SUSITNA HYDROELECTRIC PROJECT

DRAFT

FERC LICENSE APPLICATION

EXHIBIT B

PROJECT OPERATION AND RESOURCE UTILIZATION

NOVEMBER 1982

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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EXHIBIT B - PROJECT OPERATION AND RESOURCE UTILIZATION

1 - DAMSITE SELECTION

This section summarizes the previous site selection studies and the studies done during the Alaska Power Authority Susitna Hydroelectric Project Feasibility Study. Additional detail on this topic can be found in Reference 1.

1.1 - Previous Studies

Prior to the undertaking of the Susitna Hydroelectric Project Feasibility Study by the applicant, the hydroelectric development potential of the Alaskan Railbelt had been studied by several entities.

(a) Early Studies of Hydroelectric Potential

Shortly after World War II ended, the United States Bureau of Reclamation (USBR) conducted an initial investigation of hydroelectric potential in Alaska and issued a report of the results in 1948. Responding to a recommendation made in 1949 by the nineteenth Alaska territorial legislature that Alaska be included in the Bureau of Reclamation program, the Secretary of Interior provided funds to update the 1948 work. The resulting report, issued in 1952, recognized the vast hydroelectric potential within the territory and placed particular emphasis on the strategic location of the Susitna River between Anchorage and Fairbanks as well as its proximity to the connecting Railbelt (Figure B.1).

A series of studies was commissioned over the years to identify damsites and conduct geotechnical investigations. By 1961, the Department of the Interior proposed authorization of a two-dam power system on the Susitna River involving the Devil Canyon and the Denali sites (Figure B.2). The definitive 1961 report was subsequently updated by the Alaska Power Administration (an agency of the USBR) in 1974, at which time the desirability of proceeding with hydroelectric development was reaffirmed.

The Corps of Engineers (COE) was also active in hydropower investigations in Alaska during the 1950s and 1960s, but focused its attention on a more ambitious development at Rampart on the Yukon River. This project was capable of generating five times as much annual electric energy as the prior Susitna proposal. The sheer size and the technological challenges associated with Rampart captured the imagination of supporters and effectively diverted attention from the Susitna Basin for more than a decade. The Rampart report was finally shelved in the early 1970s because of strong environmental concerns and the uncertainty of marketing prospects for so much energy, particularly in light of abundant natural gas which had been discovered and developed in Cook Inlet.

The energy crisis precipitated by the OPEC oil boycott in 1973 provided some further impetus for seeking development of renewable resources. Federal funding was made available both to complete the Alaska Power Administration's update report on Susitna in 1974 and to launch a prefeasibility investigation by the COE. The State of Alaska itself commissioned a reassessment of the Susitna Project by the Henry J. Kaiser Company in 1974.

Salient features of the various reports to date are outlined in the following sections.

(b) U.S. Bureau of Reclamation - 1953 Study

The USBR 1952 report to the Congress on Alaska's overall hydroelectric potential was followed shortly by the first major study of the Susitna Basin in 1953. Ten damsites were identified above the railroad crossing at Gold Creek. These sites are identified on Figure B.2, and are listed below:

- Gold Creek;
- Olson;
- Devil Canyon;
- Devil Creek;
- Watana;
- Vee;
- Maclaren;
- Denali;
- Butte Creek; and
- Tyone (on the Tyone River).

Fifteen more sites were considered below Gold Creek. However, more attention has been focused over the years on the Upper Susitna Basin where the topography is better suited to dam construction and where less impact on anadromous fisheries is expected. Field reconnaissance eliminated half the original Upper Basin list, and further USBR consideration centered on Olson, Devil Canyon, Watana, Vee, and Denali. All of the USBR studies since 1953 have regarded these sites as the most appropriate for further investigation.

(c) U.S. Bureau of Reclamation - 1961 Study

In 1961 a more detailed feasibility study resulted in a recommended five-stage development plan to match the load growth curve as it was then projected. Devil Canyon was to be the first development--a 635- foot-high arch dam with an installed capacity of about 220 MW. The reservoir formed by the Devil Canyon dam alone would not store enough water to permit higher capacities to be economically installed, since long periods of relatively low flow occur in the winter months. The second stage would have increased storage capacity by adding an earthfill dam at Denali in the upper reaches of the basin. Subsequent stages involved adding generating capacity to the Devil Canyon dam. Geotechnical investigations at Devil Canyon were more thorough than at Denali. At Denali, test pits were dug, but no drilling occurred.

(d) Alaska Power Administration - 1974

Little change from the basic USBR-1961, five-stage concept appeared in the 1974 report by the Alaska Power Administration. This later effort offered a more sophisticated design, provided new cost and schedule estimates, and addressed marketing, economics, and environmental considerations.

(e) Kaiser Proposal for Development

The Kaiser study, commissioned by the Office of the Governor in 1974, proposed that the initial Susitna development consist of a single dam known as High Devil Canyon located on Figure B.2. No field investigations were made to confirm the technical feasibility of the High Devil Canyon location because the funding level was insufficient for such efforts. Visual observations suggested the site was probably favorable. The USBR had always been uneasy about foundation conditions at Denali, but had to rely upon the Denali reservoir to provide storage during long periods of low flow. Kaiser chose to avoid the perceived uncertainty at Denali by proposing to build a rockfill dam at High Devil Canyon which, at a height of 810 feet, would create a large enough reservoir to overcome the storage problem. Although the selected sites were different, the COE reached a similar conclusion when it later chose the high dam at Watana as the first to be constructed.

Subsequent developments suggested by Kaiser included a downstream dam at the Olson site and an upstream dam at a site known as Susitna III (Figure B.2). The information developed for these additional dams was confined to estimating energy potential. As in the COE study, future development of Denali remained a possibility if foundation conditions were found to be adequate and if the value of additional firm energy provided economic justification at some later date.

(f) U.S. Army Corps of Engineers - 1975 and 1979 Studies

The most comprehensive study of the Upper Susitna Basin prior to the current study was completed in 1975 by the COE. A total of 23 alternative developments were analyzed, including those proposed by the USBR, as well as consideration of coal as the primary energy source for Railbelt electrical needs. The COE agreed that an arch dam at Devil Canyon was appropriate, but found that a high dam at the Watana site would form a large enough reservoir for seasonal storage and would permit continued generation during low flow periods.

The COE recommended an earthfill dam at Watana with a height of 810 feet. In the longer term, development of the Denali site remained a possibility which, if constructed, would increase the amount of firm energy available in dry years.

An ad hoc task force was created by Governor Jay Hammond upon completion of the 1975 COE Study. This task force recommended endorsement of the COE request for Congressional authorization, but pointed out that extensive further studies, particularly those dealing with environmental and socioeconomic questions, were necessary before any construction decision could be made.

At the federal level, concern was expressed at the Office of Management and Budget regarding the adequacy of geotechnical data at the Watana site as well as the validity of the economics. The apparent ambitiousness of the schedule and the feasibility of a thin arch dam at Devil Canyon were also questioned. Further investigations were funded and the COE produced an updated report in 1979. Devil Canyon and Watana were reaffirmed as appropriate sites, but alternative dam types were investigated. A concrete gravity dam was analyzed as an alternative for the thin arch dam at Devil Canyon and the Watana dam was changed from earthfill to rockfill. Subsequent cost and schedule estimates still indicated economic justification for the project.

1.2 - Plan Formulation and Selection Methodology

The proposed plan which is the subject of this license application was selected after a review and reassessment of all previously considered sites. Additional detail in support of the findings in this Exhibit is found in Reference 5.

This section of the report outlines the engineering and planning studies carried out as a basis for formulation of Susitna Basin development plans and selection of the preferred plan.

In the description of the planning process, certain plan components and processes are frequently discussed. It is appropriate that three particular terms be clearly defined:

Damsite - An individual potential damsite in the Susitna Basin, referred to in the generic process as "candidate."

Basin Development Plan - A plan for developing energy within the Upper Susitna Basin involving one or more dams, each of specified height, and corresponding power plants of specified capacity. Each plan is identified by a plan number and subnumber indicating the staging sequence to be followed in developing the full potential of the plan over a period of time.

Generation Scenario - A specified sequence of implementation of power generation sources capable of providing sufficient power and energy to satisfy an electric load growth forecast for the 1980-2010 period in the Railbelt area. This sequence may include different types of generation sources such as hydroelectric and coal, gas or oil- fired thermal. These generation scenarios were developed for the comparative evaluations of Susitna Basin generation versus alternative methods of generation.

In applying the generic plan formulation and selection methodology, five basic steps are required; defining the objectives, selecting candidates, screening, formulation of development plans, and, finally,, a detailed evaluation of the plans (Figure B.3). The objective is to determine the optimum Susitna Basin development plan. The various steps required are outlined in subsections of this section.

Throughout the planning process, engineering layout studies were made to refine the cost estimates for power generation facilities or water storage development at several damsites within the basin. These data were fed into the screening and plan formulation and evaluation studies.

The second objective, the detailed evaluation of the various plans, is satisfied by comparing generation scenarios that include the selected Susitna Basin development plan with alternative generation scenarios, including all-thermal and a mix of thermal plus alternative hydropower developments.

1.3 - Damsite Selection

In previous Susitna Basin studies, twelve damsites were identified in the upper portion of the basin, i.e., upstream from Gold Creek. These sites are listed in Table B.1 with relevant data concerning facilities, cost, capacity, and energy.

The longitudinal profile of the Susitna River and typical reservoir levels associated with these sites are shown in Figure B.4. Figure B.5 illustrates which sites are mutually exclusive, i.e., those which cannot be developed jointly, since the downstream site would inundate the upstream site.

It can be readily seen that there are several mutually exclusive schemes for power development of the basin. The development of the Watana site precludes development of High Devil Canyon, Devils Creek, Susitna III and Vee but fits well with Devil Canyon. Conversely, the High Devil Canyon site would preclude Watana and Devil Canyon but fits well with Olson and Vee or Susitna III. These downstream sites do not preclude development of the upstream storage sites Denali or Butler Creek and Maclaren.

All relevant data concerning dam type, capital cost, power, and energy output were assembled and are summarized in Table B.1. For the Devil Canyon, High Devil Canyon, Watana, Susitna III, Vee, Maclaren, and Denali sites, conceptual engineering layouts were produced and capital costs were estimated based on calculated quantities and unit rates. Detailed analyses were also undertaken to assess the power capability and energy yields. At the Gold Creek, Devil Creek, Maclaren, Butte Creek, and Tyone sites, no detailed engineering or energy studies were undertaken; data from previous studies were used with capital cost estimates updated in 1980 levels. Approximate estimates of the potential average energy yield at the Butte Creek and Tyone sites were undertaken to assess the relative importance of these sites as energy producers.

The data presented in Table B.1 show that Devil Canyon, High Devil Canyon, and Watana are the most economic large energy producers in the basin. Sites such as Vee and Susitna III have only medium energy production, and are slightly more costly that the previously mentioned damsites. Other sites such as Olson and Gold Creek are competitive provided they have additional upstream regulation. Sites such as Denali and Maclaren produce substantially higher cost energy than the other sites but can also be used to increase regulation of flow for downstream use.

(a) Site Screening

The objective of this screening process was to eliminate sites which would obviously not be included in the initial stages of the Susitna Basin development plan and which, therefore, did not deserve further study at this stage. Three basic screening criteria were used: environmental, alternative sites, and energy contribution.

The screening process involved eliminating all sites falling in the unacceptable environmental impact and alternative site categories. Those failing to meet the energy contribution criteria were also eliminated unless they had some potential for upstream regulation. The results of this process, described in detail in Reference 5, are as follows:

- The "unacceptable site" environmental category eliminated the Gold Creek, Olson, and Tyone sites.

- The alternative sites category eliminated the Devil Creek and Butte Creek sites.

- No additional sites were eliminated for failing to meet the energy contribution criteria. The remaining sites upstream from Vee, i.e., Maclaren and Denali, were retained to insure that further study be directed toward determining the need and viability of providing flow regulation in the headwaters of the Susitna.

(b) Engineering Layouts

In order to obtain a uniform and reliable data base for studying the seven sites remaining, it is necessary to develop engineering layouts and reevaluate the costs. In addition, staged developments at several of the larger dams were studied.

The basic objective of these layout studies was to establish a uniform and consistent development cost for each site. These layouts are consequently conceptual in nature and do not necessarily represent optimum project arrangements at the sites. Also, because of the lack of geotechnical information at several of the sites, judgmental decisions had to made on the appropriate foundation and abutment treatment. The accuracy of cost estimates made in these studies is of the order of plus or minus 30 percent.

(i) Design Assumptions

In order to maximize standardization of the layouts, a set of basic design assumptions was developed. These assumptions covered geotechnical, hydrologic, hydraulic, civil, mechanical, and electrical considerations and were used as guidelines to determine the type and size of the various components within the overall project layouts. As stated previously, other than at Watana, Devil Canyon, and Denali, little information regarding site conditions was available. Broad assumptions were made on the basis of the limited data, and those assumptions and the interpretation of data have been conservative.

It was assumed that the relative cost differences between rockfill and concrete dams at the site would either be marginal or greatly in favor of the rockfill. The more detailed studies carried out subsequently for the Watana and Devil Canyon sites support this assumption. Therefore, a rockfill dam has been assumed at all developments in order to eliminate cost discrepancies that might result from a consideration of dam-fill unit costs compared to concrete unit costs at alternative sites.

(ii) General Arrangements

A brief description of the general arrangements developed for the various sites is given below. Descriptions of Watana and Devil Canyon in this section are of the preliminary layouts and should not be confused with the proposed layouts in Exhibit A and Exhibit F. Figures B.6 to B.12 illustrate the layout details. Table B.3 summarizes the crest levels and dam heights considered.

In laying out the developments, conservative arrangements have been adopted, and whenever possible there has been a general standardization of the component structures.

- Devil Canyon (Figure B.6)

The development at Devil Canyon, located at the upper end of the canyon at its narrowest point, consists of a rockfill dam, single spillway, power facilities incorporating an underground powerhouse, and a tunnel diversion.

The rockfill dam would rise above the valley on the south abutment and terminate in an adjoining saddle dam of similar construction. The dam would be 675 feet above the lowest foundation level with a crest elevation of 1470 and a volume of 20 million cubic yards.

The spillway would be located on the north bank and would consist of a gated overflow structure and a concrete-lined chute linking the overflow structure with intermediate and terminal stilling basins. Sufficient spillway capacity would be provided to pass the Probable Maximum Flood safely.

The power facilities would be located on the north abutment. The massive intake structure would be founded within the rock at the end of a deep approach channel and would consist of four integrated units, each serving individual tunnel penstocks. The powerhouse would house four 150-MW vertically mounted Francis type turbines driving overhead 165 MVA umbrella type generators.

As an alternative to the full power development in the first phase of construction, a staged powerhouse alternative was also investigated. The dam would be completed to its full height but with a initial plant installed capacity in 300-MW range. The complete powerhouse would be constucted together with penstocks and a tailrace tunnel for the initial two 150-MW units, together with concrete foundations for the future units.

- Watana (Figure B.7 and B.8)

For initial comparative study purposes, the dam at Watana is assumed to be a rockfill structure located on a similar alignment to that proposed in the previous COE studies. It would be similar in construction to the dam at Devil Canyon with an impervious core founded on sound bedrock and an outer shell composed of blasted rock excavated from a single quarry located on the south abutment. The dam would rise 880 feet from the lowest point on the foundation and have an overall volume of approximately 63 million cubic yards for a crest elevation of 2225.

The spillway would be located on the north bank and would be similar in concept to that at Devil Canyon with an intermediate and terminal stilling basin.

The power facilities located within the south abutment with similar intake, underground powerhouse, and water passage concepts to those at Devil Canyon would incorporate four 200-MW turbine/generator units giving a total output of 800-MW.

As an alternative to the initial full development at Watana, staging alternatives were investigated. These included staging of both dam and powerhouse construction. Staging of the powerhouse would be similar to that at Devil Canyon, with a Stage I installation of 400-MW and a further 400-MW in Stage II.

In order to study the alternative dam staging concept it was assumed that the dam would be constructed for a maximum operating water surface elevation some 200 feet lower than that in the final stage (Figure B.8).

The powerhouse would be completely excavated to its final size during the first stage. Three oversized 135-MW units would be installed together with base concrete for an additional unit. A low level control structure and twin concrete-lined tunnels leading into a downstream stilling basin would form the first stage spillway.

For the second stage, the dam would be completed to its full height, the impervious core would be appropriately raised, and additional rockfill would be placed on the downstream face. It was assumed that before construction commences the top 400 feet of the first stage dam would be removed to ensure the complete integrity of the impervious core for the raised dam. A second spillway control structure would be constructed at a higher level and would incorporate a downstream chute leading to the Stage I spillway structure. The original spillway tunnels would be closed with concrete plugs. A new intake structure would be constructed utilizing existing gates and hoists, and new penstocks would be driven to connect with the existing ones. The existing intake would be sealed off. One additional 200 MW unit would be installed and the required additional penstock and tailrace tunnel constructed. The existing 135-MW units would be upgraded to 200 MW.

- High Devil Canyon (Figure B.9)

  The development would be located between Devil Canyon and Watana. The 855 feet high rockfill dam would be similar in design to Devil Canyon, containing an estimated 48 million cubic yards of rockfill with a crest elevation of 1775. The south bank spillway and the north bank powerhouse facilities would also be similar in concept to Devil Canyon, with an installed capacity of 800-MW.

  Two stages of 400-MW were envisaged in each which would be undertaken in the same manner as at Devil Canyon, with the dam initially constructed to its full height.

- Susitna III (Figure B.10)

  The development would involve a rockfill dam with an impervious core approximately 670 feet high, a crest elevation of 2360, and a volume of approximately 55 million cubic yards. A concrete-lined spillway chute and a single stilling basin would be located underground, with the two diversion tunnels on the south bank.

- Vee (Figure B.11)

  A 610 feet high rockfill dam founded on bedrock with a crest elevation of 2350 and total volume of 10 million cubic yards was considered.

  Since Vee is located further upstream than the other major sites the flood flows are correspondingly lower, thus allowing for a reduction in size of the spillway facilities. A spillway utilizing a gated overflow structure, chute, and flip bucket was adopted.

  The power facilities would consist of a 400-MW underground powerhouse located in the south bank with a tailrace outlet well downstream of the main dam. A secondary rockfill dam would also be required in this vicinity to seal off a low point. Two diversion tunnels would be provided on the north bank.

- Maclaren (Figure B.12)

The development would consist of a 185 feet high earthfill dam founded on pervious riverbed materials. The crest elevation of the dam would be 2405. This reservoir would essentially be used for regulating purposes. Diversion would occur through three conduits located in a open cut on the south bank and floods would be discharged via a side chute spillway and stilling basin on the north bank.

- Denali (Figure B.12)

Denali is similar in concept to Maclaren. The dam would be 230 feet high, of earthfill construction, and would have a crest elevation of 2555. As for Maclaren, no generating capacity would be included. A combined diversion and spillway facility would be provided by twin concrete conduits founded in open cut excavation in the north bank and discharging into a common stilling basin.

(c) Capital Costs

For purposes of initial comparisons of alternatives, construction quantities were determined for items comprising the major works and structures at the site. Where detail or data were not sufficient for certain work, quantity estimates were made on the basis of previous Acres' experience and the general knowledge of site conditions reported in the literature. In order to determine total capital costs for various structures, unit costs have been developed for the items measured. These have been estimated on the basis of review of rates used in previous studies, and of rates used on similar works in Alaska and elsewhere. Where applicable, adjustment factors based on geography, climate, manpower and accessibility were used. Technical publications have also been reviewed for basic rates and escalation factors.

The total capital costs developed are shown in Tables B.1 and B.2. It should be noted that the capital costs for Maclaren and Denali shown in Table B.1 have been adjusted to incorporate the costs of generation plants with capacities of 55-MW and 60-MW, respectively. Additional data on the projects are summarized in Table B.3.

1.4 - Formulation of Susitna Basin Development Plans

The results of the site screening process described above indicate that the Susitna Basin development plan should incorporate a combination of several major dams and powerhouses located at one or more of the following sites:

- Devil Canyon;
- High Devil Canyon;
- Watana;
- Susitna III; or
- Vee.

Supplementary upstream flow regulation could be provided by structures at:

- Maclaren; and
- Denali.

Cost estimates of these projects are itemized on Table B.4.

A computer assisted screening process identified the plans that are most economic as those of Devil Canyon/Watana or High Devil Canyon/Vee. In addition to these two basic development plans, a tunnel scheme which provides potential environmental advantages by replacing the Devil Canyon dam with a long power tunnel and a development plan involving Watana Dam was also introduced.

The criteria used at this stage of the process for selection of preferred Susitna Basin development plans are mainly economic (Figure B.3). Environmental considerations are incorporated into the further assessment of the plans finally selected.

The results of the screening process are shown in Table B.5. Because of the simplifying assumptions that were made in the screening model, the three best solutions from an economic point of view are included in the table.

The most important conclusions that can be drawn are as follows:

- For energy requirements of up to 1,150 Gwh, the High Devil Canyon, Devil Canyon or the Watana sites individually provided the most economic energy. The difference between the costs shown on Table B.4 is around 10 percent, which is similar to the accuracy that can be expected from the screening model.

- For energy requirements of between 1,750 and 3,500 Gwh, the High Devil Canyon site is the most economic.

- For energy requirements of between 3,500 and 5,250 Gwh the combinations of either Watana and Devil Canyon or High Devil Canyon and Vee are most economic.

- The total energy production capability of the Watana/Devil Canyon development is considerably larger than that of the High Devil Canyon/Vee alternative and is the only plan capable of meeting energy demands in the 6,000 Gwh range.

(a) Tunnel Alternative

A scheme involving a long power tunnel could conceivably be used to replace the Devil Canyon dam in the Watana/Devil Canyon development plan. It could develop similar head for power generation and may provide some environmental advantages by avoiding inundation of Devil Canyon. Obviously, because of the low winter flows in the river, a tunnel alternative could be considered only as a second stage to the Watana development.

Conceptually, the tunnel alternatives would comprise the following major components in some combination, in addition to the Watana dam reservoir and associated powerhouse:

- Power tunnel intake works;

- One or two power tunnels of up to forty feet in diameter and up to thirty miles in length;

- A surface or underground powerhouse with a capacity of up to 1200 MW;

- A re-regulation dam if the intake works are located downstream from Watana; and

- Arrangements for compensation flow in the bypassed river reach.

Four basic alternative schemes were developed and studied. Figure B.13 is a schematic illustration of these schemes. All schemes assumed an initial Watana development with full reservoir supply level at Elevation 2200 and the associated powerhouse with an installed capacity of 800 MW. Table B.6 lists all the pertinent technical information. Table B.7 lists the power and energy yields for the four schemes. Table B.8 itemizes the capital cost estimate.

Based on the foregoing economic information, Scheme 3 (Figures B.14 and B.15) produces the lowest cost energy by a factor of nearly 2.

A review of the environmental impacts associated with the four tunnel schemes indicates that Scheme 3 would have the least impact, primarily because it offers the best opportunities for regulating daily flows downstream from the project. Based on this assessment and because of its almost 2 to 1 economic advantage, Scheme 3 was selected as the only scheme worth further study (see Development Selection Report for detailed analysis). The capital cost estimate for Scheme 3 appears in Table B.8. The estimates also incorporate single and double tunnel options. For purposes of these studies, the double tunnel option has been selected because of its superior reliability. It should also be recognized that the cost estimates associated with the tunnels are probably subject to more variation than those associated with the dam schemes due to geotechnical uncertainties. In an attempt to compensate for these uncertainties, economic sensitivity analyses using both higher and lower tunnel costs have been conducted.

(b) Additional Basin Development Plan

As noted, the Watana and High Devil Canyon damsites appear to be individually superior in economic terms to all others. An additional plan was therefore developed to assess the potential for developing these two sites together. For this scheme, the Watana dam would be developed to its full potential. The High Devil Canyon dam would be constructed to a crest elevation of 1470 to fully utilize the head downstream from Watana.

(c) Selected Basin Development Plans

The essential objective of this step in the development selection process is defined as the identification of those plans which appear to warrant further, more detailed evaluation. The results of the final screening process indicate that the Watana/Devil Canyon and the High Devil Canyon/Vee plans are clearly superior to all other dam combinations. In addition, it was decided to study further Tunnel Scheme 3 as an alternative to the High Devil Canyon dam and a plan combining Watana and High Devil Canyon.

Associated with each of these plans are several options for staged development. For this more detailed analysis of these basic plans, a range of different approaches to staging the developments was considered. In order to keep the total options to a reasonable number and also to maintain reasonably large staging steps consistent with the total development size, staging of only the two larger developments, i.e., Watana and High Devil Canyon, was considered. The basic staging concepts adopted for these developments involved staging both dam and powerhouse construction, or alternatively just staging powerhouse construction. Powerhouse stages were considered in 400 MW increments.

Four basic plans and associated subplans are briefly described below. Plan 1 involves the Watana/Devil Canyon sites, Plan 2 the High Devil Canyon/Vee sites, Plan 3 the Watana-tunnel concept, and Plan 4 the Watana/High Devil Canyon sites. Under each plan several alternative subplans were identified, each involving a different staging concept. Summaries of these plans are given in Table B.9.

(i) Plan 1

- Subplan 1.1: The first stage involves constructing Watana Dam to its full height and installing 800 MW. Stage 2 involves constructing Devil Canyon Dam and installing 600 MW.

- Subplan 1.2: For this Subplan, construction of the Watana Dam is staged from a crest elevation of 2060 to 2225. The powerhouse is also staged from 400 MW to 800 MW. As for Subplan 1.1, the final stage involves Devil Canyon with an installed capacity of 600 MW.

- Subplan 1.3: This Subplan is similar to Subplan 1.2 except that only the powerhouse and not the dam at Watana is staged.

(ii) Plan 2

- Subplan 2.1: This Subplan involves constructing the High Devil Canyon Dam first with an installed capacity of 800 MW. The second stage involves constructing the Vee Dam with an installed capacity of 400 MW.

- Subplan 2.2: For this Subplan, the construction of High Devil Canyon is staged from a crest elevation of 1630 to 1775. The installed capacity is also staged from 400 to 800 MW. As for Subplan 2.1, Vee follows with 400 MW of installed capacity.

- Subplan 2.3: This Subplan is similar to Subplan 2.2 except that only the powerhouse and not the dam at High Devil Canyon is staged.

(iii) Plan 3

- Subplan 3.1: This Subplan involves initial construction of Watana and installation of 800 MW capacity. The next stage involves the construction of the downstream re-regulation dam to a crest elevation of 1500 and a 15 mile long tunnel. A total of 300 MW would be installed at the end of the tunnel and a further 30 MW at the reregulation dam. An additional 50 MW of capacity would be installed at the Watana powerhouse to facilitate peaking operations.

- Subplan 3.2: This Subplan is essentially the same as Subplan 3.1 except that construction of the initial 800 MW powerhouse at Watana is staged.

(iv) Plan 4

This single plan was developed to evaluate the development of the two most economic damsites, Watana and High Devil Canyon, jointly. Stage 1 involves constructing Watana to its full height with an installed capacity of 400 MW. Stage 2 involves increasing the capacity at Watana to 800 MW. Stage 3 involves constructing High Devil Canyon to a crest elevation of 1470 so that the reservoir extends to just downstream of Watana. In order to develop the full head between Watana and Portage Creek, an additional smaller dam is added downstream of High Devil Canyon. This dam would be located just upstream from Portage Creek so as not to interfere with the anadromous fisheries and would have a crest elevation of 1030 and an installed capacity of 150 MW. For purposes of these studies, this site is referred to as the Portage Creek site.

1.5 - Evaluation of Basin Development Plans

The overall objective of this step in the evaluation process was to select the preferred basin development plan. A preliminary evaluation of plans was initially undertaken to determine broad comparisons of the available alternatives. This was followed by appropriate adjustments to the plans and a more detailed evaluation and comparison.

In the process of initially evaluating the final four schemes, it became apparent that there would be environmental problems associated with allowing daily peaking operations from the most downstream reservoir in each of the plans described above. In order to avoid these potential problems while still maintaining operational flexibility to peak on a daily basis, re-regulation facilities were incorporated in the four basic plans. These facilities incorporate both structural measures such as re-regulation dams and modified operational procedures. Details of these modified plans, referred to as E1 to E4, are listed in Table B.10.

The plans listed in Table B.10 were subjected to a more detailed analysis as described in the following section.

(a) Evaluation Methodology

The approach to evaluating the various basin development plans described above is twofold:

- For determining the optimum staging concept associated with each basic plan (i.e., the optimum subplan), only economic criteria are used and the least cost staging concept is adopted.

- For assessing which plan is the most appropriate, a more detailed evaluation process incorporating economic, environmental, social and energy contribution aspects is taken into account.

Economic evaluation of any Susitna Basin development plan requires that the impact of the plan on the cost of energy to the Railbelt area consumer be assessed on a systemwide basis. Since the consumer is supplied by a large number of different generating sources, it is necessary to determine the total Railbelt system cost in each case to compare the various Susitna Basin development options.

The primary tool used for system costs was the mathematical model developed by the Electricity Utility Systems Engineering Department of the General Electric Company. The model is commonly known as OGP5 or Optimized Generation Planning Model, Version 5. The following information is paraphrased from GE literature on the program.

The OGP5 program was developed over ten years to combine the three main elements of generation expansion planning (system reliability, operating and investment costs) and automate generation addition decision analysis. OGP5 will automatically develop optimum generation expansion patterns in terms of economics, reliability and operation. Many utilities use OGP5 to study load management, unit size, capital and fuel costs, energy storage, forced outage rates, and forecast uncertainty.

The OGP5 program requires an extensive system of specific data to perform its planning function. In developing an optimal plan, the program considers the existing and committed units (planned and under construction) available to the system and the characteristics of these units including age, heat rate, size and outage rates as the base generation plan. The program then considers the given load forecast and operation criteria to determine the need for additional system capacity based on given reliability criteria. This determines "how much" capacity to add and "when" it should be installed. If a need exists during any monthly iteration, the program will consider additions from a list of alternatives and select the available unit best fitting the system needs. Unit selection is made by computing production costs for the system for each alternative included and comparing the results.

The unit resulting in the lowest system production cost is selected and added to the system. Finally, an investment cost analysis of the capital costs is completed to answer the question of "what kind" of generation to add to the system.

The model is then further used to compare alternative plans for meeting variable electrical demands, based on system reliability and production costs for the study period.

A minor limitation inherent in the use of the OGP5 model is that the number of years of simulation is limited to 20. To overcome this, the study period of 1980 to 2040 has been broken into three separate segments for study purposes. These segments are common to all system generation plans.

The first segment has been assumed to be from 1980 to 1990. The model of this time period included all committed generation units and is assumed to be common to all generation scenarios.

The end point of this model becomes the beginning of each 1990-2010 model.

The model of the first two time periods considered (1980 to 1990, and 1990 to 2010) provides the total production costs on a year-to-year basis. These total costs include, for the period of modeling, all costs of fuel and operation and maintenance of all generating units included as part of the system. In addition, the completed production costs include the annualized investment costs of any production plans added during the period of study. A number of factors which contribute to the ultimate cost of power to the consumer are not included in this model. These are common to all scenarios and include:

- All investment costs to plants in service prior to 1981;

- Costs of transmission systems in service both at the transmission and distribution level; and

- Administrative costs of utilities for providing electric service to the public.

