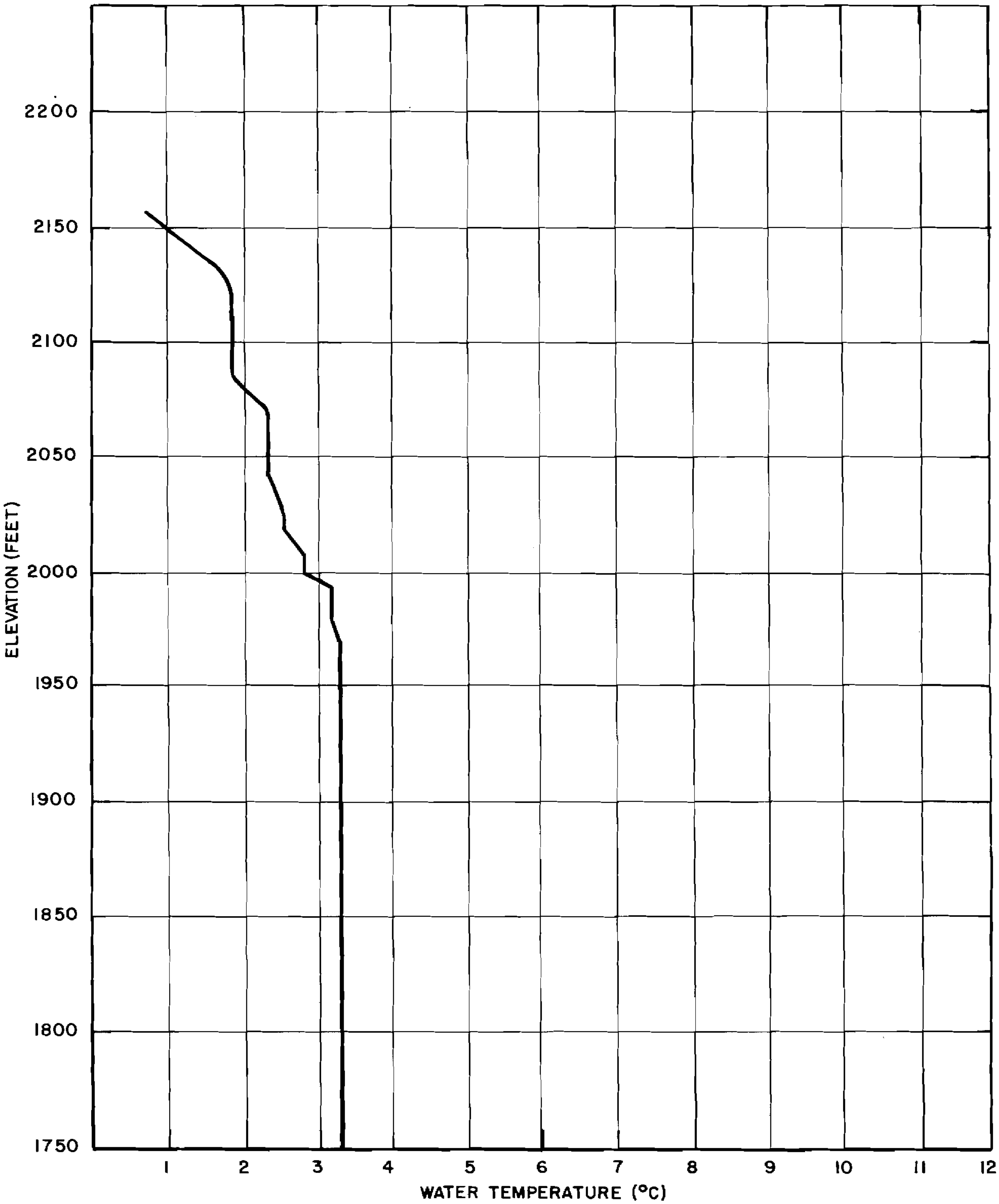
SIMULATED PROFILE IN WATANA
NOVEMBER 1, 1981

FIGURE 8.29



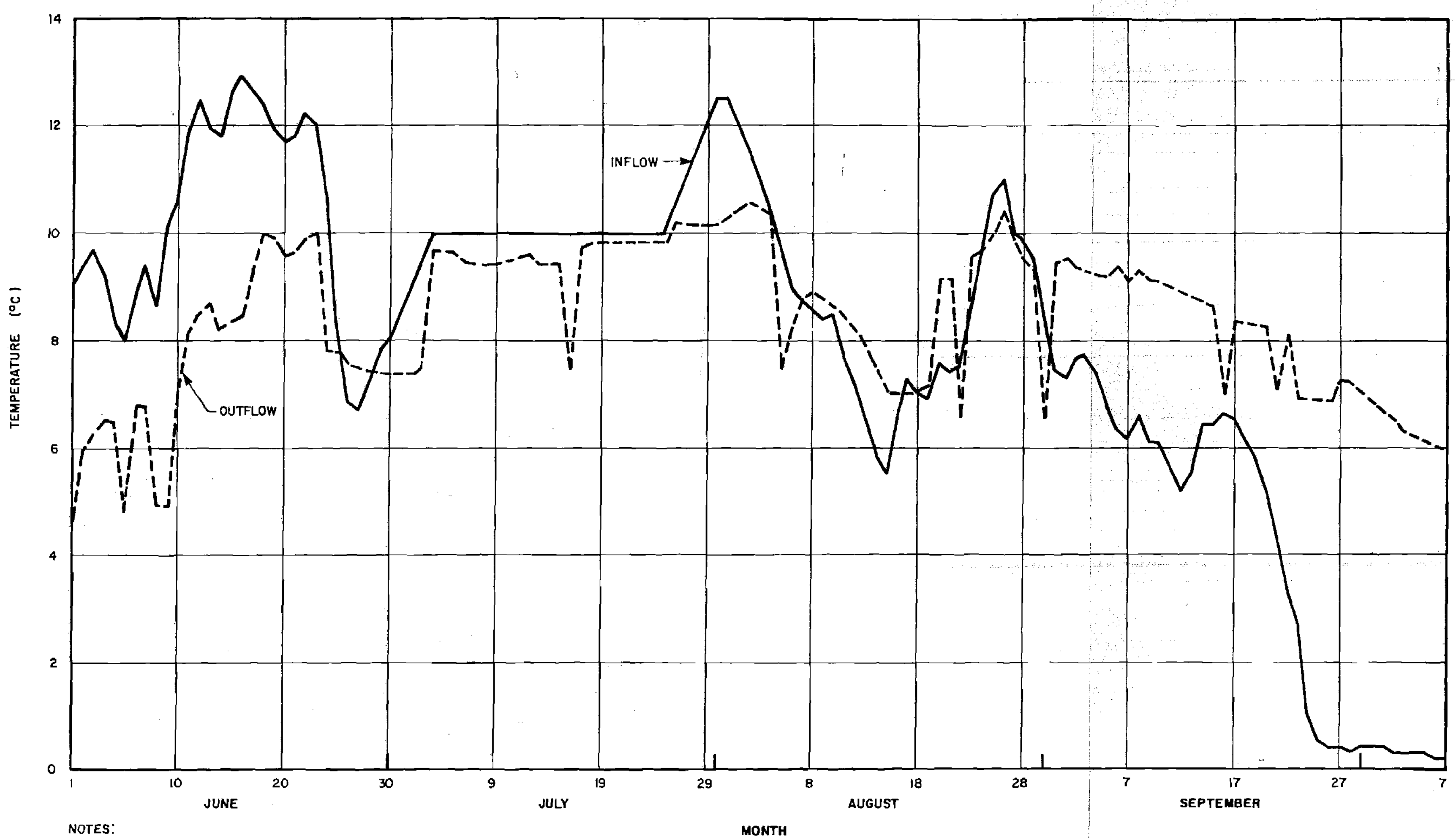
SIMULATED PROFILE IN WATANA
DECEMBER 1, 1981

FIGURE 8.30



SIMULATED PROFILE IN WATANA
DECEMBER 31, 1981

FIGURE 8.31

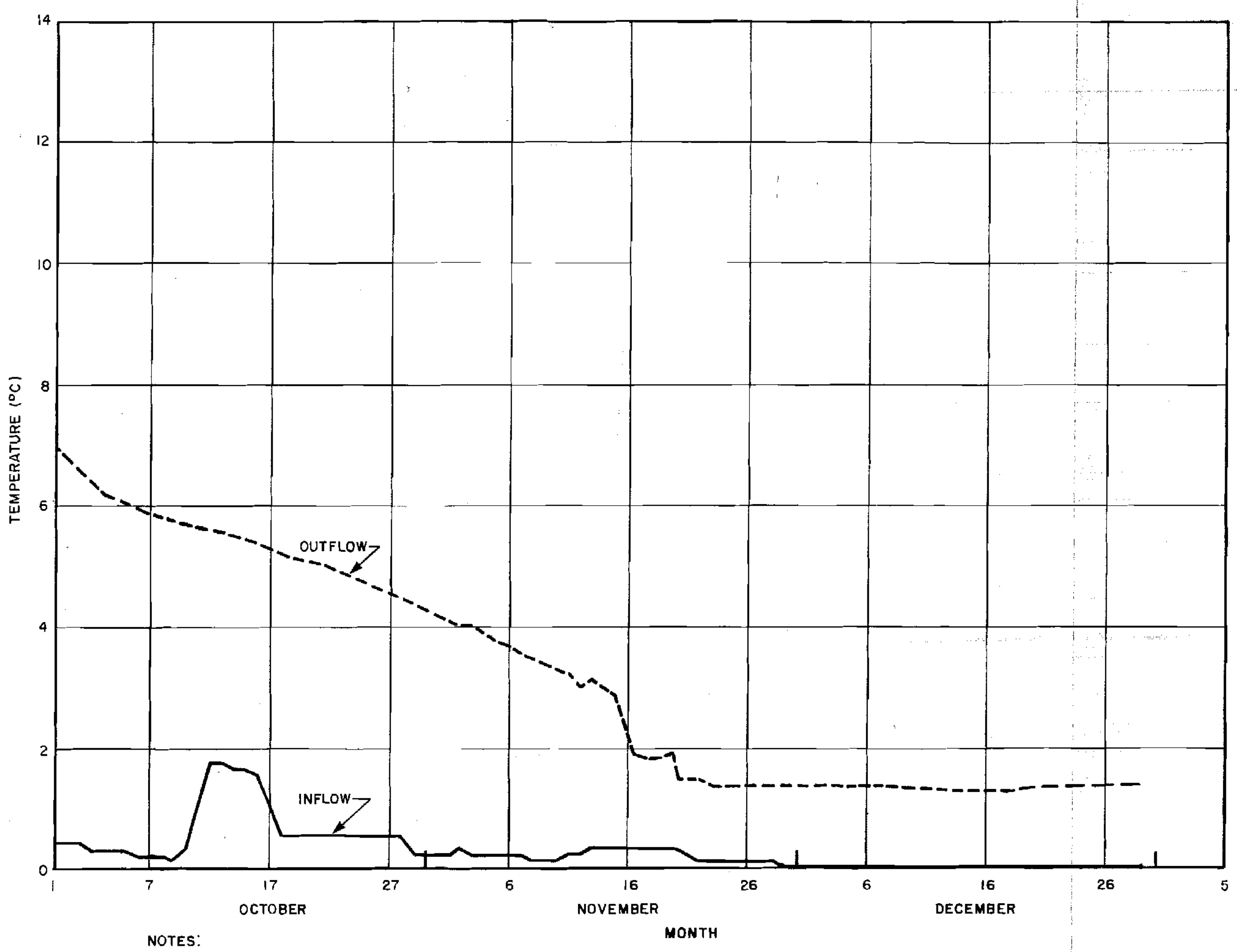


NOTES:

1) TIME SCALE IS IN INCREMENTS OF 10 DAYS.
2) BASED ON 1981 DATA, WATANA OPERATION
3) RUN W4020; WITH OUTFLOW TEMPERATURE FOLLOWING INFLOW TEMPERATURE.
4) JULY INFLOW TEMPERATURES ESTIMATED

WATANA RESERVOIR INFLOW AND OUTFLOW TEMPERATURES JUN TO SEP

FIGURE 8.32

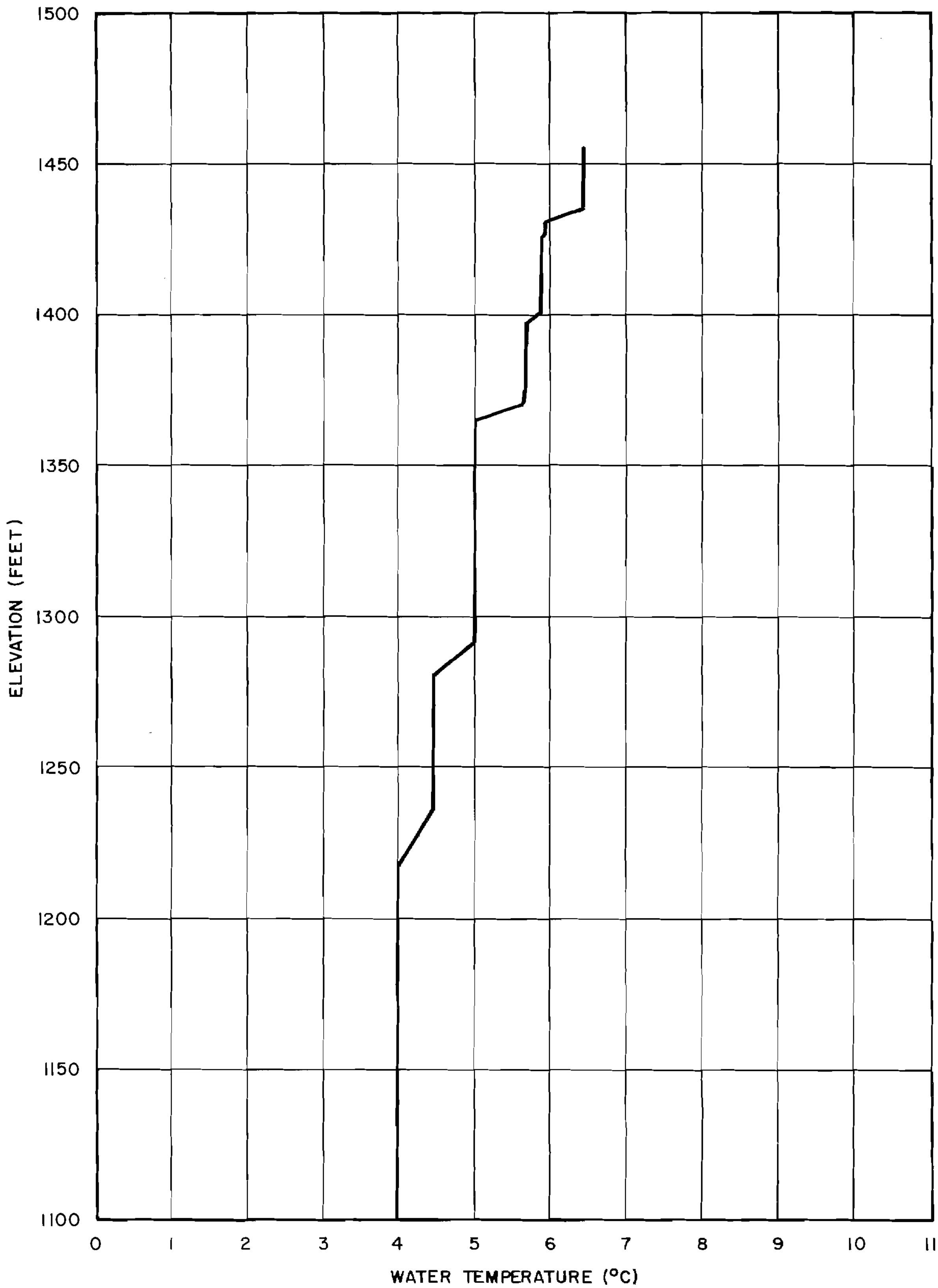


NOTES:

1) TIME SCALE IS IN INCREMENTS OF 10 DAYS.
2) BASED ON 1981 DATA, WATANA OPERATION
3) RUN W4020; WITH OUTFLOW TEMPERATURE FOLLOWING INFLOW TEMPERATURE.

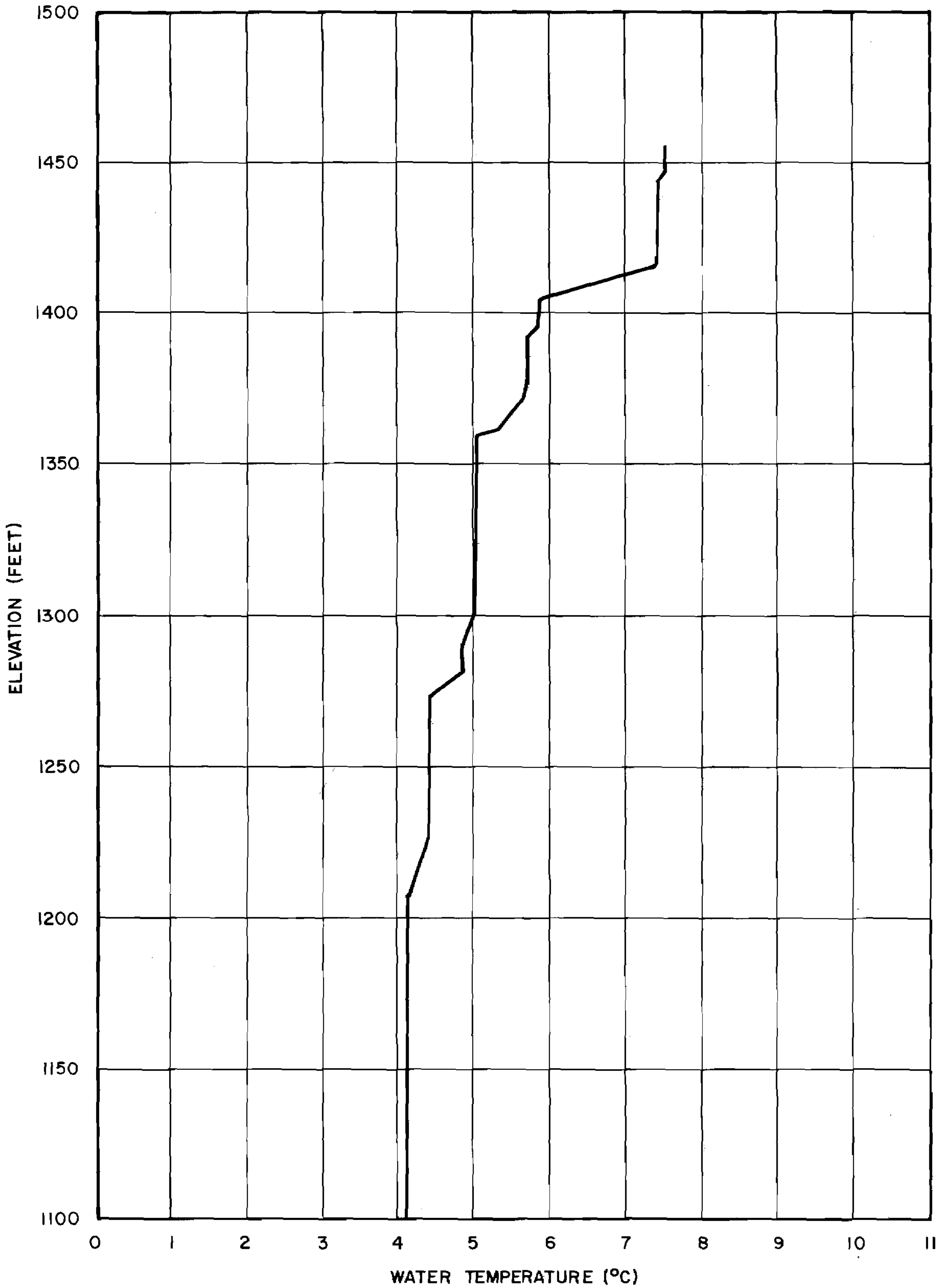
WATANA RESERVOIR INFLOW AND OUTFLOW TEMPERATURES
OCT TO DEC

FIGURE 8.33



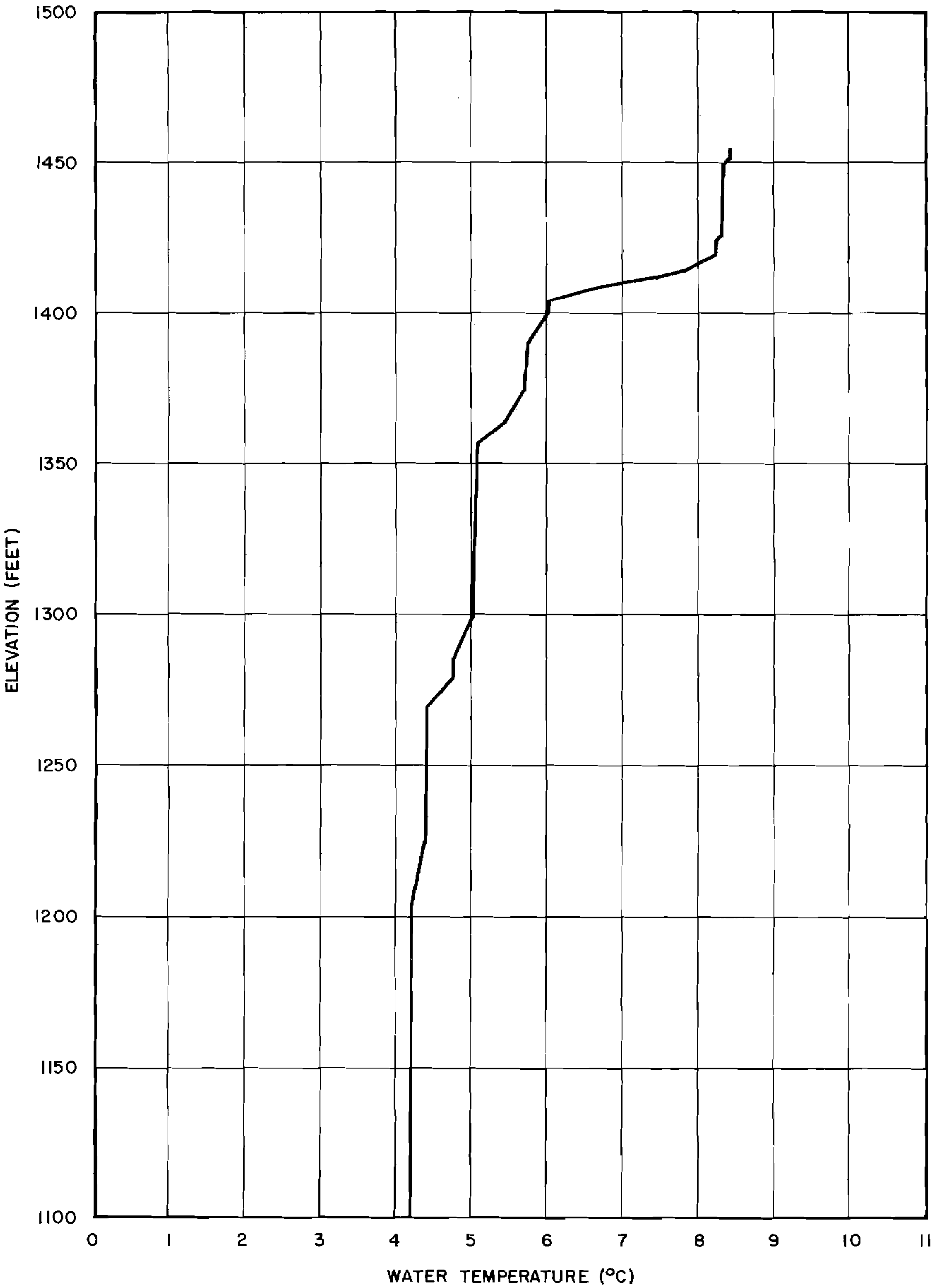
SIMULATED PROFILE IN DEVIL CANYON
JUNE 1, 1981

FIGURE 8.34



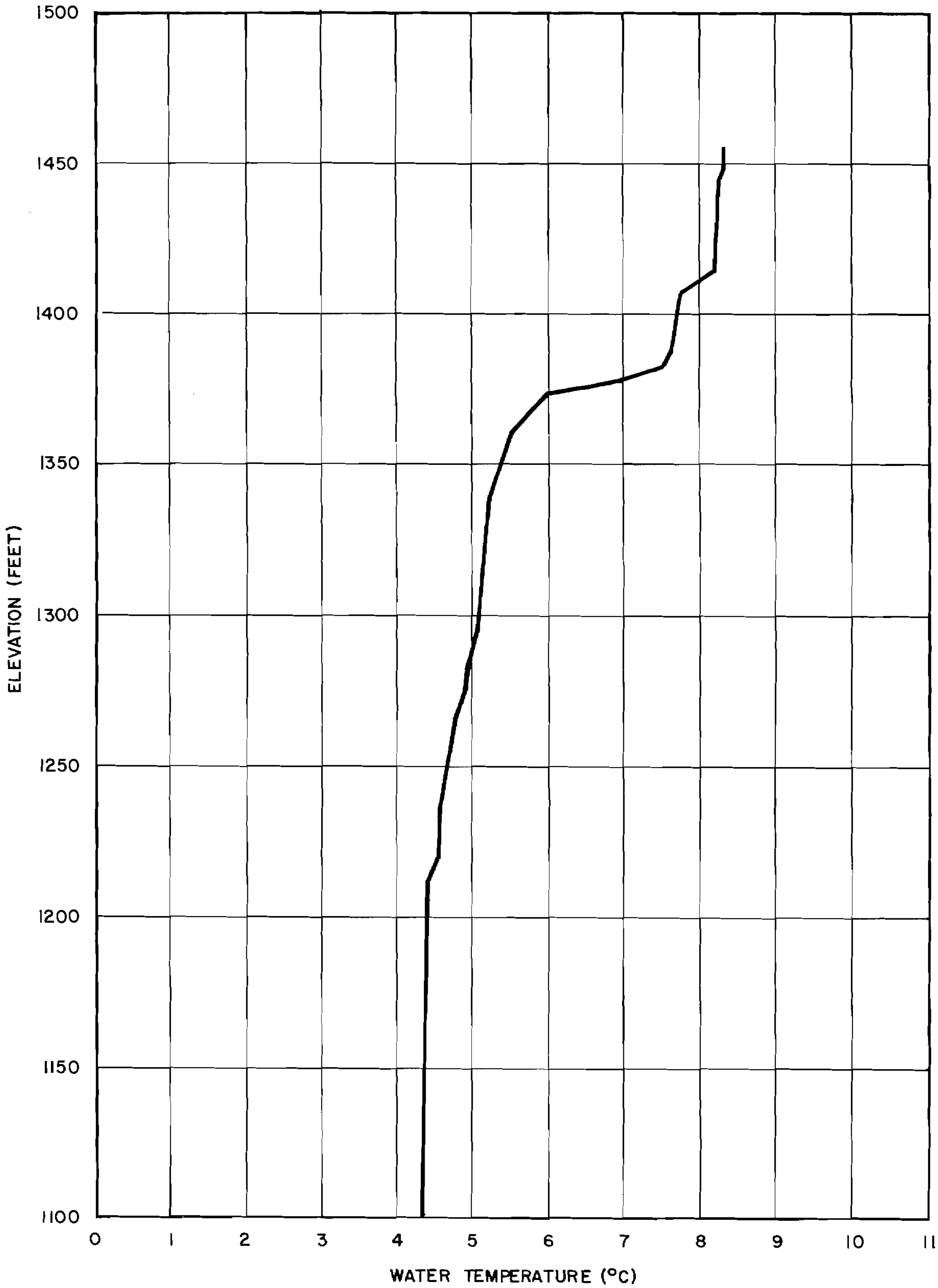
SIMULATED PROFILE IN DEVIL CANYON
JULY 1, 1983

FIGURE 8.35



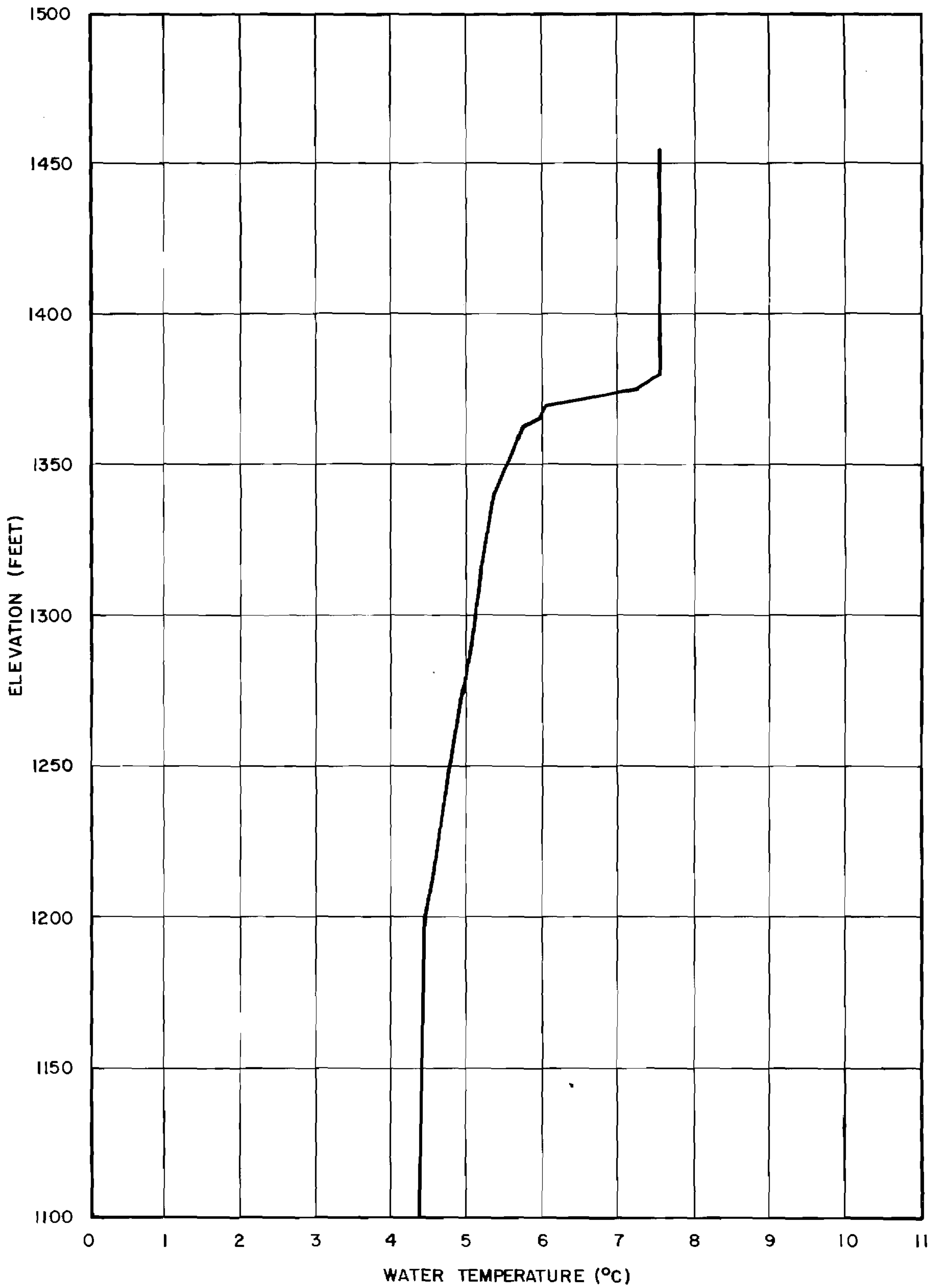
SIMULATED PROFILE IN DEVIL CANYON
AUGUST 1, 1981