Thus, it should be recognized that the production costs modeled represent only a portion of ultimate consumer costs and in effect are only a portion, albeit major, of total costs.

The third period, 2010 to 2040, was modeled by assuming that production costs of 2010 would recur for the additional 30 years to 2040. This assumption is believed to be reasonable given the limitations on forecasting energy and load requirements for this period. The additional period to 2040 is required to at least take into account the benefit derived or value of the addition of a hydroelectric power plant which has a useful life of fifty years or more.

The selection of the preferred generation plan is based on numerous factors. One of these is the cost of the generation plan. To provide a consistent means of assessing the production cost of a given generation scenario, each production cost total has been converted to a 1980 present worth basis. The present worth cost of any generation scenario is made up of three cost amounts. The first is present worth cost (PWC) of the first ten years of study (1981 to 1990), the second is the PWC of the scenario assumed during 1990 to 2010 and the third the PWC of the scenario in 2010 assumed to recur for the period 2010 to 2040. In this way the long-term (60 years) PWC of each generation scenario in 1980 dollars can be compared.

A summary of the input data to the model and a discussion of the results follow.

(i) Initial Economic Analyses

Table B.11 lists the results of the first series of economic analyses undertaken for the basic Susitna Basin development plans listed in Table B.10. The information provided includes the specified on-line dates for the various stages of the plans, the OGP5 run index number, the total installed capacity at year 2010 by category, and the total system present-worth cost in 1980 for the period 1980 to 2040. Matching of the Susitna development to the load growth for Plans E1, E2, and E3 is shown in Figure B.16, B.17 and B.18 respectively. After 2010, steady state conditions are assumed and the then-existing generation mix and annual costs for 2010 are applied to the years 2011 to 2040. This extended period of time is necessary to ensure that the hydroelectric options being studied, many of which only come on-line around 2000, are simulated as operating for periods approaching their economic lives and that their full impact on the cost of the generation system is taken into account.

- Plan E1 - Watana/Devil Canyon

. Staging the dam at Watana (Plan E1.2) is not as economic as constructing it to its full height (Plan E1.1 and E1.3). The present worth advantage of not staging the dam amounts to $180 million in 1980 dollars.

The results indicate that, with the level of analysis performed, there is no discernible benefit in staging construction of the Watana powerhouse (Plan E1.1 and E1.3). However, Plan E1.4 results indicates that, should the powerhouse size at Watana be restricted to 400 MW, the overall system present worth costs would increase.

Additional runs performed for variations of Plan E1.3 indicate that system present worth would increase by $1,110 million if the Devil Canyon dam was not constructed. A five year delay in construction of the Watana dam would increase system present worth by $220 million.

- Plan E2 - High Devil Canyon/Vee

  . The results for Plan E2.3 indicate that the system present worth is $520 million more than Plan E1.3. Present worth increases also occur if the Vee dam stage is not constructed. A reduction in present worth of approximately $160 million is possible if the Chakachamna hydroelectric project is constructed instead of the Vee dam.

  . The results of Plan E2.1 indicate that total system present worth would increase by $250 million if the total capacity at High Devil Canyon were limited to 400 MW.

- Plan E3 - Watana/Tunnel

  The results for Plan E3.1 illustrate that the tunnel scheme versus the Devil Canyon dam scheme (E1.3) adds approximately $680 million to the total system present worth cost. The availability of reliable geotechnical data would undoubtedly have improved the accuracy of the cost estimates for the tunnel alternative. For this reason, a sensitivity analysis was made as a check to determine the effect of halving the tunnel costs. This analysis indicates that the tunnel scheme is still more costly than constructing the Devil Canyon dam.

- Plan E4 - Watana/High Devil Canyon/Portage Creek

  The results indicate that system present worth associated with Plan E4.1, excluding the Portage Creek site development, are $200 million more than the equivalent E1.3 plan. If the Portage Creek development is included, the present worth difference would be even greater.

(ii) Load Forecast Sensitivity Analyses

The plans with the lowest present-worth cost were subjected to further sensitivity analyses. The objective of the analysis was to determine the impact on the development decision of a variance in forecast. The load forecasts used for this analysis were made by ISER and are presented in Section 5.1 of this Exhibit. These results are summarized in Table B.12.

At the low load forecast, full capacity development of Watana-Devil Canyon Scheme 1.3 is not warranted. Under Scheme 1.4, the most economic development includes a 400 MW development at each site, as compared to Watana only.

Similarly, it is more economic to develop High Devil Canyon and Vee, as compared to High Devil Canyon only, but at a total capacity of only 800 MW.

At this level of projected demand, the Watana-Devil Canyon Plan is more economic than the High Devil Canyon-Vee Plan or any singular development ($210 million, present worth basis). As individual developments however, the High Devil Canyon only plan is slightly superior economically than the Watana project ($90 million, present worth basis).

At the high load forecast, the larger capacities are clearly needed. In addition, both the High Devil Canyon-Vee and Watana-Devil Canyon plans are improved economically by the addition of the Chackachamna project. This illustrates the superiority of the Chackachamna project to the additon of alternative coal and gas projects using the study price projections. Similar to the low load forecast, the Watana-Devil Canyon project is superior to the High Devil Canyon-Vee alternative but the margin of difference on a present worth basis is much greater ($1.0 billion, present worth basis).

(b) Evaluation Criteria

The following criteria were used to evaluate the shortlisted basin development plans. These criteria generally contain the requirements of the generic process with the exception that an additional criterion, energy contribution, is added in order to ensure that full consideration is given to the total basin energy potential developed by the various plans.

(i) Economic

Plans were compared using long-term present worth costs, calculated using the OGP5 generation planning model. The parameters used in calculating the total present-worth cost of the total Railbelt generating system for the period 1980 to 2040 are listed in Table B.13 and B.14. Load forecasts used in the analysis are presented in Section 5.1(b).

(ii) Environmental

A qualitative assessment of the environmental impact on the ecological, cultural, and aesthetic resources is undertaken for each plan. Emphasis is placed on identifying major concerns so that these could be combined with the other evaluation attributes in an overall assessment of the plan.

(iii) Social

This attribute includes determination of the potential non-renewable resource displacement, the impact on the state and local economy, and the risks and consequences of major structural failures due to seismic events. Impacts on the economy refer to the effects of an investment plan on economic variables.

(iv) Energy Contribution

The parameter used is the total amount of energy produced from the specific development plan. An assessment of the energy development foregone is also undertaken. The energy loss that is inherent to the plan and cannot easily be recovered by subsequent staged developments is of greatest concern.

(c) Results of Evaluation Process

The various attributes outlined above have been determined for each plan and are summarized in Tables B.15 through B.23. Some of the attributes are quantitative while others are qualitative. Overall evaluation is based on a comparison of similar types of attributes for each plan. In cases where the attributes associated with one plan all indicate equality or superiority with respect to another plan, the decision as to the best plan is clear cut. In other cases where some attributes indicate superiority and others inferiority, differences are highlighted and trade-off decisions are made to determine the preferred development plan. In cases where these trade-offs have had to be made, they were relatively straightforward, and the decision-making process can, therefore, be regarded as effective and consistent. In addition, these trade-offs are clearly identified so that independent assessment can be made.

The overall evaluation process is conducted in a series of steps. At each step, only two plans are compared. The superior plan is then taken to the next step for evaluation against a third plan.

(i) Devil Canyon Dam Versus Tunnel

The first step in the process involves the comparison of the Watana-Devil Canyon dam plan (E1.3) and the Watana-Tunnel plan (E3.1). Since Watana is common to both plans, the evaluation is based on a comparison of the Devil Canyon dam and the Scheme 3 tunnel alternative.

In order to assist in the evaluation in terms of economic criteria, additional information obtained by analyzing the results of the OGP5 computer runs is shown in Table B.15. This information illustrates the breakdown of the total system present worth cost in terms of capital investment, fuel, and operation and maintenance costs.

- Economic Comparison

From an economic point of view, the Watana-Devil Canyon dam scheme is superior. As summarized in Tables B.15 and B.16, on a present worth basis the tunnel scheme is $680 million more expensive than the dam scheme. For a low demand growth rate, this cost difference would be reduced slightly to $650 million. Even if the tunnel scheme costs are halved, the total cost difference would still amount to $380 million. As highlighted in Table B.16 consideration of the sensitivity of the basic economic evaluation to potential changes in capital cost estimates, the period of economic analysis, the discount rate, fuel costs, fuel cost escalation, and economic plant life do not change the basic economic superiority of the dam scheme over the tunnel scheme.

- Environmental Comparison

The environmental comparison of the two schemes is summarized in Table B.17. Overall, the tunnel scheme is judged to be superior because:

. It offers the potential for enhancing anadromous fish populations downstream of the re-regulation dam due to the more uniform flow distribution that will be achieved in this reach;

. It would inundate 13 miles less of resident fisheries habitat in river and major tributaries;

. It has a lower potential for inundating archeological sites due to smaller reservoir involved; and

. It would preserve much of the characteristics of the Devil Canyon gorge which is considered to be an aesthetic and recreational resource.

- Social Comparison

Table B.18 summarizes the evaluation in terms of the social criteria of the two schemes. In terms of impact on state and local economics and risks because of seismic exposure, the two schemes are rated equal. However, the dam scheme has, due to its higher energy yield, more potential for displacing nonrenewable energy resources, and therefore has a slight overall advantage in terms of the social evaluation criteria.

- <u>Energy Comparison</u>

Table B.19 summarizes the evaluation in terms of the energy contribution criteria. The results show that the dam scheme has a greater potential for energy production and develops a larger portion of the basin's potential. The dam scheme is therefore judged to be superior from the energy contribution standpoint.

- <u>Overall Comparison</u>

The overall evaluation of the two schemes is summarized in Table B.20. The estimated cost saving of $680 million in favor of the dam scheme plus the additional energy produced are considered to outweigh the reduction in the overall environmental impact of the tunnel scheme. The dam scheme is therefore judged to be superior overall.

(ii) <u>Watana-Devil Canyon Versus High Devil Canyon-Vee</u>

The second step in the development selection process involves an evaluation of the Watana-Devil Canyon (E1.3) and the High Devil Canyon-Vee (E2.3) development plans.

- <u>Economic Comparison</u>

In terms of the economic criteria (see Table B.15 and B.16) the Watana-Devil Canyon plan is less costly by $520 million. Consideration of the sensitivity of this decision to potential changes in the various parameters considered (i.e., load forecast, discounted rates, etc.) does not change the basic superiority of the Watana-Devil Canyon plan.

Under the low load-growth forecast, the Watana-Devil Canyon plan is favored by only $210 million. While under the high load-growth forecast the advantage is $1040 million.

- <u>Environmental Comparison</u>

The evaluation in terms of the environmental criteria is summarized in Table B.21. In assessing these plans, a reach-by-reach comparison was made for the section of the

Susitna River between Portage Creek and the Tyone River. The Watana-Devil Canyon scheme would create more potential environmental impacts in the Watana Creek area. However, it is judged that the potential environmental impacts which would occur above the Vee Canyon dam with a High Devil Canyon-Vee development are more severe in overall comparison.

Of the seven environmental factors considered in Table B.17, except for the increased loss of river valley, bird and black bear habitat, the Watana-Devil Canyon development plan is judged to be more environmentally acceptable than the High Canyon-Vee plan.

The other six areas in which Watana-Devil Canyon was judged to be superior are fisheries, moose, caribou, furbearers, cultural resources, aesthetics, and land use.

- Energy Comparison

The evaluation of the two plans in terms of energy contribution criteria is summarized in Table B.22. The Watana-Devil Canyon scheme is assessed to be superior because of its higher energy potential and the fact that it develops a higher proportion of the basin's energy potential.

The Watana-Devil Canyon plan annually develops 1160 GWh and 1650 GWh more average and firm energy respectively than the High Devil Canyon-Vee plans.

- Social Comparison

Table B.18 summarizes the evaluation in terms of the social criteria. As in the case of the dam versus tunnel comparison, the Watana-Devil Canyon plan is judged to have a slight advantage over the High Devil Canyon-Vee plan. This is because of its greater potential for displacing nonrenewable resources. In other social impact areas there are minimal differences between plans.

1.6 - Preferred Susitna Basin Development Plan

One-on-one comparisons of the Watana-Devil Canyon plan with the Watana-tunnel plan and the High Devil Canyon-Vee plans are judged to favor the Watana-Devil Canyon plan in each case.

The Watana-Devil Canyon plan was therefore selected as the preferred Susitna Basin development plan, and the basis for continuation of more detailed design optimization and environmental studies.

2 - ALTERNATIVE FACILITY DESIGN, PROCESSES AND OPERATIONS

2 - ALTERNATIVE FACILITY DESIGNS, PROCESSES AND OPERATIONS

2.1 - Susitna Hydroelectric Development

As originally conceived the Watana project initially comprised an earthfill dam with a crest elevation of 2225 and 400 MW of generating capacity scheduled to commence operation in 1993. An additional 400 MW would be brought on-line in 1996. At Devil Canyon an additional 400 MW would be installed to commence operation in the year 2000. Detailed studies of each project have led to refinement and optimization of designs in terms of a number of key factors, including updated load forecasts and economics. Geotechnical and environmental constraints identified as a result of continuing field work have also greatly influenced the currently recommended design concepts.

Plan formulation and alternative facility designs considered for the Watana and Devil Canyon developments are discussed in this section. Background information on the site characteristics as well as additional detail on the plan formulation process are included in the Supporting Design Report of Exhibit F and the referenced reports.

2.2 - Watana Project Formulation

This section describes the evolution of the general arrangement of the Watana project which, together with the Devil Canyon project, comprises the development plan proposed. The process by which reservoir operating levels and the installed generating capacity of the power facilities were established is presented, together with the means of handling floods expected during construction and subsequent project operation.

The main components of the Watana development are as follows:

- Main dam;
- Diversion facilities;
- Spillway facilities;
- Outlet facilities;
- Emergency release facilities; and
- Power facilities.

A number of alternatives are available for each of these components and they can be combined in a number of ways. The following paragraphs describe the various components and methodology for the preliminary, intermediate, and final screening and review of alternative general arrangement of the components, together with a brief description of the selected scheme. This section presents the alternative arrangements studied for the Watana project.

(a) Selection of Reservoir Levels

The selected elevation of the Watana dam crest is based on considerations of the value of the hydroelectric energy produced from the associated reservoir, geotechnical constraints on reservoir levels, and freeboard requirements. Firm energy, average annual energy, construction costs, and operation and maintenance costs were determined for the Watana development with dam crest elevations of 2240, 2190, and 2140. The relative value of energy produced in terms of the present worth of the long-term production costs (LTPW) for each of these three dam elevations was determined by means of the OGP5 generation planning model described in Section 1 of this Exhibit. The physical constraints imposed on dam height and reservoir elevation by geotechnical considerations were reviewed and incorporated into the crest elevation selection process. Finally, freeboard requirements for the PMF and settlement of the dam after construction or as a result of seismic activity were taken into account.

(i) Methodology

Firm and average annual energy produced by the Susitna development are based on 32 years of hydrological records. The energy produced was determined by using a multi-reservoir simulation of the operation of the Watana and Devil Canyon reservoirs. A variety of reservoir drawdowns were examined, and drawdowns producing the maximum firm energy consistent with engineering feasibility and cost of the intake structure were selected. Minimum flow requirements were established at both project sites based on downstream fisheries considerations.

To meet system demand the required maximum generating capability at Watana in the period 1994 and 2010 ranges from 665 MW to 908 MW. For the reservoir level determinations, energy estimates were made on the basis of assumed average annual capacity requirements of 680 MW at Watana in 1994, increasing to 1020 MW at Watana in 2007, with an additional 600 MW at Devil Canyon coming online in the year 2002. The long term present worth costs of the generation system required to meet the Railbelt energy demand were then determined for each of the three crest elevations of the Watana dam using the OGP5 model.

The construction cost estimates used in the OGP5 modeling process for the Watana and Devil Canyon projects were based on preliminary conceptual layouts and construction schedules. Further refinement of these layouts has taken place during the optimization process. These refinements have no significant impact on the reservoir level selection.

(ii) Economic Optimization

Economic optimization of the Watana reservoir level was based on an evaluation of three dam crest elevations of 2240, 2190, and 2140. These crest elevations applied to the central portion of the embankment with appropriate allowances for freeboard and seismic settlement, and correspond to maximum operating levels of the reservoir of 2215, 2165, and 2115 feet, respectively. Average annual energy calculated for each case using the reservoir simulation model are given in Table B.24, together with corresponding project construction costs.

In the determination of LTPW, the Susitna capital costs were adjusted to include an allowance for interest during construction and then used as input to the OGP5 model. Simulated annual energy yields were distributed on a monthly basis by the reservoir operation model to match as closely as possible the projected monthly energy demand of the Railbelt and then input to the OGP5 model. The LTPW of meeting the Railbelt energy demand using the Susitna development as the primary source of energy was then determined for each of the three reservoir levels.

The results of these evaluations are shown in Table B.25, and plots showing the variation of the LTPW with dam crest elevation are shown in Figure B.19. This figure indicates that on the basis of the assumptions used, the minimum LTPW occurs at a Watana crest elevation ranging from approximately 2160 to 2200 (reservoir levels 2140 to 2180 feet). A higher dam crest will still result in a development which has an overall net economic benefit relative to thermal energy sources. However, it is also clear that as the height of the Watana dam is increased, the unit costs of additional energy produced at Watana is somewhat greater than for the displaced thermal energy source. Hence, the LTPW of the overall system would increase. Conversely, as the height of the dam is lowered, and thus Watana produces less energy, the unit cost of the energy produced by a thermal generation source to replace the lost Susitna energy is more expensive than Susitna energy. In this case also, the LTPW increases.

(iii) Geotechnical Considerations

On the north side of the reservoir created by the Watana dam a relict channel of considerable depth connects the reservoir to Tsusena Creek. As the water surface elevation of the reservoir is increased up to and beyond 2200 feet, a low area in the relict channel would require costly water retaining structures to be built and other measures to be taken. In addition to the cost the technical feasibility of these measures is not as certain as desired on a project of this magnitude. Because of the considerations relating to seismic stability, seepage problems and permafrost conditions in the relict channel area, the hydraulic head at the upstream end of the relict channel should be limited wherever possible. By comparing normal reservoir levels plus flood surcharge to ground surface contours, it was determined that with normal reservoir level of 2185 and a small freeboard dike the following conditions would exist:

- For flood magnitudes up to the 1:10,000-year event, there would be no danger of overtopping the lowest point in the relict channel.

- For the PMF a freeboard dike in the low area of up to 10 feet in height would provide adequate protection. This dike would be wetted only a few days during a PMF event.

- If seismic settlement or settlement due to permafrost melting did occur, the combination of the 10 feet freeboard dike constructed on a suitable foundation plus normal reservoir level of 2185 feet would ensure that breakthrough in the relict channel area would not occur.

With this approach, the Watana project will develop the maximum energy reasonably available without incurring the need for costly water retaining structures in the relict channel area.

(iv) Conclusions

It is important to establish clearly the overall objective used as a basis for setting the Watana reservoir level. An objective which would minimize the LTPW energy cost would lead to selection of a slightly lower reservoir level than an objective which would maximize the amount of energy which can be obtained from the available resource, while doing so with a technically sound project.

The three values of LTPW developed by the OGP5 computer runs defined a relationship between LTPW and Watana dam height which is relatively insensitive to dam height. This is highlighted by the curve of LTPW versus dam height in Figure B.19. This figure shows there is only a slight variation in the LTPW for the range of dam heights included in the analysis. Thus, from an economic standpoint the optimum crest elevation could be considered as varying over a range of elevations from 2140 to 2220 with little effect on project economics. The main factors in establishing the upper limit of dam height were consequently the geotechnical considerations discussed in (iii) above.

The normal maximum operating level of the reservoir was therefore set at Elevation 2185, allowing the objective of maximizing the economic use of the Susitna resource still to be satisfied.

(b) Selection of Installed Capacity

The generating capacity to be installed at both Watana and Devil Canyon was determined on the basis of generation planning studies described in Sections 6 and 8 of Reference 4 together with appropriate consideration of the following:

- Available firm and average energy from Watana and Devil Canyon;
- The forecast energy demand and peak load demand of the system;
- Available firm and average energy from other existing and committed plant;
- Capital cost and annual operating costs for Watana and Devil Canyon;
- Capital cost and annual operating costs for alternative sources of energy and capacity;
- Environmental constraints on reservoir operation; and
- Turbine and generator operating characteristics.

Table B.26 lists the design parameters used in establishing the dependable capacity at Watana.

(i) Installed Capacity

A computer simulation of reservoir operation over 32 years of hydrological record was used to predict firm (dependable) and average energy available from Watana and Devil Canyon reservoirs on a monthly basis. Seven alternative reservoir operating rules were assumed, varying from a maximum power generation scenario which would result in significant impact to dam stream fisheries (Case A) through to a flow that provides guaranteed minimum summer releases which minimize the impact on down-stream fisheries (Case D). For the preliminary design, Case C predicted energies have been used to assess the required plant capacity.

The computer simulation gives an estimate of the monthly energy available from each reservoir, but the sizing of the plant capacity must take into account the variation of demand load throughout each month on an hourly basis. Load forecast studies have been undertaken to predict the hourly variation of load through each month of the year, and also the growth in peak load (MW) and annual energy demand (GWh) through to the end of th eplanning horizon, 2010.

The economic analysis for the proposed development assumes that the average energy from each reservoir is available every year. The hydrological record, however, is such that this average energy is available only from a series of wetter and drier years. In order to utilize the average energy, capacity must be available to generate the energy available in the wet years up to the maximum requirement dictated by the system energy demand, less any energy available from other committed hydro plant.

Watana has been designed to operate as a peaking station, if required. Tables B.27 and B.28 show the estimated maximum capacity required in the peak demand month (December) at Watana to fully utilize the energy available from the flows of record. If no thermal energy is needed (i.e., in wetter years), the maximum requirement is controlled only by the shape of the demand curve. If thermal energy is required (in average to dry years), the maximum capacity required at Watana will depend on whether the thermal energy is provided by high merit order plant at base load (Option 1, Table B.27); or by low merit order peaking plant (Option, Table B.28).

On the basis of this evaluation, the ultimate power generation capability at Watana was selected as 1020 MW for design purposes to allow a margin for hydro spinning reserve and standby for forced outage. This installation also provides a margin in the event that the load growth exceeds the medium load forecast.

(ii) Unit Capacity

Selection of the unit size for a given total capacity is a compromise between the initial least cost solution, generally involving a scheme with a smaller number of large capacity units, and the improved plant efficiency and security of operation provided by a larger number of smaller capacity units. Other factors include the size of each unit as a proportion of the total system load and the minimum anticipated load on the station. Any requirement for a minimum downstream flow would also affect the selection. Growth of the actual load demand is also a significant factor, since the installation of units may be phased to match the actual load growth. The number of units and their individual ratings were determined by the need to deliver the required peak capacity in the peak demand month of December at the minimum December reservoir level with the turbine wicket gates fully open.

An examination was made of the economic impact on power plant production costs of various combinations of a number of units and rated capacity which would provide the selected total capacity of 1020 MW. For any given installed capacity, plant efficiency increases as the number of units increases. The assumed capitalized value used in this evaluation was $1.00 per average annual kWh over project life, based on the economic analysis completed for the thermal generation system. Variations in the number of units and capacity will affect the cost of the power intakes, penstocks, powerhouse, and tailrace. The differences in these capital costs were estimated and included in the evaluation. The results of this analysis are presented below.

Number of Units	Rated Capacity of Unit (MW)	Capitalized Value of Additional Energy ($ Millions)	Additional Capital Cost ($ Millions)	Net Benefit ($ Millions)
4	250	-	-	-
6	170	40	31	9
8	125	50	58	-8

It is apparent from this analysis that a six-unit scheme with a net benefit of approximately $9 million is the most economic alternative. This scheme also offers a higher degree of flexibility and security of operation compared to the four-unit alternative, as well as advantages if unit installation is phased to match actual load growth. The net economic benefit of the six unit scheme is $17 million greater than that of the eight-unit scheme, while at the same time no significant operational or scheduling advantages are associated with the eight-unit scheme.

A scheme incorporating six units each with a rated capacity of 170 MW, for a total of 1020 MW, has been adopted for all Watana alternatives.

(c) Selection of the Spillway Design Flood

Normal design practice for projects of this magnitude, together with applicable design regulations, require that the project be capable of passing the Probable Maximum Flood (PMF) routed through the reservoir without endangering the dam.

In addition to this requirement, the project should have sufficient spillway capacity to safely pass a major flood of lesser magnitude than the PMF without damaging the main dam or ancillary structures. The frequency of occurrence of this flood, known as the spillway design flood or Standard Project Flood (SPF), is generally selected on the basis of an evaluation of the risks to the project if the spillway design flood is exceeded, compared to the costs of the structures required to safely discharge the flood. For this study, a spillway design flood with a return frequency of 1:10,000 years was selected for Watana. A list of spillway design flood frequencies and magnitudes for several major projects is presented below.

Project	Spillway Design Flood		Basin PMF (cfs)	Spillway Capacity After Routing (cfs)*
	Frequency	Peak Inflow (cfs)		
Mica, Canada	PMF	250,000	250,000	150,000
Churchill Falls, Canada	1:10,000	600,000	1,000,000	230,000
New Bullards, USA	PMF	226,000	226,000	170,000
Oroville, USA	1:10,000	440,500	711,400	440,500
Guri, Venezuela (final stage)	PMF	1,000,000	1,000,000	1,000,000
Itaipu, Brazil	PMF	2,195,000	2,195,000	2,105,000
Sayano, USSR	1:10,000	480,000	N/A	680,000

*All spillways except Sayano have capacity to pass PMF with surcharge.

The flood frequency analysis produced the following values:

Flood	Frequency	Inflow Peak
Probable Maximum	--	326,000 cfs
Spillway Design	1:10,000 years	156,000 cfs

Additional capacity required to pass the PMF will be provided by an emergency spillway consisting of a fuse plug and rock channel on the right bank.

(d) Main Dam Alternatives

This section describes the alternative types of dams considered at the Watana site and the basis for the selected alternative.

(i) Comparison of Embankment and Concrete Type Dams

The selection between an embankment type or a concrete type dam is usually based on the configuration of the valley, the condition of the foundation rock, depth of the overburden, and the relative availability of construction materials. Previous studies by the COE envisaged an embankment dam at Watana. Initial studies completed as part of this current evaluation included comparison of an earthfill dam with a concrete arch dam at the Watana site. An arrangement for a concrete arch dam alternative at Watana is presented in Figure B.20. The results of this analysis indicated that the cost of the embankment dam was somewhat lower than the arch dam, even though the concrete cost rates used were significantly lower than those used for the Devil Canyon Dam. This preliminary evaluation did not indicate any overall cost savings in the project in spite of some savings in the earthworks and concrete structures for the concrete dam layout. A review of the overall construction schedule indicated a minimal savings in time for the concrete dam project.

Based on the above and the likelihood that the cost of the arch dam would increase relative to that of the embankment dam, the arch dam alternative was eliminated from further consideration.

(ii) Concrete-face Rockfill Type Dam

The selection of a concrete-face rock fill dam at Watana would appear to offer economic and schedule advantages when compared to a conventional impervious-core rock fill dam. For example, one of the primary areas of concern with the earth-core rock fill 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 face rock fill 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 rock fill could probably be of 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 rock fill. This would allow greater flexibility for layout of the other facilities; in particular, the

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 face-rock fill dam built to date (the 525-foot high Areia dam in Brazil completed in 1980). A review of concrete face rock fill 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 rock fill dams have generally performed well and a rock fill dam is inherently stable even with severe leakage through the face, a one-step increase in height of 70 percent over existing structures is well beyond percedent.

In addition to the height of the dam, other factors which are beyond precedent include the seismic and climatic conditions at Susitna. It has been stated that concrete face rock fill 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 slab near the base of the dam could result in excessive leakage through the dam. 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 face rock fill 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 rock fill dam appears to offer schedule advantages, the overall gain in impoundment schedule would not be so significant. With the earth-core rock fill dam, impoundment can be allowed as the dam is constructed. This is not the case for a concrete faced rock fill since the concrete face slab is normally not constructed until all rock fill has been placed and construction settlement taken place. The slab is then poured in continuous strips from the foundation to the crest. Most recent high faced rock fill dams also incorporate an impervious earth fill 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 percent cheaper. However, the managers, on the recommedation of their consultants, decided against the use of a concrete face rock fill for the required height of 500 feet in that environment.

In summary, a concrete face rock fill dam at Watana is not considered appropriate as a firm recommendation for the feasibility stage of development of the Susitna project because of:

. the 70 percent increase in height over precedent; and

. the possible impacts of high seismicity and climatic conditions.

(iii) Selection of Dam Type

Selection of the configuration of the embankment dam cross-section was undertaken within the context of the following basic considerations:

- The availability of suitable construction materials within economic haul distance, particularly core material;

- The requirement that the dam be capable of withstanding the effects of a significant earthquake shock (2) as well as well as the static loads imposed by the reservoir and its own weight;

- The relatively limited construction season available for placement of compacted fill materials.

The main dam would consist of a compacted core protected by fine and coarse filter zones on both the upstream and downstream slopes of the core. The upstream and downstream outer supporting fill zones would contain relatively free draining compacted gravel or rockfill, providing stability to the overall embankment structure. The location and inclination of the core is fundamental to the design of the embankment. Two basic alternatives exist in this regard:

- A vertical core located centrally within the dam; and
- An inclined core with both faces sloping upstream.

A central vertical core was chosen for the embankment based on a review of precedent design and the nature of the available impervious material.

The exploration program undertaken during 1980-81 indicated that adequate quantities of materials suitable for dam construction were located within reasonable haul distance from the site. The well-graded silty sand material is considered the most promising source of impervious fill. Compaction tests indicate a natural moisture content slightly on the wet side of optimum moisture content, so that control of moisture content will be critical in achieving a dense core with high shear strength.

Potential sources for the upstream and downstream shells include either river gravel from borrow areas along the Susitna River or compacted rockfill from quarries or excavations for spillways.

During the intermediate review process, the upstream slope of the dam was flattened from 2.5H:1V used during the initial review to 2.75H:1V. This slope was based on a conservative estimate of the effective shear strength parameters of the available construction materials, as well as a conservative allowance in the design for the effects of earthquake loadings on the dam.

During the final review stage, the exterior upstream slope of the dam was steepened from 2.75H:1V to 2.4H:1V, reflecting the results of the preliminary static and dynamic design analyses being undertaken at the same time as the general arrangement studies. As part of the final review, the volume of the dam with an upstream slope of 2.4H:1V was computed for four alternative dam axes. The location of these alternative axes are shown on Figure B.21. The dam volume associated with each of the four alternative axes is listed below:

Alternative Axis Number	Total Volume (million yd^3)
1	69.2
2	71.7
3	69.3
4	71.9

A section with a 2.4H:1V upstream slope and a 2H:1V downstream slope located on alternative axis number 3 was used for the final review of alternative schemes.

(e) Diversion Scheme Alternatives

The topography of the site generally dictates that diversion of the river during construction be accomplished using diversion tunnels with upstream and downstream cofferdams protecting the main construction area.

The configuration of the river in the vicinity of the site favors location of the diversion tunnels on the north bank, since the tunnel length for a tunnel on the south bank would be approximately 2,000 feet greater. In addition, rock conditions on the north bank are more favorable for tunneling and excavation of intake and outlet portals.

(i) Design Flood for Diversion

The recurrence interval of the design flood for diversion is generally established based on the characteristics of the flow regime of the river, the length of the construction period for which diversion is required and the probable consequences of overtopping of the cofferdams. Design criteria and experience from other projects similar in scope and nature have been used in selecting the diversion design flood.

At Watana damage to the partially completed dam could be significant, or more importantly would probably result in at least a one-year delay in the completion schedule. A preliminary evaluation of the construction schedule indicates that the diversion scheme would be required for 4 or 5 years until the dam is of sufficient height to permit initial filling of the reservoir. A design flood with a return frequency of 1:50 years was selected based on experience and practice with other major hydroelectric projects. This approximates a 90 percent probability that the cofferdam will not be overtopped during the 5-year construction period. The diversion design flood together with average flow characteristics of the river significant to diversion are presented below:

Average annual flow	7,990 cfs	
Maximum average monthly flow	23,100 cfs	(June)
Minimum average monthly flow	890 cfs	(March)
Design flood inflow (1:50 years)	87,000 cfs	

(ii) Cofferdams

For the purposes of establishing the overall general arrangement of the project and for subsequent diversion optimization studies, the upstream cofferdam section adopted comprises an initial closure dam structure approximately 30 feet high placed in the wet.

(iii) Diversion Tunnels

Concrete-lined tunnels and unlined rock tunnels were compared. Preliminary hydraulic studies indicated that the design flood routed through the diversion scheme would result in a design discharge of approximately 80,500 cfs. For concrete-lined tunnels, design velocities of the order of 50 ft/s have been used in several projects. For unlined tunnels, maximum design velocities ranging from 10 ft/s in good quality rock to 4 ft/s in less competent material are typical. Thus, the volume of material to be excavated using an unlined tunnel would be at least 5 times that for a lined tunnel. The reliability of an unlined tunnel is more dependent on rock conditions than is a lined tunnel, particularly given the extended period during which the diversion scheme is required to operate. Based on these considerations, given a considerably higher cost, together with the somewhat questionable feasibility of four unlined tunnels with diameters approaching 50 feet in this type of rock, the unlined tunnels have been eliminated.

The following alternative lined tunnel schemes were examined as part of this analysis:

- Pressure tunnel with a free outlet;
- Pressure tunnel with a submerged outlet; and
- Free flow tunnel.

(iv) Emergency Release Facilities

The emergency release facilities influenced the number, type, and arrangement of the diversion tunnels selected for the final scheme.

At an early stage of the study, it was established that some form of low level release facility was required to meet instream flow requirements during filling of the reservior, and to permit lowering of the reservoir in the event of an extreme emergency. The most economical alternative available would involve converting one of the diversion tunnels to permanent use as a low level outlet facility. Since it would be necessary to maintain the diversion scheme in service during construction of the emergency facilities outlet works, two or more diversion tunnels would be required. The use of two diversion tunnels also provides an additional measure of security to the diversion scheme in case of the loss of service of one tunnel.

The low level release facilities will be operated for approximately three years during filling of the reservoir. Discharge at high heads usually requires some form of energy dissipation prior to returning the flow to the river. Given the space restrictions imposed by the size of the diversion tunnel, it was decided to utilize a double expansion system constructed within the upper tunnel.

(v) Optimization of Diversion Scheme

Given the considerations described above relative to design flows, cofferdam configuration, and alternative types of tunnels, an economic study was undertaken to determine the optimum combination of upstream cofferdam height and tunnel diameter.

Capital costs were developed for three heights of upstream cofferdam embankment with a 30-foot-wide crest and exterior slopes of 2H:1V. A freeboard allowance of 5 feet for settlement and wave runup and 10 feet for the effects of downstream ice jamming on tailwater elevations was adopted.

Capital costs for the 4,700 foot long tunnel alternatives included allowances for excavation, concrete liner, rock bolts, and steel supports. Costs were also developed for the upstream and downstream portals, including excavation and support. The cost of intake gate structures and associated gates was determined not to vary significantly with tunnel diameter and was excluded from the analysis.

Curves of headwater elevation versus tunnel diameter for the various tunnel alternatives with submerged and free outlets are presented in Figure B.22. The relationship between capital cost and crest elevation for the upstream cofferdam is shown in Figure B.23. The capital cost for various tunnel diameters with free and submerged outlets is given in Figure B.24.

The results of the optimization study are presented in Figure B.25 and indicate the following optimum solutions for each alternative.

Type of Tunnel	Diameter (feet)	Cofferdam Crest Elevation (ft)	Total Cost ($)
Two pressure tunnels	30	1595	66,000,000
Two free flow tunnels	32.5	1580	68,000,000
Two free flow tunnels	35	1555	69,000,000

The cost studies indicate that a relatively small cost differential (4 to 5 percent) separates the various alternatives for tunnel diameter from 30 to 35 feet.

(vi) Selected Diversion Scheme

An important consideration at this point is ease of cofferdam closure. For the pressure tunnel scheme, the invert of the tunnel entrance is below riverbed elevation, and once the tunnel is complete diversion can be accomplished with a closure dam section approximately 10 feet high. The free flow tunnel scheme, however, requires a tunnel invert approximately 30 feet above the riverbed level, and diversion would involve an end-dumped closure section 50 feet high. The velocities of flows which would overtop the cofferdam before the water levels were raised to reach the tunnel invert level would be prohibitively higher, resulting in complete erosion of the cofferdam, and hence the dual free flow tunnel scheme was dropped from consideration.

Based on the preceeding considerations, a combination of one pressure tunnel and one free flow tunnel (or pressure tunnel with free outlet) was adopted. This will permit initial diversion to be made using the lower pressure tunnel, thereby simplifying the critical closure operation and avoiding potentially serious delays in the schedule. Two alternatives were re-evaluated as follows:

Tunnel Diameter (feet)	Upstream Cofferdam Crest Elevation (feet)	Upstream Cofferdam Approximate Height (feet)
30	1595	150
35	1555	110

More detailed layout studies indicated that the higher cofferdam associated with the 30 foot diameter tunnel alternative would require locating the inlet portal further upstream into "The Fins" shear zone. Since good rock conditions for portal construction are essential and the 35 foot diameter tunnel alternative would permit a portal location downstream of "The Fins", this latter alternative was adopted. As noted in (v), the overall cost difference was not significant in the range of tunnel diameters considered, and the scheme incorporating two 35 foot diameter tunnels with an upstream cofferdam crest elevation of 1555 was incorporated as part of the selected general arrangement.

(f) Spillway Facilities Alternatives

As discussed in subsection (c) above, the project has been designed to safely pass floods with the following return frequencies:

Flood	Frequency	Inflow Peak (cfs)	Total Spillway Discharge (cfs)
Spillway Design	1:10,000 years	156,000	119,000
Probable Maximum	--	326,000	150,000

Discharge of the spillway design flood will require a gated service spillway on either the left or right bank. Three basic alternative spillway types were examined:

- Chute spillway with flip bucket;
- Chute spillway with stilling basin; and
- Cascade spillway.

Consideration was also given to combinations of these alternatives with or without supplemental facilities such as valved tunnels and an emergency spillway fuse plug for handling the PMF discharge.

Clearly, the selected spillway alternatives will greatly influence and be influenced by the project general arrangement.

(i) Energy Dissipation

The two chute spillway alternatives considered achieve effective energy dissipation either by means of a flip bucket which would direct the spillway discharge in the form of a free-fall jet into a plunge pool well downstream from the dam or a stilling basin at the end of the chute which would dissipate energy in a hydraulic jump. The cascade type spillway would limit the free fall height of the discharge by utilizing a series of 20 to 50 foot steps down to river level, with energy dissipation at each step.

All spillway alternatives were assumed to incorporate a concrete ogee type control section controlled by fixed roller vertical lift gates. Chute spillway sections were assumed to be concrete-lined, with ample provision for air entrainment in the chute to prevent cavitation erosion, and with pressure relief drains and rock anchors in the foundation.

(ii) Environmental Mitigation

During development of the general arrangements for both the Watana and Devil Canyon dams, a restriction was imposed on the amount of excess dissolved nitrogen permitted in the spillway discharges. Supersaturation occurs when aerated flows are subjected to pressures greater than 30 to 40 feet of head which forces excess nitrogen into solution. This occurs when water is subjected to the high pressures that occur in deep plunge pools or at large hydraulic jumps. The excess nitrogen would not be dissipated within the downstream Devil Canyon reservoir and a buildup of nitrogen concentration could occur throughout the body of water. It would eventually be discharged downstream from Devil Canyon with harmful effects on the fish population. On the basis of an evaluation of the related impacts and discussions with interested federal and state agencies, spillway facilities were designed to limit discharges of water from either Watana or Devil Canyon that may become supersaturated with nitrogen to a recurrence period of not less than 1:50 years.

(g) Power Facilities Alternative

Selection of the optimum power plant development involved consideration of the following:

- Location, type and size of the power plant;
- Geotechnical considerations;
- Number, type, size and setting of generating units;
- Arrangement of intake and water passages; and
- Environmental constraints.

(i) Comparison of Surface and Underground Powerhouse

Studies were carried out to compare the construction costs of a surface powerhouse and of an underground powerhouse at Watana. These studies were undertaken on the basis of preliminary conceptual layouts assuming six units and a total installed capacity of 1020 MW. The comparative cost estimates for powerhouse civil works and electrical and mechanical equipment (excluding common items) indicated an advantage in favor of the underground powerhouse of $16,300,000. The additional cost for the surface powerhouse arrangement is primarily associated with the longer penstocks and the steel linings required.

The underground powerhouse arrangement is also better suited to the severe winter conditions in Alaska, is less affected by river flood flows in summer, and is aesthetically less obtrusive. This arrangement has therefore been adopted for further development.

(ii) Comparison of Alternative Locations

Preliminary studies were undertaken during the development of conceptual project layouts at Watana to investigate both right and left bank locations for power facilities. The configuration of the site is such that south bank locations required longer penstock and/or tailrace tunnels and were therefore more expensive.

The location on the south bank was further rejected because of indications that the underground facilities would be located in relatively poor quality rock. The underground powerhouse was therefore located on the north bank such that the major openings lay between the two major shear features ("The Fins" and the "Fingerbuster").

(iii) Underground Openings

Because no construction adits or extensive drilling in the powerhouse and tunnel locations have been completed, it has been assumed that full concrete-lining of the penstocks and tailrace tunnels would be required. This assumption is conservative and is for preliminary design only; in practice, a large proportion of the tailrace tunnels would probably be unlined, depending on the actual rock quality encountered.

The minimum center-to-center spacing of rock tunnels and caverns has been assumed for layout studies to be 2.5 times the width or diameter of the larger excavation.

(iv) Selection of Turbines

The selection of turbine type is governed by the available head and flow. For the design head and specific speed, Francis type turbines have been selected. Francis turbines have a reasonably flat load-efficiency curve over a range from about 50 percent to 115 percent of rated output with peak efficiency of about 92 percent.

The number and rating of individual units is discussed in detail in subsection (b) above. The final selected arrangement comprises six units producing 170 MW each, rated at minimum reservoir level (from reservoir simulation studies) in the peak demand month (December) at full gate. The unit output at best efficiency and a rated head of 680 feet is 181 MW.

(v) Transformers

The selection of transformer type, size, location and step-up rating is summarized below:

- Single phase transformers are required because of transport limitations on Alaskan roads and railways;

- Direct transformation from 15 kV to 345 kV is preferred for overall system transient stability;

- An underground transformer gallery has been selected for minimum total cost of transformers, cables, bus, and transformer losses; and

- A grouped arrangement of three sets of three single-phase transformers for each set of two units has been selected (a total of nine transformers) to reduce the physical size of the transformer gallery and to provide a transformer spacing comparable with the unit spacing.

(vi) Power Intake and Water Passages

The power intake and approach channel are significant items in the cost of the overall power facilities arrangement. The size of the intake is controlled by the number and minimum spacing between the penstocks, which in turn is dictated by geotechnical considerations.

The preferred penstock arrangement comprises six individual penstocks, one for each turbine. With this arrangement, no inlet valve is required in the powerhouse since turbine dewatering can be performed by closing the control gate at the intake and draining the penstocks and scroll case through a valved bypass to the tailrace. An alternative arrangement with three penstocks was considered in detail to assess any possible advantages. This scheme would require a bifurcation and two inlet valves on each penstock and extra space in the powerhouse to accommodate the inlet valves. Estimates of relative cost differences are summarized below:

Item	Cost Difference ($ x 10^6) 6 Penstocks	3 Penstocks
Intake	Base Case	-20.0
Penstocks	0	- 3.0
Bifurcations	0	+ 3.0
Valves	0	+ 4.0
Powerhouse	0	+ 8.0
Capitalized Value of Extra Head Loss	0	+ 6.0
Total	0	- 2.0

Despite a marginal saving of $2 million (or less than 2 percent in a total estimated cost of $120 million) in favor of three penstocks, the arrangement of six individual penstocks has been retained. This arrangement provides improved flexibility and security of operation.

The preliminary design of the power facilities involves two tailrace tunnels leading from a common surge chamber. An alternative arrangement with a single tailrace tunnel was also considered, but no significant cost saving was apparent.

Optimization studies on all water passages were carried out to determine the minimum total cost of initial construction plus the capitalized value of anticipated energy losses caused by conduit friction, bends and changes of section. For the penstock optimization, the construction costs of the intake and approach channel were included as a function of the penstock diameter and spacing. Similarly, in the optimization studies for the tailrace tunnels the costs of the surge chamber were included as a function of tailrace tunnel diameter.

(vii) Environmental Constraints

Apart from the potential nitrogen supersaturation problem discussed, the major environmental constraints on the design of the power facilities are:

- Control of downstream river temperatures; and
- Control of downstream flows.

The intake design has been modified to enable power plant flows to be drawn from the reservoir at four different levels throughout the anticipated range of reservoir drawdown for energy production in order to control the downstream river temperatures within acceptable limits.

Minimum flows at Gold Creek during the critical summer months have been studied to mitigate the project impacts on salmon spawning downstream of Devil Canyon. These minimum flows represent a constraint on the reservoir operation and influence the computation of average and firm energy produced by the Susitna development.

The Watana development will be operated as a daily peaking plant for load following. The actual extent of daily peaking will be dictated by unit availability, unit size, system demand, system stability, generating costs, etc.

2.3 - Selection of Watana General Arrangement

Preliminary alternative arrangements of the Watana Project were developed and subjected to a series of review and screening processes. The layouts selected from each screening process were developed in greater detail prior to the next review and, where necessary, additional layouts were prepared combining the features of two or more of the alternatives. Assumptions and criteria were evaluated at each stage and additional data incorporated as necessary. The selection process followed the general selection methodology established for the Susitna project and is outlined below.

(a) Selection Methodology

The determination of the project general arrangement at Watana was undertaken in three distinct review stages: preliminary, intermediate, and final.

(i) Preliminary Review (completed early in 1981)

This comprised four steps:

- Step 1: Assemble available data;
  Determine design criteria; and
  Establish evaluation criteria.

- Step 2: Develop preliminary layouts and design criteria based on the above data including all plausible alternatives for the constituent facilities and structures.

- Step 3: Review all layouts on the basis of technical feasibility, readily apparent cost differences, safety, and environmental impact.

- Step 4: Select those layouts that can be identified as most favorable, based on the evaluation criteria established in Step 1, and taking into account the preliminary nature of the work at this stage.

(ii) Intermediate Review (completed by mid-1981)

This involved a series of 5 steps:

- Step 1: Review all data, incorporating additional data from other work tasks.

  Review and expand design criteria to a greater level of detail.

  Review evaluation criteria and modify, if necessary.

- Step 2: Revise selected layouts on basis of the revised criteria and additional data. Prepare plans and principal sections of layouts.

- Step 3: Prepare quantity estimates for major structures based on drawings prepared under Step 2.

  Develop a preliminary construction schedule to evaluate whether or not the selected layout will allow completion of the project within the required time frame.

  Prepare a preliminary contractor's type estimate to determine the overall cost of each scheme.

- Step 4: Review all layouts on the basis of technical feasibility, cost impact of possible unknown conditions and uncertainty of assumptions, safety, and environmental impact.

- Step 5: Select the two most favorable layouts based on the evaluation criteria determined under Step 1.

(iii) Final Review (completed early in 1982)

- Step 1: Assemble and review any additional data from other work tasks.

  Revise design criteria in accordance with additional available data.

  Finalize overall evaluation criteria.

- Step 2: Revise or further develop the two layouts on the basis of input from Step 1 and determine overall dimensions of structures, water passages, gates, and other key items.

- Step 3: Prepare quantity take-offs for all major structures.

  Review cost components within a preliminary contractor's type estimate using the most recent data and criteria, and develop a construction schedule.

  Determine overall direct cost of schemes.

- Step 4: Review all layouts on the basis of practicability, technical feasibility, cost, impact of possible unknown conditions, safety, and environmental impact.

- Step 5: Select the final layout on the basis of the evaluation criteria developed under Step 1.

(b) Design Data and Criteria

As discussed above, the review process included assembling relevant design data, establishing preliminary design criteria, and expanding and refining these data during the intermediate and final reviews of the project arrangement. The design data and design criteria which evolved through the final review are presented in Table B.29.

(c) Evaluation Criteria

The various layouts were evaluated at each stage of the review process on the basis of the criteria summarized in Table B.30. These criteria illustrate the progressively more detailed evaluation process leading to the final selected arrangement.

(d) Preliminary Review

The development selection studies described in Section 8, Volume 1 of Reference 4, involved comparisons of hydroelectric schemes at a number of sites on the Susitna River. As part of these comparisons a preliminary conceptual design was developed for Watana incorporating a double stilling basin type spillway.

Eight further layouts were subsequently prepared and examined for the Watana project during this preliminary review process in addition to the scheme shown on Figure B.7. These eight layouts are shown in schematic form on Figure B.25. Alternative 1 of these layouts was the scheme recommended for further study (1).

This section describes the preliminary review undertaken of alternative Watana layouts.

(i) Basis of Comparison of Alternatives

Although it was recognized that provision would have to be made for downstream releases of water during filling of the reservoir and for emergency reservoir drawdown, these features were not incorporated in these preliminary layouts. These facilities would either be interconnected with the diversion tunnels or be provided for separately. Since the system selected would be similar for all layouts with minimal cost differences and little impact on other structures, it was decided to exclude these facilities from overall assessment at this early stage.

Ongoing geotechnical explorations had identified the two major shear zones crossing the Susitna River and running roughly parallel in the northwest direction. These zones enclose a stretch of watercourse approximately 4500 feet in length. Preliminary evaluation of the existing geological data indicated highly fractured and altered materials within the actual shear zones which would pose serious problems for conventional tunneling methods and would be unsuitable for founding of massive concrete structures. The originally proposed dam axis was located between these shear zones, and since no apparent major advantage appeared to be gained from large changes in the dam location, layouts generally were kept within the confines of these bounding zones.

An earth and rockfill dam was used as the basis for all layouts. The downstream slope of the dam was assumed as 2H:1V in all alternatives and upstream slopes varying between 2.5H:1V and 2.25H:1V were examined in order to determine the influence of variance in the dam slope on the congestion of the layout. In all preliminary arrangements except the one shown on Figure B.7, cofferdams were incorporated within the body of the main dam.

Floods greater than the routed 1:10,000 year spillway design flood and up to the probable maximum flood were assumed to be passed by surcharging the spillways, except in cases where an unlined cascade or stilling basin type spillway served as the sole discharge facility. In such instances, under large surcharges, these spillways would not act as efficient energy dissipators but would be drowned out, acting as steep open channels with the possibility of their total destruction. In order to avoid such an occurrence the design flood for these latter spillways was considered as the routed probable maximum flood.

On the basis of information existing at the time of the preliminary review, it appeared that an underground powerhouse could be located on either side of the river. A surface powerhouse on the north bank appeared feasible but was precluded from the south bank by the close proximity of the downstream toe of the dam and the adjacent broad shear zone. Locating the powerhouse further downstream would require tunneling across the shear zone, which would be expensive and would require excavating a talus slope. Furthermore, it was found that a south bank surface powerhouse would either interfere with a south bank spillway or would be directly impacted by discharges from a north bank spillway.

(ii) Description of Alternative

- Double Stilling Basin Scheme

The scheme as shown on Figure B.7 has a dam axis location similar to that originally proposed by the COE, and a north bank double stilling basin spillway. The spillway follows the shortest line to the river, avoiding interference with the dam and discharging downstream almost parallel to the flow into the center of the river. A substantial amount of excavation is required for the chute and stilling basins, although most of this material could probably be used in the dam. A large volume of concrete is also required for this type of spillway, resulting in a spillway system that would be very costly. The maximum head dissipated within each stilling basin is approximately 450 feet. Within world experience, cavitation and erosion of the chute and basins should not be a problem if the structures are properly designed. Extensive erosion downstream would not be expected.

The diversion follows the shortest route, cutting the bend of the river on the north bank, and has inlet portals as far upstream as possible without having to tunnel through "The Fins". It is possible that the underground powerhouse is in the area of "The Fingerbuster", but the powerhouse could be located upstream almost as far as the system of drain holes and galleries just downstream of the main dam grout curtain.

- Alternative 1

This alternative, Figure B.26, is that recommended for further study (1) and is similar to the layout described above except that the north side of the dam has been rotated clockwise, the axis relocated upstream, and the spillway changed to a chute and flip bucket. The revised dam alignment resulted in a slight reduction in total dam volume compared to the above alternative. A localized downstream curve was introduced in the dam close to the north abutment in order to reduce the length of the spillway. The alignment of the spillway is almost parallel to the downstream section of the river and it discharges into a pre-excavated plunge pool in the river approximately 800 feet downstream from the flip bucket. This type of spillway should be considerably less costly than one incorporating a stilling basin, provided that excessive pre-excavation of bedrock within the plunge pool area is not required. Careful design of the bucket will be required, however, to prevent excessive erosion downstream causing undermining of the valley sides and/or build up of material downstream which could cause elevation of the tailwater levels.

- Alternatives 2 through 2D

Alternative 2 consists of a south bank cascade spillway with the main dam axis curving downstream at the abutments. The cascade spillway would require an extremely large volume of rock excavation but it is probable that most of this material, with careful scheduling, could be used in the dam. The excavation would cross "The Fingerbuster" and extensive dental concrete would be required in that area. In the upstream portion of the spillway, velocities would be relatively high because of the narrow configuration of the channel, and erosion could take place in this area in proximity to the dam. The discharge from the spillway enters the river perpendicular to the general flow but velocities would be relatively low and should not cause substantial erosion problems. The powerhouse is in the most suitable location for a surface alternative where the bedrock is close to the surface and the overall rock slope is approximately 2H:1V.

Alternative 2A is similar to Alternative 2 except that the upper end of the channel is divided and separate control structures are provided. This division would allow the use of one structure or upstream channel while maintenance or remedial work is being performed on the other.

Alternative 2B is similar to Alternative 2 except that the cascade spillway is replaced by a double stilling basin type structure. This spillway is somewhat longer than the similar type of structure on the north bank in the alternative described above. However, the slope of the ground is less than the rather steep north bank and may be easier to construct, a factor which may partly mitigate the cost of the longer structure. The discharge is at a sharp angle to the river and more concentrated than the cascade, which could cause erosion of the opposite bank.

Alternative 2C is a derivative of 2B with a similar arrangement, except that the double stilling basin spillway is reduced in size and augmented by an additional emergency spillway in the form of an inclined, unlined rock channel. Under this arrangement the concrete spillway acts as the main spillway, passing the 1:10,000 year design flood with greater flows passed down the unlined channel which is closed at its upstream end by an erodible fuse plug. The problems of erosion of the opposite bank still remain, although these could be overcome by excavation and/or slope protection. Erosion of the chute would be extreme for significant flows, although it is highly unlikely that this emergency spillway would ever be used.

Alternative 2D replaces the cascade of Alternative 2 with a lined chute and flip bucket. The comments relative to the flip bucket are the same as for Alternative 1 except that the south bank location in this instance requires a longer chute, partly offset by lower construction costs because of the flatter slope. The flip bucket discharges into the river at an angle which may cause erosion of the opposite bank. The underground powerhouse is located on the north bank, an arrangement which provides an overall reduction of the length of the water passages.

- <u>Alternative 3</u>

This arrangement has a dam axis location slightly upstream from Alternative 2, but retains the downstream curve at the abutments. The main spillway is an unlined rock cascade on the south bank which passes the design flood. Discharges beyond the 1:10,000 year flood would be discharged through the auxiliary concrete-lined chute and flip bucket spillway on the north bank. A gated control structure is provided for this auxiliary spillway which gives it the flexibility to be used as a backup if maintenance should be required on the main spillway. Erosion of the cascade may be a problem, as mentioned previously, but erosion downstream should be a less important consideration because of the low unit discharge and the infrequent operation of the spillway. The diversion tunnels are situated in the north abutment, as with previous arrangements, and are of similar cost for all these alternatives.

- Alternative 4

This alternative involves rotating the axis of the main dam so that the south abutment is relocated approximately 1000 feet downstream from its Alternative 2 location. The relocation results in a reduction in the overall dam quantities but would require siting the impervious core of the dam directly over the "Fingerbuster" shear zone at maximum dam height. The south bank spillway, consisting of chute and flip bucket, is reduced in length compared to other south bank locations, as are the power facility water passages. The diversion tunnels are situated on the south bank; there is no advantage to a north bank location, since the tunnels are of similar length owing to the overall downstream relocation of the dam. Spillways and power facilities would also be lengthened by a north bank location with this dam configuration.

- Selection of Schemes for Further Study

A basic consideration during design development was that the main dam core should not cross the major shear zones because of the obvious problems with treatment of the foundation. Accordingly, there is very little scope for realigning the main dam apart from a slight rotation to place it more at right angles to the river.

Location of the spillway on the north bank results in a shorter distance to the river and allows discharges almost parallel to the general direction of river flow. The double stilling basin arrangement would be extremely expensive, particularly if it must be designed to pass the probable maximum flood. An alternative such as 2C would reduce the magnitude of design flood to be passed by the spillway but would only be acceptable if an emergency spillway with a high degree of operational predictability could be constructed. A flip bucket spillway on the north bank, discharging directly down the river, would appear to be an economic arrangement, although some scour might occur in the plunge pool area. A cascade spillway on the south bank could be an acceptable solution providing most of the excavated material could be used in the dam, and adequate rock conditions exist.

The length of diversion tunnels can be decreased if they are located on the north bank. In addition, the tunnels would be accessible by a preliminary access road from the north, which is the most likely route. This location would also avoid the area of "The Fingerbuster" and the steep cliffs which would be encountered on the south side close to the downstream dam toe.

The underground configuration assumed for the powerhouse in these preliminary studies allows for location on either side of the river with a minimum of interference with the surface structures.

Four of the preceding layouts, or variations of them, were selected for further study:

- A variation of the double stilling basin scheme, but with a single stilling basin main spillway on the north bank, a rock channel and fuse plug emergency spillway, a south bank underground powerhouse and a north bank diversion scheme;

- Alternative 1 with a north bank flip bucket spillway, an underground powerhouse on the south bank, and north bank diversion;

- A variation of Alternative 2 with a reduced capacity main spillway and a north bank rock channel with a fuse plug serving as an emergency spillway; and

- Alternative 4 with a south bank rock cascade spillway, a north bank underground powerhouse, and a north bank diversion.

(e) Intermediate Review

For the intermediate review process, the four schemes selected as a result of the preliminary review were examined in more detail and modified. A description of each of the schemes is given below and shown on Figures B.27 through B.32. The general locations of the upstream and downstream shear zones shown on these plates are approximate and have been refined on the basis of subsequent field investigations for the proposed project.

(i) Description of Alternative Schemes

The four schemes are shown on Figures B.27 through B.32.

- Scheme WP1 (Figure B.27)

This scheme is a refinement of Alternative 1. The upstream slope of the dam is flattened from 2.5:1 to 2.75:1. This conservative approach was adopted to provide an assessment of the possible impacts on project layout of conceivable measures which may prove necessary in dealing with severe earthquake design conditions. Uncertainty with regard to the nature of river alluvium also led to the location of the cofferdams outside the limits of the main dam embankment. As a result of these conditions, the intake portals of the diversion tunnels on the north bank are also moved upstream from "The Fins". A chute spillway with a flip bucket is located on the north bank. The underground powerhouse is located on the south bank.

- Scheme WP2 (Figures B.29 and B.30)

This scheme is derived from the double stilling basin layout. The main dam and diversion facilities are similar to Scheme WP1 except that the downstream cofferdam is relocated further downstream from the spillway outlet and the diversion tunnels are correspondingly extended. The main spillway is located on the north bank, but the two stilling basins of the preliminary DSR scheme are combined into a single stilling basin at the river level. An emergency spillway is also located on the north bank and consists of a channel excavated in rock, discharging downstream from the area of the relict channel. The channel is closed at its upstream end by a compacted earthfill fuse plug and is capable of discharging the flow differential between the probable maximum flood and the 1:10,000-year design flood of the main spillway. The underground powerhouse is located on the south bank.

- Scheme WP3 (Figures B.28 and B.29)

  This scheme is similar to Scheme WP1 in all respects except that an emergency spillway is added consisting of north bank rock channel and fuse plug.

- Scheme WP4 (Figures B.31 and B.32)

  The dam location and geometry for Scheme WP4 are similar to that for the other schemes. The diversion is on the north bank and discharges downstream from the powerhouse tailrace outlet. A rock cascade spillway is located on the south bank and is served by two separate control structures with downstream stilling basins. The underground powerhouse is located on the north bank.

(ii) Comparison of Schemes

The main dam is in the same location and has the same configuration for each of the four layouts considered. The cofferdams have been located outside the limits of the main dam in order to allow more extensive excavation of the alluvial material and to ensure a sound rock foundation beneath the complete area of the dam. The overall design of the dam is conservative, and it was recognized during the evaluation that savings in both fill and excavation costs can probably be made after more detailed study.

The diversion tunnels are located on the north bank. The upstream flattening of the dam slope necessitates the location of the diversion inlets upstream from "The Fins" shear zone which would require extensive excavation and support where the tunnels pass through this extremely poor rock zone and could cause delays in the construction schedule.

A low-lying area exists on the north bank in the area of the relict channel and requires approximately a 50-foot high saddle dam for closure, given the reservoir operating level assumed for the comparison study. However, the finally selected reservoir operating level will require only a nominal freeboard structure at this location.

A summary of capital cost estimates for the four alternative schemes is given in Table B.31.

The results of this intermediate analysis indicate that the chute spillway with flip bucket (Scheme WP1) is the least costly spillway alternative.

The scheme has the additional advantage of relatively simple operating characteristics. The control structure has provision for surcharging to pass the design flood. The probable maximum flood can be passed by additional surcharging up to the crest level of the dam. In Scheme WP3 a similar spillway is provided, except that the control structure is reduced in size and discharges above the routed design flood are passed through the rock channel emergency spillway. The arrangement in Scheme WP1 does not provide a backup facility to the main spillway, so that if repairs caused by excessive plunge pool erosion or damage to the structure itself require removal of the spillway from service for any length of time, no alternative discharge facility would be available. The additional spillway of Scheme WP3 would permit emergency discharge if it were required under extreme circumstances.