FIGURE 8.36



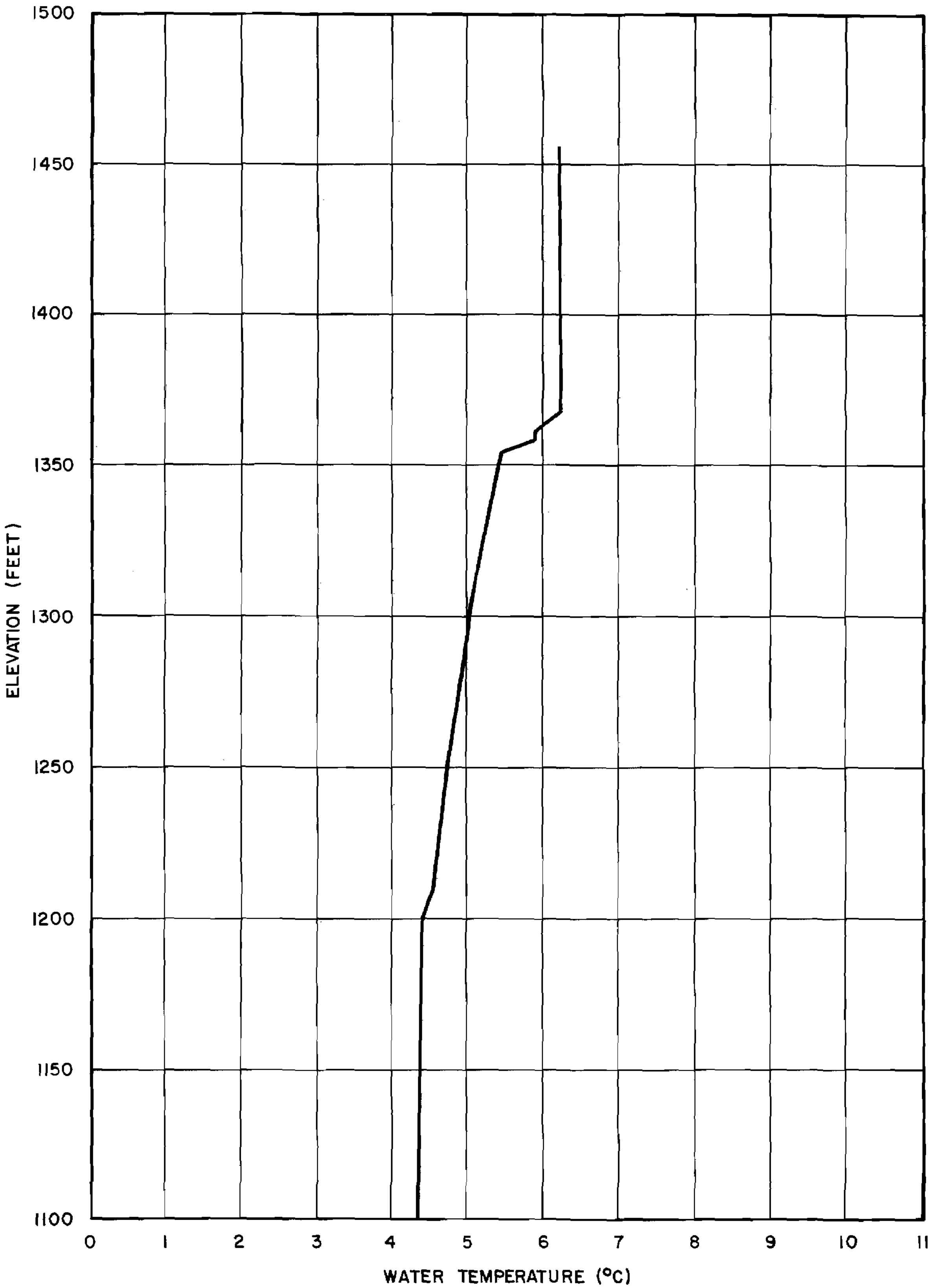
SIMULATED PROFILE IN DEVIL CANYON
SEPTEMBER 1, 1981

FIGURE 8.37



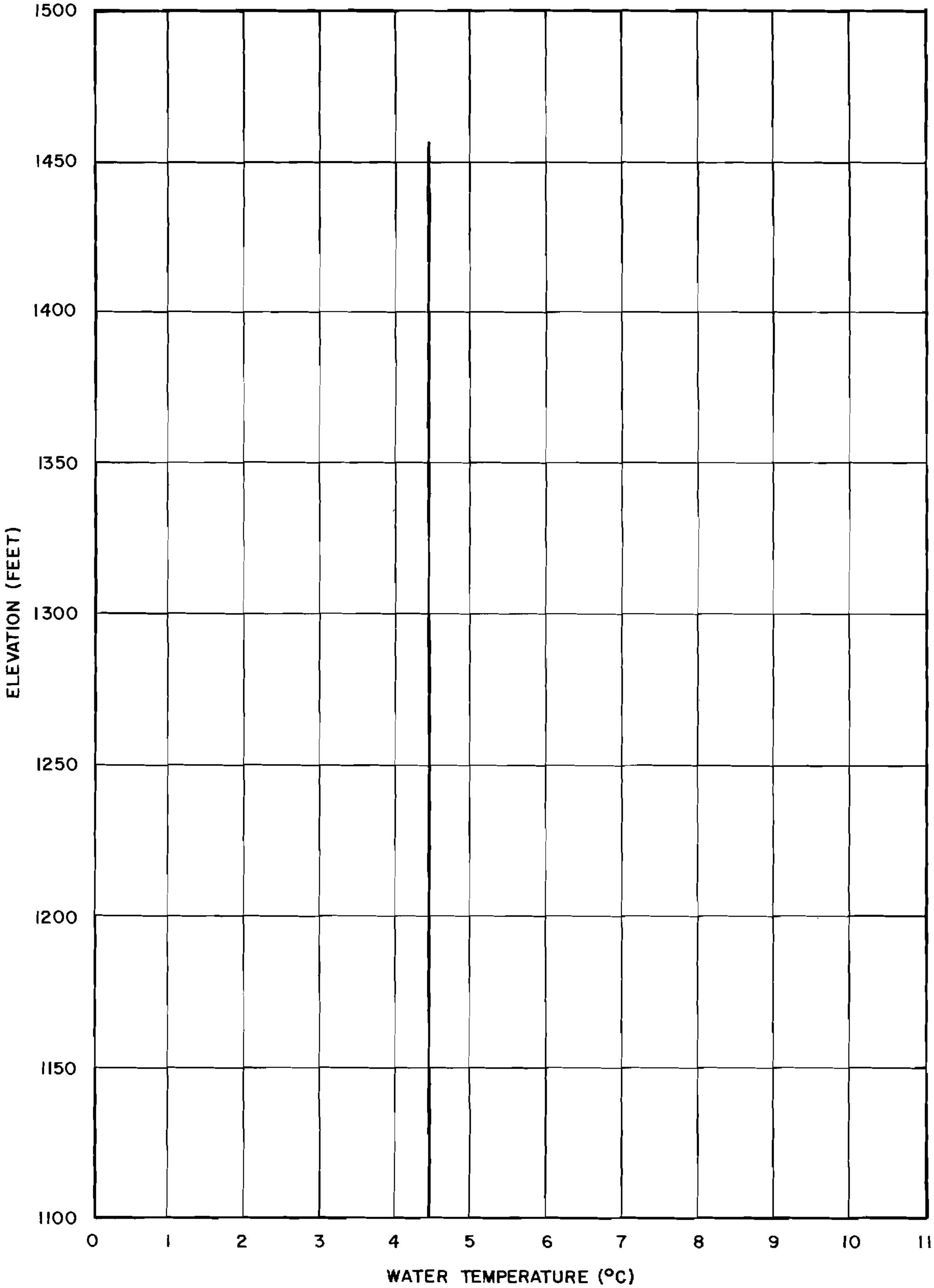
SIMULATED PROFILE IN DEVIL CANYON
OCTOBER 1, 1981

FIGURE 8.38



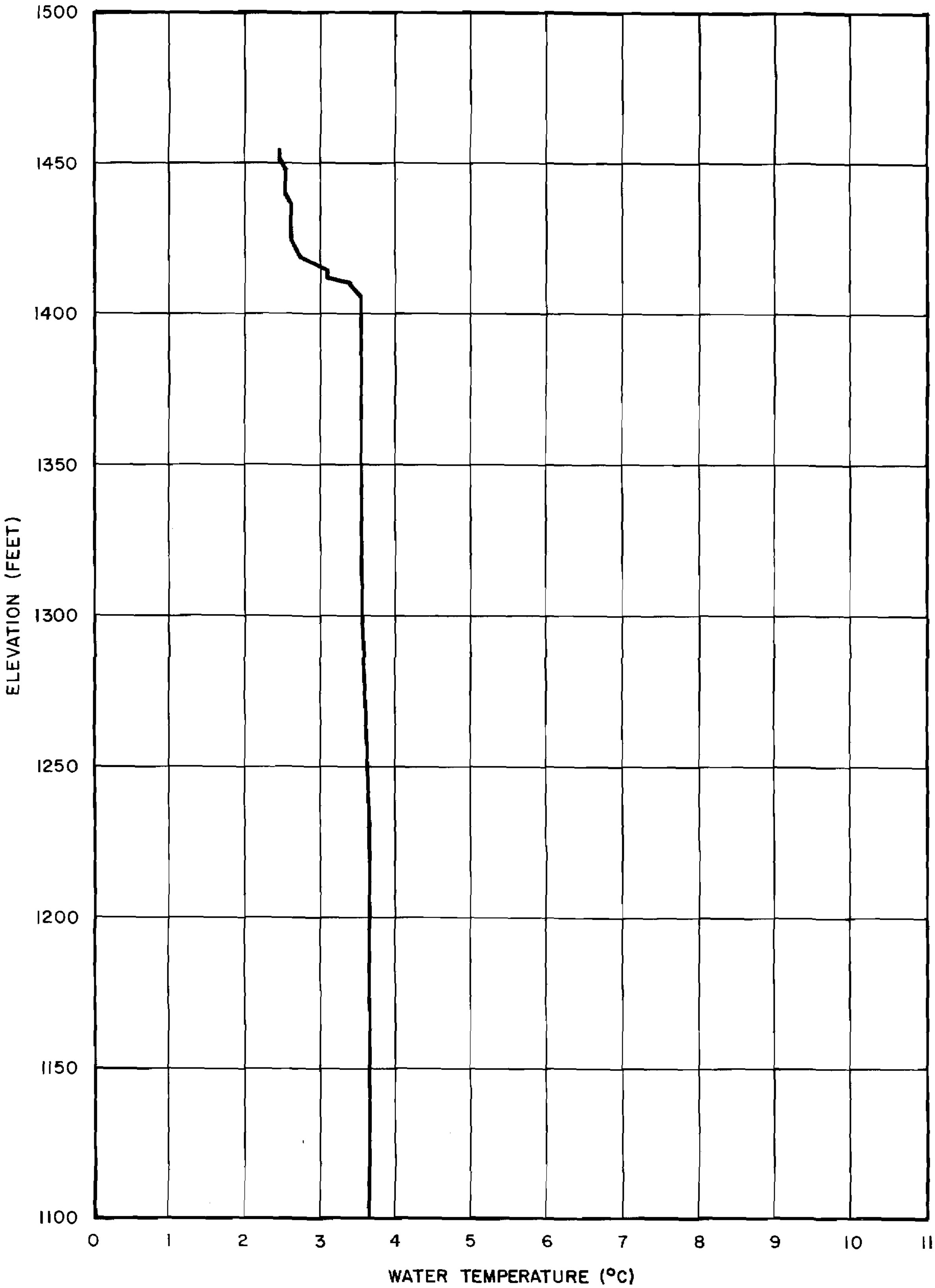
SIMULATED PROFILE IN DEVIL CANYON
NOVEMBER 1, 1981

FIGURE 8.39



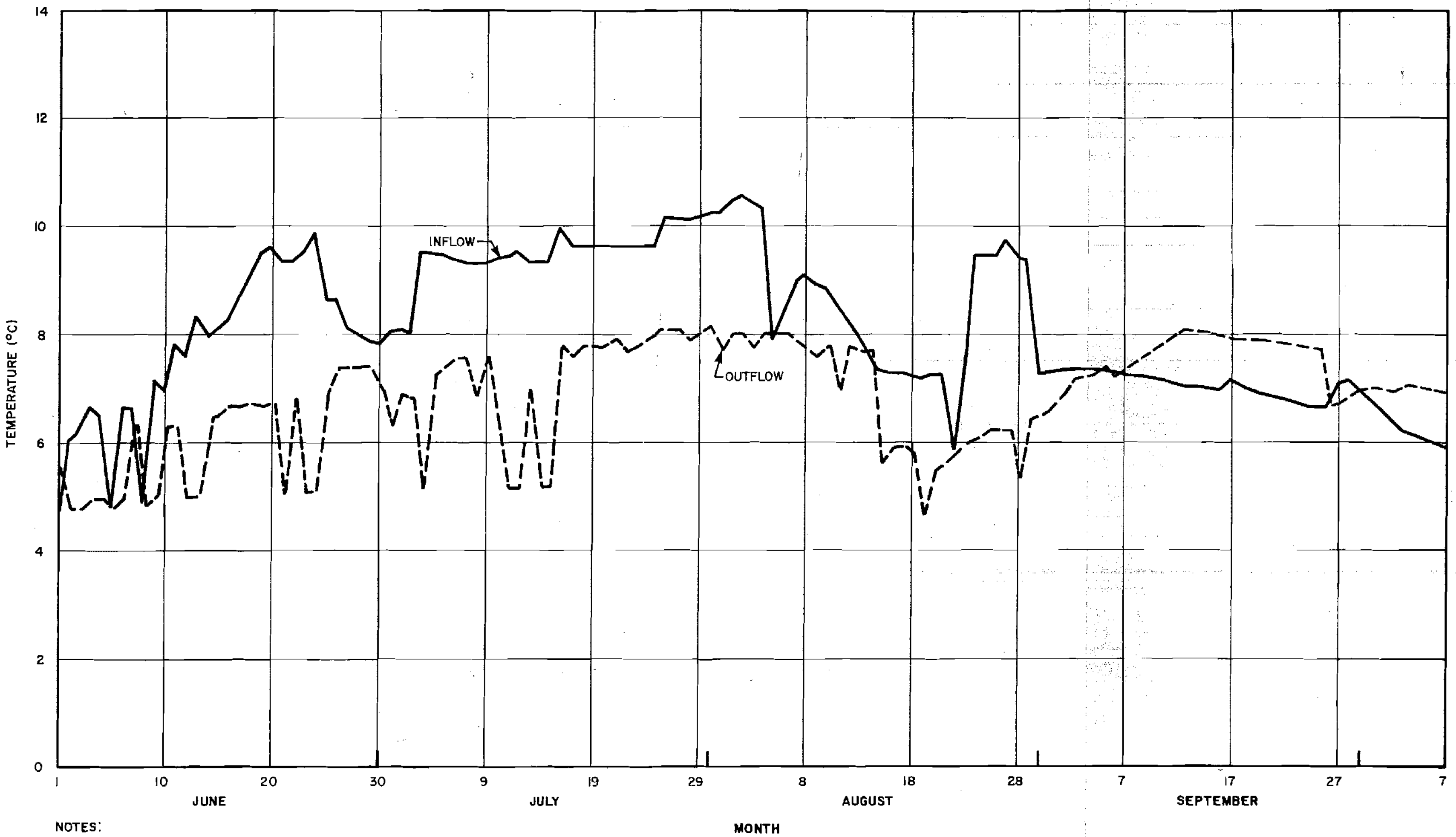
SIMULATED PROFILE IN DEVIL CANYON
DECEMBER 1, 1981

FIGURE 8.40



SIMULATED PROFILE IN DEVIL CANYON
DECEMBER 31, 1981

FIGURE 8.41

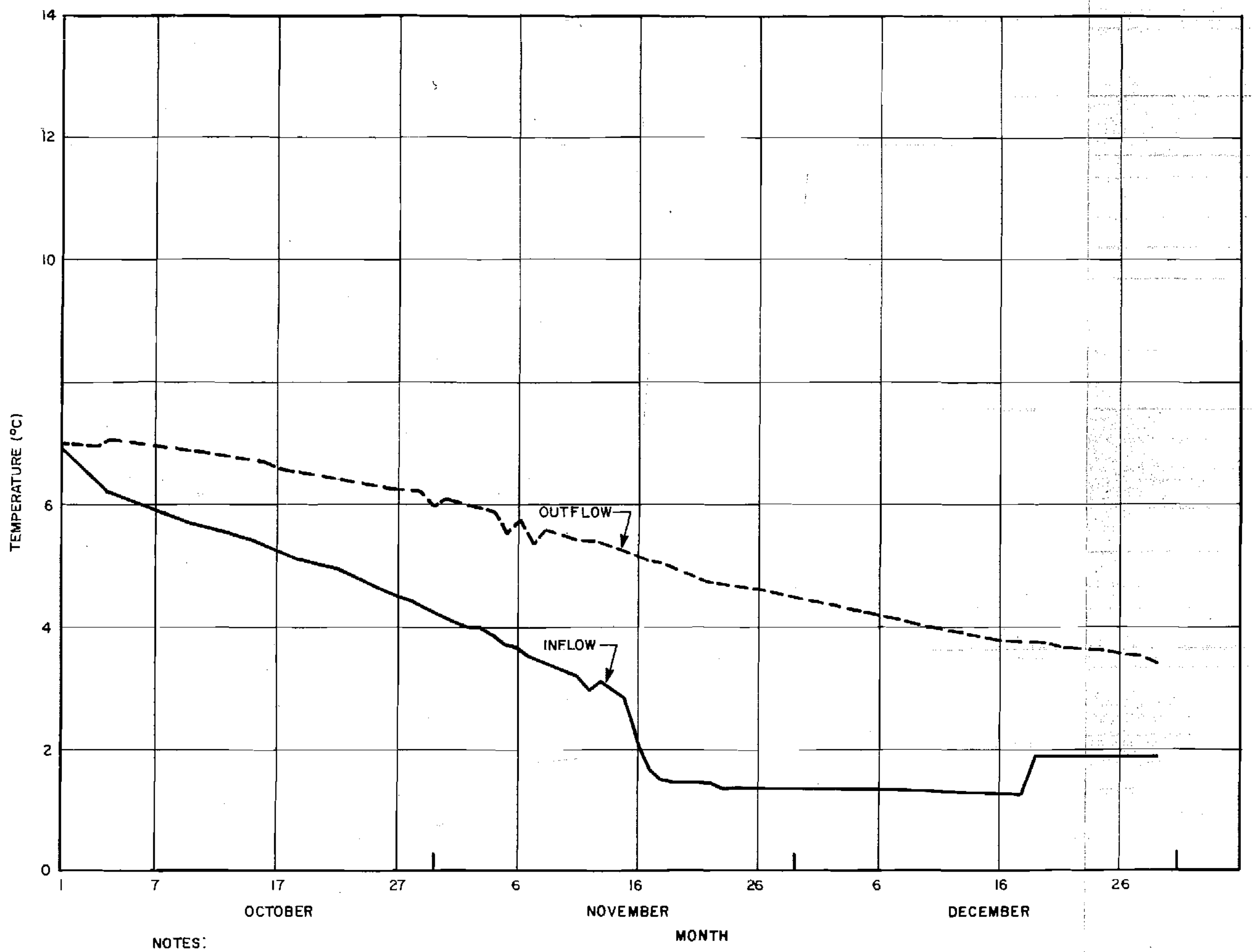


NOTES:

1. TIME SCALE IS IN INCREMENTS OF 10 DAYS.
2. BASED ON 1981 DATA.
3. WATANA ASSUMED UPSTREAM. (DYRESM RUN W4010)
4. OUTFLOW TEMPERATURES ARE BASED ON DYRESM RUNS DC1020, DC1021 AND DC1022.

DEVIL CANYON RESERVOIR INFLOW AND OUTFLOW TEMPERATURES
JUNE TO SEPTEMBER

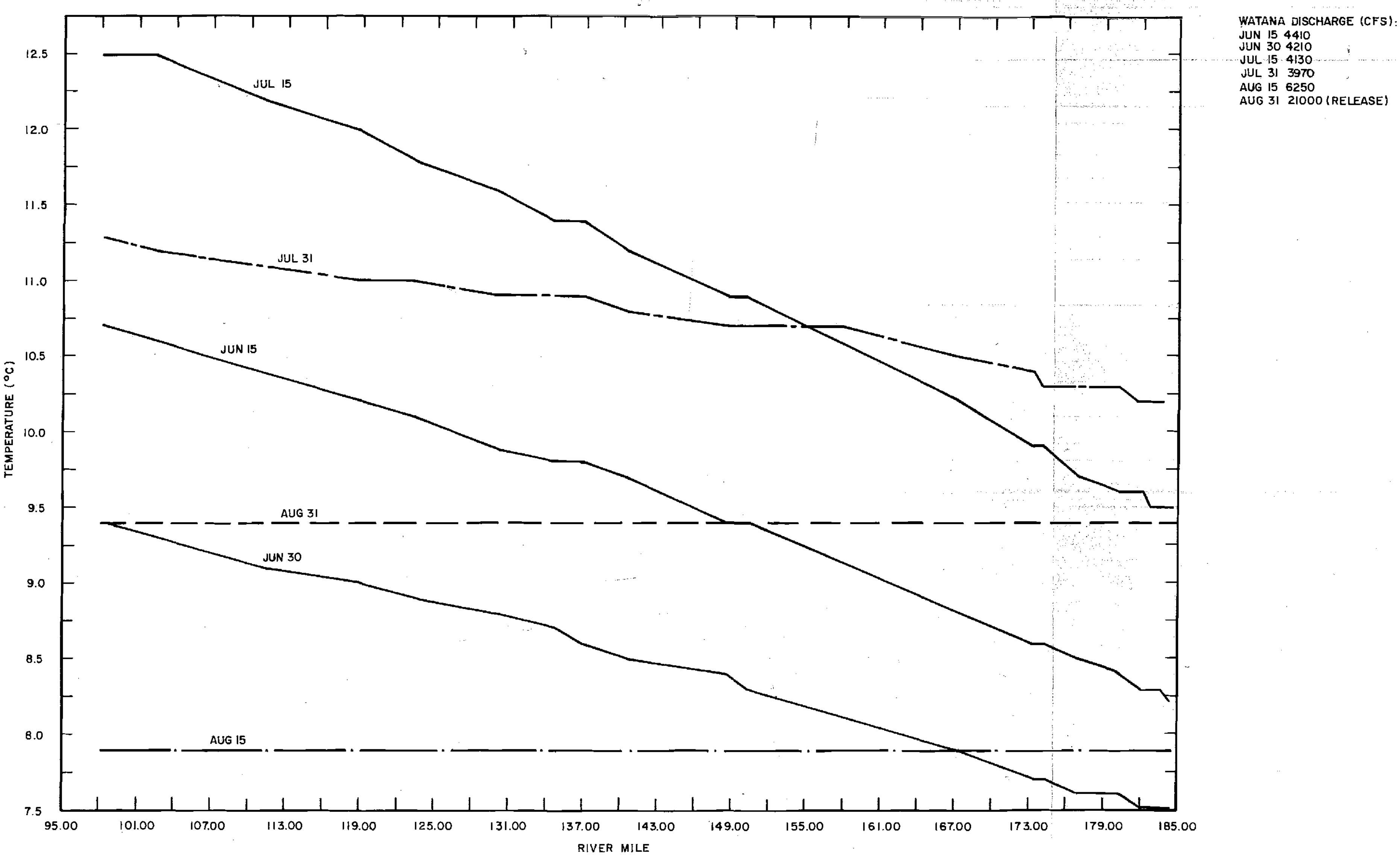
FIGURE 8.42



NOTES:
1) TIME SCALE IS IN INCREMENTS OF 10 DAYS.
2) BASED ON 1981 DATA.
3) WATANA ASSUMED UPSTREAM. (DYRESM RUN W4010)
4) OUTFLOW TEMPERATURES ARE BASED ON DYRESM RUN DC1022.

DEVIL CANYON RESERVOIR INFLOW AND OUTFLOW TEMPERATURES
OCTOBER TO DECEMBER

FIGURE 8.43

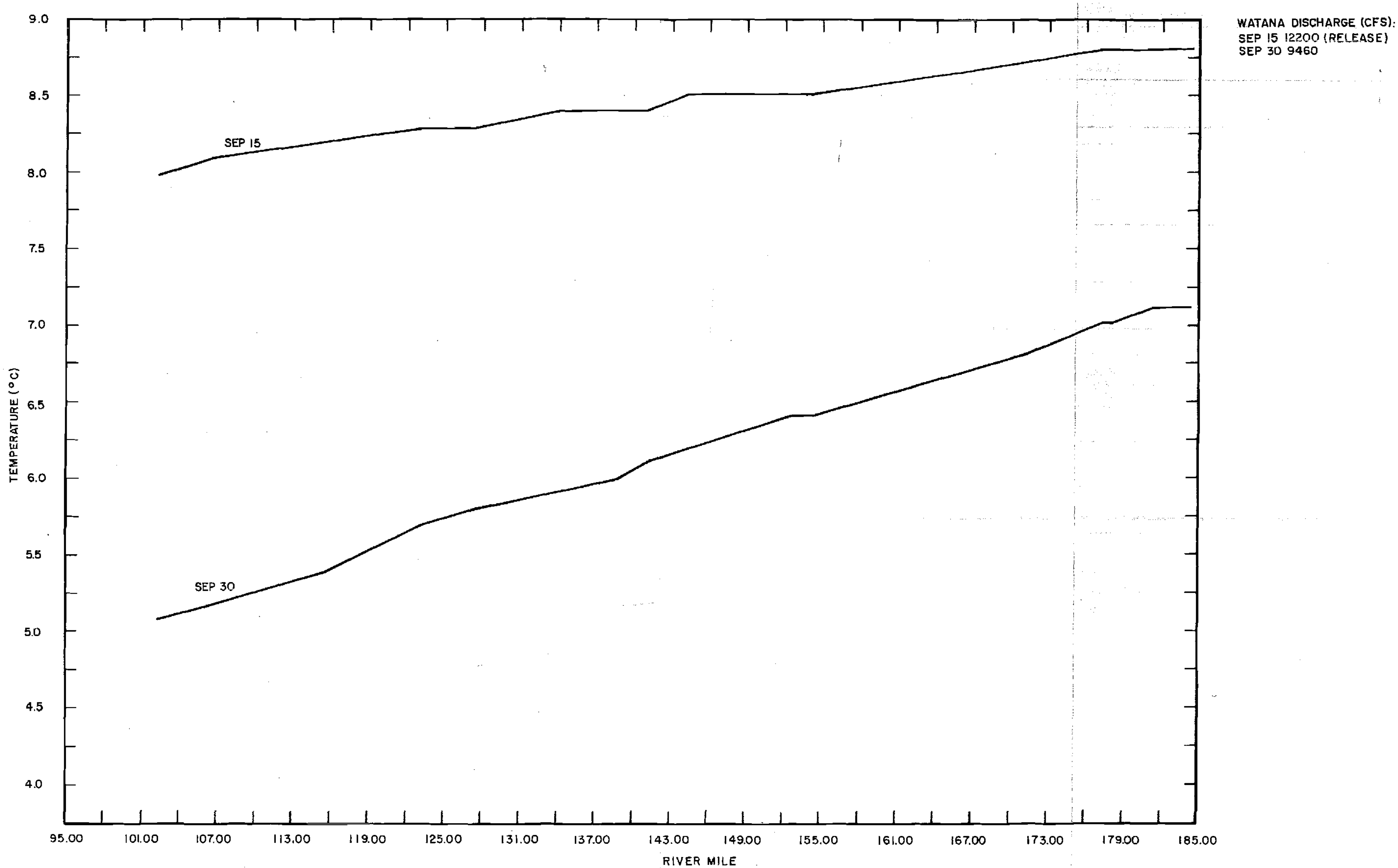


NOTE:

1. MODEL ASSUMES 1981 METEOROLOGICAL DATA RECORDED AT WATANA.
2. WATANA TEMPERATURE AND DISCHARGE FROM DYRESM MODEL. (RUN WA4020)

WATANA OPERATION:
DOWNSTREAM TEMPERATURES - JUN TO AUG

FIGURE 8.44

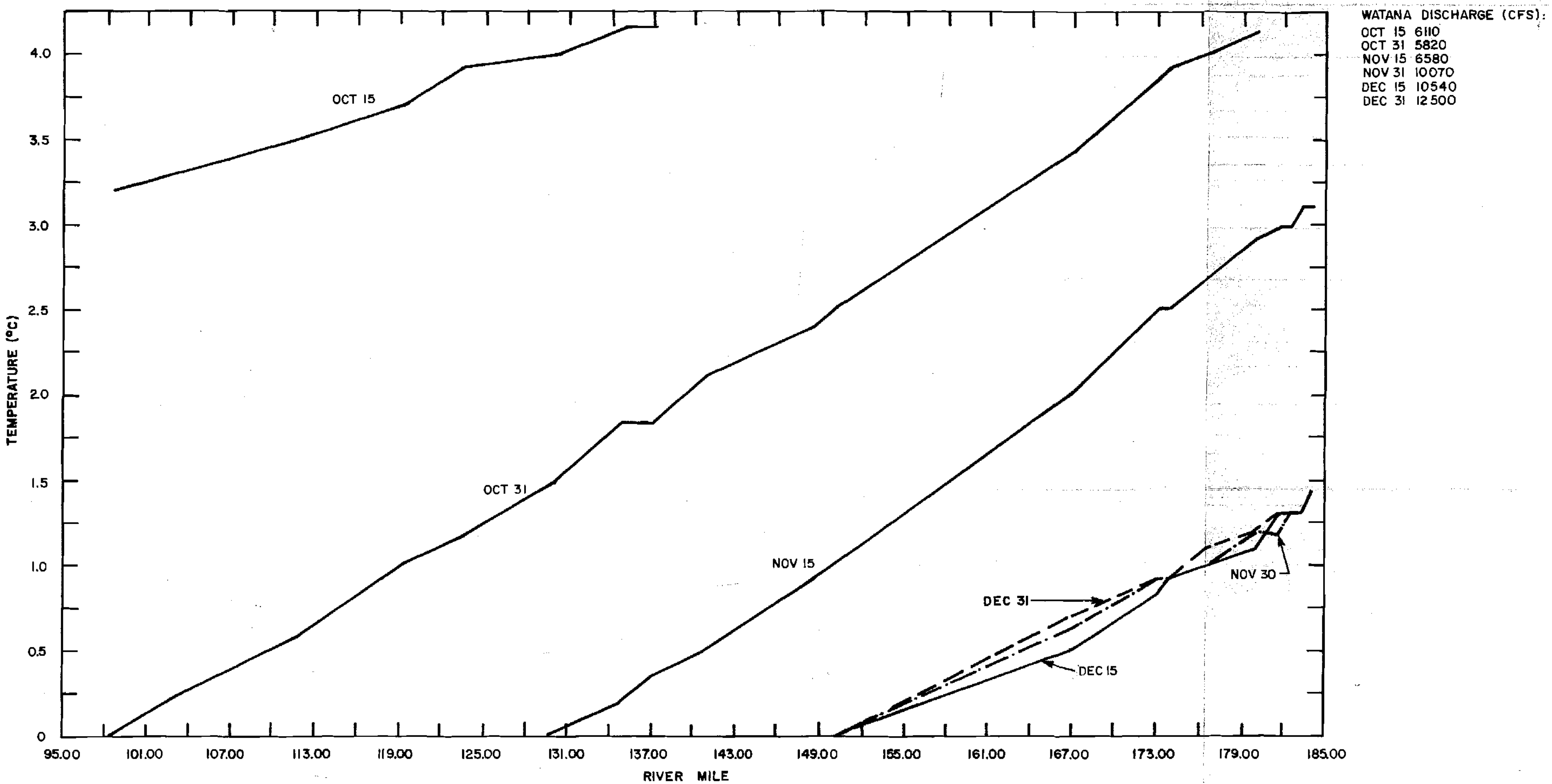


NOTE:

1. MODEL ASSUMES 1981 METEOROLOGICAL DATA RECORDED AT WATANA.
2. WATANA TEMPERATURES AND DISCHARGE FROM DYRESM MODEL. (RUN WA4020)

WATANA OPERATION
DOWNSTREAM TEMPERATURES - SEP

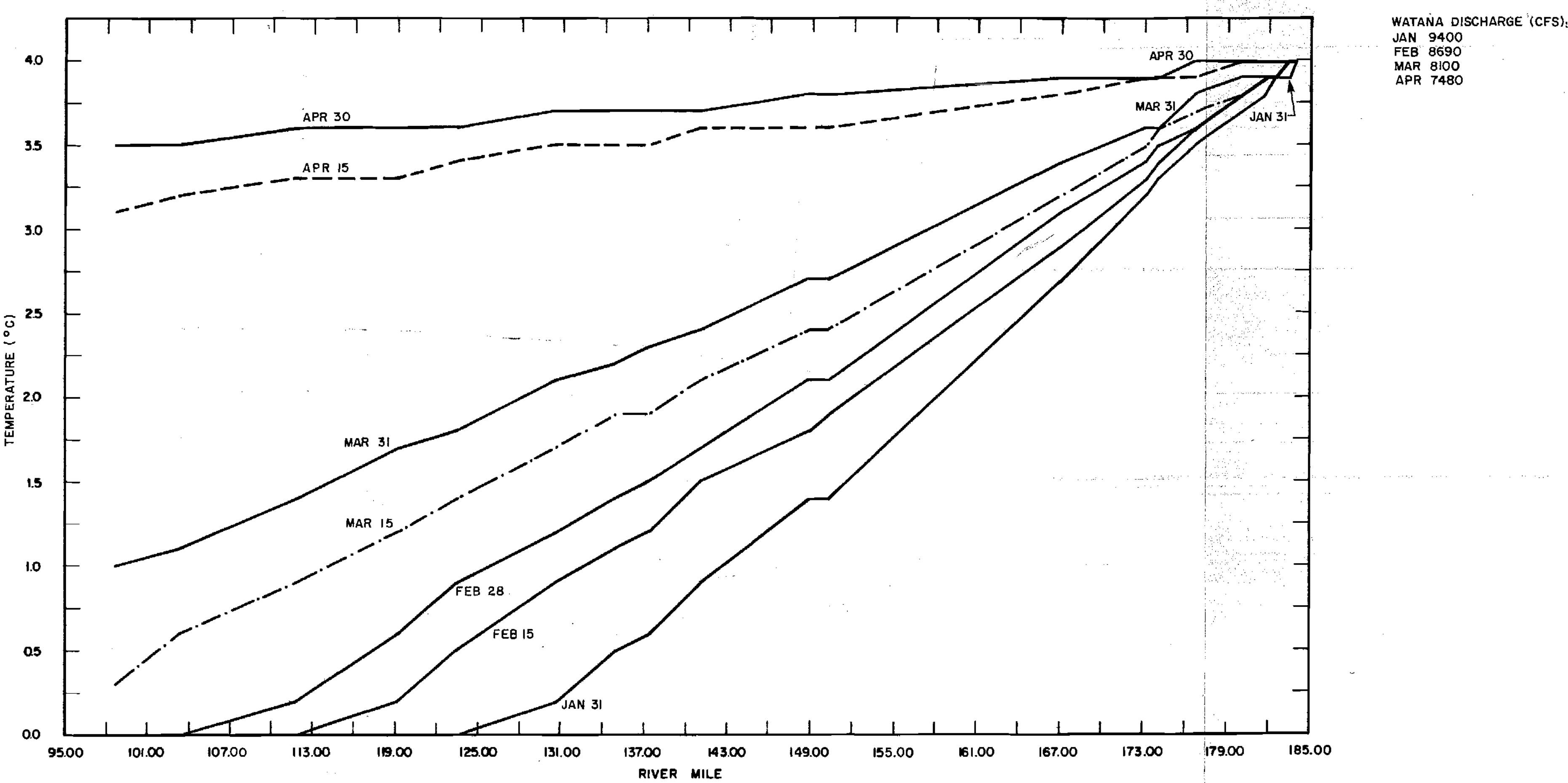
FIGURE 8.45



NOTES:
1. MODEL ASSUMES 1981 METEOROLOGICAL DATA RECORDED AT WATANA.
2. WATANA TEMPERATURES AND DISCHARGE FROM DYRESM MODEL. (RUN WA4020)

WATANA OPERATION:
DOWNSTREAM TEMPERATURES - OCT TO DEC

FIGURE 8.46

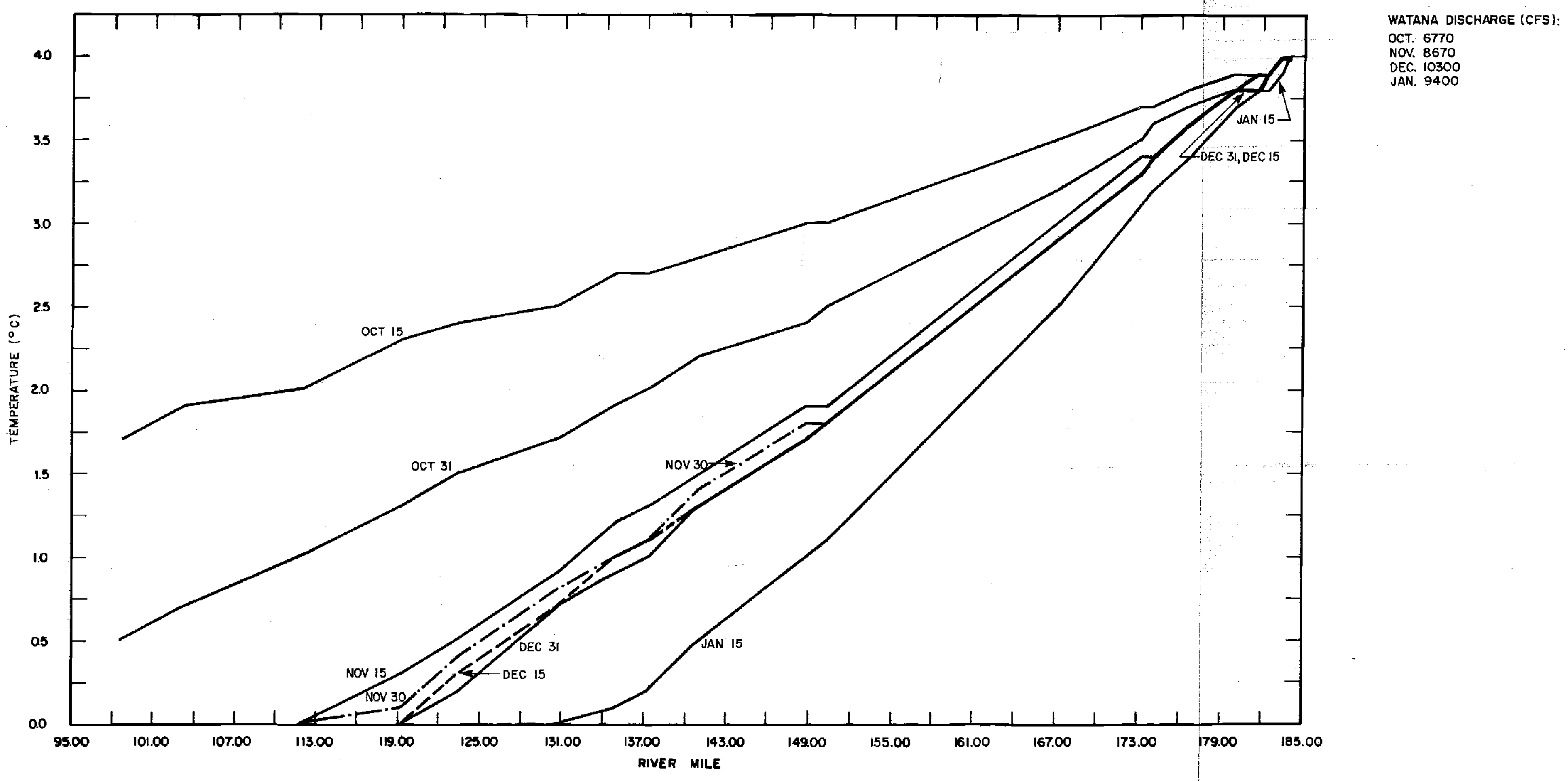


NOTE:

MODEL ASSUMES DAILY BASED LONG TERM AVERAGE METEOROLOGICAL DATA AND MEAN MONTHLY FLOWS AT WATANA.

WATANA OPERATION:
DOWNSTREAM TEMPERATURES - JAN TO APR
OUTFLOW TEMPERATURE 4°C

FIGURE 8.47

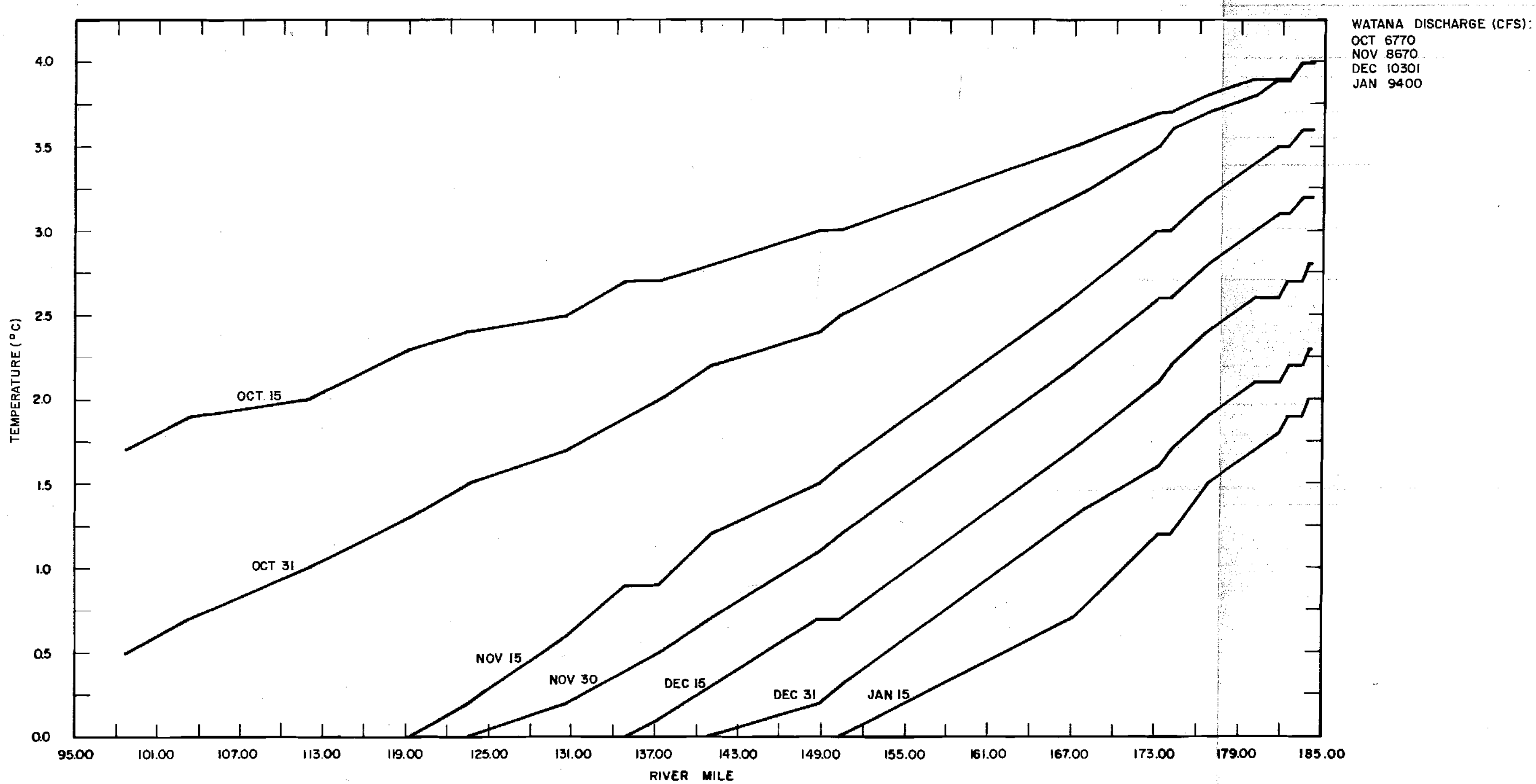


NOTE :

MODEL ASSUMES DAILY BASED LONG TERM AVERAGE METEOROLOGICAL DATA AND MEAN MONTHLY FLOWS AT WATANA.

WATANA OPERATION:
DOWNSTREAM TEMPERATURES - OCT TO JAN
OUTFLOW TEMPERATURE 4° C

FIGURE 8.48

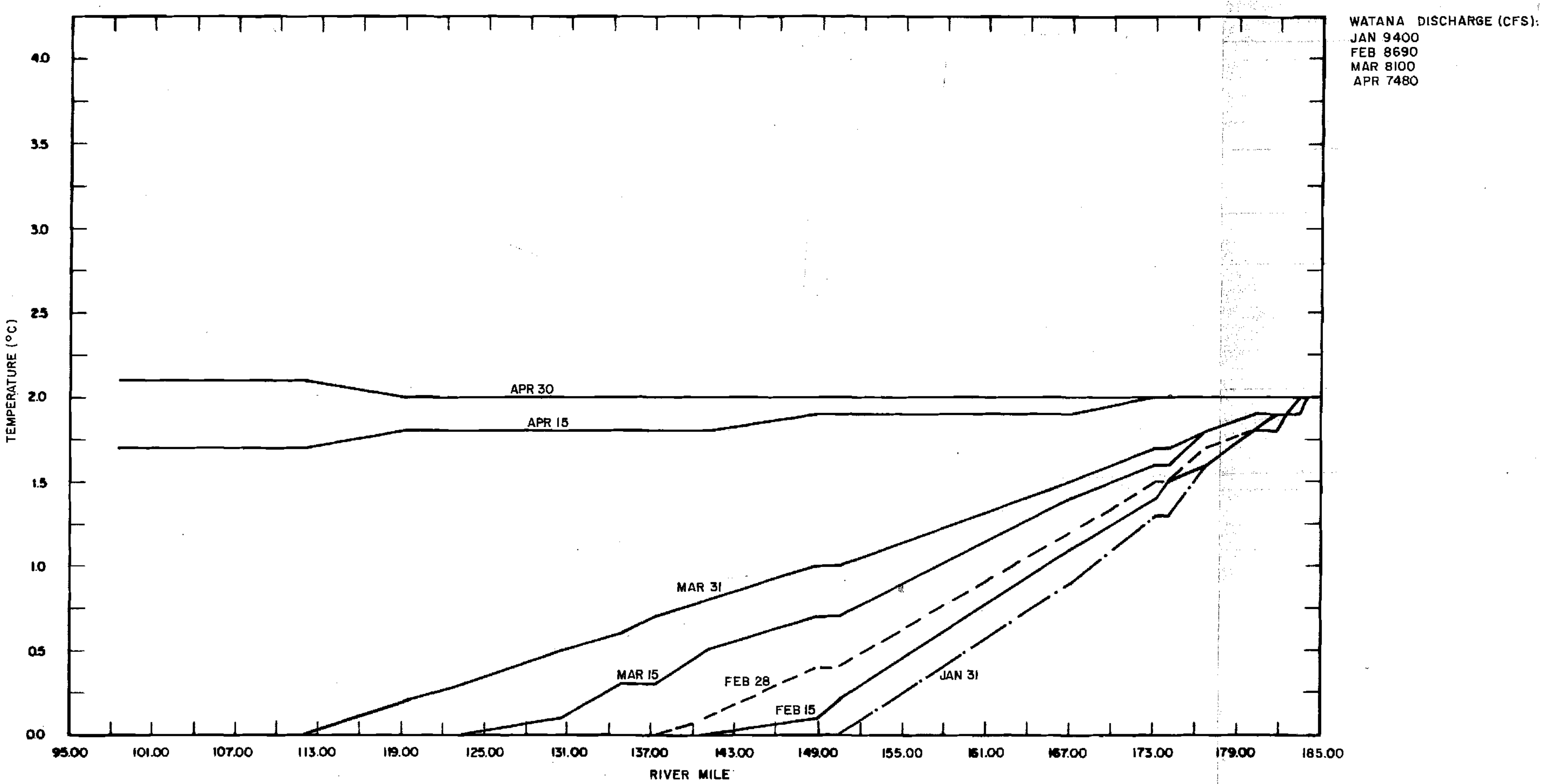


NOTE:

MODEL ASSUMES DAILY BASED LONG TERM AVERAGE METEOROLOGICAL DATA AND MEAN MONTHLY FLOWS AT WATANA.

WATANA OPERATION: DOWNSTREAM TEMPERATURES - OCT TO JAN
OUTFLOW TEMPERATURE 4 TO 2°C

FIGURE 8.49

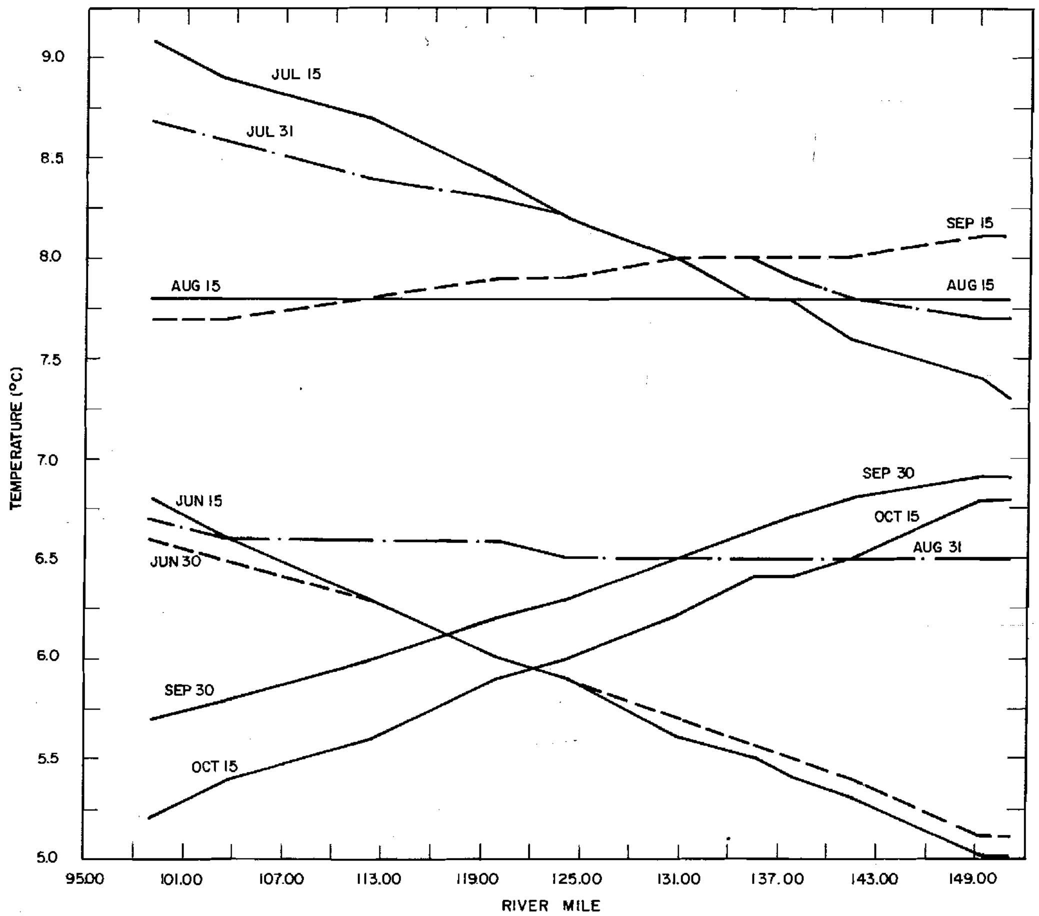


NOTE :

1. MODEL ASSUMES DAILY BASED LONG TERM AVERAGE METEOROLOGICAL DATA AND MEAN MONTHLY FLOWS AT WATANA.

WATANA OPERATION: DOWNSTREAM TEMPERATURES - JAN TO APR
OUTFLOW TEMPERATURE 4 TO 2°C

FIGURE 8.50



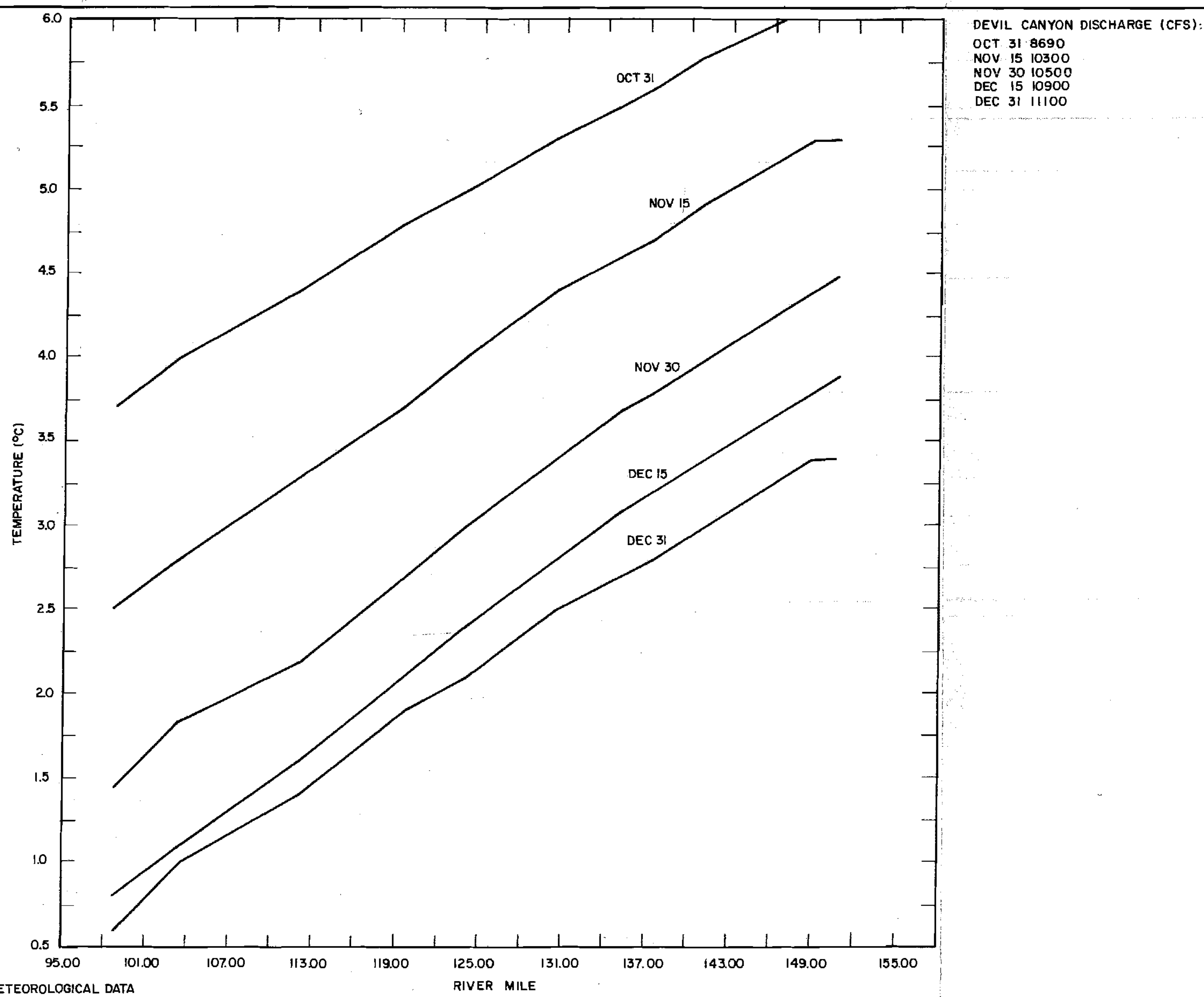
DEVIL CANYON DISCHARGE (CFS):
JUN 15 7920
JUN 30 5740
JUL 15 6830
JUL 31 6480
AUG 15 9940
AUG 31 24100 (RELEASE)
SEP 15 13750
SEP 30 10600
OCT 15 7450

NOTE:

1. MODEL ASSUMES 1981 METEOROLOGICAL DATA RECORDED AT WATANA.
2. DEVIL CANYON TEMPERATURE AND DISCHARGE FROM DYRESM MODEL. (RUNS DC1020 AND DC1021)

WATANA / DEVIL CANYON OPERATION
DOWNSTREAM TEMPERATURES - JUN TO OCT

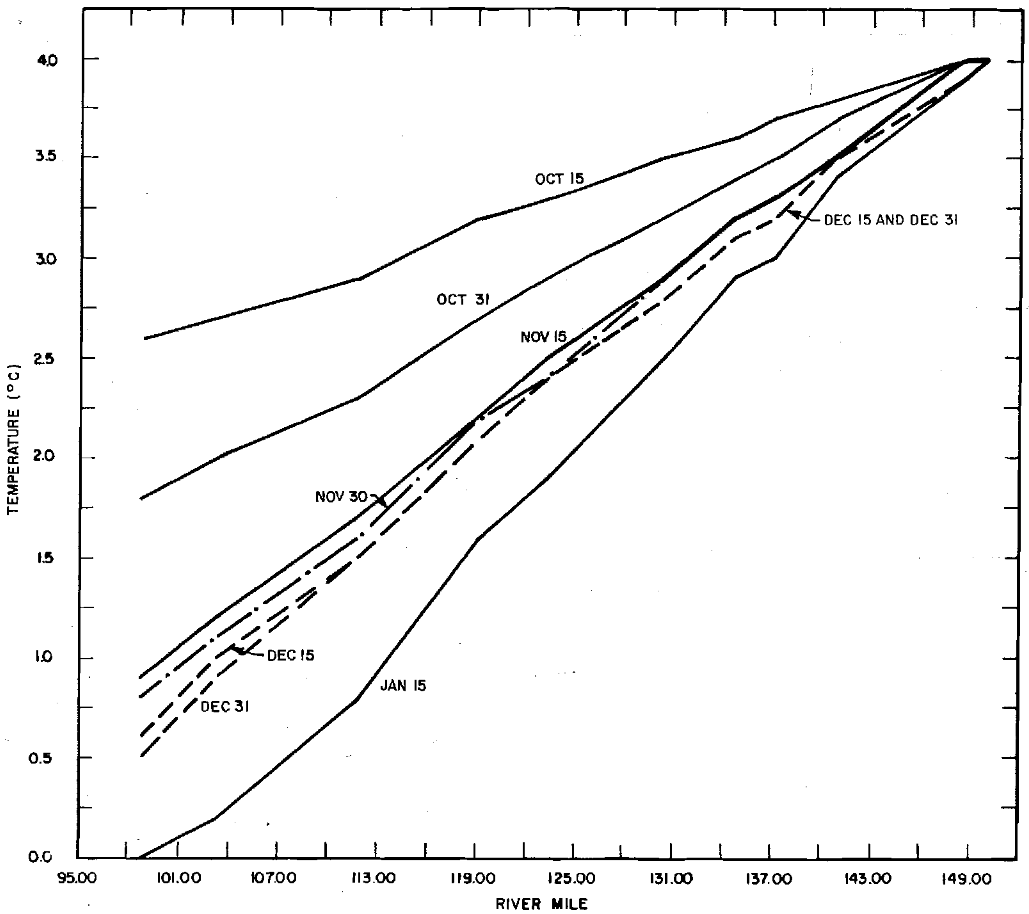
FIGURE 8.51



NOTE:
1. MODEL ASSUMES 1981 METEOROLOGICAL DATA RECORDED AT WATANA.
2. DEVIL CANYON TEMPERATURE AND DISCHARGE FROM DYRESM MODEL. (RUN DC1022)

WATANA / DEVIL CANYON OPERATION
DOWNSTREAM TEMPERATURES - OCT TO DEC

FIGURE 8.52



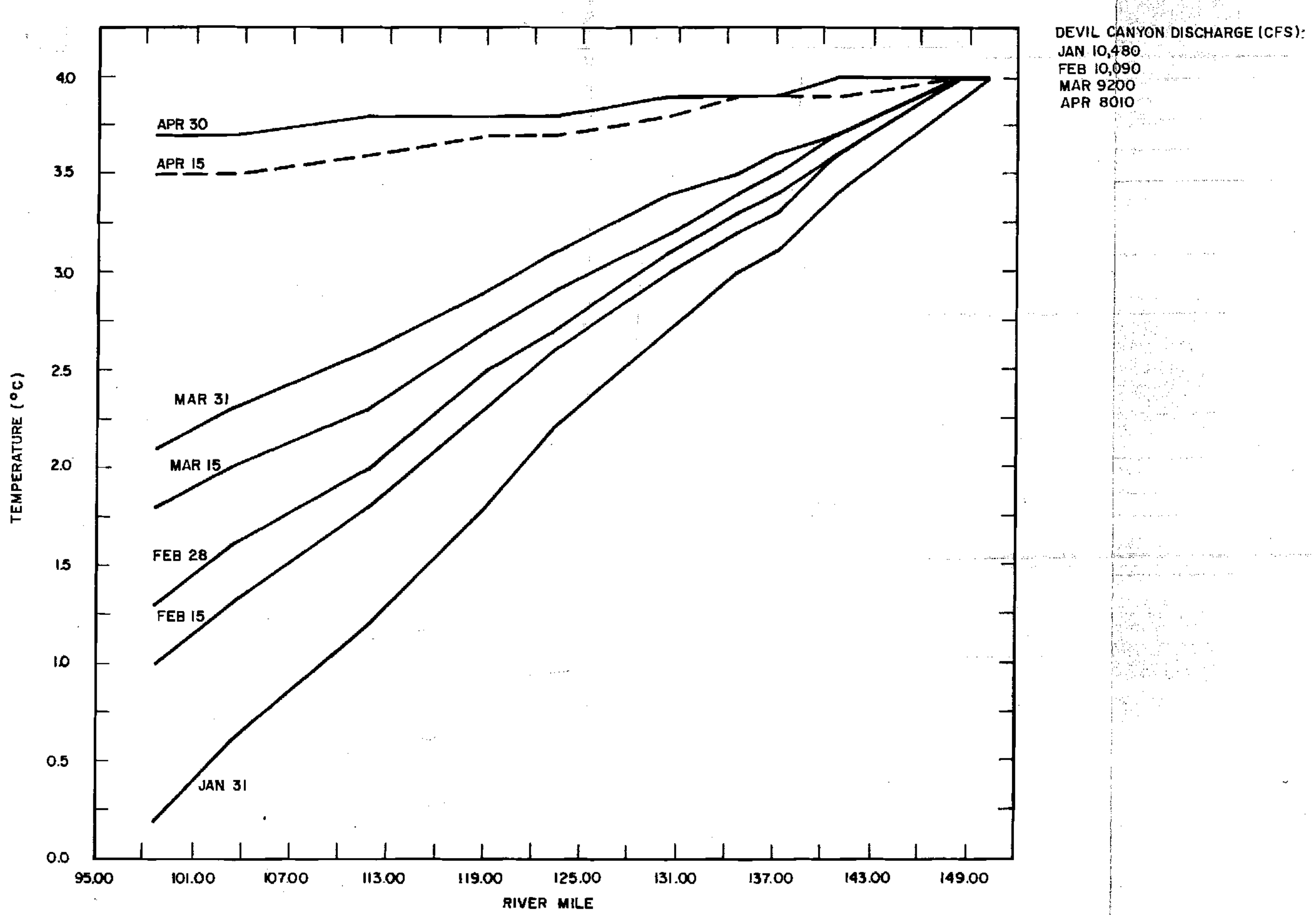
DEVIL CANYON DISCHARGE (CFS):
OCT 7320
NOV 9440
DEC 11,130
JAN 10,480

NOTE:

MODEL ASSUMES DAILY BASED LONG TERM AVERAGE METEOROLOGICAL DATA AND MEAN MONTHLY FLOWS AT DEVIL CANYON.