The stilling basin spillway (Scheme WP2) would reduce the potential for extensive erosion downstream, but high velocities in the lower part of the chute could cause cavitation even with the provision for aeration of the discharge. This type of spillway would be very costly, as can be seen from Table B.28.

The feasibility of the rock cascade spillway is entirely dependent on the quality of the rock, which dictates the amount of treatment required for the rock surface and also the proportion of the excavated material which can be used in the dam. For determining the capital cost of Scheme WP4, conservative assumptions were made regarding surface treatment and the portion of material that would have to be wasted.

The diversion tunnels are located on the north bank for all alternatives examined in the intermediate review. For Scheme WP2, the downstream portals must be located downstream from the stilling basin, resulting in an increase of approximately 800 feet in the length of the tunnels. The south bank location of the powerhouse requires its placement close to a suspected shear zone, with the tailrace tunnels passing through this shear zone to reach the river. A longer access tunnel is also required, together with an additional 1,000 feet in the length of the tailrace. The south-side location is remote from the main access road, which will probably be on the north side of the river, as will the transmission corridor.

(iii) Selection of Schemes for Further Study

Examination of the technical and economic aspects of Scheme WP1 through WP4 indicates there is little scope for adjustment of the dam axis owing to the confinement imposed by the upstream and downstream shear zones. In addition, passage of the diversion tunnels through the upstream shear zone could result in significant delays in construction and additional cost.

From a comparison of costs in Table B.28, it can be seen that the flip bucket type spillway is the most economical, but because of the potential for erosion under extensive operation it is undesirable to use it as the only discharge facility. A mid-level release will be required for emergency drawdown of the reservoir, and use of this release as the first-stage service spillway with the flip bucket as a backup facility would combine flexibility and safety of operation with reasonable cost. The emergency rock channel spillway would be retained for discharge of flows above the routed 1:10,000-year flood.

The stilling basin spillway is very costly and the operating head of 800 feet is beyond precedent experience. Erosion downstream should not be a problem but cavitation on the chute could occur. Scheme WP2 was therefore eliminated from further consideration.

The cascade spillway was also not favored for technical and economic reasons. However, this arrangement does have an advantage in that it provides a means of preventing nitrogen supersaturation in the downstream discharges from the project which could be harmful to the fish population. A cascade configuration would reduce the dissolved nitrogen content; hence, this alternative was retained for further evaluation. The capacity of the cascade was reduced and the emergency rock channel spillway was included to take the extreme floods.

The results of the intermediate review indicated that the following components should be incorporated into any scheme carried forward for final review:

- Two diversion tunnels located on the north bank of the river;

- An underground powerhouse also located on the north bank;

- An emergency spillway, comprising a rock channel excavated on the north bank and discharging well downstream from the north abutment. The channel is sealed by an erodible fuse plug of impervious material designed to fail if overtopped by the reservoir; and

- A compacted earthfill and rockfill dam situated between the two major shear zones which traverse the project site.

As discussed above, two specific alternative methods exist with respect to routing of the spillway design flood and minimizing the adverse effects of nitrogen supersaturation on the downstream fish population. These alternatives are:

- A chute spillway with flip bucket on the north bank to pass the spillway design flood, with a mid-level release system designed to operate for floods with a frequency of up to about 1:50 years; or

- A cascade spillway on the south bank.

Accordingly, two schemes were developed for further evaluation as part of the final review process. These schemes are described separately in the paragraphs below.

(f) Final Review

The two schemes considered in the final review process were essentially derivations of Schemes WP3 and WP4.

(i) Scheme WP3A (Figure B.33)

This scheme is a modified version of Scheme WP3 described above. Because of scheduling and cost considerations, it is extremely important to maintain the diversion tunnels downstream from "The Fins." It is also important to keep the dam axis as far upstream as possible to avoid congestion of the downstream structures. For these reasons, the inlet portals to the diversion tunnels were located in the sound bedrock forming the downstream boundary of "The Fins." The upstream cofferdam and main dam are maintained in the upstream locations as shown on Figure B.33. As mentioned previously, additional criteria have necessitated modifications in the spillway configuration, and low-level and emergency drawdown outlets have been introduced.

The main modifications to the scheme are as follows:

- Main Dam

Continuing preliminary design studies and review of world practice suggest that an upstream slope of 2.4H:1V would be acceptable for the rock shell. Adoption of this slope results not only in a reduction in dam fill volume but also in a reduction in the base width of the dam which permits the main project components to be located between the major shear zones.

The downstream slope of the dam is retained as 2H:1V. The cofferdams remain outside the limits of the dam in order to allow complete excavation of the riverbed alluvium.

- Diversion

In the intermediate review arrangements, diversion tunnels passed through the broad structure of "The Fins," an intensely sheared area of breccia, gouge, and infills. Tunneling of this material would be difficult, and might even require excavation in open cut from the surface. High cost would be involved, but more important would be the time taken for construction in this area and the possibility of unexpected delays. For this reason, the inlet portals have been relocated downstream from this zone with the tunnels located closer to the river and crossing the main system of jointing at approximately 45°. This arrangement allows for shorter tunnels with a more favorable orientation of the inlet and outlet portals with respect to the river flow directions.

A separate low-level inlet and concrete-lined tunnel is provided, leading from the reservoir at approximate Elevation 1550 to downstream of the diversion plug where it merges with the diversion tunnel closest to the river. This low-level tunnel is designed to pass flows up to 12,000 cfs during reservoir filling. It would also pass up to 30,000 cfs under 500-foot head to allow emergency draining of the reservoir.

Initial closure is made by lowering the gates to the tunnel located closest to the river and constructing a concrete closure plug in the tunnel at the location of the grout curtain underlying the core of the main dam. On completion of the plug, the low-level release is opened and controlled discharges are passed downstream. The closure gates within the second diversion tunnel portal are then closed and a concrete closure plug constructed in line with the grout curtain. After closure of the gates, filling of the reservoir would commence.

- Outlet Facilities

As a provision for drawing down the reservoir in case of emergency, a mid-level release is provided. The intake to these facilities is located at depth adjacent to the power facilities intake structures. Flows would then be passed downstream through a concrete-lined tunnel, discharging beneath the downstream end of the main spillway flip bucket. In order to overcome potential nitrogen supersaturation problems, Scheme WP3A also incorporates a system of fixed cone valves at the downstream end of the outlet facilities. The valves were sized to discharge in conjunction with the powerhouse operating at 7000 cfs capacity (flows up to the equivalent routed 50-year flood). Six cone valves are required, located on branches from a steel manifold and protected by individual upstream closure gates. The valves are partly incorporated into the mass concrete block forming the flip bucket of the main spillway. The rock downstream is protected from erosion by a concrete facing slab anchored back to the sound bedrock.

- Spillways

As discussed above, the designed operation of the main spillway facilities was arranged to limit discharges of potentially nitrogen-supersaturated water from Watana to flows having an equivalent return period greater than 1:50 years.

The main chute spillway and flip bucket discharge into an excavated plunge pool in the downstream river bed. Releases are controlled by a three-gated ogee structure located adjacent to the outlet facilities and power intake structure just upstream from the dam centerline. The design discharge is approximately 114,000 cfs, corresponding to the routed 1:10,000-year flood (145,000 cfs) reduced by the 31,000 cfs flows attributable to outlet and power facilities discharges. The plunge pool is formed by excavating the alluvial river deposits to bedrock. Since the excavated plunge pool approaches the limits of the calculated maximum scour hole, it is not anticipated that, given the infrequent discharges, significant downstream erosion will occur.

An emergency spillway is provided by means of a channel excavated in rock on the north bank, discharging well downstream from the north abutment in the direction of Tsusena Creek. The channel is sealed by an erodible fuse plug of impervious material designed to fail if overtopped by the reservoir, although some preliminary excavation may be necessary. The crest level of the plug will be set at Elevation 2230, well below that of the main dam. The channel will be capable of passing the excess discharge of floods greater than the 1:10,000-year flood up to the probable maximum flood of 326,000 cfs.

- Power Facilities

The power intake is set slightly upstream from the dam axis deep within sound bedrock at the downstream end of the approach channel. The intake consists of six units with provision in each unit for drawing flows from a variety of depths covering the complete drawdown range of the reservoir. This facility also provides for drawing water from the different temperature strata within the upper part of the reservoir and thus regulating the temperature of the downstream discharges close to the natural temperatures of the river. For this preliminary conceptual arrangement, flow withdrawals from different levels are achieved by a series of upstream vertical shutters moving in a single set of guides and operated to form openings at the required level. Downstream from these shutters each unit has a pair of wheel-mounted closure gates which will isolate the individual penstocks.

The six penstocks are 18-foot-diameter, concrete-lined tunnels inclined at 55° immediately downstream from the intake to a nearly horizontal portion leading to the powerhouse. This horizontal portion is steel-lined for 150 feet upstream from the turbine units to extend the seepage path to the powerhouse and reduce the flow within the fractured rock area caused by blasting in the adjacent powerhouse cavern.

The six 170 MW turbine/generator units are housed within the major powerhouse cavern and are serviced by an overhead crane which runs the length of the powerhouse and into the service area adjacent to the units. Switchgear, maintenance room and offices are located within the main cavern, with the transformers situated downstream in a separate gallery excavated above the tailrace tunnels. Six inclined tunnels carry the connecting bus ducts from the main power hall to the transformer gallery. A vertical elevator and vent shaft run from the power cavern to the main office building and control room located at the surface. Vertical cable shafts, one for each pair of transformers, connect the transformer gallery to the switchyard directly overhead. Downstream from the transformer gallery the underlying draft tube tunnels merge into two surge chambers (one chamber for three draft tubes) which also house the draft tube gates for isolating the units from the tailrace. The gates are operated by an overhead traveling gantry located in the upper part of each of the surge chambers. Emerging from the ends of the chambers, two concrete-lined, low-pressure tailrace tunnels carry the discharges to the river. Because of space restrictions at the river, one of these tunnels has been merged with the downstream end of the diversion tunnel. The other tunnel emerges in a separate portal with provision for the installation of bulkhead gates.

The orientation of water passages and underground caverns is such as to avoid, as far as possible, alignment of the main excavations with the major joint sets.

- Access

  Access is assumed to be from the north side of the river. Permanent access to structures close to the river is by a road along the north downstream river bank and then via a tunnel passing through the concrete forming the flip bucket. A tunnel from this point to the power cavern provides for vehicular access. A secondary access road across the crest of the dam passes down the south bank of the valley and across the lower part of the dam.

(ii) Scheme WP4A (Figure B.34)

This scheme is similar in most respects to Scheme WP3A previously discussed, except for the spillway arrangements.

- Main Dam

  The main dam axis is similar to that of Scheme WP3A, except for a slight downstream rotation at the south abutment at the spillway control structures.

- Diversion

  The diversion and low level releases are the same for the two schemes.

- Outlet Facilities

The outlet facilities used for emergency drawdown are separate from the main spillway for this scheme. The outlet facilities consists of a low-level gated inlet structure discharging up to 30,000 cfs into the river through a concrete-lined, free-flow tunnel with a ski jump flip bucket. This facility may also be operated as an auxiliary outlet to augment the main south bank spillway.

- Spillways

The main south bank spillway is capable of passing a design flow equivalent to the 1:10,000-year flood through a series of 50-foot drops into shallow pre-excavated plunge pools. The emergency spillway is designed to operate during floods of greater magnitude up to and including the PMF.

Main spillway discharges are controlled by a broad multi-gated control structure discharging into a shallow stilling basin. The feasibility of this arrangement is governed by the quality of the rock in the area, requiring both durability to withstand erosion caused by spillway flows and a high percentage of sound rockfill material that can be used from the excavation directly in the main dam.

On the basis of the site information developed concurrently with the general arrangement studies, it became apparent that the major shear zone known to exist in the south bank area extended further downstream than initial studies have indicated. The cascade spillway channel was therefore lengthened to avoid the shear area at the lower end of the cascade. The arrangement shown on Figure B.34 for Scheme WP4A does not reflect this relocation, which would increase the overall cost of the scheme.

The emergency spillway consisting of rock channel and fuse plug is similar to that of the north bank spillway scheme.

- Power Facilities

The power facilities are similar to those in Scheme WP3A.

(iii) Evaluation of Final Alternative Schemes

An evaluation of the dissimilar features for each arrangement (the main spillways and the discharge arrangements at the downstream end of the outlets) indicates a saving in capital cost of $197,000,000, excluding contingencies and indirect cost, in favor of Scheme WP3A. If this difference is adjusted for the savings associated with using an appropriate proportion of excavated material from the cascade spillway as rockfill in the main dam, this represents a net overall cost difference of approximately $110,000,000 including contingencies, engineering, and administration costs.

As discussed above, although limited information exists regarding the quality of the rock in the downstream area on the south bank, it is known that a major shear zone runs through and is adjacent to the area presently allocated to the spillway in Scheme WP4. This would require relocating the south bank cascade spillway several hundred feet farther downstream into an area where the rock quality is unknown and the topography less suited to the gentle overall slope of the cascade. The cost of the excavation would substantially increase compared to previous assumptions, irrespective of the rock quality. In addition, the resistance of the rock to erosion and the suitability for use as excavated material in the main dam would become less certain. The economic feasibility of this scheme is largely predicated on this last factor, since the ability to use the material as a source of rockfill for the main dam represents a major cost saving.

In conjunction with the main chute spillway, the problem of the occurrence of nitrogen supersaturation can be overcome by the use of a regularly operated dispersion type valve outlet facility in conjunction with the main chute spillway. Since this scheme presents a more economic solution with fewer potential problems concerning the geotechnical aspects of its design, the north bank chute arrangement (Scheme WP3A) has been adopted as the final selected scheme.

2.4 - Devil Canyon Project Formulation

This section describes the development of the general arrangement of the Devil Canyon project. The method of handling floods during construction and subsequent project operation is also outlined in this section.

The reservoir level fluctuations and inflow for Devil Canyon will essentially be controlled by operation of the upstream Watana project. This aspect is also briefly discussed in this section.

(a) Selection of Reservoir Level

The selected normal maximum operating level at Devil Canyon Dam is Elevation 1455. Studies by the USBR and COE on the Devil Canyon Project were essentially based on a similar reservoir level which corresponds to the tailwater level selected at the Watana site. Although the narrow configuration of the Devil Canyon site and the relatively low costs involved in increasing the dam height suggest that it might be economic to do so, it is clear that the upper economic limit of reservoir level at Devil Canyon is the Watana tailrace level.

Although significantly lower reservoir levels at Devil Canyon would lead to lower dam costs, the location of adequate spillway facilities in the narrow gorge would become extremely difficult and lead to offsetting increases in cost. In the extreme case, a spillway discharging over the dam would raise concerns regarding safety from scouring at the toe of the dam which have already led to rejection of such schemes.

(b) Selection of Installed Capacity

The methodology used for the preliminary selection of installed capacity at Devil Canyon is similar to the Watana methodology described in Section 2.2(b).

The decision to operate Devil Canyon primarily as a base-loaded plant was governed by the following main considerations:

- Daily peaking is more effectively performed at Watana than at Devil Canyon; and

- Excessive fluctuations in discharge from the Devil Canyon dam may have an undesirable impact on mitigation measures incorporated in the final design to project the downstream fisheries.

Given this mode of operation, the required installed capacity at Devil Canyon has been determined as the maximum capacity needed to utilize the available energy from the hydrological flows of record, as modified by the reservoir operation rule curves. In years where the energy from Watana and Devil Canyon exceeds the system demand, the usable energy has been reduced at both stations in proportion to the average net head available, assuming that flows used to generate energy at Watana will also be used to generate energy at Devil Canyon.

Table B.32 shows an assessment of maximum plant capacity required at Devil Canyon in the peak demand month (December). The Devil Canyon capacity is the same whether thermal energy is used for base load or for peaking since Devil Canyon is designed for peaking only.

The selected total installed capacity at Devil Canyon has been established as 600 MW for design purposes. This will provide some margin for standby during forced outage and possible accelerated growth in demand.

The major factors governing the selection of the unit size at Devil Canyon are the rate of growth of system demand, the minimum station output, and the requirement of standby capacity under forced outage conditions.

The power facilities at Devil Canyon have been developed using four units at 150 MW each. This arrangement will provide for efficient station operation during low load periods as well as during peak December loads. During final design, consideration of phasing of installed capacity to match the system demand may be desirable. However, the uncertainty of load forecasts and the additional contractual costs of mobilization for equipment installation are such that for this study it has been assumed that all units will be commissioned by 2002.

The Devil Canyon reservoir will usually be full in December; hence, any forced outage could result in spilling and a loss of available energy. The units have been rated to deliver 150 MW at maximum December drawdown occuring during an extremely dry year; this means that in an average year, with higher reservoir levels the full station output can be maintained even with one unit on forced outage.

(c) Selection of Spillway Capacity

A flood frequency of 1:10,000 years was selected for the spillway design on the same basis as described for Watana. An emergency spillway with an erodible fuse plug will also be provided to safely discharge the probable maximum flood. The development plan envisages completion of the Watana project prior to construction at Devil Canyon. Accordingly, the inflow flood peaks at Devil Canyon will be less than pre-project flood peaks because of routing through the Watana reservoir. Spillway design floods are:

Flood	Inflow Peak (cfs)
1:10,000 years	165,000
Probable Maximum	345,000

The avoidance of nitrogen supersaturation in the downstream flow for Watana also will apply to Devil Canyon. Thus, the discharge of water possibly supersaturated with nitrogen from Devil Canyon will be limited to a recurrence period of not less than 1:50 years by the use of fixed-cone valves similar to Watana.

(d) Main Dam Alternatives

The location of the Devil Canyon damsite was examined during previous studies by the USBR and COE. These studies focused on the narrow entrance to the canyon and led to the recommendation of a concrete arch dam. Notwithstanding this initial appraisal, a comparative analysis was undertaken as part of this feasibility study to evaluate the relative merits of the following types of structures at the same location:

- Thick concrete arch;
- Thin concrete arch; and
- Fill embankment.

(i) Comparison of Embankment and Concrete Type Dams

The geometry was developed for both the thin concrete arch and the thick concrete arch dam and the dams were analyzed and their behavior compared under static, hydrostatic, and seismic loading conditions. The project layouts for these arch dams were compared to a layout for a rockfill dam with its associated structures.

Consideration of the central core rockfill dam layout indicated relatively small cost differences from an arch dam cost estimate, based on a cross-section significantly thicker than the finally selected design. Furthermore, no information was available to indicate that impervious core material in the necessary quantities could be found within a reasonable distance of the damsite. The rockfill dam was accordingly dropped from further consideration. It is further noted that since this alternative dam study, seismic analysis of the rockfill dam at Watana has resulted in an upstream slope 1:2.4, thus indicating the requirement to flatten the 1:2.5 slope adopted for the rockfill dam alternative at Devil Canyon.

Neither of the concrete arch dam layouts were intended as the final site arrangement, but were sufficiently representative of the most suitable arrangement associated with each dam type to provide an adequate basis for comparison. Each type of dam was located just downstream from where the river enters Devil Canyon and close to the canyon's narrowest point, which is the optimum location for all types of dams. A brief description of each dam type and configuration is given below.

- Rockfill Dam

For this arrangement the dam axis would be some 625 feet downstream of the crown section of the concrete dams. The assumed embankment slopes would be 2.25 H:1V on the upstream face and 2H:1V on the downstream face. The main dam would be continuous with the south bank saddle dam, and therefore no thrust blocks would be required. The crest length would be 2200 feet at Elevation 1470; the crest width would be 50 feet.

The dam would be constructed with a central impervious core, inclined upstream, supported on the downstream side by a semi-pervious zone. These two zones would be protected upstream and downstream by filter and transition materials. The shell sections would be constructed of rockfill obtained from blasted bedrock. For preliminary design all dam sections would be assumed to be founded on rock; external cofferdams would be founded on the river alluvium, and would not be incorporated into the main dam. The approximate volume of material in the main dam would be 20 million cubic yards.

A single spillway would be provided on the north abutment to control all flood flows. It would consist of a gate control structure and a double stilling basin excavated into rock; the chute sections and stilling basins would be concrete-lined, with mass concrete gravity retaining walls. The design capacity would be sufficient to pass the 1:10,000 year flood without damage; excess capacity would be provided to pass the PMF without damage to the main dam by surcharging the reservoir and spillway.

The powerhouse would be located underground in the north abutment. The multi-level power intake would be constructed in a rock cut in the north abutment on the dam centerline, with four independent penstocks to the 150 MW Francis turbines. Twin concrete-lined tailrace tunnels would connect the powerhouse to the river via an intermediate draft tube manifold.

- Thick Arch Dam

The main concrete dam would be a single center arch structure, acting partly as a gravity dam, with a vertical cylindrical upstream face and a sloping downstream face inclined at 1V:0.4H. The maximum height of the dam would be 635 feet ith a uniform crest width of

30 feet, a crest length of approximately 1,400 feet, and a maximum foundation width of 225 feet. The crest elevation would be 1460. The center portion of the dam would be founded on a massive mass concrete pad constructed in the excavated river bed. This central section would incorporate the main spillway with sidewalls anchored into solid bedrock and gated orifice spillways discharging down the steeply inclined downstream face of the dam into a single large stilling basin set below river level and spanning the valley.

The main dam would terminate in thrust blocks high on the abutments. The south abutment thrust block would incorporate an emergency gated control spillway structure which would discharge into a rock channel running well downstream and terminating at a level high above the river valley.

Beyond the control structure and thrust block, a low-lying saddle on the south abutment would be closed by means of a rockfill dike founded on bedrock. The powerhouse would house four 150 MW units and would be located underground within the north abutment. The intake would be constructed integrally with the dam and connected to the powerhouse by vertical steel-lined penstocks.

The main spillway would be designed to pass the 1:10,000-year routed flood with larger floods discharged downstream via the emergency spillway.

- Thin Arch Dam

The main dam would be a two-center, double-curved arch structure of similar height to the thick arch dam, but with a 20-foot uniform crest and a maximum base width of 90 feet. The crest elevation would be 1460. The center section would be founded on a concrete pad, and the extreme upper portion of the dam would terminate in concrete thrust blocks located on the abutments.

The main spillway would be located on the north abutment and would consist of a conventional gated control structure discharging down a concrete-lined chute terminating in a flip bucket. The bucket would discharge into an unlined plunge pool excavated in the riverbed alluvium and located sufficiently downstream to prevent undermining of the dam and associated structures.

The main spillway would be supplemented by orifice type spillways located high in the center portion of the dam which would discharge into a concrete-lined plunge pool immediately downstream from the dam. An emergency spillway consisting of a fuse plug discharging into an unlined rock channel terminating well downstream would be located beyond the saddle dam on the south abutment.

The concrete dam would terminate in a massive thrust block on each abutment which, on the south abutment, would adjoin a rockfill saddle dam.

The main and auxiliary spillways would be designed to discharge the 1:10,000-year flood. Larger floods for storms up to the probable maximum flood would be discharged through the emergency south abutment spillway.

- Comparison of Arch Dam Types

Sand and gravel for concrete aggregates are believed to be available in sufficient quantities within economic distance from the damsite. The gravel and sands are formed from the granitic and metamorphic rocks of the area; at this time it is anticipated that they will be suitable for the production of aggregates after screening and washing.

The bedrock geology of the site is discussed in Reference 3. At this time it appears that there are no geological or geotechnical concerns that would preclude either of the dam types from consideration.

Under hydrostatic and temperature loadings, stresses within the thick arch dam would be generally lower than for the thin arch alternative. However, finite element analysis has shown that the additional mass of the dam under seismic loading would produce stresses of a greater magnitude in the thick arch dam than in the thin arch dam. If the surface stresses approach the maximum allowable at a particular section, the remaining understressed area of concrete will be greater for the thick arch, and the factor of safety for the dam would be correspondingly higher. The thin arch is, however, a more efficient design and better utilizes the inherent properties of the concrete. It is designed around acceptable predetermined factors of safety and requires a much smaller volume of concrete for the actual dam structure.

The thick arch arrangement did not appear to have a distinct technical advantage compared to a thin arch dam and would be more expensive because of the larger volume of concrete needed. Studies, therefore, continued on refining the feasibility of the thin arch alternative.

(e) Diversion Scheme Alternatives

In this section the selection of general arrangement and the basis for sizing of the diversion scheme are presented.

(i) General Arrangements

The steep walled valley at the site essentially dictated that diversion of the river during construction be accomplished using one or two diversion tunnels, with upstream and downstream cofferdams protecting the main construction area.

The selection process for establishing the final general arrangement included examination of tunnel locations on both banks of the river. Rock conditions for tunneling did not favor one bank over the other. Access and ease of construction strongly favored the south bank or abutment, the obvious approach being via the alluvial fan. The total length of tunnel required for the south bank is approximately 300 feet greater; however, access to the north bank could not be achieved without great difficulty.

(ii) Design Flood for Diversion

The recurrence interval of the design flood for diversion was established in the same manner as for Watana dam. Accordingly, at Devil Canyon a risk of exceedence of 10 percent per annum has been adopted, equivalent to a design flood with a 1:10-year return period for each year of critical construction exposure. The critical construction time is estimated at 2.5 years. The main dam could be subjected to overtopping during construction without causing serious damage, and the existence of the Watana facility upstream would offer considerable assistance in flow regulation in case of an emergency. These considerations led to the selection of the design flood with a return frequency of 1:25 years.

The equivalent inflow, together with average flow characteristics of the river significant to diversion, are presented below:

- Average annual flow:	9,050 cfs
- Design flood inflow (1:25 years routed through Watana reservoir):	37,800 cfs

(iii) Cofferdams

As at Watana, the considerable depth of riverbed alluvium at both cofferdam sites indicates that embankment-type cofferdam structures would be the only technically and economically feasible alternative at Devil Canyon. For the purposes of establishing the overall general arrangement of the project and for subsequent diversion optimization studies, the upstream cofferdam section adopted will comprise an initial closure section approximately 20 feet high constructed in the wet, with a zoned embankment constructed in the dry. The downstream cofferdam will comprise a closure dam structure approximately 30 feet high placed in the wet. Control of underseepage through the alluvium material may be required and could be achieved by means of a grouted zone. The coarse nature of the alluvium at Devil Canyon led to the selection of a grouted zone rather than a slurry wall.

(iv) Diversion Tunnels

Although studies for the Watana project indicated that concrete-lined tunnels are the most economically and technically feasible solution, this aspect was reexamined at Devil Canyon. Preliminary hydraulic studies indicated that the design flood routed through the diversion scheme would result in a design discharge of approximately 37,800 cfs. For concrete-lined tunnels, design velocities of approximately 50 ft/s would permit the use of one concrete-lined tunnel with an equivalent diameter of 30 feet. Alternatively, for unlined tunnels a maximum design velocity of 10 ft/s in good quality rock would require four unlined tunnels, each with an equivalent diameter of 35 feet, to pass the design flow. As was the case for the Watana diversion scheme, considerations of reliability and cost were considered sufficient to eliminate consideration of unlined tunnels for the diversion scheme.

For the purposes of optimization studies, only a pressure tunnel was considered, since previous studies indicated that cofferdam closure problems associated with free-flow tunnels would more than offset their other advantages.

(v) Optimization of Diversion Scheme

Given the considerations described above relative to design flows, cofferdam configuration, and alternative types of tunnels, an economic study was undertaken to determine the optimum combination of upstream cofferdam elevation (height) and tunnel diameter.

Capital costs were developed for a range of pressure tunnel diameters and corresponding upstream cofferdam embankment crest elevations with a 30-foot wide crest and exterior slopes of 2H:1V. A freeboard allowance of 5 feet was included for settlement and wave runup.

Capital costs for the tunnel alternatives included allowances for excavation, concrete liner, rock bolts, and steel supports. Costs were also developed for the upstream and downstream portals, including excavation and support. The cost of an intake gate structure and associated gates was determined not to vary significantly with tunnel diameter and was excluded from the analysis.

The centerline tunnel length in all cases was estimated to be 2,000 feet.

Rating curves for the single-pressure tunnel alternatives are presented in Figure B.35. The relationship between capital costs for the upstream cofferdam and various tunnel diameters is given in Figure B.36.

The results of the optimization study indicated that a single 30-foot-diameter pressure tunnel results in the overall least cost (Figure B.36). An upstream cofferdam 60 feet high, with a crest elevation of 945, was carried forward as part of the selected general arrangement.

(f) Spillway Alternatives

The project spillways have been designed to safely pass floods with the following return frequencies:

Inflow Peak Flood	Discharge Frequency	Inflow (cfs)
Spillway Design	1:10,000 years	165,000
Probable Maximum	--	345,000

A number of alternatives were considered singly and in combination for Devil Canyon spillway facilities. These included gated orifices in the main dam discharging into a plunge pool, chute or tunnel spillways with either a flip bucket or stilling basin for energy dissipation, and open channel spillways. As described for Watana, the selection of the type of spillway was influenced by the general arrangement of the major structures. The main spillway facilities would discharge the spillway design flood through a gated spillway control structure with energy dissipation by a flip bucket which directs the spillway discharge in a free fall jet into a plunge pool in the river. As noted above, restrictions with respect to limiting nitrogen supersaturation in selecting acceptable spillway discharge structures have been applied. The various spillway arrangements developed in accordance with these considerations are discussed in Section 2.5.

(g) Power Facilities Alternatives

The selection of the optimum arrangements for the power facilities involved consideration of the same factors as described for Watana.

(i) Comparison of Surface and Underground Powerhouses

A surface powerhouse at Devil Canyon would be located either at the downstream toe of the dam or along the side of the canyon wall. As determined for Watana, costs favored an underground arrangement. In addition to cost, the underground powerhouse layout has been selected based on the following:

- Insufficient space is available in the steep-sided canyon for a surface powerhouse at the base of the dam;

- The provision of an extensive intake at the crest of the arch dam would be detrimental to stress conditions in the arch dam, particularly under earthquake loading, and would require significant changes in the arch dam geometry; and

- The outlet facilities located in the arch dam are designed to discharge directly into the river valley; these would cause significant winter icing and spray problems to any surface structure below the dam.

(ii) Comparison of Alternative Locations

The underground powerhouse and related facilities have been located on the north bank for the following reasons:

- Generally superior rock quality at depth;

- The south bank area behind the main dam thrust block is unsuitable for the construction of the power intake; and

- The river turns north downstream from the dam, and hence the north bank power development is more suitable for extending the tailrace tunnel to develop extra head.

(iii) Selection of Units

The turbine type selected for the Devil Canyon development is governed by the design head and specific speed and by economic considerations. Francis turbines have been adopted for reasons similar to those discussed for Watana in Section 2.2(g).

The selection of the number and rating of individual units is discussed in detail in Section 2.4(b). The four units will be rated to deliver 150 MW each at full gate opening and minimum reservoir level in December (the peak demand month).

(iv) Transformers

Transformer selection is similar to Watana (Section 2.2(g)(v)).

(v) Power Intake and Water Passages

For flexibility of operation, individual penstocks are provided to each of the four units. Detailed cost studies showed that there is no significant cost advantage in using two larger diameter penstocks with bifurcation at the powerhouse compared to four separate penstocks.

A single tailrace tunnel with a length of 6,800 feet to develop 30 feet of additional head downstream from the dam has been incorporated in the design. Detailed design may indicate that two smaller tailrace tunnels for improved reliability may be superior to one large tunnel since the extra cost involved is relatively small. The surge chamber design would be essentially the same with one or two tunnels.