WATANA / DEVIL CANYON OPERATION DOWNSTREAM TEMPERATURES - OCT TO JAN
OUTFLOW TEMPERATURE 4°

FIGURE 8.53

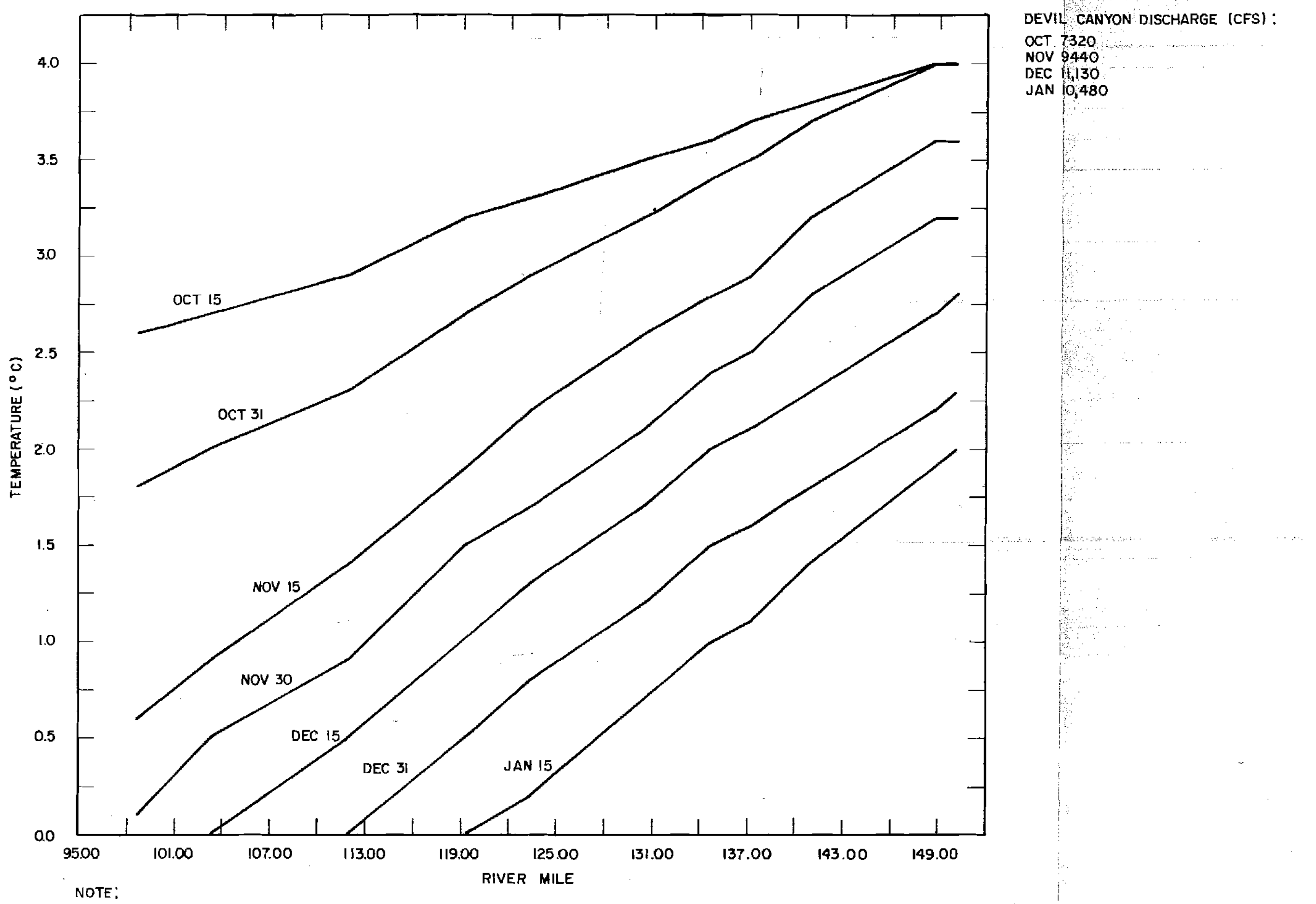


NOTE:

MODEL ASSUMES DAILY BASED LONG TERM AVERAGE METEOROLOGICAL DATA AND MEAN MONTHLY FLOWS AT DEVIL CANYON.

WATANA / DEVIL CANYON OPERATION DOWNSTREAM TEMPERATURES - JAN TO APR
OUTFLOW TEMPERATURE 4°C

FIGURE 8.54

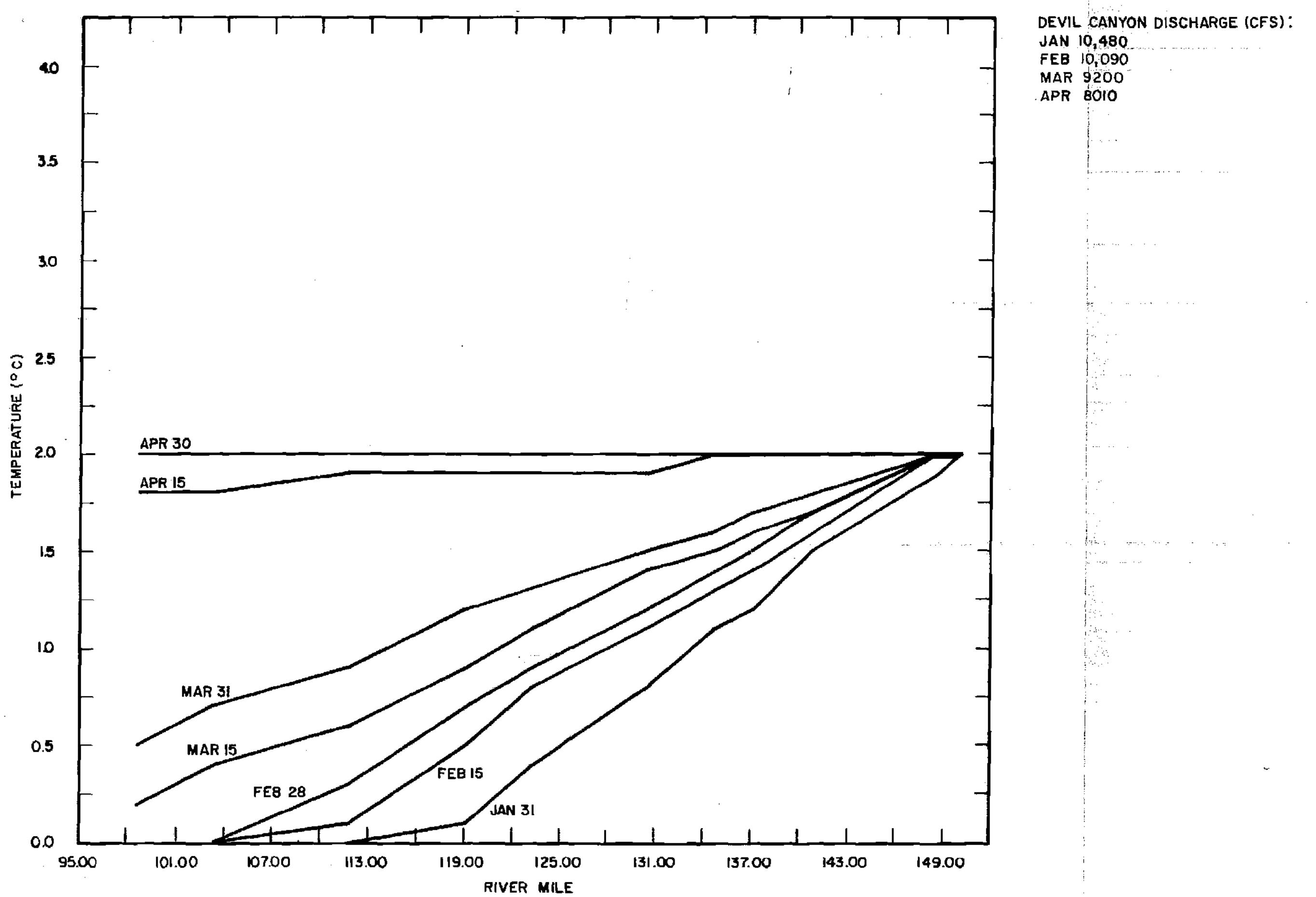


NOTE:

MODEL ASSUMES DAILY BASED LONG TERM AVERAGE METEOROLOGICAL DATA AND MEAN MONTHLY FLOWS AT DEVIL CANYON.

WATANA/DEVIL CANYON OPERATION DOWNSTREAM TEMPERATURES - OCT TO JAN OUTFLOW TEMPERATURES 4 TO 2°C

FIGURE 8.55



NOTE:
MODEL ASSUMES DAILY BASED LONG TERM AVERAGE METEOROLOGICAL DATA AND MEAN MONTHLY FLOWS AT DEVIL CANYON.

WATANA/DEVIL CANYON OPERATION DOWNSTREAM TEMPERATURES-JAN TO APR
OUTFLOW TEMPERATURE 4 TO 2°C

FIGURE 8.56

9 - ESTIMATES OF COST

This section, originally included as Section 16 in the March 1982 Feasibility Report (Acres 1982a), presents estimates of capital and operating costs for the Susitna Hydroelectric Project, comprising the Watana and Devil Canyon developments and associated transmission and access facilities, which have been updated as a result of on-going studies. The costs of design features and facilities incorporated into the project to mitigate environmental impacts during construction and operation are identified. Cash flow schedules, outlining capital requirements during planning, construction, and startup, are presented. The approach to the derivation of the capital and operating cost estimates is described.

Changes which have been made in the Watana cost estimate include:

- Access Plan 18 replaced Plan 5 (see Section 4);
- Work leading up to diversion was recosted for an accelerated schedule;
- Storage facilities were provided at Cantwell, and an item for operation and maintenance of these facilities was added to the estimate;
- Material prices were revised to reflect the longer transportation route;
- Quantities were revised for the intake and spillway;
- All work, other than noted above, was estimated on a basis of 10-hour shifts;
- Construction power was reestimated based on direct generation at site; and
- Contingencies were evaluated for each account.

Changes which have been made in the Devil Canyon cost estimate include:

- Access Plan 18 replaced Plan 5 (see Section 4);
- Intake quantities were revised;
- All work was reestimated on the basis of 10-hour shifts;
- The discussion of operation and maintenance costs was rewritten and Table 9.5 was added to show the breakdown of costs; and
- The cash flow curves were revised and Table 9.6 was added.

The total cost of the Watana and Devil Canyon projects is summarized in Table 9.1. A more detailed breakdown of cost for each development is presented in Tables 9.2 and 9.3.

9.1 - Construction Costs

This section describes the process used for derivation of construction costs and discusses the Code of Accounts established, the basis for the estimates, and the various assumptions made in arriving at the estimates. For general consistency with planning studies, all costs developed for the project are in January 1982 dollars.

(a) Code of Accounts

Estimates of construction costs were developed using the FERC format as outlined in the Federal Code of Regulations, Title 18 (Government Printing Office 1982).

The estimates have been subdivided into the following main cost groupings:

Group	Description
Production Plant	Costs for structures, equipment, and facilities necessary to produce power.
Transmission Plant	Costs for structures, equipment, and facilities necessary to transmit power from the sites to load centers.
General Plant	Costs for equipment and facilities required for the operation and maintenance of the production and transmission plant.
Indirect Costs	Costs that are common to a number of construction activities. For this estimate, only camps and electric power costs have been included in this group. Other indirect costs have been included in the costs under production, transmission, and general plant costs.
Overhead Construction Costs	Costs for engineering and administration.

Further subdivision within these groupings was made on the basis of the various types of work involved, as typically shown in the following example:

- Group:	Production Plant
- Account 332:	Reservoir, Dam, and Waterways
- Main Structure 332.3:	Main Dam
- Element 332.31:	Main Dam Structure
- Work Item 332.311:	Excavation
- Type of Work:	Rock

The detailed schedule of account items is presented in Acres (1983).

(b) Approach to Cost Estimating

The estimating process used generally included the following steps:

- Collection and assembly of detailed cost data for labor, material, and equipment as well as information on productivity, climatic conditions, and other related items;

- Review of engineering drawings and technical information with regard to construction methodology and feasibility;

- Production of detailed quantity takeoffs from drawings in accordance with the previously developed Code of Accounts and item listing;

- Determination of direct unit costs for each major type of work by development of labor, material, and equipment requirements; development of other costs by use of estimating guides, quotations from vendors, and other information as appropriate;

- Development of construction indirect costs by review of labor, material equipment, supporting facilities, and overheads; and

- Development of construction camp size and support requirements from the labor demand generated by the direct and indirect construction costs.

The above steps are discussed in detail in the following:

(c) Cost Data

Cost information was obtained from standard estimating sources, from sources in Alaska, from quotes by major equipment suppliers and vendors, and from recent representative hydroelectric projects. Labor and equipment costs for 1982 were developed from a number of sources (State of Alaska 1982; Caterpillar 1981) and from an analysis of costs for recent projects performed in the Alaska environment.

It has been assumed that most contractors will work an average of two 10-hour shifts per day, 6 days per week. Because of the severe compression of construction activities in 1985-86, it has been assumed that most work in this period will be on two 12-hour shifts, 7 days per week.

The 10-hour work shift assumption provides for high utilization of construction equipment and reasonable levels of overtime earnings to attract workers. The two-shift basis generally achieves the most economical balance between labor and camp costs.

Construction equipment costs were obtained from vendors on an FOB Anchorage basis with an appropriate allowance included for transportation to site. A representative list of construction equipment required for the project was assembled as a basis for the estimate. It has been assumed that most equipment would be fully depreciated over the life of the project. For some activities such as construction of the Watana main dam, an allowance for major overhaul was included rather than fleet replacement. Equipment operating costs were estimated from industry source data, with appropriate modifications for the remote nature and extreme climatic environment of the site; Alaskan labor rates were used for equipment maintenance and repair. Fuel and oil prices have been based upon FOB site prices.

Information for permanent mechanical and electrical equipment was obtained from vendors and manufacturers who provided guideline costs on major power plant equipment.

The costs of materials required for site construction were estimated on the basis of suppliers' quotations, with allowances for shipping to site.

(d) Seasonal Influences on Productivity

A review of climatic conditions, together with an analysis of experience in Alaska and in northern Canada on large construction projects, was undertaken to determine the average duration for various key activities. It has been projected that most aboveground activities will either stop or be curtailed during the period of December and January because of the extreme cold weather and the associated lower productivity. For the main dam construction activities, the following assumptions have been used:

- Watana dam fill - 6-month season; and
- Devil Canyon arch dam - 8-month season.

Other aboveground activities are assumed to extend up to 11 months depending on the type of work and the criticality of the schedule. Underground activities are generally not affected by climate and should continue throughout the year.

Studies by others (Roberts 1976) have indicated a 60 percent or greater decrease in efficiency in construction operations under adverse winter conditions. Therefore, it is expected that most contractors would attempt to schedule outside work over a period of 6 to 10 months.

Studies performed as part of this work program indicate that the general construction activity at the Susitna damsite during the months of April through September would be comparable with that in the northern sections of the western United States. Rainfall in the general region of the site is moderate between mid-April and mid-October, ranging from a low of 0.75-inch precipitation in April to a high of 5.33 inches in August. Temperatures in this period range from 33°F to 66°F for a twenty-year average. In the five-month period from November through March, the temperature ranges from 9.4°F to 20.3°F with snowfall of 10 inches per month.

(e) Construction Methods

The construction methods assumed for development of the estimate and construction schedule are generally considered as normal and in line with the available level of technical information. A conservative approach has been taken in those areas where more detailed information will be developed during subsequent investigation and engineering programs. For example, normal drilling, blasting, and mucking methods have been assumed for all underground excavation. Also, conventional equipment has been considered for major fill and concrete work. Various construction methods were considered for several of the major work items to determine the most economically practical method. For example, a comprehensive evaluation was made of the means of excavating material from Borrow Site E and the downstream river for the Watana dam shells. A comparison of excavation by dragline, dredge, backhoe, and scraper bucket methods was made, with consideration given to the quantity of material available, distance from the dam, and location in the river or adjacent terraces.

(f) Quantity Takeoffs

Detailed quantity takeoffs were produced from the engineering drawings using methods normal to the industry. The quantities developed are those listed in the detailed summary estimates in Appendix C of the Feasibility Report (Acres 1982b).

(g) Indirect Construction Costs

Indirect construction costs were estimated in detail for the civil construction activities. A more general evaluation was used for the mechanical and electrical work.

Indirect costs included the following:

- Mobilization;
- Technical and supervisory personnel above the level of trades foremen;
- All vehicle costs for supervisory personnel;
- Fixed offices, mobile offices, workshops, storage facilities, and laydown areas, including all services;
- General transportation for workmen onsite and offsite;
- Yard cranes and floats;
- Utilities including electrical power, heat, water, and compressed air;

- Small tools;
- Safety program and equipment;
- Financing;
- Bonds and securities;
- Insurance;
- Taxes;
- Permits;
- Head office overhead;
- Contingency allowance; and
- Profit.

In developing contractor's indirect costs, the following assumptions have been made:

- Mobilization costs have generally been spread over construction items;

- No escalation allowances have been made, and therefore any risks associated with escalation are not included;

- Financing of progress payments has been estimated for 45 days, the average time between expenditure and reimbursement;

- Holdback would be limited to a nominal amount;

- Project all-risk insurance has been estimated as a contractor's indirect cost for this estimate, but it is expected that this insurance would be carried by the owner; and

- Contract packaging would provide for the supply of major materials to contractors at site at cost. These include fuel, electric power, cement, and reinforcing steel.

9.2 - Mitigation Costs

As discussed in previous sections, the project arrangement includes a number of features designed to mitigate potential impacts on the natural environment and on residents and communities in the vicinity of the project. In addition, a number of measures are planned during construction of the project to mitigate similar impacts caused by construction activities. The measures and facilities represent more costs to the project than would normally be required for safe and efficient operation of a hydroelectric development. These mitigation costs have been estimated at $153 million and have been summarized in Table 9.4. In addition, the costs of full reservoir clearing at both sites have been estimated at $85 million. Although full clearing is considered good engineering practice, it is not essential to the operation of the power facilities. Both above cost items include direct and indirect costs, engineering, administration, and contingencies, and have been included in the accounts of construction costs in the estimate.

A number of mitigation costs are associated with facilities, improvements, or other programs not directly related to the project or located outside the project boundaries. These would include the following items:

- Caribou barriers;
- Raptor nesting platforms;
- Fish channels;
- Fish hatcheries;
- Stream improvements;
- Salt licks;
- Habitat management for moose; and
- Fish stocking program in reservoirs.

The costs of these programs, including contingencies, have been estimated as follows and listed under project indirects in the capital cost estimate.

Watana	\$32.0 million (approx.)
Devil Canyon	5.0 million (approx.)
Total Project	\$37.0 million (approx.)

Finally, a number of studies and programs will be required to monitor the impacts of the project on the environment and to develop and record various data during project construction and operation. These include the following:

- Archaeological studies;
- Fisheries and wildlife studies;
- Right-of-way studies; and
- Socioeconomic planning studies.

The costs for the above work have been included under project overheads and have been estimated at approximately \$20 million.

9.3 - Engineering and Administration Costs

Engineering has been subdivided into the following accounts for the purposes of the cost estimates:

- Account 71
  - Engineering and Project Management
  - Construction Management
  - Procurement
- Account 76
  - Owner's Costs

The total cost of engineering and administrative activities has been estimated at 12.5 percent of the total construction costs, including contingencies. This is in general agreement with experience on projects similar in scope and complexity. A detailed breakdown of these costs is dependent on the organizational structure established to undertake design and management of the project, as well as more definitive data relating to the scope and nature of the various project components. However, the main elements of cost included are as follows:

(a) Engineering and Project Management Costs

These costs include allowances for:

- Feasibility studies, including site surveys and investigations and logistics support;
- Preparation of a license application to the FERC;
- Technical and administrative input for other federal, state, and local permit and license applications;
- Overall coordination and administration of engineering, construction management, and procurement activities;
- Overall planning, coordination, and monitoring activities related to cost and schedule of the project;
- Coordination with and reporting to the Power Authority regarding all aspects of the project;
- Preliminary and detailed design;
- Technical input to procurement of construction services, support services, and equipment;
- Monitoring of construction to ensure conformance to design requirements;
- Preparation of startup and acceptance test procedures; and
- Preparation of project operating and maintenance manuals.

(b) Construction Management Costs

Construction management costs have been assumed to include:

- Initial planning and scheduling and establishment of project procedures and organization;
- Coordination of onsite contractors and construction management activities;
- Administration of onsite contractors to ensure harmony of trades, compliance with applicable regulations, and maintenance of adequate site security and safety requirements;
- Development, coordination, and monitoring of construction schedules;
- Construction cost control;
- Material, equipment, and drawing control;
- Inspection of construction and survey control;
- Measurement for payment;
- Startup and acceptance test for equipment and systems;
- Compilation of as-constructed records; and
- Final acceptance.

(c) Procurement Costs

Procurement costs have been assumed to include:

- Establishment of project procurement procedures;
- Preparation of nontechnical procurement documents;
- Solicitation and review of bids for construction services, support services, permanent equipment, and other items required to complete the project;
- Cost administration and control for procurement contracts; and
- Quality assurance services during fabrication or manufacture of equipment and other purchased items.

(d) Owner's Costs

Owner's costs have been assumed to include the following:

- Administration and coordination of project management and engineering organizations;
- Coordination with other state, local, and federal agencies and groups having jurisdiction over or interest in the project;
- Coordination with interested public groups and individuals;
- Reporting to legislature and the public on the progress of the project; and
- Legal costs (Account 72).

9.4 - Operation, Maintenance, and Replacement Costs

The facilities and procedures for operation and maintenance of the project are described in Section 15 of the Feasibility Report (Acres 1982a). Assumptions for the size and extent of these facilities have been made on the basis of experience at large hydroelectric developments in northern climates. The annual costs for operation and maintenance for the Watana development have been estimated at $10.4 million. When Devil Canyon is brought on-line, these costs increase to $15.2 million per annum. Interim replacement costs have been estimated at 0.3 percent per annum of the capital cost.

The breakdown in Table 9.5 is provided in support of the allowance used in the finance/economic analysis of Susitna Hydroelectric Power Development. It is based on an operating plan involving full staffing of power plant and permanent town site support with a total of 105 personnel at Watana and another 25 when Devil Canyon comes on-line. This provides manned supervisory staff on a 24-hour, 3-shift basis and maintenance crews to handle all but major overhauls. Overhauls would involve contracted labor for which a nominal allowance has been made. It recognized that major overhauls are normally unlikely in the first 10 years or more of plant life. In earlier years, this allowance was a prudent provision for unexpected startup costs over and above those covered by warranty.

The allowance for contracted services also covers helicopter operations and access road snow clearing/maintenance.

Allowances have also been made for environmental mitigation as well as for a contingency for unforeseen costs.

Estimates for Susitna have been based both on original estimate and actual experience at Churchill Falls. It should be realized that alternative operating plans are possible which eliminate the need for permanent townsite facilities and rely on more remote supervisory systems and/or operations/maintenance crews transported to the plant on a rotating shift basis. Cost implications of these alternatives have not yet been examined.

9.5 - Allowance for Funds Used During Construction

At current high levels of interest rates in the financial marketplace, AFDC will amount to a significant element of financing cost for the lengthy periods required for construction of the Watana and Devil Canyon projects. However, in economic evaluations of the Susitna project, the low real rates of interest assumed would have a much reduced impact on assumed project development costs. Furthermore, direct state involvement in financing of the Susitna project will also have a significant impact on the amount, if any, of AFDC. For purposes of the feasibility study, therefore, the conventional practice of calculating AFDC as a separate line item for inclusion as part of project construction cost has not been followed. Provisions for AFDC at appropriate rates of interest are made in the economic and financial analyses described in Section 18 of the Feasibility Report (Acres 1982a).

9.6 - Escalation

All costs presented in this section are at January 1982 levels, and consequently include no allowance for future cost escalation. Thus, these costs would not be truly representative of construction and procurement bid prices because provision must be made in such bids for continuing escalation of costs and the extent and variation of escalation that might take place over the lengthy construction periods involved. Economic and financial evaluations discussed in Section 18 of the Feasibility Report take full account of such escalation at appropriately assumed rates.

9.7 - Cash Flow and Manpower Loading Requirements

The cash flow requirements for construction of Watana and Devil Canyon are an essential input to economic and financial planning studies. The basis for the cash flow are the construction cost estimates in January 1982 dollars and the construction schedules presented in Section 10, with no provision being made as such for escalation. The cash flow estimates were computed on an annual basis and do not include adjustments for advanced payments for mobilization or for holdbacks on construction contracts. The results are presented in Table 9.6. The manpower loading requirements were developed from cash flow projections. These curves were used as the basis for camp loading and associated socioeconomic impact studies, and are presented in Figures 9.1 through 9.3.

9.8 - Contingency

Contingencies on construction costs have been assessed for each account within the 10 to 20 percent range and included in the cost estimates. Contingency averages approximately 15 percent over the total construction cost. The contingency includes cost increases which may occur in the detailed engineering phase of the project after more comprehensive site investigations and final designs have been completed and after the requirements of various concerned agencies have been considered. The contingency estimate also includes allowances for inherent uncertainties in cost of labor, equipment, and materials, and for unforeseen conditions which may be encountered during construction. Escalation in costs as the result of inflation is not included. No allowance has been included for costs associated with significant delays in project implementation.

9.9 - Previously Constructed Project Facilities

An electrical intertie between the major load centers of Fairbanks and Anchorage is currently under construction. The line will connect existing transmission systems at Willow in the south and Healy in the north. The intertie is being built to the same standards as those proposed for the Susitna project transmission lines and will become part of the licensed project. The line will be energized initially at 138 kV in 1984 and will operate at 345 kV after the Watana phase of the Susitna project is complete.

The current estimate for the completed intertie is $130.8 million. This cost is not included in the estimates of this section.

9.10 - Check Estimate by EBASCO

An independent check estimate was undertaken by EBASCO Services Incorporated. The estimate was based on engineering drawings, technical information, and quantities prepared by Acres. Major quantity items were checked. The EBASCO check estimated capital cost was approximately 7 percent above the Acres estimate.

A meeting was held with the Power Authority, EBASCO, and Acres to review differences in the estimates. It was generally possible to reconcile the differences and it was concluded that no major changes were required in the Feasibility Report Estimate.

REFERENCES

Acres American Incorporated. 1982a. Susitna Hydroelectric Project Feasibility Report. Prepared for the Alaska Power Authority.

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Caterpillar Tractor Co. 1981. Caterpillar Performance Handbook.

Government Printing Office. 1982. Conservation of Power and Water Resources, Part 1 and 2. Code of Federal Regulations. Title 18: Washington, D.C.

Roberts, William S. July 1976. Regionalized Feasibility Study of Cold Weather Earthwork. Special Report 76-2. Cold Regions Research and Engineering Laboratory.

State of Alaska. 1982. Agreements of Wages and Benefits for Construction Trades.

TABLE 9.1: SUMMARY OF COST ESTIMATE

Category	Watana	Devil Canyon	Total
	January 1982 Dollars $ X 10^6		
Production Plant	$2,293	$1,064	$3,357
Transmission Plant	456	105	561
General Plant	5	5	10
Indirect	442	207	649
Total Construction	3,196	1,381	4,577
Overhead Construction	400	173	573
TOTAL PROJECT	$3,596	$1,554	$5,150

ESTIMATE SUMMARY

TABLE 9.2
WATANA ESTIMATE SUMMARY

ACRES

CLIENT ALASKA POWER AUTHORITY

PROJECT SUSITNA HYDROELECTRIC PROJECT

TYPE OF ESTIMATE Feasibility

APPROVED BY JDL

JOB NUMBER P5700.00
FILE NUMBER P5700.14.09
SHEET 1 OF 5
BY DATE
CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		($\times 10^6$)	($\times 10^6$)	
	PRODUCTION PLANT			
330	Land & Land Rights	$ 51		
331	Powerplant Structures & Improvements	74		
332	Reservoir, Dams & Waterways	1,547		
333	Waterwheels, Turbines & Generators	66		
334	Accessory Electrical Equipment	21		
335	Miscellaneous Powerplant Equipment (Mechanical)	14		
336	Roads & Railroads	214		
	Subtotal	1,987		
	Contingency	306		
	TOTAL PRODUCTION PLANT		$ 2,293	

ESTIMATE SUMMARY	TABLE 9.2 WATANA		JOB NUMBER P5700.00
CLIENT ALASKA POWER AUTHORITY		TYPE OF ESTIMATE Feasibility	FILE NUMBER P5700.14.09
PROJECT SUSITNA HYDROELECTRIC PROJECT		APPROVED BY JDL	SHEET 2 OF 5
			BY DATE
			CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		(x 10^6)	(x 10^6)	
	TOTAL BROUGHT FORWARD		$ 2,293	
	TRANSMISSION PLANT			
350	Land & Land Rights	$ 8		
352	Substation & Switching Station Structures & Improvements	12		
353	Substation & Switching Station Equipment	131		
354	Steel Towers & Fixtures	131		
356	Overhead Conductors & Devices	100		
359	Roads & Trails	13		
	Subtotal	395		
	Contingency	61		
	TOTAL TRANSMISSION PLANT		$ 456	
			$ 2,749	

ESTIMATE SUMMARY

TABLE 9.2
WATANA

CLIENT: ALASKA POWER AUTHORITY

PROJECT: SUSITNA HYDROELECTRIC PROJECT

TYPE OF ESTIMATE: Feasibility

APPROVED BY: JDL

JOB NUMBER: P5700.00
FILE NUMBER: P5700.14.09
SHEET 3 OF 5
BY ______ DATE ______
CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		($x\ 10^6$)	($x\ 10^6$)	
	TOTAL BROUGHT FORWARD		$ 2,749	
	GENERAL PLANT			
389	Land & Land Rights	$ -		Included under 330
390	Structures & Improvements	-		Included under 331
391	Office Furniture/Equipment			Included under 399
392	Transportation Equipment			" "
393	Stores Equipment			" "
394	Tools Shop & Garage Equipment			" "
395	Laboratory Equipment			" "
396	Power-Operated Equipment			" "
397	Communications Equipment			" "
398	Miscellaneous Equipment			" "
399	Other Tangible Property	5		
	TOTAL GENERAL PLANT		$ 5	
			$ 2,754	

ESTIMATE SUMMARY

TABLE 9.2
WATANA

CLIENT	ALASKA POWER AUTHORITY
PROJECT	SUSITNA HYDROELECTRIC PROJECT
TYPE OF ESTIMATE	Feasibility
APPROVED BY	JDL
JOB NUMBER	P5700.00
FILE NUMBER	P5700.14.09
SHEET	4 OF 5
BY	DATE
CHKD	JRP
DATE	2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		(x 10^6)	(x 10^6)	
	TOTAL BROUGHT FORWARD		$ 2,754	
	INDIRECT COSTS			
61	Temporary Construction Facilities	$ -		See Note
62	Construction Equipment	-		See Note
63	Camp & Commissary	373		
64	Labor Expense	-		
65	Superintendence	-		See Note
66	Insurance	-		See Note
68	Mitigation	29		
69	Fees	-		See Note
	Note: Costs under accounts 61, 62, 64, 65, 66, and 69 are included in the appropriate direct costs listed above.			
	Subtotal	402		
	Contingency	40		
	TOTAL INDIRECT COSTS		$ 442	
	TOTAL CONSTRUCTION COSTS		$ 3,196	

ACRES

ESTIMATE SUMMARY

TABLE 9.2
WATANA

CLIENT: ALASKA POWER AUTHORITY

PROJECT: SUSITNA HYDROELECTRIC PROJECT

TYPE OF ESTIMATE: Feasibility

APPROVED BY: JDL

JOB NUMBER: P5700.00
FILE NUMBER: P5700.14.09
SHEET 5 OF 5
BY ____ DATE ____
CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		($\times 10^6$)	($\times 10^6$)	
	TOTAL CONSTRUCTION COSTS BROUGHT FORWARD		$ 3,196	
	OVERHEAD CONSTRUCTION COSTS (PROJECT INDIRECTS)			
71	Engineering/ Administration	$ 386		
72	Legal Expenses	14		Included in 71
75	Taxes	-		Not applicable
76	Administrative & General Expenses	-		Included in 71
77	Interest	-		Not included
80	Earnings/Expenses During Construction	-		Not included
	Total Overhead		400	
	TOTAL PROJECT COST		$ 3,596	

ACRES

ESTIMATE SUMMARY

TABLE 9.3
DEVIL CANYON ESTIMATE SUMMARY

CLIENT ALASKA POWER AUTHORITY

PROJECT SUSITNA HYDROELECTRIC PROJECT

TYPE OF ESTIMATE Feasibility

APPROVED BY JDL

JOB NUMBER P5700.00
FILE NUMBER P5700.14.09
SHEET 1 OF 5
BY DATE
CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		(x 10^6)	(x 10^6)	
	PRODUCTION PLANT			
330	Land & Land Rights	$ 22		
331	Powerplant Structures & Improvements	69		
332	Reservoir, Dams & Waterways	646		
333	Waterwheels, Turbines & Generators	42		
334	Accessory Electrical Equipment	13		
335	Miscellaneous Powerplant Equipment (Mechanical)	11		
336	Roads & Railroads	119		
	Subtotal	922		
	Contingency	142		
	TOTAL PRODUCTION PLANT		$ 1,064	

ACRES

ESTIMATE SUMMARY

TABLE 9.3
DEVIL CANYON

CLIENT ALASKA POWER AUTHORITY

PROJECT SUSITNA HYDROELECTRIC PROJECT

TYPE OF ESTIMATE Feasibility

APPROVED BY JDL

JOB NUMBER P5700.00
FILE NUMBER P5700.14.09
SHEET 2 OF 5
BY DATE
CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		($\times 10^6$)	($\times 10^6$)	
	TOTAL BROUGHT FORWARD		$ 1,064	
	TRANSMISSION PLANT			
350	Land & Land Rights	$ -		Included in Watana Estimate
352	Substation & Switching Station Structures & Improvements	7		
353	Substation & Switching Station Equipment	21		
354	Steel Towers & Fixtures	29		
356	Overhead Conductors & Devices	34		
359	Roads & Trails	-		Included in Watana Estimate
	Subtotal	91		
	Contingency	14		
	TOTAL TRANSMISSION PLANT		$ 105	
			$ 1,169	

ACRES

ESTIMATE SUMMARY

TABLE 9.3
DEVIL CANYON

CLIENT ALASKA POWER AUTHORITY

PROJECT SUSITNA HYDROELECTRIC PROJECT

TYPE OF ESTIMATE Feasibility

APPROVED BY JDL

JOB NUMBER P5700.00
FILE NUMBER P5700.14.09
SHEET 3 OF 5
BY DATE
CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		(x 10^6)	(x 10^6)	
	TOTAL BROUGHT FORWARD		$ 1,169	
	GENERAL PLANT			
389	Land & Land Rights	$		Included under 330
390	Structures & Improvements			Included under 331
391	Office Furniture/Equipment			Included under 399
392	Transportation Equipment			" "
393	Stores Equipment			" "
394	Tools Shop & Garage Equipment			" "
395	Laboratory Equipment			" "
396	Power-Operated Equipment			" "
397	Communications Equipment			" "
398	Miscellaneous Equipment			" "
399	Other Tangible Property	5		
	TOTAL GENERAL PLANT		$ 5	
			$ 1,174	

ACRES

ESTIMATE SUMMARY

TABLE 9.3
DEVIL CANYON

CLIENT: ALASKA POWER AUTHORITY

PROJECT: SUSITNA HYDROELECTRIC PROJECT

TYPE OF ESTIMATE: Feasibility

APPROVED BY: JDL

JOB NUMBER: P5700.00
FILE NUMBER: P5700.14.09
SHEET 4 OF 5
BY ______ DATE ______
CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		($\times 10^6$)	($\times 10^6$)	
	TOTAL BROUGHT FORWARD		$ 1,174	
	INDIRECT COSTS			
61	Temporary Construction Facilities	$ -		See Note
62	Construction Equipment	-		See Note
63	Camp & Commissary	184		
64	Labor Expense	-		See Note
65	Superintendence	-		See Note
66	Insurance	-		See Note
68	Mitigation	4		
69	Fees	-		See Note
	Note: Costs under accounts 61, 62, 64, 65, 66, and 69 are included in the appropriate direct costs listed above.			
	Subtotal	188		
	Contingency	19		
	TOTAL INDIRECT COSTS		$ 207	
	TOTAL CONSTRUCTION COSTS		$ 1,381	

ACRES

ESTIMATE SUMMARY

TABLE 9.3
DEVIL CANYON

CLIENT ALASKA POWER AUTHORITY

PROJECT SUSITNA HYDROELECTRIC PROJECT

TYPE OF ESTIMATE Feasibility

APPROVED BY JDL

JOB NUMBER P5700.00
FILE NUMBER P5700.14.09
SHEET 5 OF 5
BY ______ DATE ______
CHKD JRP DATE 2/82

No.	DESCRIPTION	AMOUNT	TOTALS	REMARKS
		(x 10^6)	(x 10^6)	
	TOTAL CONSTRUCTION COSTS BROUGHT FORWARD		$ 1,381	
	OVERHEAD CONSTRUCTION COSTS (PROJECT INDIRECTS)			
71	Engineering/ Administration	$ 167		
	Environmental Monitoring	6		
72	Legal Expenses	-		Included in 71
75	Taxes	-		Not Applicable
76	Administrative & General Expenses	-		Included in 71
77	Interest	-		Not Included
80	Earnings/Expenses During Construction	-		Not Included
	Total Overhead Costs		173	
	TOTAL PROJECT COST		$ 1,554	

TABLE 9.4: MITIGATION MEASURES - SUMMARY OF COSTS INCORPORATED IN CONSTRUCTION COST ESTIMATES

COSTS INCORPORATED IN CONSTRUCTION ESTIMATES	WATANA $\$ \times 10^3$	DEVIL CANYON $\$ \times 10^3$	
Outlet Facilities			
Main Dam at Devil Canyon		14,600	
Tunnel Spillway at Watana	47,100		
Restoration of Borrow Site D	1,600	NA	
Restoration of Borrow Site F	600	NA	
Restoration of Camp and Village	2,300	1,000	
Restoration of Construction Sites	4,100	2,000	
Fencing around Camp	400	200	
Fencing around Garbage Disposal Area	100	100	
Multilevel Intake Structure	18,400	NA	
Camp Facilities Associated with Trying to Keep Workers out of Local Communities	10,200	9,000	
Restoration of Haul Roads	800	500	
SUBTOTAL	85,600	27,400	
Contingency 20%	17,100	5,500	
TOTAL CONSTRUCTION	102,700	32,900	
Engineering 12.5%	12,800	4,100	
TOTAL PROJECT	115,500	37,000	152,500

TABLE 9.5

SUMMARY OF OPERATING AND MAINTENANCE COSTS

	WATANA ($ 000's Omitted)			DEVIL CANYON ($ 000's Omitted)		
	Labor	Expense Items	Subtotal	Labor	Expense Items	Subtotal
Power and Transmission Operation/ Maintenance	5,330	990	6,320	1,920	500	2,420
Contracted Services	--	900	900	--	480	480
Permanent Townsite Operations	540	340	880	120	80	200
Allowance for Environmental Mitigation	--	--	1,000	--	--	1,000
Contingency	--	--	900	--	--	500
			$10,000			$ 4,600
Additional Allowance from 2002 to Replace Community Facilities			400			200
Total Operating and Maintenance Expenditure Estimate Power Development and Transmission Facilities		WATANA	$10,400		DEVIL CANYON	$ 4,800

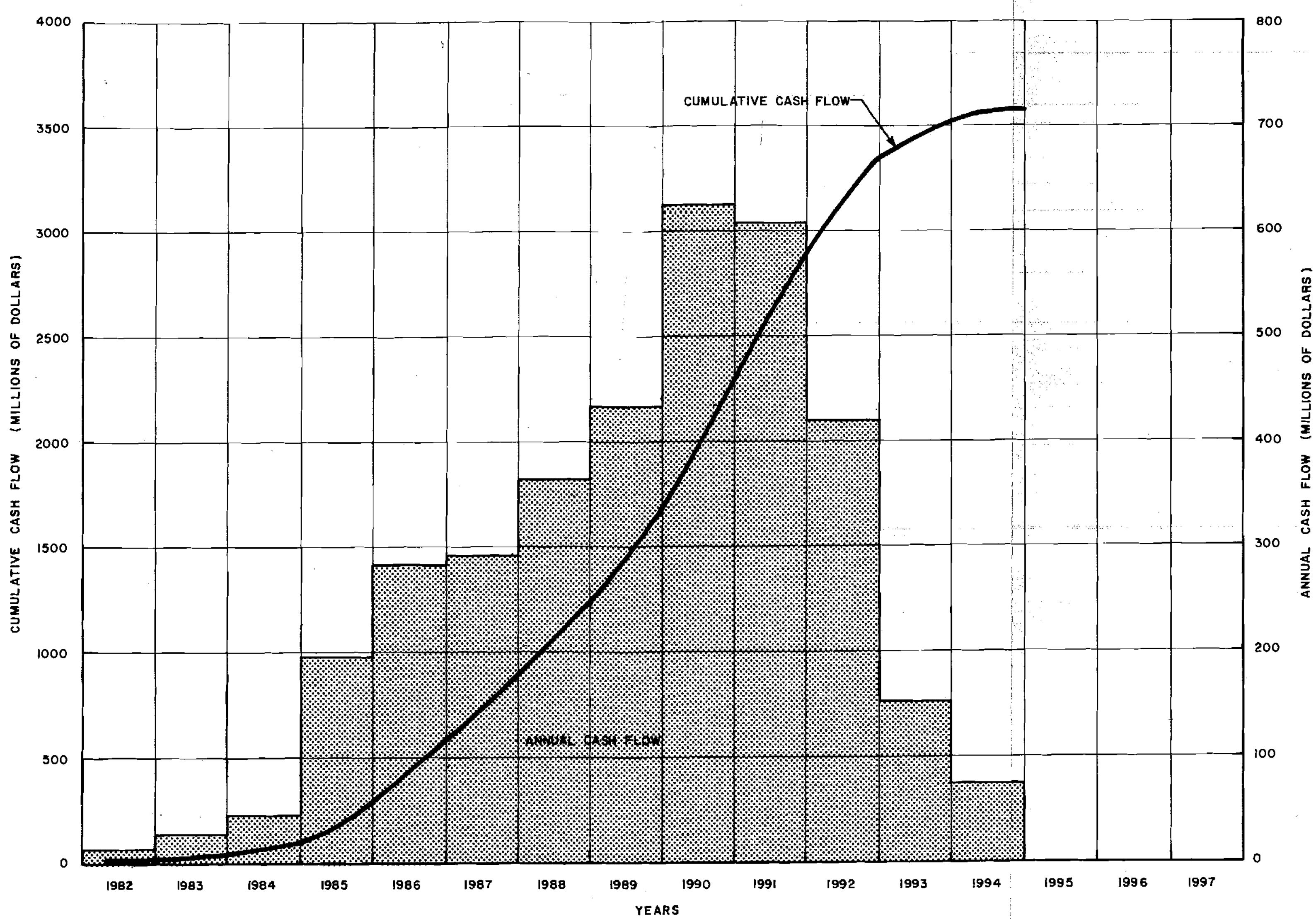
TABLE 9.6

WATANA AND DEVIL CANYON
CUMULATIVE AND ANNUAL CASH FLOW

JANUARY 1982 DOLLARS - IN MILLIONS

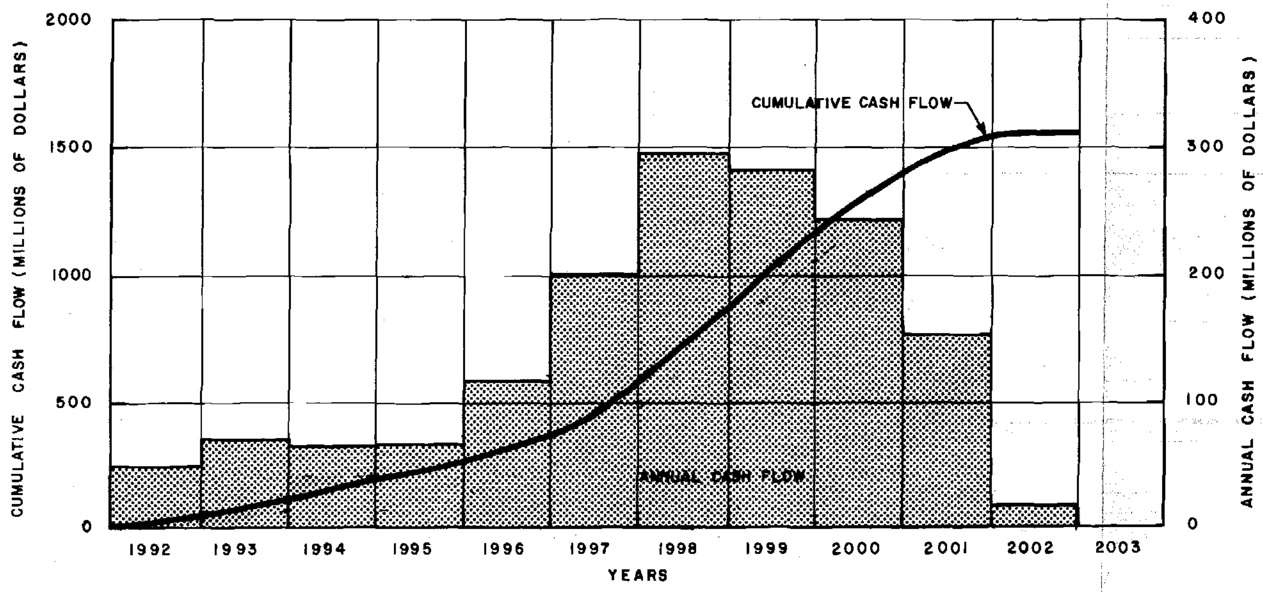
	ANNUAL CASH FLOW			CUMULATIVE CASH FLOW (TO END OF YEAR)		
YEAR	WATANA	DEVIL CANYON	COMBINED	WATANA	DEVIL CANYON	COMBINED
1981	27.6		27.6	27.6		27.6
82	12.9		12.9	40.4		40.4
83	28.7		28.7	69.2		69.2
84	48.5		48.5	117.7		117.7
85	199.5		199.5	317.2		317.2
86	283.9		283.9	601.1		601.1
87	295.4		295.4	896.5		896.5
88	369.0		369.0	1265.5		1265.5
89	438.4		438.4	1703.9		1703.9
90	627.6		627.6	2331.5		2331.5
91	608.8	4.9	613.7	2940.3	4.9	2945.2
92	429.0	47.9	476.9	3369.3	52.8	3422.1
93	153.2	68.6	221.8	3522.5	121.4	3643.9
94	73.7	64.3	138.0	3596.2	185.7	3781.9
95		64.9	64.9		250.6	3846.8
96		115.3	115.3		365.9	3962.1
97		201.3	201.3		567.2	4163.4
98		291.8	291.8		854.0	4455.2
99		279.7	279.7		1138.7	4734.9
2000		241.7	241.7		1380.4	4976.6
2001		156.0	156.0		1536.4	5132.6
2002		17.6	17.6		1554.0	5150.2
TOTAL	3596.2	1554.0	5150.2			

11/08/82, REVISED DEVIL CANYON CASH FLOW



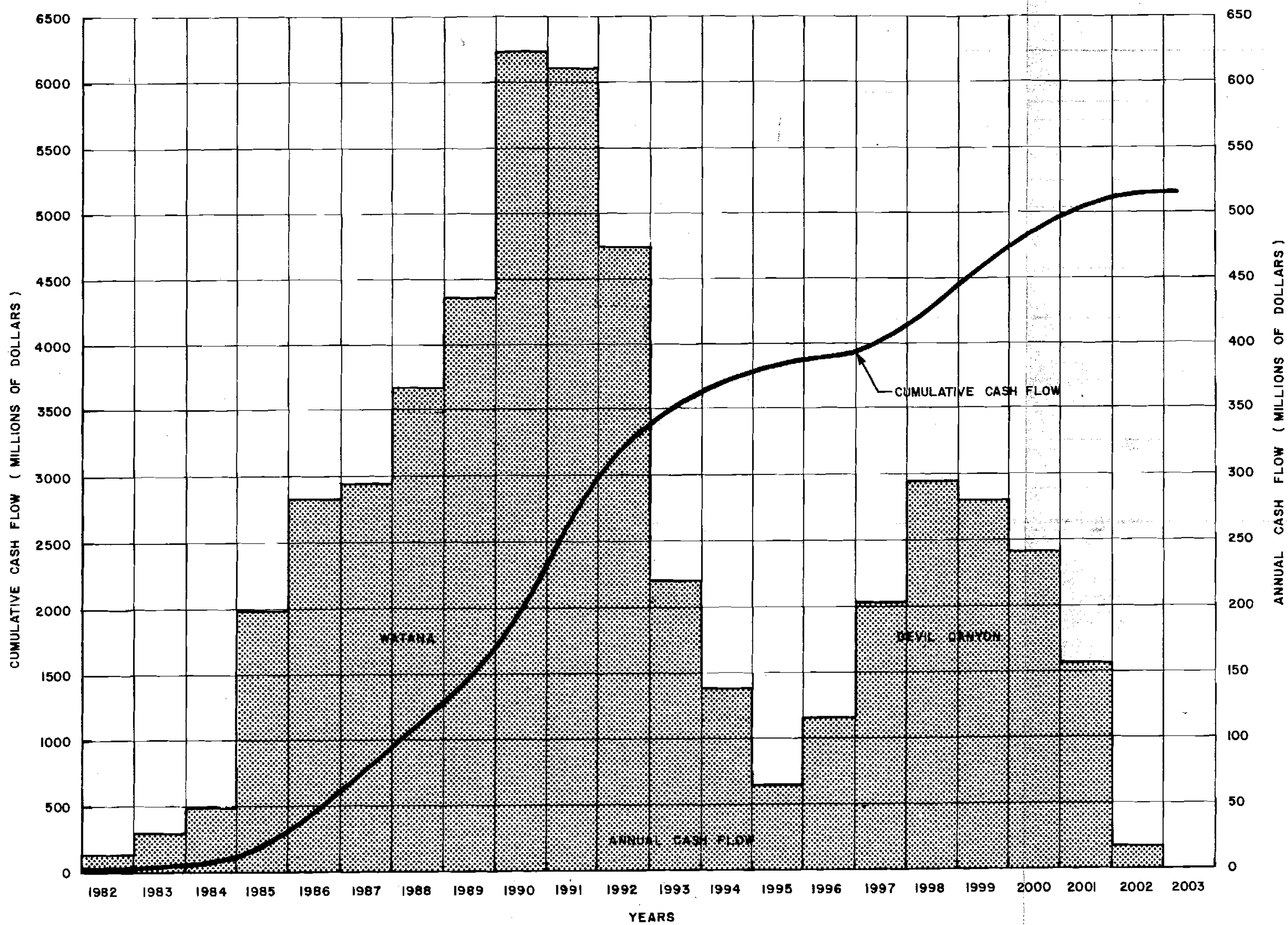
WATANA DEVELOPMENT
CUMULATIVE AND ANNUAL CASH FLOW
JANUARY, 1982 DOLLARS

FIGURE 9.1



DEVIL CANYON DEVELOPMENT
CUMULATIVE AND ANNUAL CASH FLOW
JANUARY, 1982 DOLLARS

FIGURE 9.2



SUSITNA HYDROELECTRIC PROJECT
CUMULATIVE & ANNUAL CASH FLOW ENTIRE PROJECT
JANUARY, 1982 DOLLARS

FIGURE 9.3

10 - DEVELOPMENT SCHEDULES

This section, originally included as Section 17 in the March 1982 issue of the Feasibility Report (Acres 1982a), describes the development schedules prepared for both Watana and Devil Canyon to meet the on-line power requirements of 1993 and 2002, respectively. These schedules have been updated as a result of on-going studies and span the period from 1983 until 2004. Schedules for the development of both Watana and Devil Canyon are shown in Figures 10.1 and 10.2. The main elements of the project have been shown on these schedules, as well as some key interrelationships. For purposes of planning, it has been assumed that a license will be awarded by December 31, 1984.

Revisions to the Watana schedule include the following:

- The pioneer road was replaced by Denali Access Plan 18 (Section 4). Work prior to receipt of the FERC license was eliminated;
- Activities leading up to diversion were revised for an accelerated schedule; and
- The preconstruction of one circuit of the permanent transmission line from Gold Creek was eliminated.

Revisions to the Devil Canyon schedule include the following:

- Denali Access Plan 18 was incorporated, and the start of access construction was advanced accordingly.

10.1 - Preparation of Schedules

Preliminary schedules were first developed by estimating the durations of the main construction activities and arranging these in logical sequence. Some activity adjustments were then made to reduce excessive demands on resources, such as underground excavation or concrete placing. The preliminary schedules were then used as a basis for the preparation of cost estimates. The schedules were also reviewed for overall compatibility with major constraints such as licensing, on-line power requirements, and reservoir filling.

At both sites the period for construction of the main dam is critical; other activities are fitted to the main dam work. A study of the front end requirements of Watana concluded that initial access work should commence immediately after receipt of license and be completed in the shortest possible time to permit a sufficiently rapid buildup of manpower and equipment to meet construction requirements.

During development of the final project arrangement and preparation of the cost estimates (Section 9), the preliminary schedules were modified and refined. As estimating data were developed, the production rates and construction durations were calculated. Networks were developed for the main construction activities and the durations and sequences of activities determined. The overall schedules were modified to suit.

10.2 - Watana Schedule

Commencement of construction:

Initial access road	- April 1985
Site facilities	- April 1985
Diversion	- July 1985

Completion of construction:

Four of six units ready	- January 1994
Six units ready	- July 1994

Commencement of commercial operations:

Four of six units	- January 1994
Six units	- July 1994

The Watana schedules were developed to meet two overall project constraints:

- FERC license would be issued by December 31, 1984; and
- Four units would be on-line by the end of 1993.

The critical path of activities to meet the overall constraints was determined to be through site access, site facilities, diversion, and main dam construction. In general, construction activities leading up to diversion in 1987 are on an accelerated schedule whereas the remaining activities are a normal schedule. These are highlighted as follows:

(a) Access

Initial road access to the site is required by October 1, 1985. Certain equipment will be transported overland during the preceding winter months so that an airfield can be constructed by July 1985. This effort to complete initial access is required to mobilize labor, equipment, and materials in 1985 for the construction of site facilities and diversion works.

(b) Site Facilities

Site facilities must be developed in a very short time to support the main construction activities. A camp to house approximately 1000 men must be constructed during the first 18 months. Site construction roads and contractors' work areas have to be started. An aggregate processing plant and concrete batching plant must be operational to start diversion tunnel concrete work by April 1986. At site, power generating equipment must be installed in 1985 to supply power for camp and construction activities.

(c) Diversion

Construction of diversion and dewatering facilities, the first major activity, should start by mid-1985. Excavation of the portals and tunnels requires a concentrated effort to allow completion of the lower tunnel for river diversion by October 1986. The upper tunnel is needed to handle the spring runoff by May 1987. The upstream cofferdam must be placed to divert riverflows in October 1986 and raised sufficiently to avoid overtopping by the following spring.

(d) Main Dam

The progress of work in the main dam is critical throughout the period 1986 through 1992. Mobilization of equipment and start of site work must begin in 1986. Excavation on the right abutment, as well as river alluvium under the dam core, begins in 1986. During 1987 and 1988, dewatering, excavation, and foundation treatment must be completed in the riverbed area and a substantial start made on placing fill. The construction schedule is based on the following program:

Year	Quantity ($yd^3 \times 10^6$)	Accumulated Quantity ($yd^3 \times 10^6$)	Fill Elevation October 15 (feet)	Reservoir Elevation (feet)
1987	3	--	--	--
1988	6	9	--	--
1989	12	21	1660	--
1990	13	34	1810	1460
1991	13	47	1950	1865
1992	12	59	2130	2050
1993	3	62	2210	2185

The program for fill placing has been based on an average six months season. It has been developed to provide high utilization of construction equipment required to handle and process fill materials.

(e) Spillways and Intakes

These structures have been scheduled for completion one season in advance of the requirement to handle flows. In general, excavation for these structures does not have to begin until most of the excavation work has been completed for the main dam.

(f) Powerhouse and Other Underground Works

The first four units are scheduled to be on line by late 1993 and the remaining two units in early 1994. Excavation of the access tunnel into the powerhouse complex has been scheduled to start in late 1987. Stage I concrete begins in 1989 with start of installation of major mechanical and electrical work in 1991. In general, the underground works have been scheduled to level resource demands as much as possible.

(g) Transmission Lines/Switchyards

Construction of the transmission lines and switchyards have been scheduled to begin in 1989 and be completed before commissioning of the first unit.

(h) General

The Watana schedule requires that extensive planning, bid selection, and commitments are made before the end of 1984 to permit work to progress on schedule during 1985 and 1986. The rapid development of site activities requires commitments, particularly in the areas of access and site facilities, in order that construction operations have the needed support.

The schedule has also been developed to take advantage of possible early reservoir filling to the minimum operating level by October 1992. Should this occur, power could possibly be generated by the end of 1992.

10.3 - Devil Canyon Schedule

Commencement of construction:

Main access - April 1992
Site facilities - June 1994
Diversion - June 1995

Completion of construction:

Four units - October 2002

Commencement of commercial operations:

Four units - October 2002

The Devil Canyon schedule was developed to meet the on-line power requirement of all four units in 2002. The critical path of activities was determined to follow through site facilities, diversion, and main dam construction.

(a) Access

It has been assumed that site access facilities built to Watana will exist at the start of construction. A road will be constructed connecting the Devil Canyon site to the Watana access road including a high-level bridge over the Susitna River downstream from the Devil Canyon dam. At the same time, a railroad spur will be constructed to permit railroad access to the south bank of the Susitna near Devil Canyon. These activities will be completed by mid-1994.

(b) Site Facilities

Camp facilities should be started in 1994. It has been assumed that buildings can be salvaged from Watana. Site roads and power could also be started at this time.

(c) Diversion

Excavation and concreting of the single diversion tunnel should begin in 1995. River closure and cofferdam construction will take place to permit start of dam construction in 1997.

(d) Arch Dam

The construction of the arch dam will be the most critical construction activity from start of excavation in 1996 until topping out in 2001. The concrete program has been based on an average 8-month placing season for 4-1/2 years. The work has been scheduled so that a fairly constant effort may be maintained during this period to make best use of equipment and manpower.

(e) Spillways and Intake

The spillway and intake are scheduled for completion by the end of 2000 to permit reservoir filling the next year.

(f) Powerhouse and Other Underground Works

Excavation of access into the powerhouse cavern is scheduled to begin in 1996. Stage I concrete begins in 1998 with start of installation of major mechanical and electrical work in 2000.

(g) Transmission Lines/Switchyards

The additional transmission facilities needed for Devil Canyon have been scheduled for completion by the time the final unit is ready for commissioning in late 2001.

(h) General

The development of site facilities at Devil Canyon begins slowly in 1994 with a rapid acceleration in 1995 through 1997. Within a short period of time, construction begins on most major civil structures. This rapid development is dependent on the provision of support site facilities which should be completed in advance of the main construction work.