The overall dimensions of the intake structure are governed by the selected diameter and number of the penstocks and the minimum penstock spacing. Detailed studies comparing construction cost to the value of energy lost or gained were carried out to determine the optimum diameter of the penstocks and the tailrace tunnel.

(vi) Environmental Constraints

In addition to potential nitrogen-saturation problems caused by spillway operation, the major impacts of the Devil Canyon power facilities development are:

- Changes in the temperature regime of the river; and
- Fluctuations in downstream river flows and levels.

Temperature modeling has indicated that a multiple level intake design at Devil Canyon would aid in controlling downstream water temperatures.

Consequently, the intake design at Devil Canyon incorporates two levels of draw-off.

The Devil Canyon station will normally be operated as a base-loaded plant throughout the year to satisfy the requirement of no significant daily variation in power flow.

2.5 Selection of Devil Canyon General Arrangement

The approach to selection of a general arrangement for Devil Canyon was a similar but simplified version of that used for Watana.

(a) Selection Methodology

Preliminary alternative arrangements of the Devil Canyon project were developed and selected using two rather than three review stages. Topographic conditions at this site limited the development of reasonably feasible layouts, and four schemes were initially developed and evaluated. During the final review, the selected layout was refined based on technical, operational and environmental considerations identified during the preliminary review.

(b) Design Data and Criteria

The design data and design criteria on which the alternative layouts were based are presented in Table B.33. Subsequent to selection of the preferred Devil Canyon scheme, the information was refined and updated as part of the on-going study program.

(c) Preliminary Review

Consideration of the options available for types and locations of various structures led to the development of four primary layouts for examination at Devil Canyon in the preliminary review phase. Previous studies had led to the selection of a thin concrete arch structure for the main dam, and indicated that the most acceptable technical and economic location was at the upstream entrance to the canyon. The dam axis has been fixed in this location for all alternatives.

(i) Description of Alternative Schemes

The schemes evaluated during the preliminary review are described below. In each of the alternatives evaluated, the dam is founded on the sound bedrock underlying the riverbed. The structure is 635 feet high, has a crest width of 20 feet, and a maximum base width of 90 feet. Mass concrete thrust blocks are founded high on the abutments, the south block extending approximately 100 feet above the existing bedrock surface and supporting the upper arches of the dam. The thrust block on the north abutment makes the cross-river profile of the dam more symmetrical and contributes to a more uniform stress distribution.

- Scheme DC1 (Figure B.37)

  In this scheme, diversion facilities comprise upstream and downstream earthfill and rockfill cofferdams and two 24-foot-diameter tunnels beneath the south abutment.

  A rockfill saddle dam occupies the lower lying area beyond the south abutment running from the thrust block to the higher ground beyond. The impervious fill cut-off for the saddle dam is founded on bedrock approximately 80 feet beneath the existing ground surface. The maximum height of this dam above the foundation is approximately 200 feet.

  The routed 1:10,000-year design flood of 165,000 cfs is passed by two spillways. The main spillway is located on the north abutment. It has a design discharge of 120,000 cfs, and flows are controlled by a three-gated ogee control structure. This discharges down a concrete-lined chute and over a flip bucket which ejects the water in a diverging jet into a pre-excavated plunge pool in the riverbed. The flip bucket is set at Elevation 925, approximately 35 feet above the river level. An auxiliary spillway discharging a total of 35,000 cfs is located in the center of the dam, 100 feet below the dam crest, and is controlled by three wheel-mounted gates. The orifices are designed to direct the flow into a concrete-lined plunge pool just downstream from the dam.

  An emergency spillway is located in the sound rock south of the saddle dam. This is designed to pass discharges in excess of the 1:10,000-year flood up to a probable maximum flood of 345,000 cfs, if such an event should ever occur. The spillway is an unlined rock channel which discharges into a valley downstream from the dam leading into the Susitna River.

  The upstream end of the channel is closed by an earth-fill fuse plug. The plug is designed to be eroded if overtopped by the reservoir. Since the crest is lower than either the main or saddle dams, the plug would be washed out prior to overtopping of either of these structures.

  The underground power facilities are located on the north bank of the river, within the bedrock forming the dam abutment. The rock within this abutment is of better quality with fewer shear zones and a lesser degree of jointing than the rock on the south side of the canyon, and hence more suitable for underground excavation.

The power intake is located just upstream from the bend in the valley before it turns sharply to the right into Devil Canyon. The intake structure is set deep into the rock at the downstream end of the approach channel. Separate penstocks for each unit lead to the powerhouse.

The powerhouse contains four 150 MW turbine/generator units. The turbines are Francis type units coupled to overhead umbrella type generators. The units are serviced by an overhead crane running the length of the powerhouse and into the end service bay. Offices, the control room, switchgear room, maintenance room, etc., are located beyond the service bay. The transformers are housed in a separate upstream gallery located above the lower horizontal section of the penstocks. Two vertical cable shafts connect the gallery to the surface. The draft tube gates are housed above the draft tubes in separate annexes off the main powerhall. The draft tubes converge in two bifurcations at the tailrace tunnels which discharge under free-flow conditions to the river. Access to the powerhouse is by means of an unlined tunnel leading from an access portal on the north side of the canyon.

The switchyard is located on the south bank of the river just downstream from the saddle dam, and the power cables from the transformers are carried to it across the top of the dam.

- <u>Scheme DC2</u> (Figure B.38)

The layout is generally similar to Scheme DC1 except that the chute spillway is located on the south side of the canyon. The concrete-lined chute terminates in a flip bucket high on the south side of the canyon which drops the discharges into the river below. The design flow is 120,000 cfs, and discharges are controlled by a 3-gated, ogee-crested control structure similar to that for Scheme DC1 which abuts the south side thrust block.

The saddle dam axis is straight, following the shortest route between the control structure at one end and the rising ground beyond the low-lying area at the other.

- Scheme DC3 (See Figure B.39)

  The layout is similar to Scheme DC1 except that the north side main spillway takes the form of a single tunnel rather than an open chute. A 2-gated, ogee--control structure is located at the head of the tunnel and discharges into an inclined shaft 45 feet diameter at its upper end. The structure will discharge up to a maximum of 120,000 cfs.

  The concrete-lined tunnel narrows to 35 feet diameter and discharges into a flip bucket which directs the flows in a jet into the river below as in Scheme DC1.

  An auxiliary spillway is located in the center of the dam and an emergency spillway is excavated on the south abutment.

  The layout of dams and power facilities are the same as for Scheme DC1.

- Scheme DC4 (See Figure B.40)

  The dam, power facilities, and saddle dam for this scheme are the same as those for Scheme DC1. The major difference is the substitution of a stilling-basin type spillway on the north bank for the chute and flip bucket. A 3-gated, ogee-control structure is located at the end of the dam thrust block and controls the discharges up to a maximum of 120,000 cfs.

  The concrete-lined chute is built into the face of the canyon and discharges into a 500-foot-long by 115-foot-wide by 100-foot-high concrete stilling basin formed below river level and deep within the north side of the canyon. Central orifices in the dam and the south bank rock channel and fuse plug form the auxiliary and emergency spillways, respectively, as in the other alternative schemes.

  The downstream cofferdam is located beyond the stilling basin and the diversion tunnel outlets are located farther downstream to enable construction of the stilling basin.

(ii) Comparison of Alternatives

The arch dam, saddle dam, power facilities, and diversion vary only in a minor degree among the four alternatives. Thus, the comparison of the schemes rests solely on a comparison of the spillway facilities.

As can be seen from a comparison of the costs in Table B.34, the flip bucket spillways are substantially less costly to construct than the stilling-basin type of Scheme DC4. The south side spillway of Scheme DC2 runs at a sharp angle to the river and ejects the discharge jet from high on the canyon face toward the opposite side of the canyon. Over a longer period of operation, scour of the heavily jointed rock could cause undermining of the canyon sides and their subsequent instability. The possibility also exists of deposition of material in the downstream riverbed with a corresponding elevation of the tailrace. Construction of a spillway on the steep south side of the river could be more difficult than on the north side because of the presence of deep fissures and large unstable blocks of rock which are present on the south side close to the top of the canyon.

The two north side flip bucket spillway schemes, based on either an open chute or a tunnel, take advantage of a downstream bend in the river to discharge parallel to the course of the river. This will reduce the effects of erosion but could still present a problem if the estimated maximum possible scour hole would occur.

The tunnel type spillway could prove difficult to construct because of the large diameter inclined shaft and tunnel raralleling the bedding planes. The high velocities encountered in the tunnel spillway could cause problems with the possibility of spiraling flows and severe cavitation both occuring.

The stilling basin type spillway of Scheme DC4 reduces downstream erosion problems within the canyon. However, cavitation could be a problem under the high-flow velocities experienced at the base of the chute. This would be somewhat alleviated by aeration of the flows. There is, however, little precedent for stilling basin operation at heads of over 500 feet; even where floods of much less than the design capacity have been discharged, severe damage has occurred.

(iii) Selection of Final Scheme

The chute and flip bucket spillway of Scheme DC2 could generate downstream erosion problems which could require considerable maintenance costs and cause reduced efficiency in operation of the project at a future date. Hydraulic design problems exist with Scheme DC3 which may also have severe cavitation problems. Also, there is no cost advantage in Scheme DC3 over the open chute Scheme DC1. In Scheme DC4, the operating characteristics of a high head stilling basin are little known, and there are few examples of successful operation. Scheme DC4 also costs considerably more than any other scheme (Table B.30).

All spillways operating at the required heads and discharges will eventually cause some erosion. For all schemes, the use of solid cone valve outlet facilities in the lower portion of the dam to handle floods up to 1:50-year frequency is considered a more reasonable approach to reduce erosion and eliminate nitrogen supersaturation problems than the gated high level orifice outlets in the dam. Since the cost of the flip bucket type spillway in the scheme is considerably less than that of the stilling basin in Scheme DC4, and since the latter offers no relative operational advantage, Scheme DC1 has been selected for further study as the selected scheme.

(d) Final Review

The layout selected in the previous section was further developed in accordance with updated engineering studies and criteria. The major change compared to Scheme DC1 is the elimination of the high level gated orifices and introduction of low level fixed-cone valves, but other modifications that were introduced are described below.

The revised layout is shown on Figure B.41. A description of the structures is as follows.

(i) Main Dam

The maximum operating level of the reservoir was raised to Elevation 1455 in accordance with updated information relative to the Watana tailwater level. This requires raising the dam crest to Elevation 1463 with the concrete parapet wall crest at Elevation 1466. The saddle dam was raised to Elevation 1472.

(ii) Spillways and Outlet Facilities

To eliminate the potential for nitrogen supersaturation problems, the outlet facilities were designed to restrict supersaturated flow to an average recurrence interval of greater than 50 years. This led to the replacement of high level gated orifice spillway by outlet facilities incorporating 7 fixed-cone valves, 3 with a diameter of 90 inches and 4 with a diameter of 102 inches, capable of passing a design flow of 38,500 cfs.

The chute spillway and flip bucket are located on the north bank, as in Scheme DC1; however, the chute length was decreased and the elevation of the flip bucket raised compared to Scheme DC1.

More recent site surveys indicated that the ground surface in the vicinity of the saddle dam was lower than originally estimated. The emergency spillway channel was relocated slightly to the south to accommodate the larger dam.

(iii) Diversion

The previous twin diversion tunnels were replaced by a single-tunnel scheme. This was determined to provide all necessary security and will cost approximately one-half as much as the two-tunnel alternative.

(iv) Power Facilities

The drawdown range of the reservoir was reduced, allowing a reduction in height of the power intake. In order to locate the intake within solid rock, it has been moved into the side of the valley, requiring a slight rotation of the water passages, powerhouse, and caverns comprising the power facilities.

2.6 - Selection of Access Road Corridor

(a) Previous Studies

The potential for hydroelectric power generation within the Susitna Basin has been the subject of considerable investigation over the years as is described in Section 1.1 of this exhibit. These studies produced much information on alternative development plans but little on the question of access.

The first report to incorporate an access plan was that of the Corps of Engineers in 1975. The proposed plan consisted of a 24 foot-wide road with a design speed of 30 miles per hour that connected with the Parks Highway near Chulitna Station, paralleled the Alaska railroad south and east to a crossing of the Susitna River then proceeded up the south side of the river to Devil Canyon. The road continued on the south side of the Susitna River to Watana, passing by the north end of Stephan Lake and the west end of the Fog Lakes. In addition a railhead facility was to be constructed at Gold Creek. This plan is similar to one of the selected alternative plans, Plan 16 (South), discussed later in this section.

Other studies concerning the Susitna Hydroelectric Project mentioned access only in passing and did not involve the development of an access plan.

(b) Selection Process Constraints

Throughout the development, evaluation and selection of the access plans the foremost objective has been 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 is evident that no one plan will satisfy all interests. The aim during the selection process has been to consider all factors in their proper perspective and produce a plan that represents the most favorable solution to meeting both project related goals and minimizing impacts to the environment and surrounding communities.

(c) Corridor Identification and Selection

Three general corridors were identified leading from the existing transportation network to the damsites. This network consists of the 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 B.42.

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 eighteeen 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.

(d) 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
- Pre-construction of a pioneer road.

During evaluation of the access plans, input from the public agencies and Native organizations was sought and their response resulted in an expansion of the original list of eight alternative plans to eleven. These studies culminated in the production of the Access Route Selection Report (15) which recommended Plan 5 as the route which most closely satisfies the selection criteria. Plan 5 starts from the Parks Highway near Hurricane and traverses southeast 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 pioneer road along this route prior to the FERC license being issued.

In March of 1982 the Alaska Power Authority presented the results of the Susitna Hydroelectric Feasiblity Report (4), 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 Alaska Power Authority (APA) formulated a further plan, thus increasing the total number of plans under evaluation to eighteen. This subsequently became the plan recommended by APA staff to the APA Board or Directors, and was formally adopted as the Proposed Access Plan in September 1982.

(e) Evaluation of Plans

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

- No pre-license construction
- Minimize environmental impacts
- Minimize construction duration
- 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
- Accommodate current land uses and plans
- Accommodate Agency preferences
- Accommodate preferences of Native organizations
- Accommodate preferences of local communities
- 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.

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 eliminated six plans (plans 2, 5, 8, 9, 10, 12) from further consideration.

On 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 activites 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, 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 B.43 through B.45.

(i) Plan 13 'North' (see Figure B.43)

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. This route is mountainous and includes terrain at high elevations. In addition extensive sidehill cutting in the region of Portage Creek will be necessary, however construction of the road would not be as difficult as Plan 16.

(ii) Plan 16 'South' (see Figure B.44)

This route generally parallels the Susitna River, travelling west to east form a railhead at Gold Creek to the Devil Canyon damsite, and continues following a southerly loop to the Watana damsite. Twelve miles downstream of the Watana damsite a temporary low level crossing across the Susitna River wil be used until completion of a permanent bridge. 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 Gold Creek to Devil Canyon 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.

(iii) Plan 18 'Denali-North' (see Figure B.45)

This route originates at a railhead in Cantwell, utilizing the existing Denali Highway to a point 21 miles east of the junction of the George Parks and Denali highways. A new road will be constructed from this point due south to the Watana damsite. The majority of the new road will traverse relatively flat terrain which will 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 will 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 Watana damsite and the existing highway system a connecting road will be constructed from the Devil Canyon railhead following a northerly loop to the Watana damsite. Access to the north side of the Susitna River will be attained via a high level suspension bridge constructed approximately one mile downstream of the Devil Canyon dam. In general the alignment crosses terrain with gentle to moderate slopes which will allow roadbed construction without deep cuts.

(f) Comparison of the Selected Alternative Plans

To determine which access plan best accommodates both project related goals and the concerns of the resource agencies, Native organizations and affected communitites, the three selected alternative plans were subjected to a multi-disciplinary evaluation and comparison. The key issues addressed in this evaluation and comparison were:

(i) Costs

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 approximately equal. 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.

(ii) 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 compression of on-site 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 will 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 material to the site has a distinct advantage. The forecasted construction period, including mobilization, for the three plans is:

Denali-North	6 months;
North	9 months; and
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 hence 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 B.46.

(iii) Environmental Issues

Outlined below are the key environmental impacts which have been identified for the three routes. The specific mitigaton measures necessary to avoid, minimize or compensate for these impacts are discussed in Exhibit E.

- 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 Devils 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.

The three access plans are made up of the following combinations of route segments:

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

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 due to 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. Although the Denali-North Plan has the potential for disturbances of caribou, brown bear and black bear concentrations and movement zones, it is considered that the potential for adverse impacts with the South Plan is greater.

- Fisheries

All three alternative routes would have direct and indirect impacts on the fisheries. Direct impacts include the affects 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 degrees 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 twenty streams and laterally transits four rivers for a total distance of approximately twelve 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 four miles to the east. The number of streams crossed is consequently reduced to twelve, and the number of lateral transits is reduced to two with a total distance of four 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 due to the proximity of the access road. The segment crosses both the Susitna and the Talkeetna watershed. 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 twenty-two 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 ten 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 eleven streams and laterally transits two rivers for a total distance of five miles. There is no anadromous fish spawning in this segment and little direct or indirect impact is expected.

The three alternative access routes are comprised of 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 watershed 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 also occur in the Gold Creek to Devil Canyon segment 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 due to water quality impacts through increased erosion and due to 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 areas and the design of bridges and culverts for the proposed access plan together with mitigation recommendations are discussed in Exhibit E.

(iv) Cultural Resources

A level one 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 Devils 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 resources 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.

(v) Socioeconomics

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.

- 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.

- 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.

- 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.

- Gold Creek: With the South Plan a railhead facility would be developed at Gold Creek creating a significant increase in socioeconomic 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 affected public's responses to these potential changes are mixed. The people of Cantwell are generally in favor of some economic stimulus and development in their community. Residents of Trapper Creek and Talkeetna have indicated that rapid, uncontrolled change is not desired. This and other feedback to date indicates 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.

(vi) Preferences of Native Organizations

The Tyonek Native Corporation, Cook Inlet Region Inc. (CIRI) and the CIRI Village residents all prefer the South Plan since it provides full road access to their lands south of the Susitna River. The Ahtna Native Region Corporation and the Cantwell Village Corporation support the Denali-North Plan. None of the Native Organizations support the North Plan.

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

Much of the 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 inaccesible, 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.

(g) Summary

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 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 necessary 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.

(h) Final Selection of Plan

(i) 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 twelve miles downstream of 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.

(ii) 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 sub arctic 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 5 months, and at most 6 months.

The forecasted construction period including mobilization is 6 months for the Denali-North Plan and 9 months for the North. At first glance a difference in schedule of 3 months does not seem great, however when considering that only 6 months of the year are available for construction the additional 3 months become highly significant.

If diversion is not achieved prior to spring runoff in 1987, dam foundation preparation work will be delayed one year, and hence cause a delay to the overall project of one year.

(iii) Cost Impacts

The increase in costs resulting from a one year delay have been estimated to be in the range of 100-200 million. 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.

(iv) Summary

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 is that winter construction, although difficult, would cause no significant delay for the route traverses relatively flat terrain for 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 enhance the probability of schedule delay.

(v) 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 overuns is too high with any other route.

(vi) Environmental Concerns - Recommended Plan

The main disadvantage of the Denali-North route is that it has a higher potential for adverse environmental impacts than the North route alternative. These impacts have been identified and following close consultation with environmental subconsultants many of the impacted areas have been avoided by both careful alignment of the road, and the development of design criteria which do not detract from the semi-wilderness character of the area. Some environmental impacts and conflicts are unavoidable however, and where these impacts occur, specific mitigation measures have been developed to reduce them to a minimum. These measures are outlined in detail within the relevant sections of Exhibit E.

2.7 - Selection of Transmission Facilities

The objective of this section is to describe the studies performed to select a power delivery system from the Susitna River basin generating plants to the major load centers in Anchorage and Fairbanks. This system will be comprised of transmission lines, substations, a dispatch center, and means of communications.

The major topics of the transmission studies include:

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

(a) Electric System Studies

Transmission planning criteria were developed to ensure the design of a reliable and economic electrical power system, with components rated to allow a smooth transition through early project stages to the ultimate developed potential.

Strict application of optimum, long-term criteria would require the installation of equipment with ratings larger than necessary at excessive cost. In the interest of economy and long-term system performance, these criteria were temporarily relaxed during the early development stages of the project. Although allowing for satisfactory operation during early system development, final system parameters must be based on the ultimate Susitna potential.

The criteria are intended to ensure maintenance of rated power flow to Anchorage and Fairbanks during the outage of any single line or transformer element. The essential features of the criteria are:

- Total power output of Susitna to be delivered to one or two stations at Anchorage and one at Fairbanks;

- "Breaker-and-a-half" switching station arrangements;

- Overvoltages during line energizing not to exceed specified limits;

- System voltages to be within established limits during normal operation;

- Power delivered to the loads to be maintained and system voltages to be kept within established limits for system operation under emergency conditions;

- Transient stability during a 3-phase line fault cleared by breaker action with no reclosing; and

- Where performance limits are exceeded, the most cost effective corrective measures are to be taken.

(i) Existing System Data

Data compiled in a report by Commonwealth Associates Inc. (16) has been used for preliminary transmission system analysis. Other system data were obtained in the form of single-line diagrams from the various utilities.

(ii) Power Transfer Requirements

The Susitna transmission system must be designed to ensure the reliable transmission of power and energy generated by the Susitna Hydroelectric Project to the load centers in the Railbelt area. The power transfer requirements of this transmission system are determined by the following factors:

- System demand at the various load centers;
- Generating capabilities at the Susitna project; and
- Other generation available in the Railbelt area system.

Most of the electric load demand in the Railbelt area is located in and around two main centers: Anchorage and Fairbanks. The largest load center is Anchorage, with most of its load concentrated in the Anchorage urban area. The second largest load center is Fairbanks. Two small load centers (Willow and Healy) are located along the Susitna transmission route. The only other significant load centers in the Railbelt region are Glennallen and Valdez, however, their combined demand is expected to be less than 2 percent of the total Railbelt demand in the foreseeable future. A survey of past and present load demand levels as well as various forecasts of future trends indicates these approximate load levels at the various centers.

Load Area	Percent of Total Railbelt Load
Anchorage - Cook Inlet	78
Fairbanks - Tanana Valley	20
Glennallen - Valdez	2

Considering the geographic location and the currently projected magnitude of the total load in the area, transmission to Glennallen-Valdez is not likely to be economical in the foreseeable future. If it is ever to be economical at all, it would likely be a direct radial extension, either from Susitna or from Anchorage. In either case, its relative magnitude is too small to have significant influence on either the viability or development characteristics of the Susitna project or the transmission from Susitna to the Anchorage and Fairbanks areas.

Accordingly, it has been assumed for study purposes that approximately 80 percent of the generation at Susitna will be transmitted to the Anchorage area and 20 percent to Fairbanks. To account for the uncertainties in future local load growth and local generation development, the Susitna transmission system was designed to be able to transmit a maximum of 85 percent of Susitna generation to Anchorage and a maximum of 25 percent to Fairbanks.

The potential of the Susitna Hydroelectric Project is expected to be developed in three or four stages as the system load grows over the next two decades. The transmission system must be designed to serve the ultimate Susitna development, but staged to provide reliable transmission at every intermediate stage. Present plans call for three stages of Susitna development: 680 MW at Watana in January 1994 followed by an additional 340 MW in July 1994; and, 600 MW at Devil Canyon in 2002.

Development of other generation resources could alter the geographic load and generation sharing in the Railbelt, depending on the location of this development. However, current studies indicate that no other very large projects are likely to be developed until the full potential of the Susitna project is utilized. The proposed transmission configuration and design should, therefore, be able to satisfy the bulk transmission requirements for at least the next two decades. The next major generation development after Susitna will then require a transmission system determined by its own magnitude and location.

The resulting power transfer requirements for the Susitna transmission system are indicated in Table B.35.

(iii) Transmission Alternatives

Because of the geographic location of the various centers, transmission from Susitna to Anchorage and Fairbanks will result in a radial system configuration. This allows significant freedom in the choice of transmission voltages, conductors, and other parameters for the two line sections, with only limited dependence between them. Transmission alternatives were developed for each of the two system areas, including voltage levels, number of circuits required, and other parameters, to satisfy the necessary transmission requirements of each area.

To maintain a consistency with standard ANSI voltages used in other parts of the United States, the following voltages were considered for Susitna transmission:

o Watana to Devil Canyon and on to Anchorage: 500 kV or 345 kV

o Devil Canyon to Fairbanks: 345 kV or 230 kV

- Susitna to Anchorage

Transmission at either of two different voltage levels (345 kV or 500 kV) could reasonably provide the necessary power transfer capability over the distance of approximately 140 miles between Devil Canyon and Anchorage. The required transfer capability of 1,377 MW is 85 percent of the ultimate generating capacity of 1,620 MW. At 500 kV, two circuits would provide more than adequate capacity. At 345 kV, either three circuits uncompensated or two circuits with series compensation are required to provide the necessary reliability for the single contingency outage criterion. At lower voltages, an excessive number of parallel circuits are required, while above 500 kV, two circuits are still needed to provide service in the event of a line outage.

- Susitna to Fairbanks

Applying the same reasoning used in choosing the transmission alternatives to Anchorage, two circuits of either 230 kV or 345 kV were chosen for the section from Devil Canyon to Fairbanks. The 230 kV alternative requires series compensation to satisfy the planning criteria in case of a line outage.

- Total System Alternatives

The transmission section alternatives mentioned above were combined into five realistic total system alternatives. Three of the five alternatives have different voltages for the two sections. The principal parameters of the five transmission system alternatives analyzed in detail are as follows:

	Susitna to Anchorage		Susitna to Fairbanks	
Alternative	Number of Circuits	Voltage (kV)	Number of Circuits	Voltage (kV)
1	2	345	2	345
2	3	345	2	345
3	2	345	2	230
4	3	345	2	230
5	2	500	2	230

Electric system analyses, including simulations of line energizing, load flows of normal and emergency operating conditions, and transient stability performance, were carried out to determine the technical feasibility of the various alternatives. An economic comparison of transmission system life cycle costs was carried out to evaluate the relative economic merits of each alternative. All five transmission alternatives were found to have acceptable performance characteristics. The most significant difference was that single-voltage systems (345 kV, Alternatives 1 and 2) and systems without series compensation (Alternative 2) offered reduced complexity of design and operation and therefore were likely to be marginally more reliable. The present-worth life cycle costs of Alternatives 1 through 4 were all within one percent of each other. Only the cost of the 500/230 kV scheme (Alternative 5) was 14 percent above the others. A summary of the life cycle cost analyses for the various alternatives is shown in Table B.36.

A technical and economic comparison was also carried out to determine possible advantages and disadvantages of HVDC transmission, as compared to an ac system, for transmitting Susitna power to Anchorage and Fairbanks. HVDC transmission was found to be technically and operationally more complex as well as having higher life cycle costs.

(iv) Configuration at Generation and Load Centers

Interconnections between generation and load centers and the transmission system were developed after reviewing the existing system configurations at both Anchorage and Fairbanks as well as the possibilities and current development plans in the Susitna, Anchorage, Fairbanks, Willow, and Healy areas.

- Susitna Configuration

  Preliminary development plans indicated that the first project to be constructed would be Watana with an initial installed capacity of 680 MW, to be increased to 1020 MW in the second development stage. The next project, and the last to be considered in this study, would be Devil Canyon, with an installed capacity of 600 MW.

- Switching at Willow

  Transmission from Susitna to Anchorage is facilitated by the introduction of an intermediate switching station. This has the effect of reducing line energizing overvoltages and reducing the impact of line outages on system stability. Willow is a suitable location for this intermediate switching station; in addition, it would make it possible to supply local load when this is justified by development in the area. This local load is expected to be less than 10 percent of the total Railbelt area system load, but the availability of an EHV line tap would definitely facilitate future power supply.

- Switching at Healy

  A switching station at Healy was considered early in the analysis but was found to be unnecessary to satisfy the planning criteria. The predicted load at Healy is small enough to be supplied by local generation and the existing 138 kV transmission from Fairbanks.

- Anchorage Configuration

  Analysis of system configuration, distribution of loads, and development in the Anchorage area led to the conclusion that a transformer station near Palmer would be of little benefit. Most of the major loads are concentrated in and around the urban Anchorage area at the mouth of Knik Arm. In order to reduce the length of subtransmission feeders, the transformer stations should be located as close to Anchorage as possible.

The routing of transmission into Anchorage was chosen from the following three possible alternatives:

- Submarine Cable Crossing From Point MacKenzie to Point Woronzof

  This would require transmission through a very heavily developed area. It would also expose the cables to damage by ships' anchors, which has been the experience with existing cables, resulting in questionable transmission reliability.

- Overland Route North of Knik Arm via Palmer

  This may be most economical in terms of capital cost in spite of the long distance involved. However, approval for this route is unlikely since overhead transmission through this developed area is considered environmentally unacceptable. A longer overland route around the developed area is considered unacceptable because of the mountainous terrain.

- Submarine Cable Crossing of Knik Arm, In the Area of Lake Lorraine and Six Mile Creek

  This option, approximately parallel to the new 230 kV cable under construction for Chugach Electric Association (CEA), includes some 3 to 4 miles of submarine cable and requires a high capital cost. Since the area is upstream from the shipping lanes to the port of Anchorage, it will result in a reliable transmission link, and one that does not have to cross environmentally sensitive conservation areas.

The third alternative is clearly the best of the three options.

With this configuration a different option is possible for the submarine cable crossing. To reduce cable costs the crossing could be constructed with two cable circuits plus one spare phase. This option requires a switching station at the west terminal of Knik Arm. A switching station at the west terminal would clearly require increased costs and complications for construction and operation as a result of poor access.

- Fairbanks Configuration

Susitna power for the Fairbanks area is recommended to be delivered to a single EHV/138 kV transformer station located at Ester. No alternatives were given detailed consideration.

(b) Corridor Selection

(i) Methodology

Development of the proposed Susitna project will require a transmission system to deliver electric power to the Railbelt area. The building of the Anchorage to Fairbanks Intertie system will result in a defined corridor and route for the Susitna transmission lines between Willow and Healy. Therefore, three areas require study for corridor selection: the northern area to connect Healy with Fairbanks; the central area to connect the Watana and Devil Canyon damsites with the Intertie; and the southern area to connect Willow with Anchorage.

Using the selection criteria discussed below, corridors 3 to 5 miles wide were selected in each of the three study areas. These corridors were then evaluated to determine which ones met the more specific screening criteria. This screening process resulted in one corridor in each area being designated as the recommended corridor for the transmission line.

(ii) Selection Criteria

Since the corridors studied range in width from three to five miles, the base criteria had to be applied in broad terms. The study also indicated that the criteria listed for technical purposes could reappear in the economic or environmental classification. The technical criteria were defined as requirements for the normal and safe performance of the transmission system and its reliability.

The selection criteria are in three categories, technical, economic and environmental. The criteria are listed in Table B.37.

(iii) Identification of Corridors

As discussed previously, the Susitna transmission line corridors studied are located in three geographical areas; namely:

- The southern study area between Willow and Anchorage.
- The central study area between Watana, Devil Canyon, and the Intertie.
- The northern study area between Healy and Fairbanks.