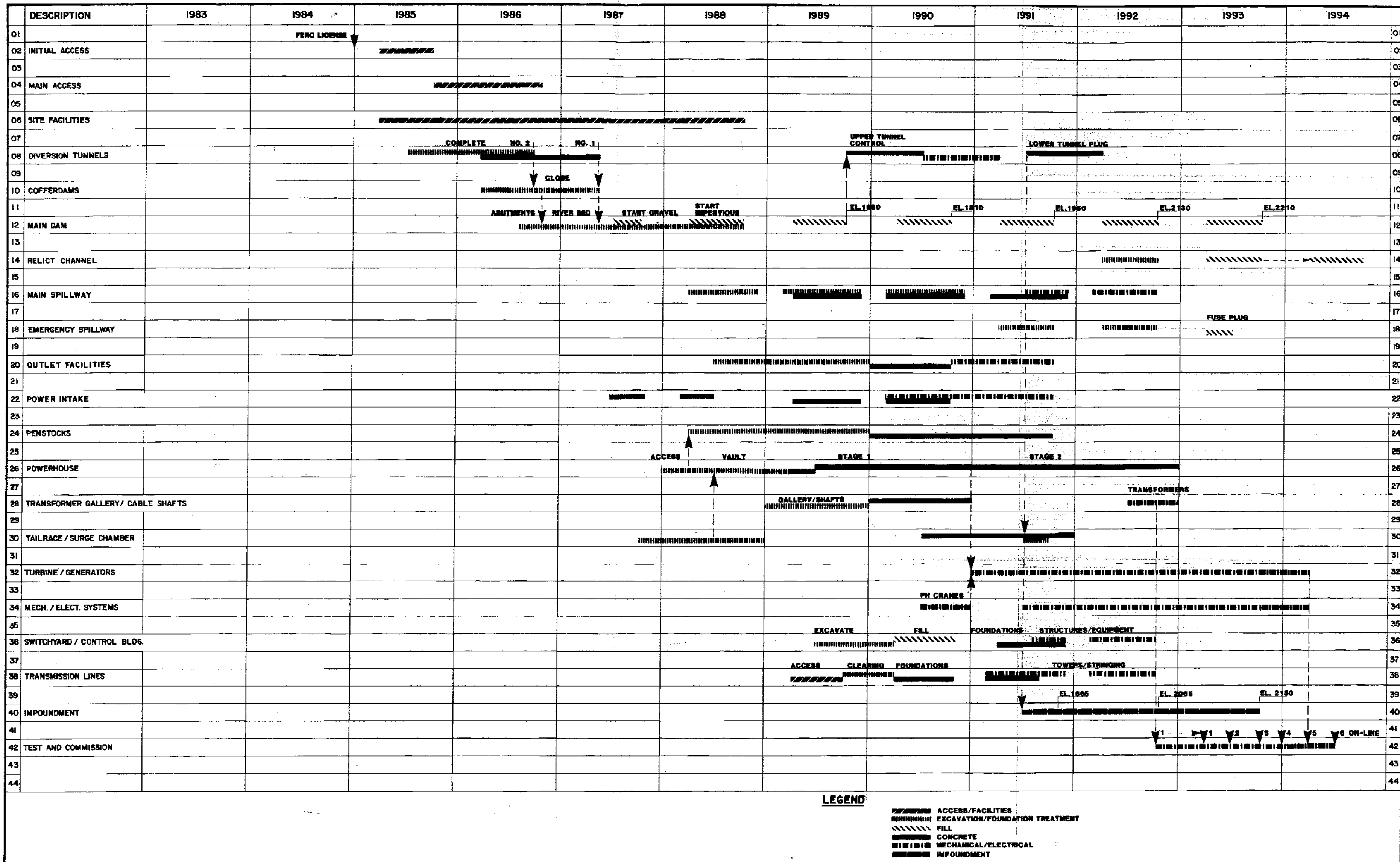
10.4 - History of Existing Project

An intertie is planned to permit the economic interchange of up to 70 megawatts of power between major load centers at Anchorage and Fairbanks. Connecting to existing transmission systems at Willow in the south and Healy in the north, the intertie will be built to the same standards as those proposed for the Susitna project transmission system. It will be energized initially at 138 kv. Subsequent to construction of the Watana project, the intertie will be incorporated into the Susitna transmission system and will operate at 345 kV.

Construction of the intertie is scheduled to begin in March 1983. Completion and initial operation is planned for September 1984, well in advance of the anticipated date for receipt of a FERC license on December 31, 1984.

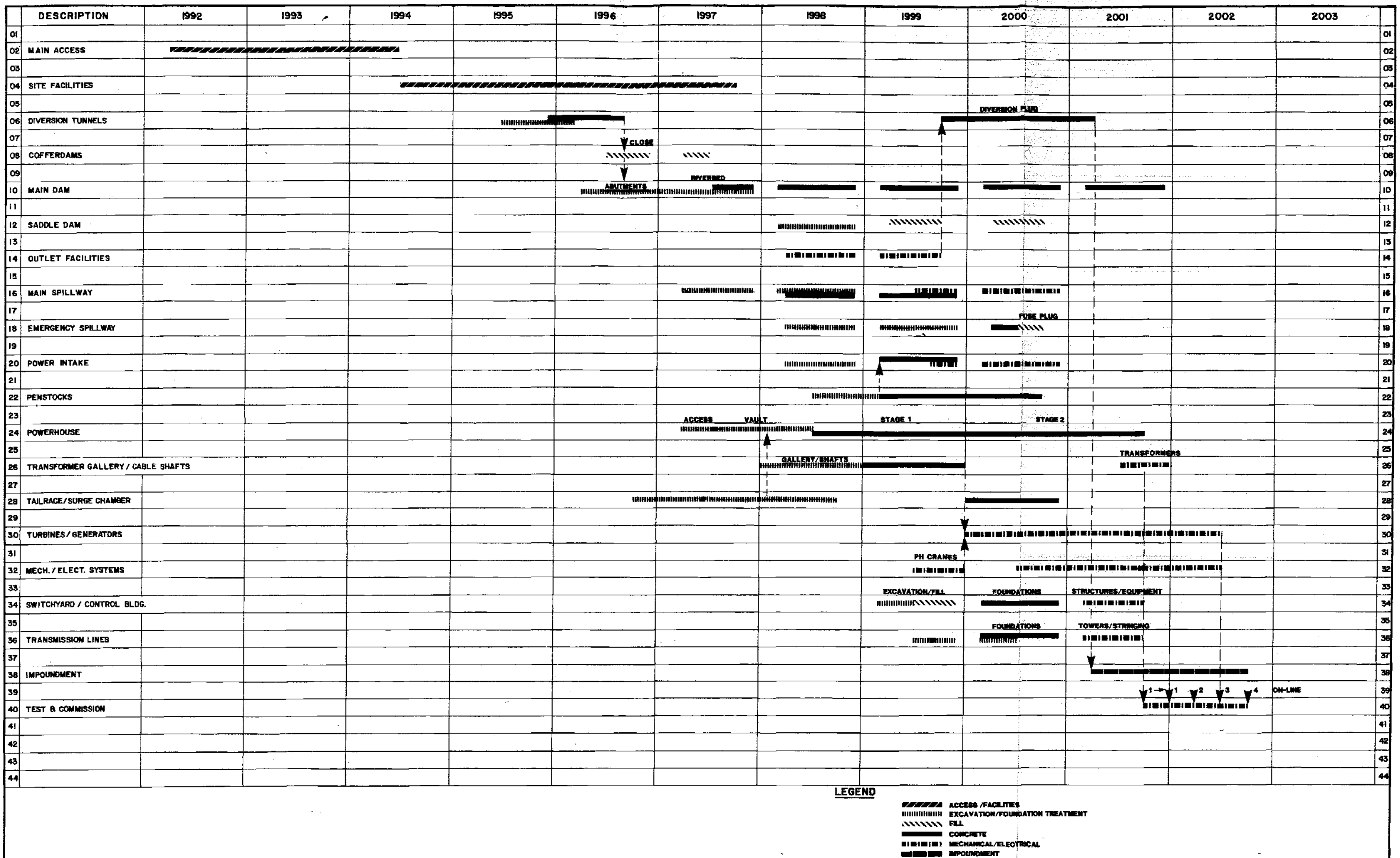
REFERENCES

Acres American Incorporated. 1982a. Susitna Hydroelectric Project Feasibility Report. Prepared for the Alaska Power Authority.



WATANA
CONSTRUCTION SCHEDULE

FIGURE 10.1



DEVIL CANYON
CONSTRUCTION SCHEDULE

FIGURE 10.2

11 - ECONOMIC, MARKETING, AND FINANCIAL EVALUATION

11.1 - Introduction

The purpose of this section is to document the changes and further studies which have taken place since the publication of the Feasibility Report (Acres 1982a). There have been few changes in the financial studies presented. For the FERC license application, a calculation for the cost of power was made and a financing plan was selected as the most probable.

In August, a report reviewing the Feasibility Study from a financial purview was published by Arlon Tussing and Associates. The findings of this report prompted a reassessment and update of several underlying factors in the financial and risk analyses. The results of those considerations are presented in Subsection 11.5.

The third area of update is in the generation planning studies which formed the basis of the project economic analysis. One critical factor of change is in the cost of the projects. The impact of the cost change on the economic and financial analyses has been addressed.

Similar to project costs, a change in the proposed project operation has been made since the Feasibility Report. The change resulted from mitigation studies involving the maintenance of downstream flows for fishery spawning. As a result of the operation change, the energy produced by the plant and the monthly distribution has changed. The impacts of this shift on project economics have been reviewed.

The primary tool used for generation planning studies is the General Electric Optimized Generation Planning (OGP) simulation model. Version 5 of the model was used for the feasibility report analysis. In May 1982, GE released Version 6 of the program. The changes in the program and its impacts on study results have been checked and documented in Subsection 11.6.

Finally, there were several issues raised in reviews of the Feasibility Report. These issues included the assessment of Watana, Devil Canyon, and Chakachamna as single projects and an alternative staging from the recommended plan. They are:

- The impact of changing probabilities in the multivariate sensitivity analysis;

- A discussion of percent reserve margins;

- Annual system cost components; and

- Delay of the project.

The following subsections address each of the areas mentioned individually.

11.2 - Cost of Power

One requirement of Exhibit D of the FERC license application was for an annual cost to be presented. As a two-stage (Watana and Devil Canyon) development with varying levels of energy output and the assumption of ongoing inflation (at 7 percent per annum), the real cost of Susitna power will be continually varying. As a consequence, no simple, single-value real cost of power can be used. For the purposes of the application, the following cost was adopted.

Table D.9 in Exhibit D (Acres 1983) gives the year-by-year projected energy levels on the first line; and on the second, the year-by-year unit cost of power in 1982 dollars. Costs are based on power sales at cost assuming 100 percent debt-finance at 10 percent interest. This is seen to result in a real cost of power of 122 mills in 1994 (first "normal" year of Watana), falling to 73.95 mills in 2003 (the first "normal" year of Watana and Devil Canyon). The real cost of power would then fall progressively for the whole remaining life.

The cost of power given in Table D.10 in Exhibit D (Acres 1983) is designed to reflect as fully as possible the economic cost of power for purposes of broad comparison with alternative power options. It is, therefore, based on the capacity cost which would arise if the project were 100 percent debt-financed at market rates of interest. It does not reflect the price at which power will be charged into the system.

11.3 - Financing Plan

In the Feasibility Report, several plans were presented for financing the Susitna project. At this time, one plan has emerged as the most likely. This plan is presented in the FERC license application (Acres 1983).

The financing of the Susitna project is expected to be accomplished by a combination of direct state-of-Alaska appropriations and revenue bonds issued by the Power Authority but carrying the "moral obligation" of the State. On this basis, it is expected that project costs for Watana through the end of 1989 will be financed by $1.8 billion (1982 dollars) of state appropriations. Thereafter completion of Watana is expected to be accomplished by issuance of approximately $2.4 billion (1982 dollars) of revenue bonds. The year-by-year expenditures in constant and then current dollars are detailed in Table 11.1. These annual borrowing amounts do not exceed the Authority's estimated annual debt capacity for the period.

The revenue bonds are expected to be secured by project power sales contracts, other available revenues, and by a Capital Reserve Fund (funded by a State appropriation equal to a maximum annual debt service) and backed by the "moral obligation" of the state of Alaska.

The completion of the Susitna project by the building of Devil Canyon is expected to be financed on the same basis requiring (as detailed in Table 11.1) the issuance of approximately $2.1 billion of revenue bonds (in 1982 dollars) over the years 1994 to 2202.

Summary financial statements based on the assumption of 7 percent inflation and bond financing at a 10 percent interest rate and other estimates in accordance with the above economic analysis are given in Table 11.2.

The actual interest rates at which the project will be financed in the 1990s and the related rate of inflation evidently cannot be determined with any certainty at the present time.

A material factor will be securing tax-exempt status for the revenue bonds. This issue has been extensively reviewed by the Power Authority's financial advisors, and it has been concluded that it would be reasonable to assume that by the operative date the relevant requirements of Section 103 of the IRS code would be met. On this assumption, the 7 percent inflation and 10 percent interest rates used in the analysis are consistent with authoritative estimates (Data Resources Inc. July 1982) forecasting a Consumer Price Index (CPI) rate of inflation 1982-1991 of approximately 7 percent and interest rates of AA Utility Bonds (nonexempt) of 11.43 percent in 1991 dropping to 10.02 percent in 1995.

11.4 - Change in the Cost Estimate

As discussed in Section 9, the cost estimate has been revised to reflect adjustments to the project made since the Feasibility Report. The following summarizes those estimated changes.

January 1982 $ $x10^6$

	Feasibility Study Estimate	License Application Estimate	Change	Percent Change
Watana	3647	3596	(51)	(1.4)
Devil Canyon	1480	1554	74	5.0
Total	5127	5150	23	0.44

Because of the relatively minor changes in the cost estimate, no changes have been made in the financial analysis. Since the Watana project cost has decreased and it is the more critical project to finance, and, since it is the first to be constructed, the change would in theory make financing easier. However, because of the minimal change in numbers, the impact on the financial projections is insignificant.

11.5 - Comments from "Review Report"

After publication of the Feasibility Report, a report entitled "Alaska Energy Planning Studies - Substantiative Issues and the Effects of Recent Events," a review by A. R. Tussing and G. K. Ericson, was prepared for the Division of Policy Development and Planning, Office of the Governor of the State of Alaska.

This document, "Alaska Energy Planning Studies - Substantiative Issues and Effects of Recent Events" (the review), covered four reports submitted to Alaska state agencies including the draft Susitna Hydroelectric Project Feasibility Report.

After publication of the review, a commentary responding to comments was prepared. This subsection is a summary of the key comments and responses.

This summary confines itself to the review only of the feasibility report study and related data. It does not respond to the comments made in the review on data developed by Battelle and the Institute of Social and Economic Research, University of Alaska.

The review commentary deals with:

- World Oil Prices: long-term future of world oil prices.

- Alaskan Fossil Fuel Prices: market prices versus opportunity values, linkage between coal and oil prices, and linkage between gas and oil prices.

- Reliability of Susitna Construction Cost Estimate: construction cost estimates, and risk analysis.

- Financing Issues: real discount and interest rates.

These issues are identified as those requiring further treatment to deal with apparent misunderstandings and need for further comment arising from the review. The summary here presents the issue and commentary in support of the feasibility report relative to the issues.

(a) World Oil Prices, Long Term

The review asserts that oil price forecasts are too high and suggests that real (inflation-adjusted) prices will continue to be below 1982 levels for the remainder of the century.

Price forecasts used in the feasibility report were adopted from the Battelle Alternatives Study. Nonetheless, an updated check of forecasting was done to confirm or indicate the necessity for changes in the oil price base used in the feasibility report. The results of the survey of forecasts is presented in Table 11.3.

The forecasts used in the report are in close agreement with those of all the major forecasting organizations shown in Table 11.3. The forecasts are all of recent date and take into account all recent trends.

Thus, one piece of evidence cited in the review is that Data Resources, Inc. (DRI) now forecasts a decline in Europe's oil consumption during the rest of this century, while today there is an excess oil-producing capacity in the world. Such partial analysis cannot lead to the conclusion that oil prices will decline over the next 20 years. This requires consideration of the future levels of oil demand outside Europe: worldwide supply/demand conditions, etc. DRI, taking all such factors into account, supports the position taken in the report with a forecast of 2.8 percent growth in real terms.

A second factor cited by the review is the scaling down of oil price projections by the Alaska Department of Revenues in its Petroleum Production Revenue Forecast. The state's forecasts made in the spring of 1982 point to declining real oil prices through 1998. Of the numerous eminent authorities engaged in long-term energy forecasting, this alone is cited by the review.

Table 11.3 summarizes all the major forecasts for comparison with the report's base case scenario of 2 percent real escalation, bounded by low and high scenarios of 0 percent and 4 percent, respectively. Of the 16 authorities surveyed, only one presented a case with long-term declining real oil prices.

Although a wide range of oil prices is reflected in these projections, it is clear that with the single qualification already noted, they are all calling for positive real growth in world oil prices over the long-term horizon required for power planning studies. The report did not, however, exclude the possibility of zero real growth in oil prices; it merely assigned it a lower possibility of 25 percent compared with the 50 percent probability assigned to the 2 percent growth case. It is Acres assessment that the review does not present a case for rejecting this assessment (and the similar forecasts shown in Table 11.3) and effectively assigning 100 percent probability to the zero growth scenario.

(b) Alaskan Fossil Fuel Prices

(i) Market Prices Versus Opportunity Values

An issue raised by the review was the assessment of probable future costs of fossil fuels for generation in the Railbelt from local coal or gas supply conditions.

Both the Feasibility Study and the Battelle study reviewed the prior studies made of Beluga coal costs and worldwide coal production cost estimates. The use of production costs for natural gas and coal would be wholly appropriate and desirable for the financial analysis of a power project from the narrow perspective of private investors or owners. As a public project, however, Susitna should be, and was, appraised from the point of view of the state as a whole and valued the fossil fuels at its opportunity cost in terms of potential exports.

It is for this reason that Acres supported the net-back approach in which the value of coal and natural gas in Alaska was determined as the c.i.f. (landed) price in the most likely (East Asian) market less the cost of transportation from Alaska to that market.

(ii) Linkage Between Coal and Oil Prices

The review is critical of the approach whereby "both contractors have deduced their price assumptions for Railbelt coal and gas wholly from forecasts of oil prices in Japan."

The statement may be misleading as, in fact, it is the real growth rates in coal and gas export prices that are estimated, in the most likely case, to equal real rates of world oil price escalation. Base period (1982) opportunity values of coal and gas were determined (as shown above) independently of oil prices. In the most likely (base) case, it forecasts that there would be no change in relative prices; that is, the 1982 price ratios among oil, gas, and coal would be maintained during the planning period. This estimation is supported by forecasts of coal and natural gas prices provided in the report. A moving average of coal/oil price ratios exhibits relatively little fluctuation over the 8-year period. (There is an estimated probability of over 65 percent that the ratio is 0.42 $\pm$0.04.)

(iii) Linkage Between Gas and Oil Prices

The emphasis of the criticism of Feasibility Report assumptions relating to natural gas is centered on the fact that the current price of Cook Inlet natural gas is significantly below the "opportunity value" suggested in the report, and that this price is not expected to increase to levels in line with the opportunity value. It is maintained that "Cook Inlet gas prices will be established largely on the basis of factors local to the region," and thus, these prices will be insulated from the effects of world price movements.

Regardless of whether Cook Inlet gas prices do or do not equal opportunity values, the results of the Susitna public cost/benefit analysis would not be altered. In fact, it is only the opportunity values which are of relevance, and the Cook Inlet domestic gas prices at any point in time should not be an issue of any concern in an analysis of net economic benefits.

This results solely from the fact that, if export markets exist for LNG at the prices which have been determined in the Report, then it must be assumed that the rational gas producer in Alaska would select the opportunity to receive the highest price that is offered for the gas.

(c) Reliability of Susitna Construction Cost Estimates

(i) Construction Cost Estimates

A third area of concern expressed in the review was the reliability of the project capital cost estimate. The concern appears to be based on generalizations stemming from the "mega project" experience of the last decade.

This questioning does not appear to be founded on any detailed data or experience of hydroelectric power development engineering and construction. The only specific mega projects cited to justify allegations of "misplaced specificity, subjectivity, and over-optimism, institutional blind spots, and underallowance for noncompletion" in the Acres construction cost estimate are the Trans Alaska oil pipeline and the Washington Public Power Supply System nuclear reactor program. It is Acres view that neither of these projects has any practical bearing on a site-specific, basically conventional engineering hydroelectric power development such as Susitna where the project estimate has been as extensive, evaluated and assigned as high a confidence level as in the Susitna case.

Cost-estimate review on a risk basis was conducted in the Feasibility Report by relating to a list of projects compiled by an external source. It is recognized that this approach did not include major hydroelectric projects in northern areas, nor did it reflect the Acres experience in project cost-estimating. To provide further support for the project cost estimate, Acres experience on a project similar to Susitna was reviewed. Table 11.4 provides in detail a review of Acres Churchill Falls Hydroelectric Power Project estimate versus outcome.

Two estimates of costs are given. The first, for 1963, is in the nature of an early stage feasibility estimate, while the second, for 1968, is a final, pre-contract estimate broadly comparable in confidence level to that produced in the Susitna Feasibility Report. It is seen that, reduced to comparable purchasing power (1963 dollars), the 1963 estimate is at variance from the final cost by 4.2 percent. This favorable (negative) variance has to be viewed, furthermore, in light of the fact that between 1963 and 1968 there was an increase from 10 to 11 in the number of hydroelectric units and an increase in the rating of all generators from 450 MW to 475 MW.

The Churchill Falls Power Development in Labrador, Newfoundland, is a 5225 MW development in a remote area. It is comparable to Susitna as a giant hydroelectric project. It will be noted that in place of the single large dam which creates the operating head and storage reservoir for Watana, a large number of fill structures were constructed at Churchill Falls with an aggregate length of over 42 miles and volume of more than 40 million cubic yards. Construction work spread out over 2500 square miles of reservoir area was inherently more difficult to control than a concentrated development area such as Watana.

Other examples of estimate/final cost comparisons uphold Acres record of performance on major hydroelectric power projects in northern latitudes and at remote sites.

(d) <u>Real Discount and Interest Rates</u>

The review took issue with the standard methodology by which Acres derived the 3 percent real discount rate used in the cost/benefit analysis in the feasibility report (Section 18.3 to 18.21) and argues for 4.5 percent as the appropriate rate.

The 3 percent discount rate was derived from two sources. First, it was given as a guideline for economic evaluation by the Department of Commerce of the State of Alaska. The second source was the generally accepted studies summarized on page 18.4 of the Feasibility Report.

It is clearly possible to question the standard methodology giving rise to this parameter. Here, as in other parts of the study, however, it was study policy to avoid unnecessary controversy by not questioning accepted methodology or guidelines unless the alternative approaches materially affected Acres conclusions.

A more precise approach is that of determining the Project Specific Rate (PSR). This is done by first estimating the weighted average interest cost of project borrowing and the opportunity interest cost of any funds provided by the state of Alaska, with the weightings being the proportions of these two types of capital. This weighted average is then converted into a real discount rate (approximately) by deducting the relevant rate of inflation. The interest rates used would be those obtained at the time that the capital is to be raised; and the rate of inflation, the long-term rate expected over the life of the borrowing.

On the basis of the DRI forecasts and on the assumption that the opportunity cost of state-provided funds is the interest rate forecast for federal government securities while the project borrowing is in the form of tax-exempt bonds (see Table 18.22 in the Feasibility Report), the weighted averaged interest rate with the state appropriation of $2.3 billion can be determined. The DRI forecast interest rate on federal funds and on tax-exempt bonds, both over the relevant capital raising periods and unweighted, are 10.4 percent and 8.1 percent, respectively. This gives a weighted average PSR of 9.1 percent in money terms.

The long-term forecast rate of CPI inflation from 1985 to 1995 (again as given by DRI) varies between 7.1 (1985-90) and 6.5 percent (1990-95). No forecast is given for the post-1995 period. The implied real rate of interest relevant to the cost/benefit at a long-term inflation rate of 6.5 percent is, therefore, approximately 9.1 - 6.5 = 2.6 percent. At these rates of inflation, therefore, this alternative methodology, using DRI data, does not support a higher discount rate than the 3 percent discount rate used in cost/benefit analysis carried out for the feasibility study and dealt with in the report.

The position taken in the review is that the discount rate should be that at which the project is financed. This is the PSR approach just described. As such, it produces a lower (not higher) rate than that used in the Acres analysis.

The review suggests, however, that the appropriate rate is 4.5 percent on the grounds that this is the DRI forecast of real interest rates on corporate bonds* in 1992. Since the project is not being financed by corporate bonds but by tax-exempt bonds and by the state of Alaska, it cannot be argued that this 4.5 percent has any relevance. The relevant tax-exempt and federal bond rates consistent with the 4.5 percent corporate bond rate give the result outlined above.

It would also be noted that the DRI 4.5 percent real interest rate on corporate bonds is very much higher than the Wharton or Chase forecasts or indeed any of the other main forecasting agencies. These are generally in the range of 3-2.4 percent. If these forecasts, rather than the DRI forecast used above, are accepted, then, taking into account the advantages of tax exemption, the 3 percent discount rate used for the Susitna cost/benefit analysis is conservative in that the appropriate PSR should be significantly lower. This became apparent in the course of the Acres analysis but was not pursued, since it merely had the effect of reinforcing rather than controverting the conclusions reached.

In summary, it appears to Acres that the review is mistaken as to the outcome of the methodology which it proposes and that, correctly stated, this methodology (which Acres stresses is only an approximation) gives a result which would argue that the discount rate promulgated by the Alaska Department of Commerce and used by Acres is too high, not too low.

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* Using the CPI and not IPD, the rate is 4.0 percent.

11.6 - Generation Planning

After circulation of the feasibility report, several items of work were accomplished in response to questions and comments. These involved the following areas of analysis:

- Multivariate analysis - sensitivity of load probability;
- Changes to the generation planning model;
- Impacts of project changes; and
- Other issues.

Each of these areas is explored individually in the following text.

(a) Multivariate Analysis - Sensitivity of Load Probability

To account for variance in forecasting, the economic analysis was approached on a probabilistic basis. Several key variables were chosen; a range of low, medium, and high variable values were estimated; and probabilities were assigned to each value. A probability tree was constructed with each combination of variables assigned a resultant probability. The original analysis is discussed in more detail in Section 18 of the feasibility report.

The multivariate sensitivity analysis analyzed the four variables: load forecast, alternatives capital cost, fuel cost escalation and Susitna capital cost; and assigned a range of probabilities to each. Some concern has been expressed regarding the likelihood of the probability distribution being different from the assumed "base case" of 0.20, 0.60, and 0.20 for the low, medium, and high load forecast scenarios. A recalculation of the probabilities was made using the distribution 0.60, 0.30, and 0.10. Tables 11.5 and 11.6 summarize the calculation for the non-Susitna and Susitna trees.

The results of the analysis show that the expected value of net benefits is $971 million. This is a result of the difference in the non-Susitna and Susitna plans ($7,624 - $6,653 = $971). Compared to the base case multivariate analysis, the $971 million expected value is approximately 33 percent less than the base case value of $1,450 million. Figure 11.1 plots the net benefit curves.

(b) Changes to the Generation Planning Model

In May 1982, General Electric released Version 6 of the OGP Program. Version 5 of the program was used as the primary tool for the generation planning studies for the feasibility report.

Several changes were made to the program in Version 6 in response to user comments. These include a possible 30-year study period (replacing 20), more options for maintenance scheduling, and increased program flexibility. Two changes particularly relevant to the Susitna analysis are the possibility of economic overbuilding (adding units on an accelerated schedule) and carryover of excess hydropower from wet months to dry months. The latter gives a more favorable (and accurate) value to the potential hydro energy produced by the project.

In order to test the impact of these terms on the results of the generation planning, the base case, with and without Susitna, was reanalyzed with OGP-6. Table 11.7 summarizes the results. The results were reduced to a long-term cost in a manner identical to the feasibility report.

The revisions in the program had no impact on the non-Susitna case. For the with-Susitna case, the increased value of the hydro energy increased net benefits by about 5 percent.

(c) Impact of Project Changes

Two changes in the project affecting economic analysis have taken place since completion of the Feasibility Report; a change in cost estimate, and a change in operation schedule.

The change in the cost estimate is small. The most current estimate for the total project in 1982 dollars is $5,150 million, 0.44 percent higher than the feasibility estimate. The cost of the Watana project went down $51 million, while the Devil Canyon cost went up $74 million. These minor changes would have a negligible impact on the results of economic studies. Therefore, no revision in analysis or sensitivity to cost-change data tests were done.

After completion of the Feasibility Study, a major focus of instream flow study was the selection of a project operation scheme with mitigation of downstream filling impacts as an objective, along with optional power production. A series of cases were tested with flows varying from optimal energy production to "no-impact" case. A case which fell into the middle of these extreme was selected. The net benefit of this case are $114 million as compared to $1176 million. This 3 percent difference in net benefit did not warrant a full revision of the economic study.

(d) Other Issues

After completion of the Feasibility Report, several comments were raised which required additional study or explanation. Those issues are presented in the following paragraphs.

(i) Discussion of Percent Reserve Margin

In planning system electrical need, there are a number of methods that can be used to measure a system's reliability and determine the need for the addition of capacity. It is common utility practice to plan to a statistical measure of reliability: loss of load probability (LOLP) in conjunction with some minimum percent reserve margin. Computation of LOLP involves probabilistic forced outage rates, planned maintenance, peak load, and reliable energy considerations. LOLP is commonly expressed as a loss in days per year or, in some systems, hours per year depending on the size of individual units in the operating system. Percent reserve margin can also be calculated in a variety of ways relating capacity, load, contracts for power exchange, and the largest units on the system to a single measure of available capacity.

In modeling the Alaskan Railbelt System for generation planning studies, the LOLP criteria of 0.1 day per year was used as the "trigger point" for capacity additions. In other words, in every year, the OGP model calculates the system reliability LOLP without any additions. If the system as it exists violates the LOLP criterion of 0.1 day/year, the model then examines combinations of available alternative unit capacity additions that would meet this reliability criterion. From these alternative system mixes, the least cost (or production cost optimal choice) is selected and the system is operated for the following year. At this time, the percent reserve margin is calculated for that year using the equation:

$$\text{percent reserve} = \frac{\text{capacity - load}}{\text{load}} \quad \text{in the peak month}$$

(December in the Railbelt System)

Therefore, the calculation of percent reserve in this context is independent of the "need" for capacity which is determined by the LOLP criterion.

Alternatively, the OGP model can plan to a percent reserve margin and calculate LOLP after expansion has been made. However, this option was not exercised because of the variety of methods for computing percent reserve and the difficulty in arriving at a consensus on a reliable percent reserve resulting from the system size.