(iv) Description of Corridors

Figures B.47 through B.49 portray the corridors evaluated in the southern, central, and northern study areas, respectively. For purposes of simplification, only the centerline of the three-to-five-mile-wide corridors are shown in the figures.

In each of the three figures, each corridor under consideration has been identified by the use of letter symbols. The various segment intersections and the various segments, where appropriate, have been designated. Thus, segments in each of the three study areas can be separately referenced. Furthermore, the segments are joined together to form corridors. For example, in the northern study area Corridor ABC is composed of Segments AB and BC.

The alternative corridors selected for each study area are described in detail in the following paragraphs. In addition, Tables B.38, B.39 and B.40 contain detailed environmental data for each corridor segment.

- Southern Study Area

o Corridor One - Willow to Anchorage via Palmer

Corridor ABC', consisting of Segments AB and BC', begins at the intersection with the Intertie in the vicinity of Willow. From here, the corridor travels in a southeasterly direction, crossing wetlands, Willow Creek, and Willow Creek Road before turning slightly to the southeast following the drainage of Deception Creek. The topography in the vicinity of this segment of the corridor is relatively flat to gently rolling with standing water and tall-growing vegetation in the vicinity of the creek drainages.

At a point northwest of Bench Lake, the corridor turns in an easterly direction crossing the southern foothills of the Talkeetna Mountains. The topography here is gently to moderately rolling with shrub- to tree-sized vegetation occurring throughout. As the corridor approaches the crossing of the Little Susitna River, it turns and heads southeast again, crossing the Little Susitna River and Wasilla Fishhook Road.

Passing near Wolf Lake and Gooding Lake, the corridor then crosses a secondary road, some agricultural lands, State Route 3, and the Glenn Highway, before intersecting existing transmission lines south of Palmer. In the vicinity of the Little Susitna River, the topography is gently rolling. As the corridor travels toward Palmer, the land flattens, more lakes are present, and some agricultural development is occurring. After crossing the Glenn Highway, the corridor passes through a residential area before crossing the broad floodplain of the Matanuska River.

Just west of Bodenburg Butte, the corridor turns due south through more agricultural land before crossing the Knik River and eventually connecting with the Eklutna Power Station. All of the land south of Palmer is very flat with some agricultural development. Just south of Palmer, the proposed corridor intersects existing transmission facilities and parallels or replaces them from a point just south of Palmer, across the river, and into the vicinity of the Eklutna Power House. From here into Anchorage, the corridor as proposed would parallel existing facilities, crossing near or through the communities of Eklutna, Peters Creek, Birchwood, and Eagle River by using one of the two existing transmission line rights-of-way in this area. The land here is flat to gently rolling with a great deal of residential development. This corridor segment is the most easterly of the three considered in the southern study area and avoids an underwater crossing of Knik Arm.

o Corridor Two - Willow to Point MacKenzie via Red Shirt Lake

Corridor ADFC, consisting of Segments ADF and FC, commences again at the point of intersection with the Intertie in the vicinity of Willow; but immediately turns to the southwest, first crossing the railroad, then the Parks Highway, then Willow Creek just west of Willow. The land in the vicinity of this part of the segment is very flat, with wetlands dominating the terrain.

Southwest of Florence Lake, the proposed corridor turns, crosses Rolly Creek, and heads nearly due south, passing through extensive wetlands west and wetlands west and south of Red Shirt Lake. The corridor in this area parallels existing tractor trails crossing very flat lands with significant amounts of tall-growing vegetation in the better drained locations.

Northwest of Yohn Lake, the corridor segment turns to the southeast, passing Yohn Lake and My Lake before crossing the Little Susitna River. Just south of My Lake, the corridor turns in a generally southerly direction, passing Middle Lake, and east of Horseshoe Lake before finally intersecting the existing Beluga 230 kV transmission line at a spot just north of MacKenzie Point. From here, the corridor parallels MacKenzie Point's existing transmission facilities before crossing under Knik Arm to emerge on the easterly shore of Knik Arm in the vicinity of Anchorage. The land in the vicinity of this segment is extremely flat and very wet, supporting dense stands of tall-growing vegetation on any of the higher or better drained areas.

o <u>Corridor Three - Willow to Point MacKenzie via Lynx Lake</u>

Corridor AEFC is very similar to and is a derivation of Corridor ADFC; it consists of Segments AEF and FC. This corridor also extends to the southwest of Willow. West of the Parks Highway, however, just north of Willow Lake, this corridor turns and travels southwest of Willow and east of Long Lake, passing between Honeybee Lake and Crystal Lake. The corridor then turns southeastward to pass through wetlands east of Lynx Lake and Butterfly Lake before crossing the Little Susitna River. The land is well developed in this area. It is very flat and, while it is wet, also supports dense stands of tall growing vegetation on the better drained sites. Corridor Three rejoins Corridor Two at a point south of My Lake.

- <u>Central Study Area</u>

The central study area encompasses a broad area in the vicinity of the damsites. From Watana, the study area extends to the north as far as the Denali Highway and to the south as far as Stephan Lake. From this point westward, the study area encompasses the foothills of the Alaska Range and, to the south, the foothills of the Talkeetna Mountains. Included in this study area are lands under consideration by the Intertie Project investigators. The alternative corridors would connect both Devil Canyon and Watana dams with the Intertie at one of four locations, which are identified in Figure B.48.

As for the southern study area, individual corridor segments are listed in the text. This is to aid the reader both in determining corridor locations in the figures and in examining the environmental inventory data listed for each segment in Tables B.38, B.39, and B.40.

- Corridor One - Watana to Intertie via South Shore, Susitna River

  Corridor ABCD consists of three segments: AB, BC, and CD. This corridor originates at the Watana Dam site and follows the southern boundary of the river at an elevation of approximately 2,000 feet from Watana to Devil Canyon. From Devil Canyon, the corridor continues along the southern shore of the Susitna River at an elevation of about 1,400 feet to the point at which it connects with the Intertie, assuming the Intertie follows the railroad corridor. The land surface in this area is relatively flat, though incised at a number of locations by tributaries to the Susitna River. The relatively flat hills are covered by discontinuous stands of dense, tall-growing vegetation.

- Corridor Two - Watana to Intertie via Stephan Lake

  ABECD, the second potential corridor, is essentially a derivation of Corridor One and is formed by replacing Segments BC with BEC. Originating at Point B, Corridor Segment BEC leaves the river and generally parallels one of the proposed Watana Dam access road corridors. This corridor extends southwest from the river, passing near Stephan Lake to a point northwest of Daneka Lake. Here the route turns back to the northwest and intersects Corridor One at the Devil Canyon Dam site. The terrain in this area, again, is gently rolling hills with relatively flat benches. Vegetation cover ranges from sparse at the higher elevations to dense along the river bottom and along gentler slopes of the Susitna River and its tributaries.

o <u>Corridor Three - Watana to Intertie via North Shore, Susitna River</u>

Corridor Three (AJCF), located on the north side of the river, consists of Segments AJ and CF. Starting at the Watana Dam site, the corridor crosses Tsusena Creek and heads westerly, following a small drainage tributary to the Susitna River. Once crossing Devil Creek, the corridor passes north and west of High Lake.

The corridor stays below an elevation of 3,700 feet as it crosses north of the High Lake area, east of Devil Creek, on its approach to Devil Canyon. From Devil Canyon, the corridor again extends to the west, crossing Portage Creek and intersecting the Intertie in the vicinity of Indian River. In the drainages, to elevations of about 2,000 feet, tree heights range to 60 feet. Between Devil Creek and Tsusena Creek, however, at the higher elevations, very little vegetation grows taller than three feet. Once west of Devil Creek, discontinuous areas of tall-growing vegetation exist.

o <u>Corridor Four - Watana to Intertie via Devil Creek Pass/East Fork Chulitna River</u>

Another means of connecting the two dam schemes with the Intertie is to follow Corridor One from Watana to Devil Canyon and then exit the Devil Canyon project to the north (ABCJHI). This involves connecting Corridor Segments AB, BC, CJ, HJ, and HI. With this alternative, the corridor extends northeast at Devil Canyon past High Lake to Devil Creek drainage. From there, it moves northward to a point north of the south boundary of the Fairbanks Meridian. The corridor then follows the Portage Creek drainage beyond its point of origin to a site within the Tsusena Creek drainage. Likewise, it follows the Tsusena Creek drainage to a point near Jack River, at which point it parallels this drainage into Caribou Pass. From Caribou Pass, the corridor turns to the west, following the Middle Fork Chulitna River until meeting the Intertie in the vicinity of Summit Lake.

While along much of this corridor the route follows river valleys, the plan also requires crossing high mountain passes in rugged terrain. This is especially true in the crossing between Portage Creek and Tsusena Creek drainages, where elevations of over 4,600 feet are involved. Tall-growing vegetation is restricted to the lower elevations along the river drainages with little other than low-growing forbs and shrubs present at higher elevations.

- Corridor Five - Watana to Intertie via Stephan Lake and the East Fork Chulitna River

A variation of Corridor Four, Corridor Five (ABECJHI) replaces Segment BC with Corridor Segment BEC (of Corridor Two) with the previously described corridor. This results in a corridor that extends from the Watana Dam site southwesterly to the vicinity of Stephan Lake, and from Stephan Lake into the Devil Canyon Dam site. From Devil Canyon to the Intertie, the corridor follows the Devil Creek, Portage Creek, and Middle Fork Chulitna drainages previously mentioned. As before, the corridor crosses rolling terrain throughout the length of the paralleled drainages, with some confined, higher elevation passes encountered between Portage Creek and Tsusena Creek.

- Corridor Six - Devil Canyon to the Intertie via Tsusena Creek/Chulitna River

Another option (CBAHI) for connecting the dam projects to the Intertie involves connecting Devil Canyon and Watana along the south shore of the Susitna River via Corridor Segment CBA, then exiting Watana to the north on Segments AH and HI along Tsusena Creek to follow this drainage to Caribou Pass. The corridor then contains the previously described route along the Jack River and Middle Fork Chulitna until connecting with the Intertie near Summit Lake. The terrain in this corridor proposal would be of moderate elevation with some confined, higher elevation passes between the drainages of Tsusena Creek and the Jack River.

- Corridor Seven - Devil Canyon to Intertie via Stephan Lake and Chulitna River

This alternative uses Corridor Six but replaces Segment BC with Segment BEC from Corridor Two. This route would thus be designated CEBAHI. Terrain features are as described in Corridors Two and Six.

- Corridor Eight - Devil Canyon to Intertie via Deadman/Brushkana Creeks and Denali Highway

Yet another option to the previously described corridors is the interconnection of Devil Canyon with Watana via Corridor One (Segment CBA), with a segment then extending from Watana northeasterly along the Deadman Creek drainage (Segment AG). The segment proceeds north of Deadman Lake and Deadman Mountain, then turns to the west and intersects the Brushkana Creek drainage. It then follows Brushkana Creek north to a point east of the Kana Bench Mark. This segment of the corridor would parallel one of the proposed access roads. From there, the corridor turns west, generally parallel to the Denali Highway, to the point of interconnection with the Intertie in the vicinity of Cantwell. The area encompasses rolling hills with modest elevation changes and some forest cover, especially at the lower elevations.

- <u>Corridor Nine - Devil Canyon to Intertie via Stephan Lake and Denali Highway</u>

  Corridor Nine (CEBAG) is exactly the same as Corridor Eight with the exception of Corridor Segment BEC, utilized to replace Segment BC. Each combination of segments has been previously described.

- <u>Corridor Ten - Devil Canyon to Intertie via North Shore, Susitna River, and Denali Highway</u>

  Corridor Ten connects Devil Canyon-Watana with the Intertie in the vicinity of Cantwell by means of Corridor Segments CJAG. Segment CJA is part of Corridor Three and, as such, has been previously described. Segment AG has also been described above as part of Corridor Eight. As noted earlier, the Corridor Ten terrain consists of mountainous stretches with accompanying gently rolling to moderately rolling hills and flat plains covered in places with tall-growing vegetation.

- <u>Corridor Eleven - Devil Canyon to the Intertie via Tsusena Creek/Chulitna River</u>

  Another northern route connecting Devil Canyon with Watana is that created by connecting Corridor Segment CJA (part of Corridor Three) with Segment AHI of Corridor Six.

- <u>Corridor Twelve - Devil Canyon-Watana to the Intertie via Devil Creek/Chulitna River</u>

  Another route under consideration is Corridor JA-CJHI. From north to south, this involves a corridor extending from the Intertie near Summit Lake, heading easterly along the Middle Fork Chulitna drainage into Caribou Pass. From here, it parallels the Jack River and connects with the Portage Creek-Devil Creek route, Segment HJ. At point J, located in the Devil Creek drainage east of High Lake, the corridor splits, with one segment extending westerly to Devil Canyon and the other extending east to the Watana Dam site along previously described Corridor Segments JC and JA, respectively. Terrain features of this route have been previously described.

o <u>Corridor Thirteen - Watana to Devil Canyon via South Shore, Devil Canyon to Intertie via North Shore, Susitna River</u>

Corridor Segments AB, BC, and CF are combined to form this corridor. Descriptions of the terrain crossed by these segments appear in discussions of Corridor One (ABCD) and Corridor Three (AJCF).

o <u>Corridor Fourteen - Watana to Devil Canyon via North Shore, Devil Canyon to Intertie via South Shore, Susitna River</u>

This corridor would connect the damsites in the directionally opposite order of the previous corridor, and include Corridor Segment AJCD. Again, as parts of Corridors One and Three, the terrain features of this corridor have been previously described.

o <u>Corridor Fifteen - Watana to Devil Canyon via Stephan Lake, Devil Canyon to Intertie via North Shore, Susitna River</u>

Corridor Two (ABEC) and Corridor Three (CF) form to create this study-area corridor. Terrain features have been presented under the discussions of each of these two corridors.

- <u>Northern Study Area</u>

In the northern study area, four transmission line corridor options exist for connecting Healy and Fairbanks (Figure B.49).

o <u>Corridor One - Healy to Fairbanks via Parks Highway</u>

Corridor One (ABC), consisting of Segments AB and BC, starts in the vicinity of the Healy Power Plant. From here, the corridor heads northwest, crossing the existing Golden Valley Electric Association Transmission Line, the railroad, and the Parks Highway before turning to the north and paralleling this road to a point due west of Browne. Here, as a result of terrain features, the corridor turns northeast, crossing the Parks Highway once again as well as the existing transmission line, the Nenana River, and the railroad, and continues northeasterly to a point northeast of the Clear Missile Early Warning Station (MEWS).

Continuing northward, the corridor eventually crosses the Tanana River east of Nenana, then heads northeast, first crossing Little Goldstream Creek, then the Parks Highway just north of the Bonanza Creek Experimental Forest. Before reaching the drainage of Ohio Creek, this corridor turns back to the northeast, crossing the old Parks Highway and heading into the Ester Substation west of Fairbanks.

Terrain along this entire corridor segment is relatively flat, with the exception of the foothills north of the Tanana River. Much of the route, especially that portion between the Nenana and the Tanana River crossings, is very broad and flat, has standing water during the summer months and, in some places, is overgrown by dense stands of tall-growing vegetation. This corridor segment crosses the foothills northeast of Nenana, also a heavily wooded area.

An option to the above (and not shown in the figures), that of closely paralleling and sharing rights-of-way with the existing Healy-Fairbanks transmission line, has been considered. While it is usually attractive to parallel existing corridors wherever possible, this option necessitates a great number of road crossings and an extended length of the corridor paralleling the Parks Highway. A potentially significant amount of highway-abutting land would be usurped for containment of the right-of-way. These features, in combination, eliminated this corridor from further evaluation.

- Corridor Two - Healy to Fairbanks via Crossing Wood River

The second corridor (ABDC) is a variation of Corridor One and consists of Segments AB and BDC. At point B, east of the Clear MEWS, instead of turning north, the corridor continues to the northeast, crossing Fish

Creek, the Totatlanika River, Tatlanika Creek, the Wood River, and Crooked Creek before turning to the north. At a point equidistant from Crooked and Willow Creeks, the corridor turns north, crosses the Tanana River east of Hadley Slough, and extends to the Ester Substation. North of the Tanana River, this corridor segment also crosses Rose Creek and the Parks Highway.

Where it diverges from the original corridor, this corridor traverses extensive areas of flat ground, with standing water very prevalent throughout the summer months. Heavily wooded areas occur in the broad floodplain of the Tanana River, in the vicinity of the river crossing, and in the foothills around Rose Creek.

- Corridor Three - Healy to Fairbanks via Healy Creek and Japan Hills

Corridor Three (AEDC), consisting of Segments AE and EDC, exits the Healy Power Plant in an easterly direction. Instead of proceeding northwest, this corridor, following its interconnection with the Intertie Project, heads east up Healy Creek, passing the Usibelli Coal Mine. Near the headwaters of Healy Creek, the corridor cuts to the east, crossing a high pass of approximately 4,700 feet elevation and descending into the Cody Creek drainage. From Healy to the Cody Creek drainage, the terrain is relatively gentle but bounded by very rugged mountain peaks. The elevation gain from the Healy Power Plant to the pass between the Healy Creek-Cody Creek drainages is approximately 3,300 feet. From here, the segment turns to the northeast, following the lowlands accompanying the Wood River. The corridor next parallels the Wood River from the Anderson Mountain area, past Mystic Mountain, and out into the broad floodplain of the Tanana River east of Japan Hills. Near the confluence of Fish Creek and the Wood River, the corridor turns north and intersects the north-south portion of Corridor Two (Segment DC), after first passing through Wood River Buttes. Much of the area north of Japan Hills is flat and very wet with stands of dense, tall-growing vegetation.

o Corridor Four - Healy to Fairbanks via Wood River and Fort Wainwright

Corridor Four (AEF) is a derivation of Corridor Three and is composed of Segments AE and EF. Point E is located just north of Japan Hills along the Wood River. From here, the corridor deviates from Corridor Three by running north across the Blair Lake Air Force Range, Fort Wainwright, and several tributaries of the Tanana River, before reaching the crossing of Salchaket Slough. Corridor Four passes Clear Creek Butte on the east. A new substation would be located on the Fairbanks side of the Tanana River just north of Goose Island. From Point E to Point F, the terrain of the corridor is flat and very wet, and again, dense stands of tall-growing vegetation exist both in the better drained portions of the flat lands and in the vicinity of the river crossing.

(c) Corridor Screening

The objectives of the screening process were to focus on the previously selected corridors and select those best meeting technical, economic, and environmental criteria.

(i) Reliability

Reliability is an uncompromising factor in screening alternative transmission line corridors. Many of the criteria utilized for economic, environmental, and technical reasons also relate to the selection of a corridor within which a line can be operated with minimum power interruption. Six basic factors were considered in relation to reliability:

- Elevation: Lines located at elevations below 4,000 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 risks from collisions.
- Stability: Avoidance of areas susceptible to land, ice, and snow slides will reduce chance of power failures.
- Existing Power Lines: Avoidance of crossing existing transmission lines will reduce the possibility of lines touching during failures and will facilitate repairs.

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

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

(ii) Technical Screening Criteria

Four primary and two secondary technical factors were considered in the screening of alternative corridors.

- Primary Aspects:

  o Topography

  o Climate and Elevation

  Low temperatures, snow depth, icing, and severe winds are very important parameters in transmission design, operation, and reliability.

  Climatic factors become more severe in the mountains, where extreme winds are expected for exposed areas and passes. Alaska Power Administration believes that elevations above 4,000 feet in the Alaska Range and Talkeetna Mountains are completely unsuitable for locating major transmission facilities. Significant advantages of reliability and cost are expected if the lines are routed below 3,000 feet in elevation. This elevation figure was used in the screening process.

  o Soils

  Although transmission lines are less affected by soils and foundation limitations than railroads and pipelines, it is more reliable to build a transmission line on soil that does not appear to be underlain by seismically induced ground failures or on a swampy area where maintenance and inspection may create problems. These factors were utilized in the screening process. Because of the vast areas of wetlands in the study area, particularly in the southern portion, it was not possible to locate a corridor that would avoid all wetland areas.

o Length of Corridors

- Secondary Aspects:

o Vegetation and Clearing

Heavily forested areas must be cleared prior to construction of the transmission line. Clearing the vegetation will cause some disruption of the soil. If not properly stabilized through restoration and vegetation, increased erosion will result. If the vegetation is cleared up to river banks on stream crossings, it may result in additional sedimentation. During the corridor screening, those corridors crossing through large expanses of heavily timbered areas were eliminated.

o Other

Highway and river crossings were avoided as much as possible.

(iii) Economic Screening Criteria

Three primary and one secondary aspect of the economic criteria were considered.

- Primary Aspects:

o Length

o Right-of-Way

Whenever possible, existing rights-of-ways were shared or paraleled to avoid the problems associated with pioneering a corridor in previously inaccessible areas.

o Access Roads

- Secondary Aspects:

In addition to the major considerations concerning economic screening of corridors, some other aspects were also considered. These include topography, since it is more economical to build a line on a flat corridor than on a rugged or a mountainous one; and limiting the number of stream, river, highway, road, and railroad crossings in order to minimize costs.

(iv) Environmental Screening Criteria

Because of the potential, adverse environmental impacts from transmission line construction and operation, environmental criteria were carefully scrutinized in the screening process. Past experience has shown the primary environmental considerations to be:

- Aesthetic and Visual (including impacts to recreation)
- Land Use (including ownership and presence of existing rights-of-way)

Also of significance in the evaluation process are:

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

A description and rationale for use of these criteria are presented below:

- Primary Aspects:

  o Aesthetic and Visual

    The presence of large transmission line structures in undeveloped areas has the potential for adverse aesthetic impacts. Furthermore, the presence of these lines can conflict with recreational use, particularly those nonconsumptive recreational activities such as hiking and bird watching where great emphasis is placed on scenic values. The number of road crossings encountered by transmission line corridors is also a factor that needs to be inventoried because of the potential for visual impacts. The number of roads crossed, the manner in which they are crossed, the nature of existing vegetation at the crossing site (i.e., potential visual screening), and the number and type of motorists using the highway all influence the desirability of one corridor versus another. Therefore, when screening the previously selected corridors, consideration was focused on the presence of recreational areas, hiking trails, heavily utilized lakes, vistas, and highways where views of transmission line facilities would be undesirable.

o <u>Land Use</u>

The three primary components of land use considerations are: 1) land status/ownership, 2) existing rights-of-way, and 3) existing and proposed development.

- <u>Land/Status/Ownership</u>

  The ownership of land to be crossed by a transmission line is important because certain types of ownership present more restrictions than others. For example, some recreation areas such as state and federal parks and areas like game refuges and military lands, among others, present possible constraints to corridor routing. Private landowners generally do not want transmission lines on their lands. This information, when known in advance, permits corridor routing to avoid such restrictive areas and to occur in areas where land use conflicts can be minimized.

- <u>Existing Rights-of-Way</u>

  Paralleling existing rights-of-way tends to result in less environmental impact than that which is associated with a new right-of-way because the creation of a new right-of-way may provide a means of access to areas normally accessible only on foot. This can be a critical factor if it opens sensitive, ecological areas to all terrain vehicles.

Impact on soils, vegetation, stream crossings, and others of the inventory categories can also be lessened through the paralleling of existing access roads and cleared rights-of-way. Some impact is still felt, however, even though a right-of-way may exist in the area. For example, cultural resources may not have been identified in the original routing effort. Wetlands present under existing transmission lines may likewise be negatively influenced if ground access to the vicinity of the tower locations is required.

There are common occasions where paralleling an existing facility is not desirable. This is particularly true in the case of highways that offer the potential for visual impacts and in situations where paralleling a poorly sited transmission facility would only compound an existing problem.

. Existing and Proposed Developments

This inventory identifies such things as agricultural use; planned urban developments, such as the proposed capital site; existing residential and cabin developments; the location of airports and of lakes used for float planes; and similar types of information. Such information is essential for locating transmission line corridors appropriately, as it presents conflicts with these land use activities.

- Secondary Aspects:

o Length

The length of a transmission line is an environmental factor and, as such, was considered in the screening process. A longer line will require more construction activity than a shorter line, will disturb more land area, and will have a greater inherent probability of encountering environmental constraints.

o Topography

The natural features of the terrain are significant from the standpoint that they offer both positive and negative aspects to transmission line routing. Steep slopes, for example, present both difficult construction and soil stabilization problems with potentially long-term, negative environmental consequences. Also, ridge crossings have the potential for visual impacts. At the same time, slopes and elevation changes present opportunities for routing transmission lines so as to screen them from both travel routes and existing communities. When planning corridors then, the identification of changes in relief is an important factor.

- <u>Soils</u>

  Soils are important from several standpoints. First of all, scarification of the land often occurs during the construction of transmission lines. As a result, vegetation regeneration is affected, as are the related features of soil stability and erosion potential. In addition, the development and installation of access roads, where necessary, are very dependent upon soil types. Tower designs and locations are dictated by the types of soils encountered in any particular corridor segment. Consequently, the review of existing soils information is very significant. This inventory was conducted by means of a Soil Associations Table, Table B.41. Table B.42 presents the related definitions as they apply to the terms used in Table B.41.

- <u>Cultural Resources</u>

  The avoidance of known or potential sites of cultural resources is an important component of the routing of transmission lines. In planning for Susitna Project transmission lines, however, information on the presence of cultural resources is, for the most part, unavailable. An appropriate program for identifying and mitigating impacts of the finally selected route is necessary.

- <u>Vegetation</u>

  The consideration of the presence and location of various plant communities is essential in transmission line siting. The inventory of plant communities, such as those of a tall-growing nature or wetlands, is significant from the standpoint of construction, clearing, and access road development requirements. In addition, identification of locations of endangered and threatened plant species is also critical. While several Alaskan plant species are currently under review by the U.S. Fish and Wildlife Service, no plant species are presently listed under the Endangered Species Act of 1973 as occurring in Alaska. No corridor currently under consideration has been identified as traversing any location known to support these identified plant species.

- Fishery Resources

The presence or absence of resident or anadromous fish in a stream is a significant factor in evaluating suitable transmission line corridors. The corridor's effects on a stream's resources must be viewed from the standpoint of possible disturbance to fish species, potential loss of habitat, and possible destruction of spawning beds. In addition, certain species of fish are more sensitive than others to disturbance.

Closely related to this consideration is the number of stream crossings. The nature of the soils and vegetation in the vicinity of the streams and the manner in which the streams are to be crossed are also important environmental considerations when routing transmission lines. Potential stream degradation, impact on fish habitat through disturbance, and long-term negative consequences resulting from siltation of spawning beds are all concerns that need evaluation in corridor routing. Therefore, the number of stream crossings and the presence of fish species and habitat value were considered when data were available.

- Wildlife Resources

The three major groups of wildlife which must be considered in transmission corridor screening are big game, birds, and furbearers. Of all the wildlife species to be considered in the course of routing studies for transmission lines, big game species (together with endangered species) are most significant. Many of the big game species, including grizzly bear, caribou, and sheep, are particularly sensitive to human intrusion into relatively undisturbed areas. Calving grounds, denning areas, and other important or unique habitat areas as identified by the Alaska Department of Fish and Game were identified and incorporated into the screening process.

Many species of birds such as raptors and swans are sensitive to human disturbance. Identifying the presence and location of nesting raptors and swans permits avoidance of traditional nesting areas. Moreover, if this category is investigated, the presence of endangered species (viz, peregrine falcons) can be determined.

Important habitat for furbearers exists along many potential transmission line corridors in the railbelt area, and its loss or disruption would have a direct effect on these animal populations. Investigating habitat preferences, noting existing habitat, and identifying populations through available information are important steps in addressing the selection of environmentally acceptable alternatives.

(v) Screening Methodology

- Technical and Economical Screening Methodology

The parameters required for the technical and economical analyses were extracted from the environmental inventory tables (Tables B.38 through B.40). The tables, together with the topographic maps, aerial photos, and existing published materials, were used to compare the alternative corridors from a technical and economical point of view. The parameters used in the analysis were: length of corridors, approximate number of highway/road crossings, approximate number of river/creek crossings, land ownership, topography, soils, and existing rights-of-way. The main factors contributing to the economical and technical analyses are combined and listed in Tables B.43, B.44, and B.45. It should be noted that most of the parameters are in miles of line length, except the tower construction. In this analysis, it was decided to assign 4.5 towers for each mile of 345-kV line.

In order to screen the most qualified corridor, it was decided to rate the corridors as follows:

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

From the technical point of view, reliability, is the main objective. An environmentally and economically sound transmission line was rejected if the line was not reliable. Thus, any line which received an F technical rating, was assigned an overall rating of F and eliminated from further consideration.

The ratings appear in each of the economical and technical screening tables (Tables B.43, B.44, and B.45) and are summarized in Table B.46.

- Environmental Screening Methodology

In order to compare the alternative corridors (Figures B.47, B.48, and B.49) from an environmental standpoint, the environmental criteria discussed above were combined into environmental constraint tables (Tables B.47, B.48, and B.49). These tables combine information for each corridor segment into the proper corridors under study. This permitted the assignment of an environmental rating, which identifies the relative rating of each corridor within each of the three study areas. The assignment of environmental ratings is a subjective, qualitative technique intended as an aid to corridor screening. Those corridors that are recommended are identified with and "A," while those corridors that are acceptable but not preferred are identified with a "C." Finally, those corridors that are considered unacceptable are identified with an "F."

(d) Selected Corridor

The selected corridor consists of the following segements:

- Southern Study Area: Corridor ADFC (Figures B.50 and B.51)
- Central Study Area: Corridor ABCD (Figures B.52 and B.53)
- Northern Study Area: Corridor ABC (Figures B.54 through B.57)

Specifics of these corridors and reasons for rejection of others are discussed below. More detail on the screening process and the specific technical ratings of each alternative are in Chapter 10 of Exhibit E.

(i) Southern Study Area

In the southern study area, Corridor Segment AEF and, hence, Corridor Three (AEFC) were determined unacceptable. This results primarily from the routing of the segment through the relatively well-developed and heavily utilized Nancy Lake state recreation area. Adjustments to this route to make it more acceptable were attempted but no alterations proved successful. Consequently, it was recommended this corridor be dropped from further consideration.

Corridor One (ABC') was identified as acceptable but not preferred, thus given the C rating. Its great length, its traversing of residential and other developed lands, and the numerous creek crossings and extensive forest clearing involved relegate this corridor to this environmental rating. Economically and technically, this corridor has more difficulties than the other two considered. This is a longer line and crosses areas which may require easements in the area north of Anchorage.

Corridor Two (ADFC) was identified as the candidate which would satisfy most of the screening criteria. This corridor is shown in Figures B.50 and B.51, and stretches from an area north of Willow Creek to Point MacKenzie in the south. The corridor is located east of the lower Susitna River and crosses the Little Susitna River. The corridor also crosses an existing 138 kV line owned and operated by Chugach Electric Association (CEA), which starts at Point MacKenzie and extends to Teeland Substation.

Up to this point in the corridor selection study, Point MacKenzie has been considered a terminal point for Susitna power. It was assumed that an underwater cable crossing would be provided at this location. Upon further study and data-gathering it has become known that the existing crossing at Point MacKenzie has experienced power interruptions caused by ship's anchors snagging the submarine cables. CEA, which owns the submarine cables, required additional transmission capacity to Anchorage. After thoroughly studying the matter, it has opted for a combined submarine/overhead cable transmission across Knik Arm and onto Anchorage. This was the most desirable option to CEA, both from the environmental and technical point of view.

The CEA crossing will be located approximately eight miles northeast of Point MacKenzie on the west shore of the Knik Arm and across from Elmendorf Air Force Base in the vicinity of Six Mile Creek. This crossing is located northeast of the Anchorage Harbor, away from the heavy ship traffic, thereby reducing risk of anchor damage to the cable.

- It is intended to terminate Corridor ADFC at this new crossing point and extend the transmission corridor to Elemendorf Air Force Base and beyond to Anchorage.

Although the crossing is approximately eight miles northeast of Point MacKenzie, it does not influence the results of this corridor selection and screening process. The best corridor has been selected and screened. During routing studies minor deviations outside the corridor will have to occur in order to terminate at the revised crossing point. However, preliminary investigations indicate it will be possible to select a technically, economically, and environmentally acceptable route, particularly since an existing transmission line can likely be paralleled from the selected corridor to the revised crossing point. Furthermore, CEA has received the necessary permits and is constructing an underwater crossing at Knik Arm, indicating acceptable levels of environmental impact.

(ii) Central Study Area

In the central study area, several corridor segments and, hence, their associated corridors were determined to be unacceptable. The first of these, Corridor Segment BEC, appears as part of Corridors Two (ABECD), Five (ABECJHI), Seven (CEJAHI), Nine (CEBAG), and Fifteen (ABECF). The reason for rejecting this segment is primarily that the developed recreation area around Stephan Lake would be needlessly harmed, because viable options exist to avoid intruding into this area. Again, modifying this route to something more acceptable failed. Consequently, it is recommended that these five corridors be dropped from further consideration.

Corridor Segment AG was also determined not to warrant further consideration because of its approximate 65-mile length, two-thirds of which would possibly require a pioneer access road. Also, extensive areas of clearing would be required, opening the corridor to view in some scenic locations. Finally, the impacts on fish and wildlife habitats are potentially severe. These preliminary findings, coupled with the fact that more viable options to Segment AG exist, suggest that consideration of this corridor segment and, therefore, Corridors Eight (CBAG) and Ten (CJAG) should be terminated.

Corridors Eleven (CJAHI) and Twelve (JA-CJHI) were identified as acceptable. This rating arose from the fact that, as shown in Environmental Constraint Table B.48, numerous constraints affect this routing. Information from recently completed field investigations suggest that these constraints cannot be overcome and the routes should be rejected. Furthermore, the technical and economical ratings preclude these corridors from further consideration.

Corridor Segment HJ has been moved so that it no longer parallels the Devil Creek drainage; the new location HC is selected to avoid both High Lake and the Devil Creek drainage. It then follows the Portage Creek drainage to the point of intersection with Corridor Segment JH, near the creek's headwaters. Subsequent investigations have confirmed that this corridor segment is not viable and, consequently, Corridors Four and Five are eliminated from further consideration.

Corridors Six intrudes on valuable wildlife habitat and would cross numerous creeks, none of which are currently crossed by existing access roads. In addition, a high mountain pass and its associated shallow soils, steep slopes, and surficial bedrock constrain this routing. Finally, its crossing of areas over 4,000 feet in elevation makes it technically unacceptable, so this corridor is dropped from further consideration.

Corridors Three (AJCF) and Fourteen (AJCD) have been identified as acceptable but not recommended because of the CJ Corridor Segment. This corridor segment intrudes upon an existing recreation area at High Lake and contravenes existing views of the Alaska Range; it also crosses valuable habitat for sensitive big game species.

Corridor One (ABCD), as shown in Figure B.48, was one of the three recommended corridors. Constraints to this routing do exist, however, and will need to be further evaluated before modifications to this corridor are suggested. This corridor is one of the shortest in length (38 miles) of all corridors considered in this area. It is recommended, therefore, because of its technical and economical rating.

Corridor Thirteen (ABCF) is also an acceptable but not preferred corridor. With the presence of the developed recreation area at Otter Lake, Corridor Thirteen could require special attention in Segment CF. The technical rating for this corridor is attractive because of the short length of transmission line and the fact that the lines could be constructed within a reasonable distance to the access roads. Because of crossings of deep ravines and forest clearing, this corridor is not recommended economically.

Figures B.52 and B.53 show the location of the recommended corridor in the area from Watana to an area in the vicinity of Gold Creek, and it essentially straddles the Upper Susitna River. The area of the corridor between Watana and Devil Canyon may be extended to the north and is dependent on the route the access road may take. Every effort will be made to coordinate the transmission lines with the access road.

(iii) Northern Study Area

Corridors Three (AEDC) and Four (AEF) were determined unacceptable because of many constraints, and thus, rated F. They include: the lack of an existing access road; problems in dealing with tower erection in shallow bedrock zones; the need for extensive wetland crossings and forest clearing; the 75 river or creek crossings involved; and the fact that prime habitat for waterfowl, peregrine falcons, caribou, bighorn sheep, golden eagle, and brown bear would be crossed. In addition, Corridor Four crosses areas of significant land use constraints and elevations of over 4,000 feet.

Corridor Two (ABDC) was identified as acceptable but not preferred, and thus, rated C. Certain constraints identified for this corridor suggest that an alternative is preferable. Compared with Corridor One, Corridor Two crosses additional wetlands and requires the development of more access roads and the clearing of additional forest lands.

Corridor One (ABC), shown in Figures B.54 to B.57, was the only recommended corridor in the northern study area. While many constraints were identified under the various categories, it appears possible to select a route within this corridor to minimize constraint influences. This corridor is attractive economically, because it is close to access roads and the Parks Highway. The visual impact can be lessened by strategic placement of the line. This line also best meets technical and economical requirements.

(e) Route Selection

(i) Methodology

After identification of the preferred transmission line corridors, the next step in the route selection process involved the analysis of the data as gathered and presented on the base map. Overlays were compiled so that various constraints affecting construction or maintenance of a transmission facility could be viewed on a single map. The map was used to select possible routes within each of the three selected corridors. By placing all major constraints (e.g., areas of high visual exposure, private lands, endangered species, etc.) on one map, a route of least impact was selected. Existing facilities, such as transmission lines and tractor trails within the study area, were also considered during the selection of a minimum impact route. Whenever possible, the routes were selected near existing or proposed access roads, sharing whenever possible existing rights-of-way.

The data base used in this analysis was obtained from the following sources:

- An up-to-date land status study;
- Existing aerial photos;
- New aerial photos conducted 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.

(ii) Selection Criteria

The purpose of this section is to identify three selected routes; one from Healy to Fairbanks, the second from the Watana and Devil Canyon damsites to the intertie, and the third from Willow to Anchorage.

The previously chosen corridors were subject to a process of refinement and evaluation based on the same technical, economic, and environmental criteria used in corridor selection. In addition, special emphasis was concentrated on the following points:

- Satisfying the regulatory and permit requirements;
- Selection of routing that provides for minimum visibility from highways and homes; and
- Avoidance of developed agricultural lands and dwellings.

(iii) Environmental Analysis

The corridors selected were analysed to arrive at the route which is the most compatible with the environment and also meet the engineering and economic objectives. The environmental analysis was conducted by the process described below:

- Literature Review

  Data from various literature sources, agency communications, and site visits were reviewed to inventory existing environmental variables. From such an inventory, it was possible to identify environmental constraints in the recommended corridor locations. Data sources were cataloged and filed for later retrieval.

- Avoidance Routing by Constraint Analysis

  To establish the most appropriate location for a transmission line route, it was necessary to identify those environmental constraints that could be impediments to the development of such a route. Many specific constraints were identified during the preliminary screening; others were determined during the 1981 field investigations.

  By utilizing information on topography, existing and proposed land use, aesthetics, ecological features, and cultural resources as they exist within the corridors, and by careful placement of the route with these considerations in mind, impact on these various constraints was minimized.

- Base Maps and Overlays

  Constraint analysis information was placed on base maps. Constraints were identified and presented on overlays to the base maps. This mapping process involved using both existing information and that acquired through Susitna Project studies. This information was first categorized as to its potential for constraining the development of a transmission line route within the preferred corridor and then placed on maps of the corridors. Environmental constraints were identified and recorded directly onto the base maps. Overlays to the base maps were prepared indicating the type and extent of the encountered constraints.

  Three overlays were prepared for each map: one for visual constraints, one for man-made, and one for biological constraints. These maps are presented as a separate document (12).

(iv) Technical and Economic Analysis

Route location objectives are to obtain an optimum combination of reliability and cost with the fewest environmental problems. In many cases, these objectives are mutually compatible.

Throughout the evaluation, much emphasis was placed on locating the route relatively close to existing surface transportation facilities whenever possible.

The factors that contributed heavily in the technical and economic analysis were: topography, climate and elevation, soils, length, and access roads. Other factors of less importance were vegetation, and river and highway crossings. These factors are detailed in Tables B.37 and B.50.

- Selection of Alternative Routes

The next step in the route selection process involved the analysis of the data presented on the base maps. The data were used to select possible routes within each corridor. By placing all major constraints on one map, routes of smallest impacts were selected. Existing facilities, such as transmission lines and tractor trails within the study area, were also taken into consideration during the selection of a least impact route.

- Evaluation of a Primary Route

The evaluation and selection of alternative routes to arrive at a primary route involved a closer examination of each of the possible routes using mapping process and data previously described. Preliminary routes were compared to determine the route of least impact within the primary corridors of each study area. For example, such variables as number of stream and road crossings required were noted. Then, following the field studies and through a comparison of routing data, including the route's total length and its use of existing facilities, one route was designated the primary route. Land use, land ownership, and visual impacts were key factors in the selection process.

(v) Route Soil Conditions

- Description

Baseline geological and geotechnical information has been compiled through photointerpretation and terrain unit mapping. The general objective was to document the conditions that would significantly affect the design and construction of the transmission line towers. More specifically, the conditions included the forms o' various origins, noting the occurrence and distribution of significatn geologic factors such as permafrost, potentially unstable slopes, potentially eordible soils, possible active fault traces, potential construction materials, active floodplains, organic materials, etc.

Work on the airphoto interpretation consisted of several activities culminating in a set of terrain unit maps showing surface materials, geologic features and conditions in the project area.

The first activity consisted of a review of the literature concerning the geology of the intertie corridors and transfer of the information gained to high-level photographs at a scale of 1:63,000. Interpretation of the high-level photos created a regional terrain framework which assisted in interpretation of the low-level 1:30,000 project photos. Major terrain divisions identified on the high-level photos were then used as an aerial guide for delineation of more detailed terrain units on the low-level photos. The primary effort of the work was the interpretation of over 140 photos covering about 300 square miles of varied terrain. The land area covered in the mapping exercise is shown on map sheets and displayed in detail on photo mosaics (13).

As part of the terrain analysis, the various bedrock units and dominant lithologies were identified using published U.S. Geological Survey reports. The extent of these units was approximately shown on the photographs, and using exposure patterns, shade, texture, and other features of the rock unit as they appeared on the photographs, unit boundaries were drawn.

Physical characteristics and typical engineering properties of each terrain unit were considered and a chart for each corridor was developed. The charts identify the terrain units as they have been mapped and characterize their properties in numerous categories. This allows an assessment of each unit's influence on various project features.

- Terrain Unit Analysis

The terrain unit is a special purpose term comprising the land forms expected to occur from the ground surface to a depth of about 25 feet.

The terrain unit maps for the proposed Anchorage to Fairbanks transmission line show the aerial extent of the specific terrain units which were identifed during the air photo investigation and were corroborated in part by a limited onsite surface investigation. The units document the general geology and geotechnical characteristics of the area.

The north and south corridors are separated by several hundred miles and not surprisingly encounter different geomorphic provinces and climatic conditions. Hence, while there are many land forms (or individual terrain units) that are common to both corridors, there are also some landforms mapped in just one corridor. The landforms or individual terrain units mapped in both corridors were breifly described.

Several of the landforms have not been mapped independently but rather as compound or complex terrain units. Compound terrain units result when one landform overlies a second recognized unit at a shallow depth (less than 25 feet), such as a thin deposit of glacial till overlying bedrock or a mantle of lacustrine sediments overlying till. Complex terrain units have been mapped where the surficial exposure pattern of two landforms are so intricately related that they must be mapped as a terrain unit complex, such as some areas of bedrock and colluvium. The compound and complex terrain units were described as a composite of individual landforms comprising them. The stratigraphy, topographic position, and aerial extent of all units, as they appear in each corridor, were summarized on the terrain unit properties and engineering interpretations chart (13).

(vi) Results and Conclusions

A study of existing information and aerial overflights, together with additional aerial coverage, was used to locate the recommended route in each of the southern, central, and northern study areas.

Additional environmental information and land status studies made it possible to align the routes to avoid any restraints.

Terrain unit maps describing the general material expected in the area were prepared specifically for transmission line studies and were used to locate the routes away from unfavorable soil conditins whenever possible.

The selected transmission line route for the three areas of study is presented in Exhibit G. As a first step, the 3 to 5 mile wide corridor previously selected for each of the three study areas was narrowed to a half mile-wide corridor based on the previous criteria. This centerline represents a right-of-way width of 500 feet. The width is adequate for three, single-circuit, parallel lines with tower structures having horizontal phase spacing of 33 feet. However, between the Devil Canyon damsite and Gold Creek, the width of the right-of-way is 650 feet which is needed to accommodate four single-circuit lines. Enviromental constraint analysis information was placed on base maps and overlays (12).

Subsequent to the submission of the Feasibility Study (4) a further refinement process on the line route has taken place to reflect the possibility of land acquisition problems at locations along the corridor. This process has resulted in an improved routing, generally close to the earlier proposal, in the Fairbanks to Healy and the Willow to Anchorage line sections.

Also since the Feasibility Study the proposals for access to the power development have undergone reassessment. This has resulted in a decision to provide access to Watana from the Denali Highway and not build the Watana to Devil Canyon link until the latter site is developed. Because of this lack of early access to Devil Canyon the main Switching Station for the transmission has been relocated at Gold Creek. The earlier line routing proposals were accordingly reviewed to establish the optimum location for lines for Watana to Gold Creek and from Devil Canyon to Gold Creek. This route was established within the corridors examined in detail earlier, using the same methodology as before.

(f) Towers, Foundations and conductors

The Anchorage and Fairbanks Intertie will consist of existing lines and a new section between Willow and Healy. The new section will be built to 345 kV standards but will be temporarily operated at 138 kV and will be fully compatible with Susitna requirements.

(i) Transmission Line Towers

- Section of Tower Type

Because of the unique soil conditions in Alaska which are characterized by extensive regions of muskeg and permafrost, conventional self-supporting or rigid towers will not provide a satisfactory solution for the proposed transmission line.

Permafrost and seasonal changes in the soil are known to cause large earth movements at some locations, requiring towers with a high degree of flexibility and capability to sustain appreciable loss of structural integrity.

A guyed tower is well suited to these conditions; these include the guyed-V, guyed-Y, guyed delta, and guyed portal type structures. The type of structure selected for the construction of the Intertie is the hinged-guyed steel X-tower, a refinement of the guyed structure concept; this type of tower is, therefore, a prime candidate for use on the Watana transmission system. Guyed pole-type structures will be used on larger angle and dead end structures; a similar arrangement will be used in specially heavy loading zones.

The design feature of the X-tower include hinged connections between the legs and the foundation and four longitudinal guys attached in pairs to two guy anchors, providing a high degree of flexibility with excellent structural strength. The wide leg spacing results in relatively low foundation forces which are carried on pile type footings in soil and steel grillage or rock anchor footings where rock is close to the surface.

In narrow right-of-way situations, cantilever steel pole structures are anticipated with foundations consisting of cast-in-place concrete augered piles.

In the final design process, experience gained in the construction and operation of the Intertie will be used in the final selection of the structue type to be used for the Watana transmission.

All tower structures will be constructed of "weathering" type steel which matures to a dark brown color over a period of a few years and is considered to have a more aesthetically pleasing appearance than either galvanized steel or aluminum.

- Climatic Studies and Loadings

Climatic studies for transmission lines were performed to determine probable maximum wind and ice loads based on historical data. A more detailed study incorporating additional climatic data was carried out for the Intertie final design. These studies have resulted in the selection of preliminary loading for the line design.

Details of the climatic studies for Watana transmission lines may be found in Reference 14.

Preliminary loadings selected for line design should be confirmed by a detailed study, similar to that performed for the Intertie, that will examine conditions for the Healy to Fairbanks, Willow to Anchorage and Gold Creek to Watana sections of the route together with an update of the Healy to Willow study incorporating any data from field measurement stations collected in the interim period.

Based on data currently available, it appears that the line can be divided up into zones as far as climatic loading is concerned as follows:

- Normal Loading Zone
- Heavy Ice Loading Zone
- Heavy Wind Loading Zone

The heavy ice and heavy wind zones will have an additional critical loading case including to reflect the special nature of the zone.

- Tower Family

A family of tower designs will be developed as follows:

. Suspension towers will be provided for both standard span plus angle (up to 3°) application and for long span or light angle (0° to 8°) application.

. Tension towers will be provided for light angle and dead end (0° to 8°), for large angle and dead end (8° to 50°) and for minimum angle and dead end (50° to 90°).

The maximum wind span and weight span ratios to be utilized will be set in final design to reflect the rugged nature of the terrain along the line route. Some trial spotting of towers in representative terrains will be used to guide this selection. Minimum weight span to wind span ratio limits will be set during tower spotting and a "low temperature template" used to check that unexpected uplift will not develop at low weight span towers for very low temperatures.

The span to be used in design will be the subject of an economic optimization study. A span of not less than 1,200 ft is expected with spans in the field varying to greater and lesser values in specific cases depending upon span and loading zone.

(ii) Tower Foundations

- Geotechnical Conditions

The generalized terrain analysis (13) was conducted to collect geologic and geotechnical data for the transmission line corridors, a relatively large area. The engineering characteristics of the terrain units have been generalized and described qualitatively. When evaluating the suitability of a terrain unit for a specific use, the actual properties of that unit must be verified by onsite subsurface investigation, sampling, and laboratory testing.

The three main types of foundation materials along the transmission line are:

. Good material, which is defined as overburden which permits augered excavation and allows installation of concrete without special form work;

. Wetland and permafrost material which requires special design details; and

. Rock material defined as material in which drilled-in anchors and concrete footings can be used.

Based on aerial, topographic, and terrain unit maps, the following was noted:

. For the southern study area: Wetland and permafrost materials constitue the major part of this area. Some rock and good foundation materials are present in this area in a very small proportion.

- For the central study area: Rock foundation and good materials were observed in most of this study area.
- For the northern study area: The major part of this area is wetland and permafrost materials. Some parts have rock materials.

- Types of Foundation

The types of tangent tower envisaged for these lines will require foundations to suppot the leg or mast capable of carrying a predominantly vertical load with some lateral shear, and a guy anchor foundation.

The cantilever pole structure foundation is required to resist the high overturning moment inherent in the cantilever arrangement.

The greater part of the combined maximum reactions on a transmission tower footing is usually from short duration loads such as broken wire, wind, and ice. With the exception of heavy-angle, dead-end or terminal structures, only a part of the total reaction is of a permanent nature. As a consequence, the permissible soil pressure, as used in the design of building foundations, may be considerably increased for footing for transmission structures.

The permissible values of soil pressure used in the footing design will depend on the structure and the supporting soil. The basic criterion is that displacement of the footing is not restricted because of the flexibility of the selected x-frame tower and its hinged connection to the footing. The shape and configuration of the selected tower are important factors in foundation considerations.

Loads on the tower consist of vertical and horizontal loads and are transmitted down to the foundation and then distributed to the soil. In a tower placed at an angle or used as dead-end in the line, the horizontal loads are responsible for a large portion of the loads on the foundation. In addition to the horizontal shear, a moment is also present at the top of the foundation, creating vertical download and uplift forces on the footing.

To enable the selection of a safe and economical tower foundation design for each tower site it is necessry to select a footing which takes account of the actual soil conditions at the site. This is done by matching the soil conditions to a series of ranges in soil types and groundwater conditions which have been predetermined during the design phase to cover the full range of soils expected to be encountered along the line length. Preconstruction drilling, soil sampling, and laboratory testing at representative locations along the line enable the design of a family of footings to be prepared for each tower type from which a selection of the appropriate footing for the specific site can be made during construction.

The fondation types for structure legs and masts will be grouted anchor where rock is very shallow or at surface and steel grillage with granular backfill where soil is competent and not unduely frost sensitive. In areas where soils are weak and where permafrost or particularly forst-heave prone material is encountered driven steel piles will be used.

Guy anchors will use grouted anchors in rock. Grouted earth or helical plate screw-in anchors with driven piles will be used in permafrost or very weak soils.

Proof load testing of piles and drilled in anchors will be required both for design and to check on the as-built capacity of these foundation elements during construction.

(iii) Voltage Level and Conductor Size

Economic studies were carried out of transmission utilizing 500 kV, 345 kV, and 230 kV ac. At each voltage level an optimum conductor capacity was developed. Schemes involving use of 500 kV or 345 kV on the route to Anchorage and 345 kV or 230 kV to Fairbanks were investigated. The study recommended the adoption of two 345 kV units to Fairbanks and three 345 kV units to Anchorage. Comparative studies were carried out of the possible use of HVDC which indicated no economic advantage of such a scheme.

The 345 kV system studies indicated that a conductor capacity of 1950 MCM per phase was economical with due account for the value of losses. A phase bundle consisting of twin 754 MCM Rail (45/7) ACSR was proposed as meeting the required capacity and also having acceptable corona and radio interference performance. Detailed design studies as part of the final design will compare the economics of ths conductor configuration with the use of alternatives such as twin 954 MCM Cardinal (54/7) ACSR and single 215.6 MCM Bluebird (84/19) ACSR which could give comparable electrical performance with better structural performance. Cardinal because of a 15 percent superior strength-to-weight ratio can be sagged tighter than Rail, to result in savings in tower height and/or increased spans. Bluebird because of a smaller circumference and projected area compared with a twin conductor bundle attracts some 15 percent less load from ice or wind; together with its greater strength this leads to less sag under heavyloadings and lighter loads for the structures to carry. conductor swing angles will also be reduced thus reducing tower head size requirements and edge of right-of-way clearing.

2.8 - Selection of Project Operation

A reservoir simulation model was used to evaluate the optimum method of operating the Susitna hydroelectric project for a range of past project flows at the Gold Creek gaging station 25 miles downstream of the Devil Canyon damsite. The process that led to the selection of the flow scenario used in this license application includes the following steps:

- Determination of pre-project flows at Gold Creek, Watana and Devil Canyon for 32 years of record;
- Selection of range of flows to be included in the analysis;
- Selection of timing of flow releases to match fishery requirements;
- Selection of maximum drawdown at Watana;
- Determination of energy produced for the seven flow release scenarios being studied;
- Determination of net benefits for each flow scenario;
- Selection of range of flows acceptable based on ecomomic factors; and
- Influence of instream flow and fishery considerations on selection of project operational flows.

A summary discussion of the detailed analysis is presented in the following paragraphs.

(a) Pre-Project Flows

The USGS has operated a gaging station (Station 15292000) at Gold Creek on the Susitna River continuously since 1950. They have also operated the Cantwell gage near Vee Canyon on the upper end of the proposed Watana Reservoir since 1961. These two gaging stations combined with a regional analysis were used to develop a 32 year record for the Cantwell gage. 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. The resulting flows at Watana and Devil Canyon are presented in Tables B.51 and B.52.

(b) Range of Post-Project Flows

During investigation of the full range of flows appropriate for use as operational target flows at Gold Creek, two factors were considered: that operational flow which would produce the maximum amount of usable energy from the project neglecting all other considerations (Case A), and that operational summer flow which would have minimum impact on downstream fishery and instream flow uses (Case D). Between these two end points five additional flow scenarios were established. The minimum target flows for all seven flow scenarios are presented in Table B.53.

(c) Timing of Flow Releases

In the reach of the river between Talkeetna and Devil Canyon it is presently perceived that the most important aspect of successful salmon spawning is providing access to the side channel and slough areas connected to the main stem spawning areas. Access to these areas is primarily a function of water level (flow) in the main channel of the river during the period when the solmon must gain access to the spawning areas. Field studies during 1981 and 1982 have indicated the access should be provided in late July, 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 demands in mid to late September.

(d) Maximum Drawdown

In Reference 4 the maximum drawdown was selected as 140 feet for Watana and 50 feet for Devil Canyon. Because the Devil Canyon maximum drawdown would be controlled by technical considerations the 50 foot drawdown was not reconsidered and has been retained as the upper limit for Devil Canyon. On the other hand, the Watana maximum drawdown is governed by intake structure cost, energy production, and downstream flow considerations; thus, it was refined during the 1982 studies. This refinement process resulted in the selection of 120 feet as the maximum drawdown for the Watana development.

(e) Energy Production

Using the pre-project flows, the seven flow release scenarios, and the maximum drawdowns established in subsections (a)-(d) above were input to the reservoir simulation model. The amount of energy produced, the flow at Gold Creek and the reservoir levels were determined for the 32 years of record. A summary of the energy produced using the seven flow scenarios is presented in Table B.54.

(f) Net Benefits

To determine the net economic value of the energy produced by the Susitna Hydroelectric Project the mathematical model commonly known as OGP 5 (Optimized Generation Planning Model, Version 5) was used to determine the present worth value (1982 dollars) of the long-term (1993 to 2051) production costs (LTPWC) of supplying the Railbelt energy needs by various alternative means of generation. A more detailed description of the OGP model is contained in the Section 1.5. The analysis was performed for the "best thermal option" as well as for the seven flow scenarios for operating Susitna. The results are presented in Table B.55.

The net benefit presented in Table B.55 is the difference between the LTPWC for the "best thermal option" and the LTPWC for the various Susitna options. In Table B.55, Case A represents the maximum usable energy option and results in a net benefit of $1215 million. As flow is transferred from the winter to the August-September time period for fishery and instream flow mitigation purposes the amount of usable energy decreases. This decrease is not significant until the flow provided at Gold Creek during August reaches the 12,000 to 14,000 cfs range. For a flow of 19,000 cfs at Gold Creek, a flow scenario that represents minimum downstream fishery impact, approximately 45 percent of the potential project net benefits have been foregone.

(g) Operational Flow Scenario Selection

Based on the economic analysis discussed above, it was judged that, while case A flows produced the maximum net benefit, the loss in net benefits (compared to Case A) for cases A_1, A_2, and C were of an acceptable magnitude. The loss associated with Case C_1 is on the borderline between acceptable and unaccepable. As fishery and instream flow impact (and hence mitigation costs associated with the various flow scenarios) are quantified the decrease in mitigation costs associated with high flows may warrant selecting a higher flow case such as C_1. However, the loss in net benefits associated with Cases C_2 and D was not acceptable and it is doubtful that the mitigation cost reduction associated with these higher flows will bring them into the accepable range.

(h) Instream Flow and Fishery Impact on Flow Selection

As noted earlier, the primary function controlled by the late summer flow is the ability of the salmon to gain access to their traditional spawning grounds. Instream flow assessment conducted during 1981 (the wettest July-August on record) and 1982 (one of the driest July-Augusts on record) has indicated that, for flows of the Case A magnitude, severe impacts would occur which can not be mitigated except by compensation through hatchery construction.

For flows in the 10,000 to 12,000 cfs range (flows similar to those that occured in August, 1982) the salmon can, with difficulty, obtain access to their spawning grounds. To insure that the salmon can always obtain access to spawning areas during a flow of 10,000 to 12,000 cfs simple, relatively low cost physical mitigation measures are incorporated into the mitigation plan presented in Chapter 3 of Exhibit E. Based on this assessment the Case A and A_1 flow scenarios are considered unacceptable, thus establishing a lower limit for the acceptable flow range as approximately 10,000 cfs (Case A_2) at Gold Creek during August.

As a result, by combining the economic analysis and the instream flow considerations the Case C scenario providing a flow of 12,000 cfs at Gold Creek during August (see Table B.53) has been selected as the project operational flow. As a more refined assessment of fishery impact, mitigation costs and projected project net benefits becomes available, the project operational flow will be adjusted. However, it is unlikely that the final flow selection will be less than 10,000 cfs or greater than 16,000 cfs during August at Gold Creek.

3 - DESCRIPTION OF PROJECT OPERATION

3 - DESCRIPTION OF PROJECT OPERATION

3.1 - Operation Within Railbelt Power System

A staged development is planned for implementation of Susitna power generation. The following schedule for unit start-up is proposed:

Start-up Date	Dam Site	No. and Size of Units (MW) Brought On-line	Total Susitna On-line Capacity* (MW)
1994 (Jan.)	Watana	4 x 170	680
1994 (July)	Watana	2 x 170	1020
2002	Devil Canyon	4 x 150	1620

* Installed generating capacity.

As shown above, the first four units are scheduled to be on line at Watana in early 1994, followed by the remaining two Watana units in mid 1994. Startup of all four units at Devil Canyon is planned for 2002.

Of the total project installed capacity of 1620 MW, 1280 MW were utilized as the basis for generation planning. The remaining 340 MW are planned to meet the needs for spinning reserve capacity.

This section describes the operation of the Watana and Devil Canyon power plants in the Railbelt electrical system. Under current conditions in the Railbelt, a total of nine utilities share responsibility for generation and distribution of electric power, with limited interconnections. The proposed arrangements for optimization and control of the dispatch of Susitna power to Railbelt load centers is based on the expectation that a single entity will eventually be set up for this purpose. In the year 2010 the projected Railbelt system, with Susitna on line, is projected to comprise:

Coal-fired Steam:	13 MW
Natural Gas GT:	326 MW
Diesel:	6 MW
Natural Gas CC:	317 MW
Hydropower:	1775 MW
TOTAL	2437 MW

It is important to note that the Susitna project will be the single most significant power source in the system. The dispatch and distribution of power from all sources by the most economical and reliable means is therefore essential. The general principles of reliability of plant and system operation, reservoir regulation, stationary and spinning reserve requirements, and maintenance programming are discussed in this section. Estimates of dependable capacity and annual energy production for both Watana and Devil Canyon are presented. Operating and maintenance procedures are described, and the proposed performance monitoring system for the two projects is also outlined.

3.2 - Plant and System Operation Requirements

The main function of system planning and operation control is the allocation of generating plant on a short-term operational basis so that the total system demand is met by the available generation at minimum cost consistent with the security of supply. The objectives are generally the same for long-term planning or short-term operational load dispatching, but with important differences in the latter case. In the short-term case, the actual state of the system dictates system reliability requirements, overriding economic considerations in load dispatching. An important factor arising from economic and reliability considerations in system planning and operation is the provision of stationary reserve and spinning reserve capacity. Figure B.58 shows the daily variation in demand for the Railbelt system during typical winter and summer weekdays and the seasonal variation in monthly peak demands for estimated loads in a typical year (the year 2000).

3.3 - General Power Plant and System Railbelt Criteria

The following basic reliability standards and criteria have been adopted for planning the Susitna project.

(a) Installed Generating Capacity

Sufficient generating capacity is installed in the system to insure that the probability of occurrence of load exceeding the available generating capacity shall not be greater than one day in ten years (Loss-of-load probability (LOLP) of 0.1).

(b) Transmission System Capability

The high-voltage transmission system should be operable at all load levels to meet the following unscheduled single or double contingencies without instability, cascading or interruption of load.