An alternative method of calculating reserve margins involves subtracting the largest unit of capacity out of the total available system capacity. Other methods subtract the largest "string" of intertied units from the total capacity to arrive at a reserve margin. In any case, the percent reserve is merely a simple statistic of available capacity to meet load regardless of "acts of God" and forced outages.

Table 11.8 summarizes the two sets of statistics for the medium-load, forecast-base non-Susitna and Susitna plans. The planning criteria were LOLP less than 0.1 day per year, and percent reserve was calculated using the noted equation. Figure 11.2 plots percent reserve versus time for the two plans. The following paragraphs discuss the variations among plans.

As previously mentioned, the system model examines the available units for addition in a year when reliability is not met. In the first year of the study, 1993, the units available for the non-Susitna plan are 200-MW coal, 200-MW combined cycle, 70-MW gas turbine, and 10-MW diesel units. Of these, a single 200-MW unit meets the LOLP criterion in the most cost-effective manner. In the Susitna plan, the Watana project added in a single stage is 680-MW, which is considerable for that particular year; however, as load grows and existing units retire, percent reserve decreases. No other units are needed in the system. In year 2002, additional capacity is needed. The Susitna plan adds the 600-MW Devil Canyon project which again raises the percent reserve.

The non-Susitna plan has the capability to add only small increments of capacity relative to the Susitna project. The addition of 200-MW or smaller units meets reliability criteria with a smaller reserve margin. As Susitna is added in 600+ MW increments to take advantage of its full energy potential, the reserve margin becomes very large. Much of the reserve margin capacity rests idle from 1993 on.

In year 2010, the non-Susitna plan has a calculated LOLP of 0.099 indicating that criterion is nearly violated in that year. This LOLP corresponds to a percent reserve of 32.5 percent, which indicates the level of capacity installation over LOLP needs. In both plans, the percent reserve is always above this level, varying as the various size units are installed.

(ii) Annual System Costs

Each year the OGP model dispatches available energy generation to meet load. Table 11.9 shows the annual energy dispatch in GWh by generating unit type for the two plans. Figure 11.3 shows the annual system costs plotted for the two plans. This figure represents the initial cost of the Watana project having higher system cost during the first few years, remaining about the same during the years 1996 to 2001, and showing significant savings in the years 2003 to 2010.

(iii) Annual System Cost Components

The annual system costs consist of a number of components:

	Non-Susitna	Susitna
Investment Costs:	Coal NGGT	Susitna NGGT
O&M:	Coal Combined Cycle NGGT Other Hydro Diesels	Susitna Combined Cycle NGGT Other Hydro Diesels
Fuel Costs:	Coal GT Natural Gas CC Natural Gas Oil	GT Natural Gas CC Natural Gas

Tables 11.10 and 11.11 list the annual yearly costs by components for the non-Susitna plan and the Susitna plan. Figures 11.4 and 11.5 depict the components graphically. The most dramatic comparison is the portion of Susitna investment cost versus the coal investment and fuel cost components in the non-Susitna plan.

Figure 11.6 plots the annual system long-term costs for both plans during the 1993 to 2010 system modeled period and the 2011 to 2051 economic extension period.

(iv) Discussion of Delay of Project

The Railbelt system technically needs capacity installation in December 1992 to meet the LOLP reliability criteria. However, Acres has scheduled the study to start in 1993, suggesting that the December 1992 peak would be met by extending one or two retiring units until major new units are on line in January of 1993. Delaying Watana Stage One to 1994, therefore, poses a problem, since it is necessary to have some type of capacity in 1993.

Two impacts occur when a Susitna project stage is delayed. First, there is an increase in fuel costs during the year of delay to make up generation not provided by Susitna. For example, with Watana, in 1993, fuel costs are $25 million. Without Watana and using two new natural gas turbines, fuel costs are $128 million in 1993. Second, there is a decrease in Susitna investment cost present worth. For example, $100 invested in 1993 is $76 in 1982 dollars. One hundred dollars invested in 1994 is $74 in 1982 dollars at a 3 percent discount rate.

The lowest production cost alternative in 1993 is a 200-MW coal unit. However, this unit, followed by the large Watana project in 1994, is only used one year, hardly a justification for building a large plant. Alternatively, two 70-MW gas turbines can be installed in 1993, run to meet peak until Watana comes on line, then used as standby until the later years. This system plan (C3) is shown in Table 11.12. This plan reduces net benefits approximately 4 percent to $1,133 million.

Delaying both stages of the Susitna plan one year results in essentially the same net benefit as the previous case. This plan (C4) has a long-term (LTC) cost of $7,165 million. However, it must be compared to a without-Susitna plan which has been extended to year 2053 rather than 2052, since the Susitna project life is 50 years from the year Devil Canyon is installed. This modification makes the non-Susitna plan LTC $8,299 million; therefore, net benefits are $1,134 million.

Delaying both stages of the project two years (plan C5) increases fuel costs in years 1993, 1994, 2002, and 2003 as the result of dispatching of thermal units to meet load. Again, the net impact is partially offset by the decrease in present worth of Susitna costs; and the net benefits are $1,130 million, 4 percent less than the base case.

(v) Watana Project Alone

Only the Watana projections were examined in the medium- and low-load forecast cases. Table 11.13 summarizes these plans.

Under the medium-load forecast, the Watana only project was tested at two installed capacities: 680 MW and 1020 MW. Although the larger capacity plan displaced some additional capacity and since no additional average or firm energy is associated with these units, the net effect is a negative benefit of $102 million. The second stage of Watana was capital cost of the $58.8 million.

The low-load forecast plan shows a negative net benefit of $96 million for the Watana-only scheme.

Two notes on the calculation of net benefits and long-term cost are:

(1) When comparing Watana-only project plans with the base case alternative plan, it is necessary to compute the LTC cost to year 2043, when Watana is installed in 1993 (medium-load case), and 2045, when Watana is installed in 1995 (low-load case).

(2) When a Susitna plan installs a 200-MW coal plan in the planning horizon, it is necessary to add in the cost of a Beluga transmission tie in the year it is added, calculated in 1982 dollars. This cost was estimated as $53.5 million (from the upper limit capital cost report, July 1981), and is added to the long-term cost.

(vi) Alternative Railbelt Hydro Assessment

Previously, the Development Selection Report (DSR) examined various alternative developments of the Susitna Basin. The Watana/Devil Canyon selection was chosen as the least-cost, long-term generation plan. This assessment reviews some of the possible alternatives, using the same criteria as the Susitna feasibility study and updated data on the hydropower alternatives. Generation plans were developed for the following scenarios and long-term costs compared to the base case without-Susitna plan.

- Devil Canyon - Watana
- Chakachamna - Devil Canyon
- Chakachamna - Watana
- Watana only
- Devil Canyon only
- Chakachamna only

- Devil Canyon - Watana

Reverse staging of the Susitna project has some unique cost implications. First, the possibility exists that the Devil Canyon project could be on line sooner than 1993, perhaps as early as late 1991. This situation was not modeled; however, in the without-Bradley Lake case, it may reduce the long-term cost and increase net benefits over the value presented here. Second, the interim years between Devil Canyon (1993) and Watana (2002) require additional capacity to be added. Five 70-MW gas turbines are needed to supply energy to the system.

Capital Cost (including IDC) impacts of Devil Canyon first followed by Watana are summarized below:

	1982$ x 10^6		
Watana	$4,094	Devil Canyon	$2,203
Devil Canyon	1,631	Watana	3,558
Total	$5,725		$5,761

Building Devil Canyon first increases the cost compared to a later staging because of additional adjustments of transmission, intakes, diversions, cofferdams, access roads, and site facilities.

Total energy impacts of Devil Canyon first compared to Watana/Devil Canyon are as follows:

Available Energy, GWh

Watana	3,459	2,631	Devil Canyon	2,585	2,264
Devil Canyon	3,334	2,763	Watana	4,208	3,130
Total	6,793	5,394		6,793	5,394

Note that this is a tally of available energy which is slightly greater than usable energy by year 2010.

The results of the generation plans for the base case - Watana/Devil Canyon and the reverse staging Devil Canyon/ Watana are summarized in Table 11.14. Long-term costs in the latter case increase by 4 percent over the Watana first case reducing net benefits to $896 million.

- Chakachamna - Susitna

The 330-MW Chakachamna hydroelectric project was also examined in the DSR. Two updated generation plans--one with the Chakachamna project in 1993 followed by Devil Canyon, the other Chakachamna followed by Watana--were analyzed under the same parameters as the feasibility study base case. Capital costs and energies were provided by Bechtel, Alternative "B" with average annual energy of 1,492 GWh, firm energy of 1,374 GWh, and a capital cost of $1,450 million including IDC and transmission costs.

With the addition of Chakachamna in 1993, Devil Canyon can most effectively be staged in 1997 with further expansion of Beluga coal units in 2003 and 2010. Six 70-MW gas turbines are added in the post-2000 period. The total LTC (1993-2051) of this plan is $8,186 million as shown in Table 11.15.

The Chakachamna-Watana generation plan was staged as 1993-2000, respectively, since Watana alone is a larger energy project than Devil Canyon. Additional capacity added are three 70-MW gas turbines and a 200-MW combined cycle unit. This plan has a 1993-2051 LTC of $8,241 million, with negative net benefits of $4 million when compared to the base case non-Susitna plan.

The possibility of a Chakachamna-Devil Canyon-Watana or Chakachamna-Watana-Devil Canyon plan was examined; however, the excess capacity and energy provided in these scenarios, given the medium load forecast, are over 1,000 GWh and were, therefore, not modeled as such.

- Single Hydro Project Developments

  Three single development cases were examined under this topic: Watana, Devil Canyon, or Chakachamna alone.

  Table 11.15 summarizes energies, capital costs, and long-term costs for each of these scenarios. LTCs are computed for 50 years of the project.

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TABLE 11.1: FINANCING REQUIREMENTS - $ MILLION FOR $1.8 BILLION STATE APPROPRIATION

	$ Million Interest Rate 10% Inflation Rate 7% Actual	1982 Purchasing Power
1985 State Appropriation	404	318
86 " "	473	348
87 " "	480	331
88 " "	500	323
89 " "	798	480
Total State Appropriation	2655	1800
1989 Revenue Bonds	140	84
90 " "	1564	880
91 " "	1418	746
92 " "	989	486
93 " "	396	182
Total Watana Bonds	4507	2378
1994 Revenue Bonds	230	99
95 " "	386	155
96 " "	364	136
97 " "	325	114
98 " "	1085	355
99 " "	1346	412
2000 " "	1513	433
01 " "	1377	368
02 " "	269	67
Total Devil Canyon Bonds	6895	2139
TOTAL SUSITNA BONDS	11402	4517

TABLE 11.2: $1.8 BILLION (1982 DOLLARS) STATE APPROPRIATION SCENARIO
7% INFLATION AND 10% INTEREST

CASH FLOW SUMMARY ($Million)

		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
73	Energy GWH	0	0	0	0	0	0	0	0	3387	3387
521	Real Price-Mills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.85	62.99
466	Inflation Index	126.72	135.59	145.08	155.24	166.10	177.73	190.17	203.48	217.73	232.97
520	Price-Mills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	110.73	146.75
	INCOME										
516	Revenue	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	375.0	497.0
170	Less Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.9	29.3
517	Operating Income	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	348.1	467.7
214	Add Interest Earned on Funds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6
550	Less Interest on Short-Term Debt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1
391	Less Interest on Long-Term Debt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	411.1	444.4
548	Net Earnings From Opers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-63.0	12.8
	CASH SOURCE AND USE										
548	Cash Income From Opers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-63.0	12.8
446	State Contribution	403.7	472.7	479.7	499.5	797.9	0.0	0.0	0.0	0.0	0.0
143	Long-Term Debt Drawdowns	0.0	0.0	0.0	0.0	140.4	1564.4	1417.6	988.6	396.1	229.7
248	Worcap Debt Drawdowns	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.0	17.7
549	Total Sources of Funds	403.7	472.7	479.7	499.5	938.3	1564.4	1417.6	988.6	431.1	260.2
320	Less Capital Expenditure	403.7	472.7	479.7	499.5	938.3	1564.4	1417.6	988.6	333.1	259.2
448	Less Worcap and Funds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.0	17.7
260	Less Debt Repayments	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.4
141	Cash Surplus (Deficit)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-33.1
249	Short-Term Debt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1
444	Cash Recovered	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	BALANCE SHEET										
225	Reserve and Cont. Fund	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.5	61.6
371	Other Working Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.5	54.1
454	Cash Surplus Retained	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
370	Cum. Capital Expenditure	403.7	876.4	1356.1	1855.6	2794.0	4358.4	5775.9	6764.6	7097.7	7356.9
465	Capital Employed	403.7	876.4	1356.1	1855.6	2794.0	4358.4	5775.9	6764.6	7195.7	7472.6
461	State Contribution	403.7	876.4	1356.1	1855.6	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5
462	Retained Earnings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-63.0	-50.2
555	Debt Outstanding - Short Term	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	161.0	211.8
554	Debt Outstanding - Long Term	0.0	0.0	0.0	0.0	140.4	1704.8	3122.4	4111.0	4444.1	4657.4
542	Annual Debt Drawdown $ 1982	0.0	0.0	0.0	0.0	84.5	880.2	745.4	485.8	181.9	98.6
543	Cum. Debt Drawdown $ 1982	0.0	0.0	0.0	0.0	84.5	964.7	1710.1	2196.0	2377.9	2476.5
519	Debt Service Cover	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.99

CASH FLOW SUMMARY
($Million)

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
73	Energy GWH	3387	3387	3387	3387	3387	3387	3387	5223	5414	5605
521	Real Price-Mills	61.36	69.57	65.59	61.68	58.03	54.61	51.40	63.57	59.90	62.52
466	Inflation Index	249.28	266.73	285.40	305.38	326.75	249.62	374.10	400.29	428.31	458.29
520	Price-Mills	152.95	185.56	187.18	188.34	189.61	190.92	192.30	254.47	256.58	286.53
	INCOME										
516	Revenue	518.0	628.4	633.9	637.9	642.2	646.6	651.3	1329.0	1389.0	1605.9
170	Less Operating Costs	32.0	35.0	38.1	41.6	45.4	49.6	54.1	91.1	99.4	108.5
517	Operating Income	486.0	593.5	595.8	596.2	596.7	597.0	597.2	1237.9	1289.6	1497.4
214	Add Interest Earned on Funds	6.2	6.7	7.3	8.0	8.7	9.5	10.4	11.4	19.1	20.9
550	Less Interest on Short-Term Debt	21.2	24.2	27.1	28.2	29.5	30.5	31.6	32.8	45.6	48.4
391	Less Interest on Long-Term Debt	442.8	441.0	439.0	436.8	434.4	431.8	428.9	1088.3	111.81	1105.3
548	Net Earnings From Opers	28.2	135.0	137.0	139.2	141.6	144.3	147.2	128.1	151.4	364.5
	CASH SOURCE AND USE										
548	Cash Income From Opers	28.2	135.0	137.0	139.2	141.6	144.3	147.2	128.1	151.4	364.5
446	State Contribution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
143	Long-Term Debt Drawdowns	386.1	363.6	324.8	1085.4	1346.9	1513.1	1377.3	269.3	0.0	0.0
248	Worcap Debt Drawdowns	8.1	29.3	11.2	12.2	10.6	10.4	12.3	128.0	24.7	42.8
549	Total Sources of Funds	422.4	527.9	473.0	1236.8	1499.1	1667.8	1536.7	525.4	176.1	407.3
320	Less Capital Expenditure	418.2	478.8	440.0	1200.6	1462.1	1628.3	1492.5	362.3	90.9	99.2
448	Less Worcap and Funds	8.1	29.3	11.2	12.2	10.6	10.4	12.3	128.0	24.7	42.8
260	Less Debt Repayments	18.0	19.8	21.8	24.0	26.4	29.0	32.0	35.1	64.1	70.5
141	Cash Surplus (Deficit)	-22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.6	194.8
249	Short-Term Debt	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	-58.7
444	Cash Recovered	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	136.1
	BALANCE SHEET										
225	Reserve and Cont. Fund	67.2	73.4	80.1	87.4	95.4	104.1	113.7	191.3	208.8	227.8
371	Other Working Capital	56.6	79.7	84.2	89.1	91.7	93.4	96.2	146.6	153.8	177.6
454	Cash Surplus Retained	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
370	Cum. Capital Expenditure	7775.1	8253.9	8693.9	9894.5	11356.6	12984.9	14477.4	14839.7	14930.5	15029.7
465	Capital Employed	7898.9	8407.0	8858.3	10071.1	11543.7	13182.5	14687.2	15177.5	15293.1	15435.1
461	State Contribution	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5
462	Retained Earnings	-22.0	113.0	250.1	389.3	530.9	675.1	822.3	950.4	1101.8	1330.2
555	Debt Outstanding - Short Term	241.9	271.2	282.4	294.7	305.2	315.7	328.0	455.9	484.3	468.4
554	Debt Outstanding - Long Term	5025.5	5369.2	5672.2	6733.6	8054.1	9538.1	10883.4	11117.6	11053.5	10983.0
542	Annual Debt Drawdown $ 1982	154.9	136.3	113.8	355.4	412.2	432.8	368.1	67.3	0.0	0.0
543	Cum. Debt Drawdown $ 1982	2631.3	2767.7	2881.5	3236.9	3649.1	4081.8	4450.0	4517.3	4517.3	4517.3
519	Debt Service Cover	1.02	1.25	1.25	1.25	1.25	1.25	1.25	1.08	1.07	1.25

CASH FLOW SUMMARY
($Million)

		2005	2006	2007	2008	2009	2010	2011	2012	2013	TOTAL
73	Energy GWH	6092	6147	6250	6472	6544	6616	6638	6660	6682	104826
521	Real Price-Mills	53.98	50.38	46.72	42.59	39.74	37.11	34.95	32.91	31.02	0.00
465	Inflation Index	390.27	524.69	561.42	600.72	642.77	687.77	735.91	787.42	842.54	0.00
520	Price-Mills	264.68	264.32	262.31	255.84	255.46	255.25	257.23	259.16	261.34	0.00
	INCOME										
516	Revenue	1612.3	1624.7	1639.3	1655.7	1671.6	1688.6	1707.3	1725.9	1746.1	24625.8
170	Less Operating Costs	118.4	129.2	141.0	153.9	168.0	183.4	200.1	218.4	238.4	2202.0
517	Operating Income	1493.9	1495.5	1498.3	1501.8	1503.6	1505.3	1507.2	1507.5	1507.8	22423.8
214	Add Interest Earned on Funds	22.8	24.9	27.1	29.6	32.3	35.3	38.5	42.0	45.9	412.4
550	Less Interest on Short-Term Debt	46.8	50.5	55.6	61.5	66.1	70.7	75.9	79.7	83.8	925.8
391	Less Interest on Long-Term Debt	1093.3	1090.5	1082.0	1072.6	1062.3	1050.9	1038.4	1024.7	1009.6	16744.9
548	Net Earnings From Opers	371.5	379.3	387.8	397.2	407.5	418.9	431.4	445.1	460.3	5165.4
	CASH SOURCE AND USE										
548	Cash Income From Opers	371.5	379.3	387.8	397.2	407.5	418.9	431.4	445.1	460.3	5165.4
446	State Contribution	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2653.5
143	Long-Term Debt Drawdowns	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11403.2
248	Worcap Debt Drawdowns	36.4	51.3	59.3	45.8	45.9	52.0	37.7	41.2	44.9	819.7
549	Total Sources of Funds	408.0	430.5	447.1	443.0	453.4	470.8	469.1	486.3	505.2	20041.9
320	Less Capital Expenditure	108.2	118.1	128.9	140.7	153.6	167.6	182.9	199.7	217.9	16447.4
448	Less Worcap and Funds	36.4	51.3	59.3	45.8	45.9	52.0	37.7	41.2	44.9	819.7
260	Less Debt Repayments	77.6	85.3	93.9	103.2	113.6	124.9	137.4	151.2	166.3	1410.7
141	Cash Surplus (Deficit)	185.7	175.8	165.0	153.3	140.4	126.4	111.0	94.3	76.1	1364.1
249	Short-Term Debt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
444	Cash Recovered	185.7	175.8	165.0	153.3	140.4	126.4	111.0	94.3	76.1	1364.1
	BALANCE SHEET										
225	Reserve and Cont. Fund	248.7	271.4	296.2	323.3	352.8	385.1	420.3	458.7	500.6	500.6
371	Other Working Capital	193.2	221.7	256.2	274.9	291.2	310.9	313.4	316.2	319.2	319.2
454	Cash Surplus Retained	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
370	Cum. Capital Expenditure	15138.0	15256.1	15385.0	15525.7	15679.3	15846.9	16029.9	16229.5	16447.4	16447.4
465	Capital Employed	15579.8	15749.2	15937.4	16123.9	16323.3	16542.9	16763.5	17004.3	17267.2	17267.2
461	State Contribution	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5	2653.5
462	Retained Earnings	1516.0	1719.5	1942.3	2186.3	2453.4	2745.9	3066.3	3417.1	3801.3	3801.3
555	Debt Outstanding - Short Term	504.8	556.1	615.3	661.1	707.0	759.0	796.7	837.8	882.7	882.7
554	Debt Outstanding - Long Term	10905.4	10820.1	10726.2	10622.9	10509.4	10384.4	10247.0	10095.8	9929.6	9929.6
542	Annual Debt Drawdown $ 1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4517.3
543	Cum. Debt Drawdown $ 1982	4517.3	4517.3	4517.3	4517.3	4517.3	4517.3	4517.3	4517.3	4517.3	4517.3
519	Debt Service Cover	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	0.00

TABLE 11.3: SUMMARY OF MAJOR FORECASTS OF OIL PRICE TRENDS

Source	Date of Forecast	Forecast Trend (percent)
Date Resources Inc.	Summer 1982	+2.8
International Energy Agency	Spring 1982	
- Low		-0.5
- High		+2.0
US Energy Information Administration	Spring 1982	above +3
Energy Mines and Resources Canada	Summer 1982	+1.7
Ontario Hydro	Spring 1982	+1.8
Energy Modeling Forum, World Oil Report*	February 1982	
- average of 10 models		+3.4
- range of 10 models		+1.9 +5.3
Dr. F. Fesharaki, Resource Systems Institute East-West Centre, Honolulu	Spring 1982	+1.7

* The 10 models are: Gately-Kyle-Fischer (New York Univ.), IEES - OMS (U.S. Dept. of Energy), IPE (M.I.T.), Salant-ICF (U.S. Federal Trade Commission and ICF, Inc.), ETA-MARCO (Stamford Univ.), WOIL (U.S. Dept. of Energy and Environmental Analysis, Inc), Kennedy-Nehring (Univ. of Texas and the Rand Corp.), OILTANK (Chr. Michelsen Institute), Opeconomics (BP Co. Ltd.), OILMAR (Energy and Power Subcommittee, U.S. House of Representatives).

TABLE 11.4: COMPARISON OF ACRES ESTIMATE AND ACTUAL COST REDUCED TO COMMON (1963) LEVEL

	$ Millions Current Dollars	1963 Dollars	Percent of 1963 Estimate
1963 Estimate (incl. contingency) (1)	488.2	488.2	100.0
1966 Estimate (incl. contingency) (2)	563.3	489.5	100.3
Completion Cost	665.6	467.8	95.8

NOTE: (1) 1963 Estimate was for 10 x 450 MW Units; 1966-68 Estimate and Actual was for 11 x 475 MW Units.

(2) The project budget provided for a contingency allowance of $41 million, i.e., approximately 8 percent of the base construction cost estimate and a provision for escalation of $102 million based on a rate of 4.5 percent per annum, constant over the construction period.

TABLE 11.5: MULTIVARIATE SENSITIVITY ANALYSIS, LONG-TERM COSTS AND PROBABILITY, NON-SUSITNA TREE

Rank (Low-High)	ID	(1982$) $ x 10^6 Long-Term Cost	Probability	Cumulative Probability	Incremental LTC 1/	Cumulative LTC
1	T27	4412	.03	.03	132.36	132
2	T24	4590	.09	.12	413.10	545
3	T21	4856	.03	.15	145.68	691
4	T18	5489	.015	.165	82.34	773
5	T15	5661	.045	.21	254.75	1,028
6	T12	5991	.015	.225	89.87	1,118
7	T26	6101	.06	.285	366.06	1,484
8	T23	6878	.18	.465	1,238.04	2,722
9	T09	7184	.005	.47	35.92	2,758
10	T06	7313	.015	.485	109.70	2,868
11	T20	7460	.06	.545	447.60	3,315
12	T03	7624	.005	.55	38.12	3,354
13	T17	7915	.03	.58	237.45	3,591
14	T14	8238	.09	.67	741.42	4,332
15	T25	8492	.03	.70	254.76	4,587
16	T22	8746	.09	.79	787.14	5,374
17	T11	8858	.03	.82	265.74	5,640
18	T19	9253	.03	.85	277.59	5,918
19	T16	10321	.015	.865	154.82	6,072
20	T08	10503	.01	.875	105.03	6,177
21	T13	10637	.045	.92	478.67	6,656
22	T05	10859	.03	.95	325.77	6,982
23	T10	11272	.015	.965	169.08	7,151
24	T02	11569	.01	.975	115.69	7,267
25	T07	13742	.005	.980	68.71	7,335
26	T04	14194	.015	.995	212.91	7,548
27	T01	15058	.005	1.000	75.29	7,624
			1.000			

1/ LTC - long-term costs

Using probability distributions:

Low Load Forecast	0.60
Medium Load Forecast	0.30
High Load Forecast	0.10
	1.00

TABLE 11.6: MULTIVARIATE SENSITIVITY ANALYSIS
LONG-TERM COSTS AND PROBABILITY, SUSITNA TREE

Rank (Low-High)	ID	(1982$) $ x 10^6 Long-Term Cost	Probability	Cumulative Probability	Incremental LTC 1/	Cumulative LTC
1	S45	5543	.09	.09	498.87	499
2	S42	5757	.18	.27	1,036.26	1,535
3	S36	5827	.045	.315	262.22	1,797
4	S39	6097	.09	.405	548.73	2,346
5	S33	6151	.09	.495	553.59	2,900
6	S44	6437	.0375	.5325	241.39	3,141
7	S30	6477	.045	.5775	291,47	3,432
8	S41	6650	.075	.6525	498.75	3,931
9	S35	6738	.01875	.67125	126.34	4,058
10	S38	6991	.0375	.70875	262.16	4,320
11	S32	7062	.0375	.74625	264.83	4,585
12	S27	7087	.003	.74925	21.26	4,606
13	S18	7108	.009	.75825	63.97	4,670
14	S09	7151	.003	.76125	21.45	4,691
15	S43	7331	.0225	.78375	164.95	4,856
16	S29	7388	.01875	.8025	138.53	4,995
17	S40	7543	.045	.8475	339.44	5,334
18	S34	7650	.01125	.85875	86.06	5,420
19	S37	7884	.0225	.88125	177.39	5,598
20	S31	7974	.0225	.90375	179.42	5,777
21	S26	7986	.00125	.905	9.98	5,787
22	S17	8008	.00375	.90875	30.03	5,817
23	S08	8050	.00125	.91	10.06	5,827
24	S24	8326	.006	.916	49.96	5,877
25	S15	8347	.018	.934	150.25	6,027
26	S28	8371	.01125	.94525	94.17	6,121
27	S06	8390	.006	.95125	50.34	6,172
28	S25	8886	.00075	.952	6.66	6,178
29	S16	8908	.00225	.95425	20.04	6,199
30	S07	8951	.00075	.955	6.71	6,205
31	S23	9225	.0025	.9575	23.06	6,228
32	S14	9247	.0075	.9650	69.35	6,297
33	S05	9290	.0025	.9675	23.23	6,321
34	S21	9614	.003	.9705	28.84	6,350
35	S12	9758	.009	.9795	87.82	6,437
36	S03	9784	.003	.9825	29.35	6,467
37	S22	10126	.0015	.9840	15.19	6,482
38	S13	10147	.0045	.9885	45.66	6,528
39	S04	10190	.0015	.99	15.29	6,543
40	S20	10514	.00125	.99125	13.14	6,556
41	S11	10658	.00375	.995	39.97	6,596
42	S02	10683	.00125	.99675	13.35	6,609
43	S19	11414	.00075	.997	8.56	6,618
44	S10	11558	.00225	.99925	26.01	6,644
45	S01	11584	.00075	1.00000	8.69	6,653
			1.00000			

1/ Using probability distributions:

Low Load Forecast	0.60
Medium Load Forecast	0.30
High Load Forecast	0.10
	1.00

TABLE 11.7: COMPARISON OF BASE CASES
REVISED OGP-5 PROGRAM

OGP-5	Cumulative Costs 1993-2010	2010 [1/] Annual	1982 Present Worth of System Costs $\$ \times 10^6$ Estimated 2011-2051	Long-Term Cost 1993-2001	Net Benefit
Non-Susitna	3,213	491	5,025	8,238	---
Susitna	3,197	385	3,943	7,062	1,176
OGP-6					
Non-Susitna	3,213	491	5,025	8,238	---
Susitna	3,066	384	3,929	6,995	1,243

1/ 2010 annual cost is projected 41 years at 3% and present worth 26 years to 1982 at 3% to arrive at the 2011-2051 estimated present worth.

TABLE 11.8: PERCENT RESERVE - MEDIUM LOAD FORECAST[1/]

		Non-Susitna			Susitna		
Year	Peak Load (MW)	Total Capability (MW)	% Reserve	LOLP days/years	Total Capability (MW)	% Reserve	LOLP days/year
1993	947	1373	45.0	0.063	1853	95.7	0.000
1994	965	1542	59.8	0.027	1822	88.8	0.000
1995	983	1495	52.0	0.077	1774	80.5	0.000
1996	1003	1624	61.9	0.059	1704	69.9	0.000
1997	1023	1620	58.4	0.084	1630	59.4	0.000
1998	1044	1635	56.6	0.092	1575	50.8	0.001
1999	1064	1635	53.6	0.055	1575	48.0	0.002
2000	1084	1591	46.8	0.059	1531	41.2	0.015
2001	1121	1661	48.2	0.038	1531	36.6	0.032
2002	1158	1608	38.9	0.062	2079	79.5	0.000
2003	1196	1625	35.9	0.087	2026	69.4	0.001
2004	1233	1695	37.5	0.057	2027	64.4	0.001
2006	1323	1794	35.6	0.049	1939	52.7	0.017
2006	1323	1794	35.6	0.052	1917	44.9	0.068
2007	1377	1994	44.8	0.023	1987	44.3	0.025
2008	1430	1968	37.6	0.066	2032	42.1	0.029
2009	1484	2037	37.3	0.051	2031	36.9	0.050
2010	1537	2037	32.5	0.099	2102	36.8	0.025

1/ As calculated in peak month: % reserve = $\frac{\text{capacity - load}}{\text{load}}$

TABLE 11.9: ANNUAL ENERGY DISPATCH 1/

NON-SUSITNA PLAN (GWh)

Year	Coal	NG GT	NG CC	OIL	HYDRO	TOTAL
1993	1758	610	1733	4.0	631	4736
1995	2887	226	1177	0.6	631	4922
2000	3983	68	787	0	631	5469
2002	4236	95	891	0	631	5853
2005	4283	300	1214	0	631	6428
2010	5486	434	1240	0	631	7791

SUSITNA PLAN (GWh)

Year	COAL	NG GT	NG CC	OIL	OTHER HYDRO	SUSITNA	TOTAL
1993	140	0	578	0	631	3387	4736
1995	183	2	719	0	631	3387	4922
2000	239	83	1129	0	631	3387	5469
2002	0	0	0	0	631	5222	5853
2005	3	0	0	0	631	5539	6428
2010	53	6	616	0	631	6485	7791

1/ Medium Load Forecast.

TABLE 11.10: COMPONENTS OF ANNUAL COSTS - NON-SUSITNA PLAN 1/

(Millions $)

Year	Coal INV	Coal O/M	Coal Fuel	NGGT INV	NGGT O/M	NGGT Fuel	NGCC O/M	NGCC Fuel	OIL O/M&Fuel	TOTAL
1993	44.2	6.6	36.7	0	5.1	26.2	6.4	47.0	3.9	176.1
Cum.	44.2	50.8	87.5	87.5	92.6	118.8	125.2	172.2	176.1	
1995	73.9	12.1	61.6	0	2.7	10.4	5.5	37.3	3.4	206.9
Cum.	73.9	86.0	147.6	174.6	150.3	160.7	166.2	203.5	206.9	
2000	114.2	18.4	100.5	6.4	2.2	4.6	5.1	40.4	3.2	295.0
Cum.	114.2	132.6	233.1	239.5	241.7	246.3	251.4	291.8	295.0	
2002	114.2	19.3	109.0	9.8	2.6	6.7	5.6	45.8	3.3	316.4
Cum.	114.2	133.5	242.5	252.3	254.9	261.6	267.2	313.0	316.3	
2005	114.2	20.0	111.4	24.3	5.0	25.2	6.8	62.0	3.5	372.4
Cum.	114.2	134.2	254.6	269.9	274.9	300.1	306.9	368.9	372.4	
2010	152.8	29.1	150.8	32.0	7.1	38.3	7.5	69.5	3.9	491.0
Cum.	152.8	181.9	332.7	364.7	371.8	410.1	417.6	487.1	491.0	

1/ Medium Load Forecast

TABLE 11.11: COMPONENTS OF ANNUAL COSTS - SUSITNA PLAN 1/

(Million $)

Year	Susitna Investment	Susitna O/M	Other Hydro O/M	NGGT Inv	Thermal O/M	Coal Fuel	NG Fuel	Total
1993	199.1	12.2	2.8	0	7.3	4.7	20.4	246.5
1995	199.1	12.7	2.9	0	7.7	6.4	26.9	255.9
Cum.	199.1	211.8	214.7	214.7	222.4	228.8	255.9	
2000	199.1	14.1	3.2	0	8.8	7.8	59.6	292.6
Cum.	199.1	213.2	216.4	216.4	225.2	233.0	292.6	
2002	294.0	22.4	3.3	0	5.3	0	0	325.0
Cum.	294.0	316.4	319.7	319.7	325.0	325.0	325.0	
2005	294.0	23.8	3.5	0	5.2	0.7	16.0	343.2
Cum.	294.0	317.8	321.3	321.3	326.5	327.2	343.2	
2010	294.0	26.2	3.9	11.9	7.7	1.9	39.7	385.3
Cum.	294.0	320.2	324.1	336.0	343.7	345.6	385.3	

1 Medium Load Forecast

TABLE 11.12: SUSITNA PROJECT DELAYED

	Base Case Non-Susitna A	Base Case Susitna C	Susitna Delayed C3	Susitna Delayed C4	Susitna Delayed C5
OGP ID	L9J9	L9K3	L0W9	L2W5	L2W7
DATES:[1] WATANA/DC	--	93/2002	94/2002	94/2003	95/2004
ADDITIONS	4 Coal 9 GT's	3 GT's 2007 2008 2010	3 GT's 1993* 1993* 2010	3 GT's 1993* 1993* 2010	3 GT's 1993* 1993* 2010
$\$ \times 10^6$ (198 2 PW)					
1993 - 2010	$3,212.8	$3,199.4	$3,140.1	$3,137.9	$3,099.2
2010 Cost	491.0	385.3	387.4	388.7	394.1
2010 to 20XX Cost[2]	5,024.7	3,943.0	3,964.5	4,026.9	4,131.1
Long-Term Cost	8,238 8,299 C4 8,360 C5	7,062	7,105	7,165	7,230
Net Benefit	--	$1,176	$1,133	$1,134	$1,130

1/ Dates modeled are from 1993 through 2010 in all cases.

2/ Factors: 2010-2051 = 10.2336 (A, C, C3)
2010-2052 = 10.3598 (C4)
2010-2053 = 10.4824 (C5)

TABLE 11.13: WATANA PROJECT ALONE

	Medium Load Forecast				Low Load Forecast		
	Non-Susitna	1280 MW Susitna	680 MW Watana	1020 MW Watana	Non-Susitna	1280 MW Susitna	680 MW Watana
OGP ID	L919	L9K3	L189	L671	L195	L9K7	L4R7
System	600 MW B 200 MW N 630 MW GT	680 MW 93 600 MW 02 210 MW GT	680 MW 93 400 MW B 420 MW GT	680 MW 93 340 MW 02 400 MW B 350 MW GT	400 MW B 200 MW N 560 MW GT	680 MW 95 600 MW 04	680 MW 95 200 MW B 280 MW GT
$ Millions							
2010 yearly 1/	491.0	385.3	479.8	485.5	404.3	359.5	394.2
1993-2010	3,212.8	3,119.4	3,295.3	3,344.4	2,639.9	2,881.9	2,805.9
LTC $82	8,238	7,062	7,571	8,313	6,878	6,650	6,447
Transmission 2/	--	--	27	27	--	--	23
Totals	8,238(A)	7,062	8,232	8,340	6,878(C)	6,650	--
	7,589(B)	--	7,598	--	6,374 (D)	--	6,470
Net Benefit	--	1,176(A)	(9) (B)	(102)(A)	--	228(C)	(96)(D)

1/ Economic Factors:

Medium Load:		Low Load:	
to 2051	10.2336	to 2054	10.4824
to 2043	8.9119	to 2045	9.2367

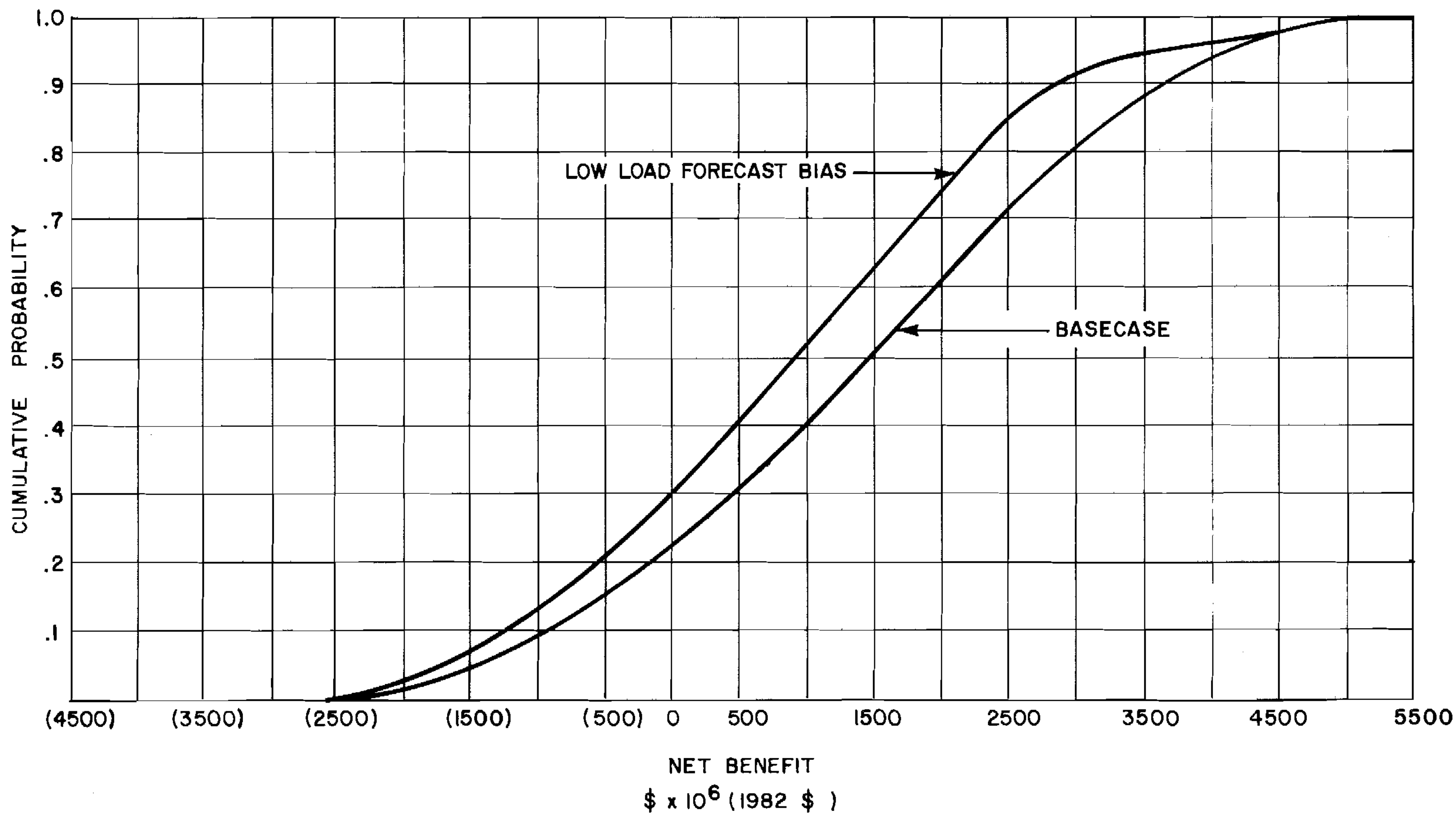
2/ $53.5 in 2005 = $27 1982 PW
2010 = $23 1982 PW

TABLE 11.14: ALTERNATIVE GENERATION PLANS

Case	Non-Susitna Plan	Watana Devil Canyon	Devil Canyon Watana	Chakachamna DC	Chakachamna Watana
ID	L9J9	L9K3	L5XZ9	L2Z3	L309
System Mix (Added capacity only)	800 Coal 560 GT	W/93 DC/02 210 GT	DC/93 W/02 350 GT	C/93 DC/97 400 Coal 420 GT	C/93 W/00 200 CC 210 GT
$\$ \times 10^6$ (1982)					
1993-2010	$3,121.8	$3,119.4	$3,168.3	$3,206.6	$3,259.9
2010	491.0	385.3	407.8	486.6	486.7
2011-2051	5,024.7	3,943.0	4,173.3	4,979.7	4,980.7
Long-term cost (1993-2051)	$8,237	$7,062	$7,341	$8,186	$8,241
Net Benefit	---	$1,176	$ 986	$ 51	($4)

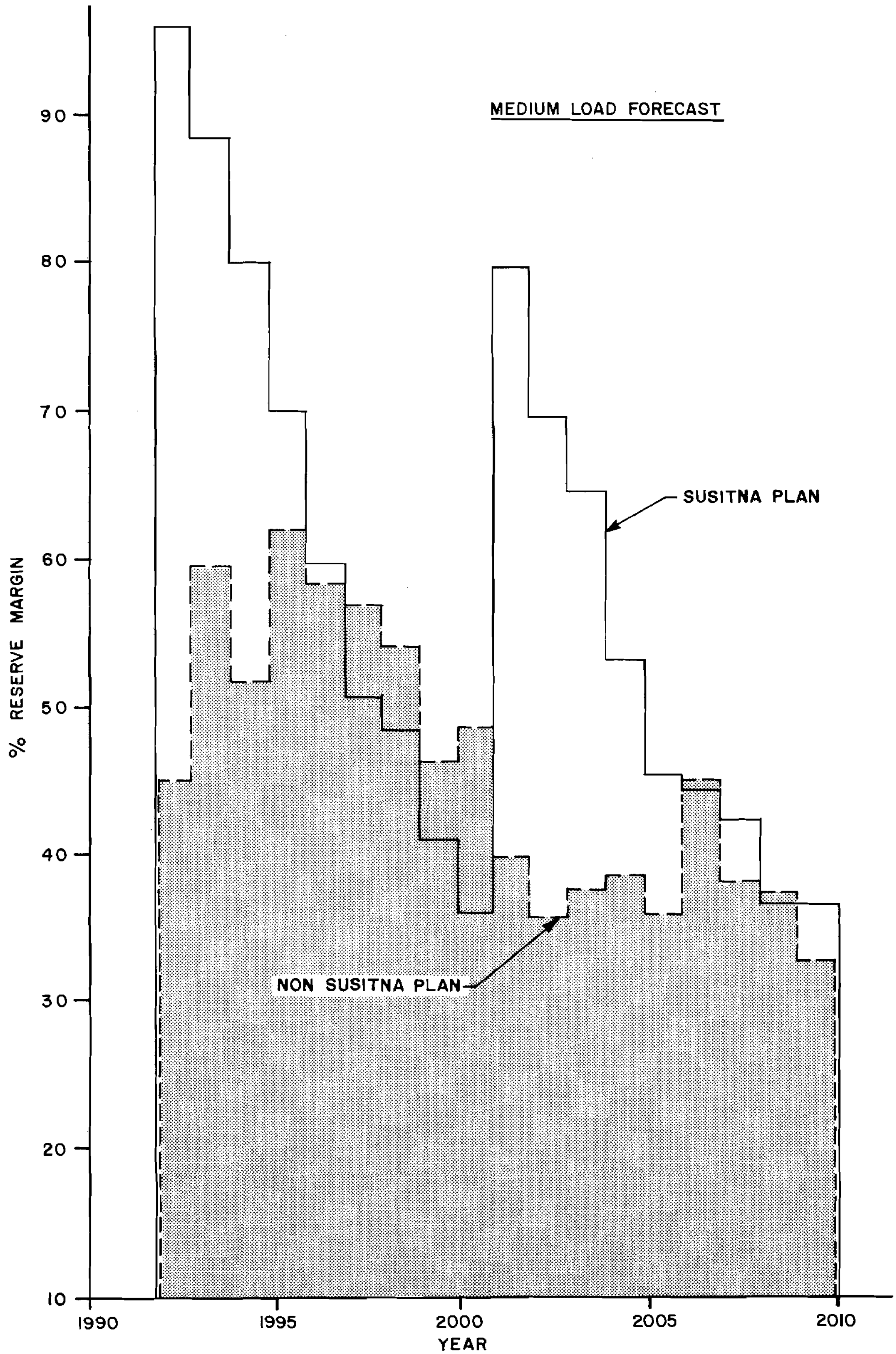
TABLE 11.15: SINGLE HYDRO PROJECT DEVELOPMENTS

Case	Watana	Devil Canyon	Chakachamna
ID	L189	L6I1	L9E1
Capacity Available	680 MW 1993	600 MW 1993	330 MW 1993
Average Energy	3459 GWh	2589 GWh	1492 GWh
Firm Energy	2631 GWh	2264 GWh	1374 GWh
$ x 10^6 (1982)			
Capital Cost (including IDC and transmission)	$4,094	$2,203	$1,450
Long-term costs (1993-2042)	$7,598	$7,656	$7,271
Net Benefits compared to non-Susitna plan LTC (1993-2042) of $7,589 million	(9)	($67)	($317)



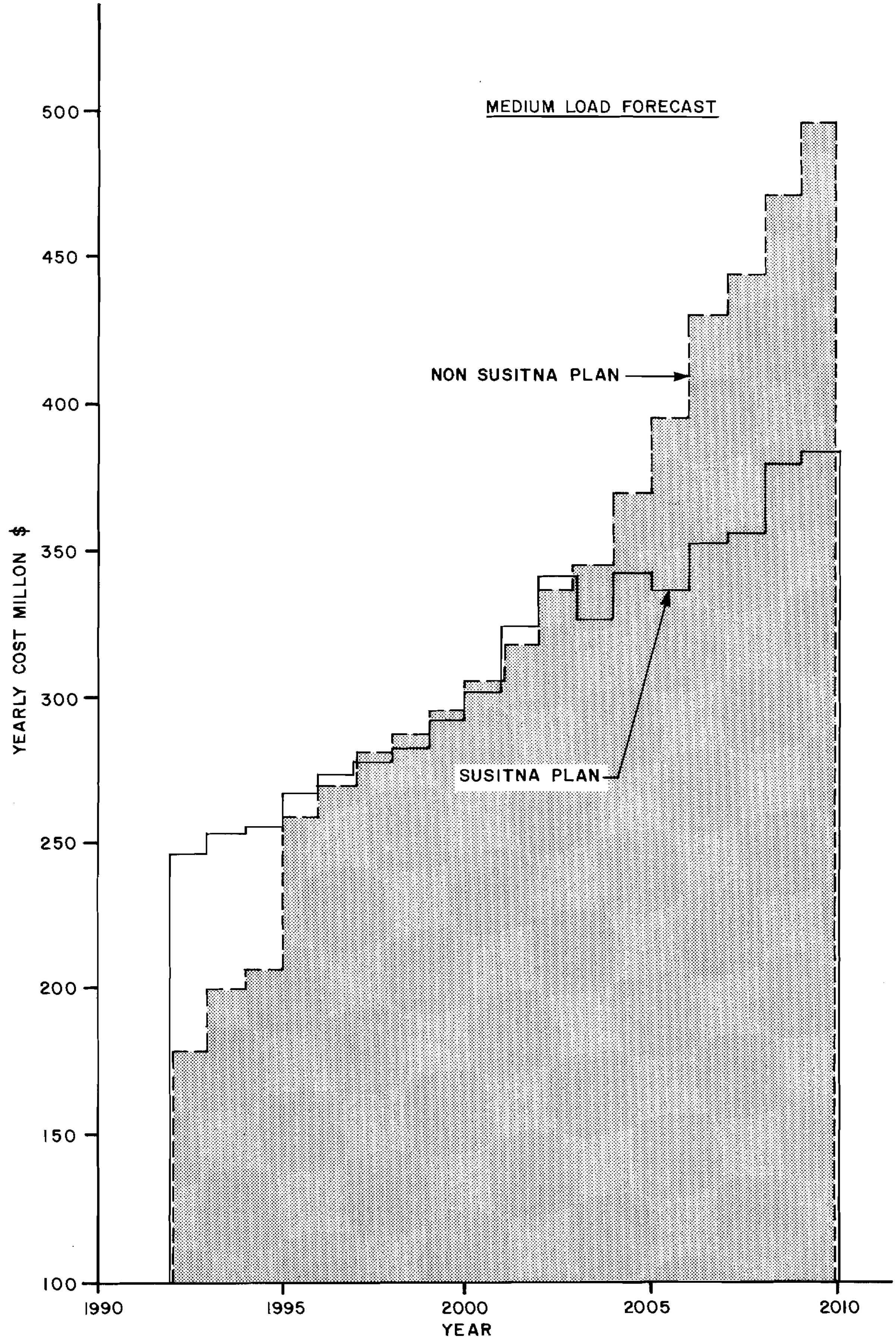
SUSITNA MULTIVARIATE SENSITIVITY ANALYSIS
CUMULATIVE PROBABILITY VS. NET BENEFITS

FIGURE 11.1



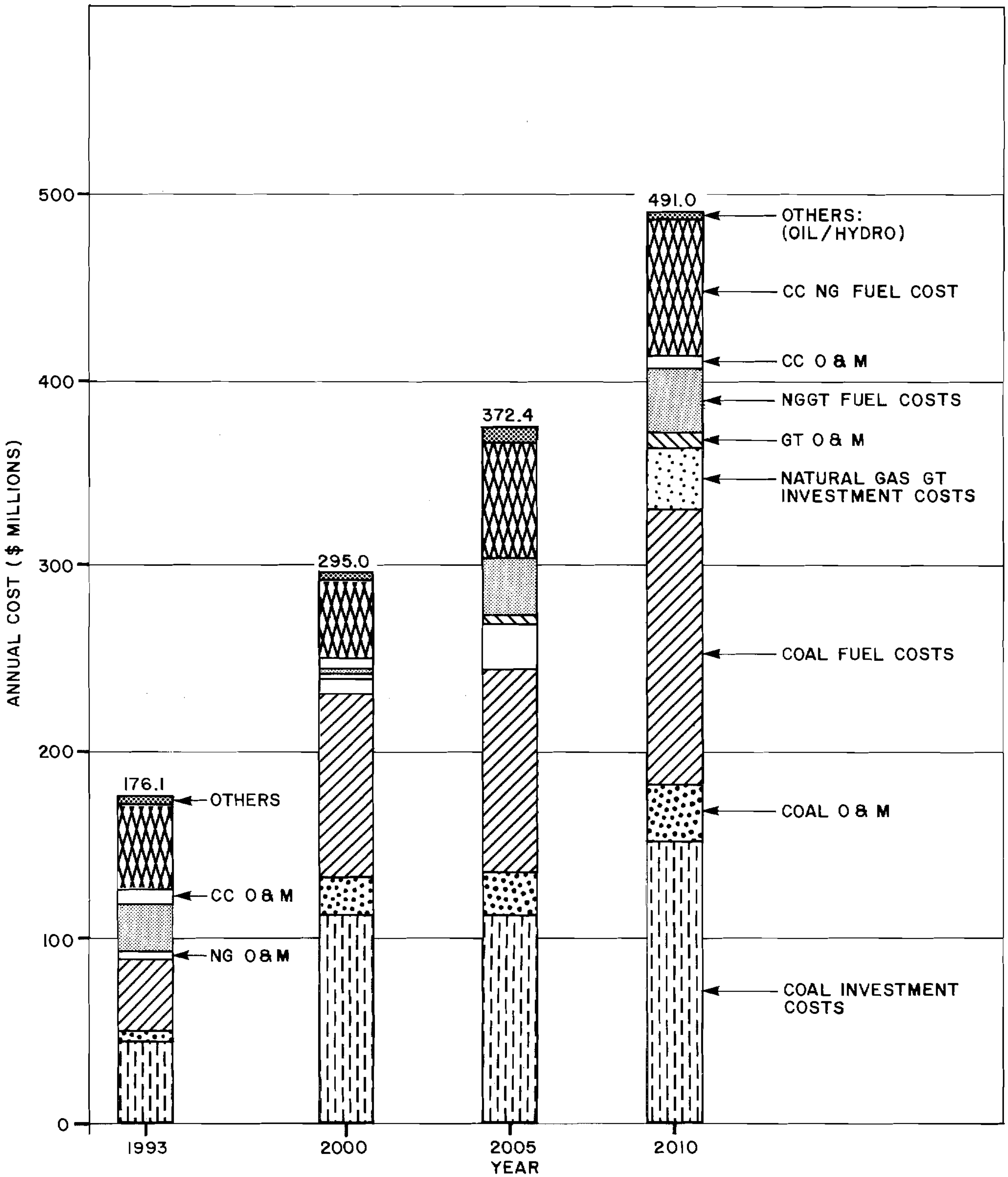
PERCENT RESERVE VS. TIME

FIGURE II.2



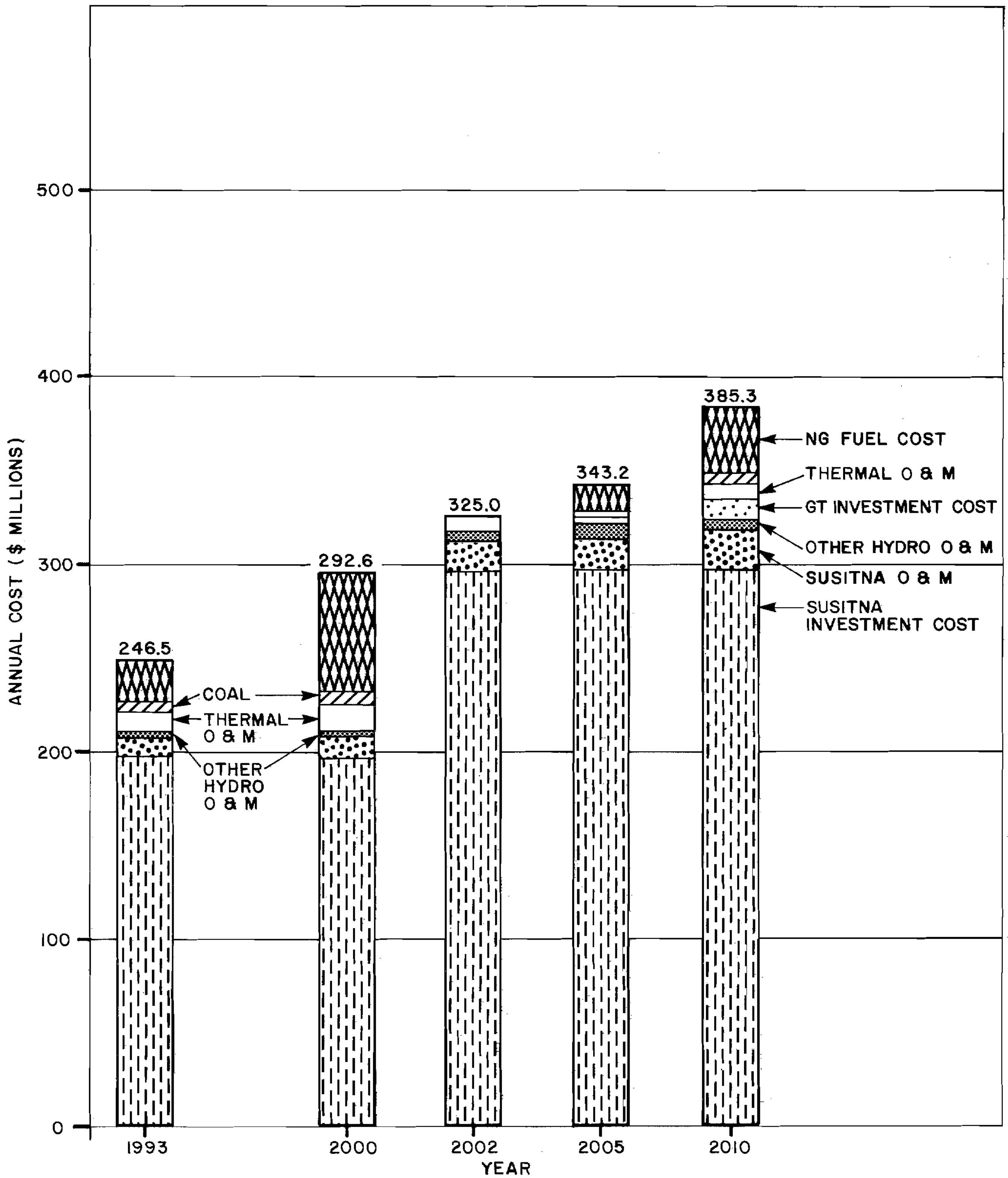
YEARLY ANNUAL COSTS

FIGURE 11.3



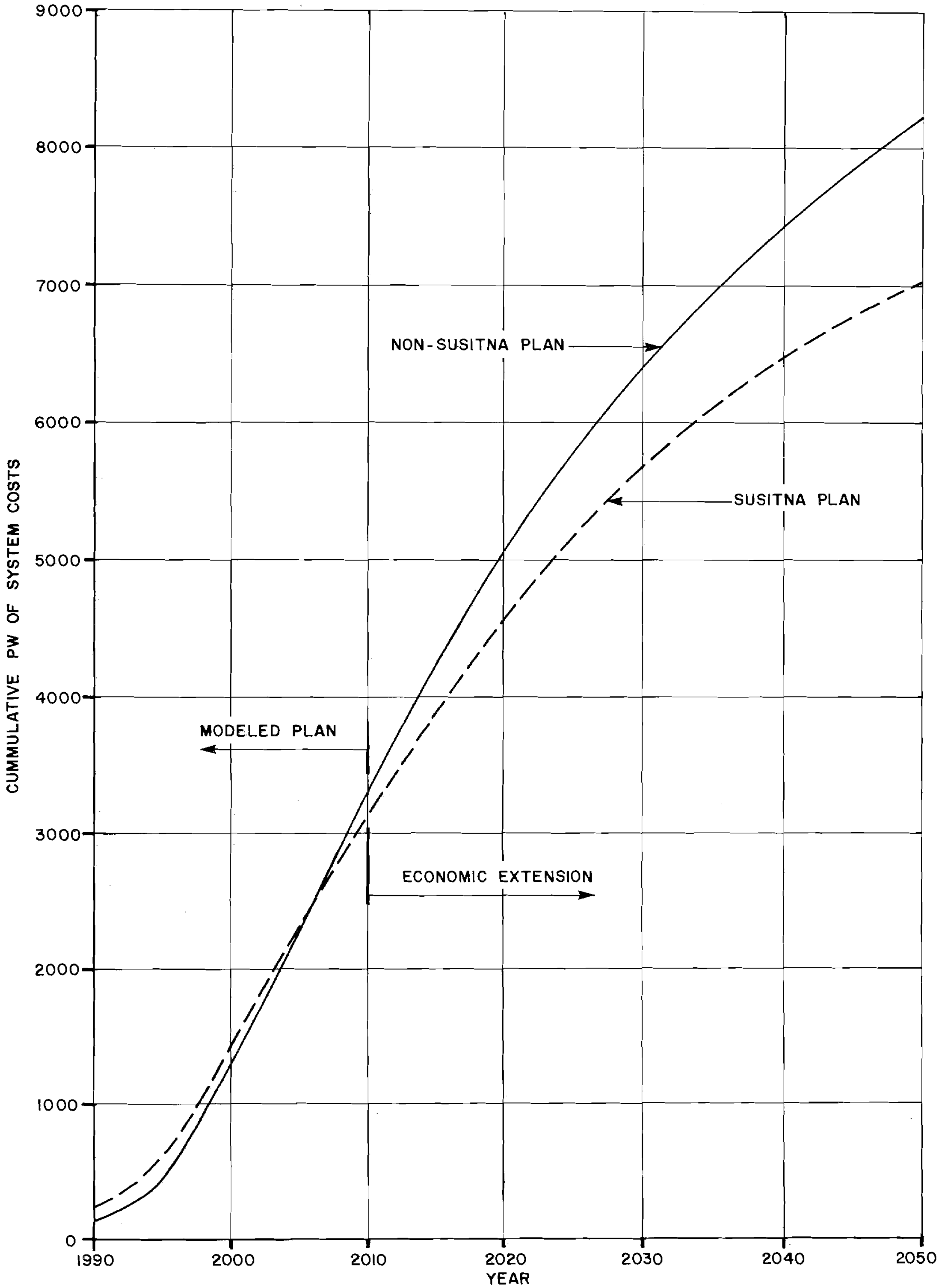
NON-SUSITNA PLAN MEDIUM LOAD FORECAST

FIGURE 11.4



SUSITNA PLAN MEDIUM LOAD FORECAST

FIGURE II.5



MEDIUM LOAD FORECAST - LONG TERM COSTS

FIGURE 11.6