- The single contingency situation is the loss of any single generating unit, transmission line, transformer, or bus (in addition to normal scheduled or maintenance outages) without exceeding the applicable emergency rating of any facility; and

- The double contingency situation is the subsequent outage of any remaining equipment, line or subsystem without exceeding the short time emergency rating of any facility.

In the single contingency situation, the power system must be capable of readjustment so that all equipment would be loaded within normal ratings, and in the double contingency situation, within emergency ratings for the probable duration of the outage.

During any contingency:

- Sufficient reactive power (MVAR) capacity with adequate controls is installed to maintain acceptable transmission voltage profiles.

- The stability of the power system is maintained without loss of load or generation during and after a three-phase fault, cleared in normal time, at the most critical location.

(c) Summary

Operational reliability criteria thus fall into four main categories:

- LOLP of 0.1, or one day in ten years, is maintained for the recommended plan of operation;

- The single and double contingency requirements are maintained for any of the more probable outages in the plant or transmission system;

- System stability and voltage regulation are assured from the electrical system studies. Detailed studies for load frequency control have not been performed, but it is expected that the stipulated criteria will be met with the more than adequate spinning reserve capacity with six units at Watana and four units at Devil Canyon; and

- The loss of all Susitna transmission lines on a single right-of-way has a low level of probability. In the event of the loss of all lines, the hydro plants at Watana and Devil Canyon are best suited to restore power supply quickly after the first line is restored since they are designed for "black start" operation. In this respect, hydro plans are superior to thermal plants because of their inherent black start capability for restoration of supply to a large system.

3.4 - Economic Dispatch of Units

A Susitna Area Control Center will be located at Watana to control both the Watana and the Devil Canyon power plants. The control center will be linked through the supervisory system to the Central Dispatch Control Center at Willow.

Operation will be semi-automatic with generation instructions input from the Central Dispatch Center at Willow, but with direct control of the Susitna system at the control center at Watana.

The supervisory control of the entire Alaska Railbelt system will be done at the Central Dispatch Center at Willow. A high level of control automation with the aid of digital computers will be sought, but not a complete computerized direct digital control of the Watana and Devil Canyon power plants. Independent operator controlled local-manual and local-auto operations will still be possible at Watana and Devil Canyon power plants for testing/commissioning or during emergencies. The control system will be designed to perform the following functions at both power plants:

- Start/stop and loading of units by operator;
- Load-frequency control of units;
- Reservoir/water flow control;
- Continuous monitoring and data logging;
- Alarm annunciation; and
- Man-machine communication through visual display units (VDU) and console.

In addition, the computer system will be capable of retrieval of technical data, design criteria, equipment characteristics and operating limitations, schematic diagrams, and operating/maintenance records of the units.

The Susitna Area Control Center will be capable of completely independent control of the Central Dispatch Center in case of system emergencies. Similarly it will be possible to operate the Susitna units in an emergency situation from the Central Dispatch Center, although this should be an unlikely operation considering the size, complexity, and impact of the Susitna generating plants on the system.

The Central Dispatch Control Engineer decides which generating units should be operated at any given time. Decisions are made on the basis of known information, including an "order-of-merit" schedule, short-term demand forecasts, limits of operation of units, and unit maintenance schedules.

(a) Merit-Order Schedule

In order to decide which generating unit should run to meet the system demand in the most economic manner, the Control Engineer is provided with information of the running cost of each unit in the form of an "order-of-merit" schedule. The schedule gives the capacity and fuel costs for thermal units, and reservoir regulation limits for hydro plants.

(b) Optimum Load Dispatching

One of the most important functions of the Control Center is the accurate forecasting of the load demands in the various areas of the system.

Based on the anticipated demand, basic power transfers between areas, and an allowance for reserve, the planned generating capacity to be used is determined by taking into consideration the reservoir regulation plans of the hydro plants. The type and size of the units should also be taken into consideration for effective load dispatching.

In a hydro-dominated power system such as the Railbelt system would be if Susitna is developed, the hydro unit will take up a much greater part of base load operation than in a thermal dominated power system. The planned hydro units at Watana typically are well suited to load following and frequency regulation of the system and providing spinning reserve. Greater flexibility of operation was a significant factor in the selection of six units of 170 MW capacity at Watana, rather than fewer larger-size units.

(c) Operating Limits of Units

There are strict constraints on the minimum load and the loading rates of machines: to dispatch load to these machines requires a systemwide dispatch program taking these constraints into consideration. In general, hydro units have excellent startup and load following characteristics; thermal units have good part-loading characteristics.

Typical plant loading limitations are given below:

(i) Hydro Units

- Reservoir regulation constraints resulting in not-to-exceed maximum and minimum reservoir levels, daily or seasonally.

- Part loading of units is impossible in the zone of rough turbine operation (typically from above no-load-speed to 50 percent load) due to vibrations arising from hydraulic surges.

(ii) Steam Units

- Loading rates are slow (10 percent per minute).

- The units may not be able to meet a sudden steep rate of rise of load demand.

- The units have a minimum economic shutdown period (about 3 hours).

- The total cost of using conventional units includes banking, raising pressure and part-load operations prior to maximum economic operation.

(iii) Gas Turbines

- Cannot be used as spinning reserve because of very poor efficiency and reduced service life.
- Require 8 to 10 minutes for normal start-up from cold. Emergency start up times are of the order of 5 to 7 minutes.

(d) Optimum Maintenance Program

An important part of operational planning which can have a significant effect on operating costs is maintenance programming. The program specifies the times in the year and the sequence in which plant is released for maintenance.

3.5 - Unit Operation Reliability Criteria

During the operational load dispatching conditions of the power system, the reliability criteria often override economic considerations in scheduling of various units in the system. Also important in considering operational reliability are system response, load-frequency control, and spinning reserve capabilities.

(a) Power System Analyses

Load-frequency response studies determine the dynamic stability of the system due to the sudden forced outage of the largest unit (or generation block) in the system. The generation and load are not balanced, and if the pick-up rate of new generation is not adequate, loss of load will eventually result from under-voltage and under-frequency relay operation, or load-shedding. The aim of a well designed high security system is to avoid load-shedding by maintaining frequency and voltage within the specified statutory limits.

(b) System Response and Load-Frequency Control

To meet the frequency requirements, it is necessary that the effective capacity of generating plant supplying the system at any given instant should be in excess of the load demand. In the absence of detailed studies, an empirical factor of 1.67 times the capacity of the largest unit in the system is normally taken as a design criterion to maintain system frequency within acceptable limits in the event of the instantaneous loss of the largest unit. It is recommended that a factor of 1.5 times the largest unit size be considered as a minimum for the Alaska Railbelt system, with 2 times the largest unit size as a fairly conservative value (i.e., 300 to 340 MW).

The quickest response in system generation will come from the hydro units. The large hydro units at Watana and Devil Canyon on spinning reserve can respond in the turbining mode within 30 seconds. This is one of the particularly important advantages of the Susitna hydro units. Gas turbines can only respond in a second stage operation within 5 to 10 minutes and would not strictly qualify as spinning reserve. If thermal units are run part-loaded (e.g., 75 percent), this would be another source of spinning reserve. Ideally, it would be advantageous to provide spinning reserve in the thermal generation as well, in order to spread spinning reserves evenly in the system, with a compromise to economic loading resulting from such an operation.

(c) Protective Relaying System and Devices

The primary protective relaying systems provided for the generators and transmission system of the Susitna project are designed to disconnect the faulty equipment from the system in the fastest possible time. Independent protective systems are installed to the extent necessary to provide a fast-clearing backup for the primary protective system so as to limit equipment damage, to limit the shock to the system and to speed restoration of service. The relaying systems are designed so as not to restrict the normal or necessary network transfer capabilities of the power system.

3.6 - Dispatch Control Centers

The operation of the Watana and Devil Canyon power plant in relation to the Central Dispatch Center can be considered to be the second tier of a three-tier control structure as follows:

- Central Dispatch Control Center (345 kV network) at Willow: manages the main system energy transfers, advises system configuration and checks overall security.
- Area Control Center (Generation connected to 345 kV system; for example, Watana and Devil Canyon): deals with the loading of generators connected directly to the 345 kV network, switching and safety precautions of local systems, checks security of interconnections to main system.
- District or Load Centers (138 kV and lower voltage networks): generation and distribution at lower voltage levels.

For the Anchorage and Fairbanks areas, the district center functions are incorporated in the respective area control centers.

Each generating unit at Watana and Devil Canyon is started up, loaded and operated, and shut down from the Area Control Center at Watana according to the loading demands from the Central Dispatch Control Center with due consideration to:

- Watana reservoir regulation criteria;

- Devil Canyon reservoir regulation criteria;

- Turbine loading and de-loading rates;

- Part loading and maximum loading characteristics of turbines and generators;

- Hydraulic transient characteristics of waterways and turbines;

- Load-frequency control of demands of the system; and

- Voltage regulation requirements of the system.

The Watana Area Control Center is equipped with a computer-aided control system to efficiently carry out these functions. The computer-aided control system allows a minimum of highly trained and skilled operators to perform the control and supervision of Watana and Devil Canyon plants from a single control room. The data information and retrieval system will enable the performance and alarm monitoring of each unit individually as well as the plant/reservoir and project operation as a whole.

3.7 - Susitna Project Operation

Substantial seasonal as well as over-the-year regulation of the river flow is achieved with the two reservoirs. The simulation of the reservoirs and the power facilities at the two developments was carried out on a monthly basis to assess the energy potential of the schemes, river flows downstream and flood control possibilities with the reservoirs. The following paragraphs summarize the main features of reservoir operation.

An optimum reservoir operation was established by an iterative process to minimize net system operating costs while maximizing firm and usable energy production. Seven alternative operating cases for the Watana reservoir (A, A_1, A_2, C, C_1, C_2, and D) were selected for study to define the possible range of operation. Case A represents an optimum power and energy scenario, while Case D reflects a case of "minimum impact on downstream fisheries". The other five cases are intermediate levels of power operation and downstream impact. These essentially define monthly minimum flows at Gold Creek that must be maintained while providing energy consistent with other project constraints. For feasibility report purposes, operation model "A" was adopted for project design. Studies with appropriate fisheries mitigation measures were developed based on Case A flows at Gold Creek. Table B.54 presents a summary of potential energy generation with three of the seven different operating rules for Watana and Devil Canyon developments.

Average annual energy potential of Watana development is 3460 GWh, and that of Devil Canyon development is 3450 GWh. A frequency analysis of the river hydrology was made to derive the firm annual energy potential (or the dependable capacity) of the hydro development.

The Federal Energy Regulatory Commission (FERC) defines the dependable capacity of hydroelectric plants as: "the capacity which, under the most adverse flow conditions of record can be relied upon to carry system load, provide dependable reserve capacity, and meet firm power obligations taking into account seasonal variations and other characteristics of the load to be supplied". Based on the Railbelt system studies and previous experience on large hydroelectric projects, it was assumed that a dry hydrological sequence with a recurrence period of the order of 1:50 years would constitute an adequate reliability for the Railbelt electrical system.

An analysis of annual energy potential of the reservoirs showed that the lowest annual energy generation, 5380 GWh, has a recurrence frequency 1 in 300 years. The second lowest annual energy of 5400 GWh has a recurrence frequency of 1 in 70 years. This latter figure has been adopted as the firm energy from the development.

The monthly distribution of firm annual energy from the reservoir simulation has been used in system generation planning studies. Average monthly energy based on the recorded sequence hydrology is used in the economic analysis.

4 - ENERGY PRODUCTION AND SUPPORTING DATA

4 - DEPENDABLE CAPACITY AND ENERGY PRODUCTION

Table B.26 summarizes design parameters for dependable capacity and energy production levels.

4.1 - Hydrology

(a) Historical Streamflow Records

Historical streamflow data are available for several gaging stations on the Susitna River and its main tributaries. Continuous gaging records were available for the following eight stations on the river and its tributaries: Maclaren River near Paxson, Denali, Cantwell, Gold Creek and Susitna stations on the Susitna River, Chulitna Station on the Chulitna River, Talkeetna on the Talkeetna River, and Skwentna on the Skwentna River. The longest period of record available is for the station at Gold Creek (32 years from 1949 to 1981). At other stations, record length varies from 6 to 23 years. Gaging was continued at all these stations as part of the project study program. A gaging station was established at the Watana damsite in 1980, and streamflow records are available for the study period. Partial streamflow records are available at several other stations on the river for varying periods; the station locations are shown in Figure B.59. It should be noted that gaging will continue as the project progresses in order to improve the streamflow record, as well as after project completion at selected sites required for project operation.

(b) Water Resources

Above its confluence with the Chulitna River, the Susitna contributes approximately 20 percent of the mean annual flow measured at Susitna Station near Cook Inlet. Figure B.60 shows how the mean annual flow of the Susitna increases towards the mouth of the river at Cook Inlet.

Seasonal variation of flow in the river is extreme and ranges from very low values in winter (October to April) to high summer values (May to September). For the Susitna River at Gold Creek, the average winter and summer flows are 2210 and 20,200 cfs respectively, i.e., a 1 to 10 ratio. This large seasonal difference is mainly due to effects of glacial and snow melt in the summer.

The monthly average flows in the Susitna River at Gold Creek are given in Figure B.61. Some 40 percent of the streamflow at Gold Creek originates above the Denali and Maclaren gages. This catchment generally comprises the glaciers and associated high mountains. On the average, approximately 87 percent of the streamflow recorded at Gold Creek station occurs during the summer months. At higher elevations in the basin the distribution of flows is concentrated even more in the summer months. For the Maclaren River near Paxson (Elevation 4520), the average winter and summer flows are 144 and 2,100 cfs respectively, i.e. a 1 to 15 ratio. The monthly percent of annual discharge and mean monthly discharges for the Susitna River and tributaries at the gaging stations above the Chulitna confluence are given in Table B.56.

(c) Streamflow Extension

Synthesized flows at the Watana and Devil Canyon damsites are presented in Tables B.51 and B.52. Flow duration curves based on these monthly estimates are presented for Watana and Devil Canyon damsites in Figures B.62 and B.63.

The inhouse FILLIN computer program developed by the Texas Water Development Board was used to fill in gaps in historical streamflow records at the eight continuous gaging stations. The 32 year record (up to 1981) at Gold Creek was used as the base record. The procedure adopted for filling in the data gaps uses a multisite regression technique which analyzes monthly time-series data. Flow sequences for the 32-year period were generated at the remaining seven stations. Using these flows at Cantwell station and observed Gold Creek flows, 32-year monthly flow sequences at the Watana and Devil Canyon damsites were generated on the basis of prorated drainage areas. Recorded streamflows at Watana and Devil Canyon were included in the historical record where available.

(d) Critical Streamflow Used for Dependable Capacity

Average annual energy potential of Watana development is 3460 GWh, and that of Devil Canyon development is 3450 GWh. A frequency analysis of the river hydrology was made to derive the firm annual energy potential (or the dependable capacity) of the hydro development. The analysis of annual energy potential of the reservoirs showed that the lowest annual energy generation has a recurrence frequency approximately equal to 1 in 50 years reulting in an annual energy of 5380 GWh (see Figure B.64).

This figure has been adopted as the firm energy from the development. Experience with other large hydroelectric projects indicates that 1 in 50 years provides adequate reliability.

(e) Floods

The most common causes of flood peaks in the Susitna River Basin are snowmelt or a combination of snowmelt and rainfall over a large area. Annual maximum peak discharges generally occur between May and October with the majority (approximately 60 percent) occurring in June. Some of the annual maximum flood peaks have also occurred in August or later and are the result of heavy rains over large areas augmented by significant snowmelt from higher elevations and glacial runoff. Table B.57 presents selected flood peaks recorded at different gaging stations.

Routing of floodthrough the Watana and Devil Canyon dams is presented in Figure B.58.

A regional flood peak and volume frequency analysis was carried out using the recorded floods in the Susitna River and its principal tributaries. These analyses were conducted for two different time periods. The first period, after the ice breakup and before freezeup (May through October), contains the largest floods which must be accommodated by the project. The second period represents that portion of time during which ice conditions occur in the river (October through May). These floods, although smaller, can be accompanied by ice jamming and must be considered during the construction phase of the project in planning the design of cofferdams for river diversion.

A set of multiple linear regression equations were developed using physiographic basin parameters such as catchment area, stream length, precipitation, snowfall amounts, etc., to estimate flood peaks at ungaged sites in the basin. In conjunction with the analysis of shapes and volumes of recorded large floods at Gold Creek, a set of project design flood hydrographs of different recurrence intervals were developed (see Figures B.65 and B.66).

The results of the above analysis were used for estimating flood hydrographs at the damsites and ungaged streams and rivers along the access road alignments for design of spillways, culverts, etc. Table B.58 lists mean annual, 50-, 100-, and 10,000-year floods at the Watana and Devil Canyon damsites and at the Gold Creek gage. The proposed reservoirs at Watana and Devil Canyon would be classified as "large" and with "high hazard potential" according to the guidelines for safety inspection of dams laid out by the Corps of Engineers. This would indicate the need for the probable maximum flood (PMF) to be considered in the evaluation of the proposed projects. Estimated peak discharges during the PMF at selected locations are included in Table B.58, and the PMF hydrograph is presented in Figure B.66.

Table B.59 lists the maximum flows through the various dam facilities for the 50, 10,000, and PMF events.

(f) Flow Adjustments

Evaporation from the proposed Watana and Devil Canyon reservoirs has been evaluated to determine its significance. Evaporation is influenced by air and water temperatures, wind, atmospheric pressure, and dissolved solids within the water. However, the evaluation of these factors' effects on evaporation is difficult because of their interdependence on each other. Consequently, more simplified methods were preferred and have been utilized to estimate evaporation losses from the two reservoirs.

The monthly evaporation estimates for the reservoirs are presented in Table B.60. The estimates indicate that evaporation losses will be less than or equal to additions due to precipitation on the reservoir surface. Therefore, a conservative approach was taken, with evaporation losses and precipitation gains neglected in the energy calculations.

Leakage is not expected to result in significant flow losses. Seepage through the relict channel is estimated as less than one-half of one percent of the average flow and therefore has been neglected in the energy calculations to date. This approach will be reviewed when further investigations of the relict channel are completed.

Minimum flow releases are required throughout the year to maintain downstream river stages. The most significant factor in determining the minimum flow value is the maintenance of downstream fisheries. The monthly flow requirements that were used in determination of project energy potential are given in Table B.53.

The numbers shown in Table B.53 represent the minimum stream flow required at Gold Creek. These requirements would remain constant for all phases of project development. The actual flows released from the project at Watana (when Watana is operating alone) and at Devil Canyon (for combined operation of both dams) will be less than the required Gold Creek flows prorated on the basis of streamflow contributions from the intervening basin area. Tables B.61 and B.62 give the typical minimum required flow releases at Watana and Devil Canyon for a 32-year period of record.

After completion of Devil Canyon, flow releases from Watana will be regulated by system operation requirements. Because the tail-water of the Devil Canyon reservoir will extend upstream to the Watana tailrace, there will be no release requirements for stream-flow maintenance of Watana for the Watana/Devil Canyon combined operating configuration.

Existing water rights in the Susitna Basin were investigated to determine impacts on downstream flow requirements. Based on inventory information provided by the Alaska Department of Natural Resources, it was determined that existing water users will not be affected by the project. A listing of all water appropriations located within one mile of the Susitna River is provided in Table B.63.

4.2 - Reservoir Data

(a) Reservoir Storage

Gross storage volume of the Watana reservoir at its normal maximum operating level of 2185 feet is 9.5 million acre-feet, which is about 1.6 times the mean annual flow (MAF) at the damsite. Live storage in the reservoir is 3.7 million acre-feet. Devil Canyon reservoir has a gross storage of 1.1 million acre-feet and live storage of 0.35 million acre-feet.

The area-capacity curves for the Watana and Devil Canyon reservoirs are provided in Figure B.67 and Figure B.68, respectively.

(b) Rule Curves

Operation of the reservoirs for energy production is based on target water surface levels set for the end of each month. The target level represents that level below which no energy beyond firm energy can be produced. In other words, if the reservoir level drops below the target only firm energy will be produced. In wetter years when the reservoir level surpasses the target level, energies greater than firm energy can be produced, but only as great as the system energy demand allows.

With a reservoir rule curve which establishes minimum reservoir levels at different times during the year, it will be possible to produce more energy in wetter years during winter than by following a set energy pattern. At the same time, the rule curve ensures that low flow sequences do not materially reduce the energy potential below a set minimum or firm annual energy.

The rule curves for Watana and Devil Canyon under combined operation are shown in Figure B.69.

4.3 - Operating Capabilities of Susitna Units

The operating conditions of both the Watana and Devil Canyon turbines are summarized in Table B.64.

(a) Watana

The Watana powerhouse will have six generating units with a nominal capacity of 170 MW corresponding to the minimum December reservoir level (Elevation 2114).

The gross head on the plant will vary from 610 feet to approximately 735 feet. The maximum unit output will change with head, as shown on Figure B.70.

The rated head for the turbine has been established at 680 feet, which is the weighted average operating head on the station. Allowing for generator losses, the rated turbine output is 250,000 hp (186.5 MW) at full gate.

The rated output of the turbines will be 250,000 hp at 680 feet rated net head. Maximum and minimum heads on the units will be 728 feet and 604 feet, respectively. The full gate output of the turbines will be about 275,000 hp at 728 feet net head and 209,000 hp at 604 feet net head. Overgating of the turbines may be possible, providing approximately 5 percent additional power; however, at high heads the turbine output will be restricted to avoid overloading the generators. The best efficiency point of the turbines will be established at the time of preparation of bid documents for the generating equipment and will be based on a detailed analysis of the anticipated operating range of the turbines. For preliminary design purposes, the best efficiency (best gate) output of the units has been assumed as 85 percent of the full gate turbine output. This percentage may vary from about 80 percent to 90 percent; in general, a lower percentage reduces turbine cost.

The full gate and best gate efficiencies of the turbines will be about 91 percent and 94 percent respectively at rated head. The efficiency will be about 0.5 percent lower at maximum head and 1 percent lower at minimum head. The preliminary performance curve for the turbine is shown on Figure B.71.

The Watana plant output may vary from zero, with the units at standstill or at spinning reserve, to approximately 1200 when all six units are operating under maximum output at maximum head. A graph of plant efficiency versus output and the number of on-line units is shown in Figure B.72. The load following requirements of the plant results in widely varying loading, but because of the multiple unit installation the total plant efficiency varies only slightly.

(b) Devil Canyon

The Devil Canyon powerhouse will have four generating units with a nominal capacity of 150 MW based on the minimum December reservoir level (Elevation 1405) and a corresponding gross head of 555 feet in the station.

The gross head on the plant will vary from 555 feet to 605 feet. The maximum unit output will change with head as shown in Figure B.73.

The rated average operating head for the turbine has been established at 575 feet. Allowing for generator losses, this results in a rated turbine output of 225,000 hp (168 MW) at full gate.

The generator rating has been selected as 180 MVA with a 90 percent power factor. The generators will be capable of continuous operation at 115 percent rated power. Because of the high capacity factor for the Devil Canyon station, the generators will therefore be sized on the basis of maximum turbine output at maximum head, allowing for a possible 5 percent addition in power from the turbine. This maximum turbine output (250,000 hp) is within the continuous overload rating of the generator.

Maximum and minimum heads on the units will be 542 feet and 600 feet, respectively. The full gate output of the turbines will be about 240,000 hp at maximum net head and 205,000 hp at minimum net head. Overgating of the turbines may be possible, providing approximately 5 percent additional power. For preliminary design purposes, the best efficiency (best gate) output of the units has been assumed at 85 percent of the full gate turbine output.

The full gate and best gate efficiencies of the turbines will be about 91 percent and 94 percent, respectively, at rated head. The efficiency will be about 0.2 percent lower at maximum head and 0.5 percent lower at minimum head. The preliminary performance curve for the turbine is shown in Figure B.74.

The Devil Canyon plant output may vary from zero to 700 MW with all four units operating at maximum output. The combined plant efficiency varies with output and number of units operating as shown in Figure B.75. As with Watana, the plant efficiency varies only slightly with loading due to the load following capabilities of multiple units.

4.4 - Tailwater Rating Curve

The tailwater rating curve for the Watana development is shown on Figure B.67 and for the Devil Canyon development on Figure B.68.

5 - STATEMENT OF POWER NEEDS AND UTILIZATION

5 - STATEMENT OF POWER NEEDS AND UTILIZATION

5.1 - Railbelt Load Forecasts

In this section of the Exhibit, the electrical demand forecasts for the Railbelt region are described. Historical and projected trends are identified and discussed, and the forecasts used in Susitna generation planning studies are presented.

The feasibility of a major hydroelectric project depends in part upon the extent the available capacity and energy are consistent with the needs of the market to be served by the time the project comes on line. The Alaska Power Authority and the State of Alaska authorized load forecasts for the Alaska Railbelt region to be prepared independently of the Susitna feasibility study.

The Railbelt region, shown in Figure B.76, contains three electrical load centers: the Anchorage-Cook Inlet area, the Fairbanks-Tanana Valley area, and the Glennallen-Valdez area. These areas are represented by the shaded areas in the figure. Because of the relatively small electrical requirements of the Glennallen-Valdez load center (approximately 2 percent of the demand of the Anchorage-Cook Inlet area) it is not specifically analyzed as an individual load center. For this study the Glennallen-Valdez load center is considered to be part of the Anchorage-Cook Inlet load center. The electrical demands for the Glennallen-Valdez area are determined as part of these projections and are combined with the Anchorage-Cook Inlet loads. Actually, these loads will not be served for the foreseeable future by capacity from the intertied Railbelt area.

(a) Scope of Studies

There have been two sets of forecasts developed and used during the feasibility study. In 1980, the Institute for Social and Economic Research (ISER) prepared economic and accompanying end-use energy demand projections for the Railbelt. The end-use forecasts were further refined as part of the feasibility study to estimate capacity demands and demand patterns. Also estimated was the potential impact on these forecasts of additional load management and energy conservation efforts. These forecasts were used in several portions of the feasibility study, including the development selection study, and initial economic, financial and sensitivity analyses. These forecasts are discussed in more detail in Subsection (b) below.

In December 1981, Battelle Pacific Northwest Laboratories produced a series of revised load forecasts for the Railbelt. These forecasts were developed as a part of the Railbelt Alternatives Study completed by Battelle under contract to the State of Alaska. Battelle's forecasts were a result of further updating of economic projections by ISER and some revised end-use models developed by Battelle, which took into account price sensitivity and several other factors not included in the 1980 projections. The December 1981 Battelle forecasts were used in the final project staging, economic, financial and sensitivity analyses. The December 1981 Battelle forecasts are presented in subsection (c) below.

Both forecasting groups produced high, medium and low forecasts for use in Susitna planning studies. The medium forecast was used for determining base generation plans, with the high and low forecasts used in sensitivity analyses.

(b) Electricity Demand Profiles

This section reviews the historical growth of electricity consumption in the Railbelt and compares it to the national trend. Earlier forecasts of Railbelt electricity consumption by ISER, which were used in Susitna development selection studies, are also described.

(i) Historical Trends

Between 1940 and 1978, electricity sales in the Railbelt grew at an average annual rate of 15.2 percent. This growth was roughly twice that for the nation as a whole. Table B.65 shows U.S. and Alaskan annual growth rates for different periods between 1940 and 1978. The historical growth of Railbelt utility sales from 1965 is illustrated in Figure B.77.

Although the Railbelt growth rates consistently exceeded the national average, the gap has been narrowing in later years due to the gradual maturing of the Alaskan economy. Growth in the Railbelt has exceeded the national average for two reasons: population growth in the Railbelt has been higher than the national rate, and the proportion of Alaskan households served by electric utilities was lower than the U.S. average so that some growth in the number of customers occurred independently of population growth. Table B.66 compares U.S. and Alaskan growth rates in the residential and commercial sectors.

The distribution of electricity consumption between residential and commercial-industrial-government sectors has been fairly stable. By 1978, the commercial-industrial-government and residential sectors accounted for 52 percent and 47 percent respectively. In contrast, the 1978 nationwide shares were 65 percent and 34 percent, respectively.

Historical electricity demand in the Railbelt, disaggregated by regions, is shown in Table B.67. During the period from 1965 to 1978, Greater Anchorage accounted for about 75 percent of Railbelt electricity consumption followed by Greater Fairbanks with 24 percent and Glennallen-Valdez with 1 percent. The pattern of regional sharing during this period has been quite stable and no discernible trend in regional shift has emerged. This is mainly a result of the uniform rate of economic development in the Alaskan Railbelt.

(ii) ISER Electricity Consumption Forecasts

The methodology used by ISER to estimate electric energy sales for the Railbelt is summarized in this section and the results obtained are discussed.

- Methodology

The ISER electricity demand forecasting model conceptualized in computer logic the linkage between economic growth scenarios and electricity consumption. The output from the model is in the form of projected values of electricity consumption for each of the three geographical areas of the Railbelt (Greater Anchorage, Greater Fairbanks and Glennallen-Valdez) and is classified by final use (i.e., heating, washing, cooling, etc.) and consuming sector (commercial, residential, etc). The model produces output on a five-year time basis from 1985 to 2010, inclusive.

The ISER model consists of several submodels linked by key variables and driven by policy and technical assumptions and state and national trends. These submodels are grouped into four economic models which forecast future levels of economic activity and four electricity consumption models which forecast the associated electricity requirements by consuming sectors. For two of the consuming sectors it was not possible to set up computer models and simplifying assumptions were made.

- Forecasting Uncertainty

To adequately address the uncertainty associated with the prediction of future demands, a number of different economic growth scenarios were considered. These were formulated by alternatively combining high, moderate and low growth rates in the area of special projects and industry with state government fiscal policies aimed at stimulating either high, moderate or low growth. This resulted in a total of nine potential growth scenarios for the state. In addition to these scenarios, ISER also considered the potential impact of a price reduced shift towards increased electricity demand. A short list of six future scenarios was selected. These concentrated around the mid-range or "base case" estimate and the upper and lower and extremes (see Table B.68).

- Demand Forecasts

An important factor to be considered in generation planning studies is the peak power demand associated with a forecast of electric energy demand. The overall approach to derivation of the peak demand forecasts for the Railbelt region was to examine the available historical data with regard to the generation of electrical energy and to apply the observed generation patterns to existing sales forecasts. Information routinely supplied by the Railbelt utilities to the Federal Energy Regulatory Commission was utilized to determine these load patterns.

The first step involved an adjustment to the allocated sales to reflect losses and energy unaccounted for. The adjustment was made by increasing the energy allocated to each utility by a factor computed from historical sales and generation levels. This resulted in a gross energy generation for each utility.

The factors determined for the monthly distribution of total annual generation were then used to distribute the gross generation for each year. The resulting hourly loads for each utility were added together to obtain the total Railbelt system load pattern for each forecast year. Table B.69 summarizes the total energy generation and the peak loads for each of the low, medium, and high ISER sales forecasts, assuming moderate government expenditure.

- Adjusted ISER Forecasts

Three of the initial ISER energy forecasts were considered in generation planning studies for development selection studies. These included the base case (MES-GM) or medium forecast, a low forecast and a high forecast. The low forecast was that corresponding to the low economic growth as proposed by ISER with an adjustment for low government expenditure (LES-GL). The high forecast corresponded to the ISER high economic growth scenario with an adjustment for high government expenditure (HES-GH).

The electricity forecasts summarized in Table B.69 represent total utility generation and include projections for self-supplied industrial and military generation sectors. Included in these forecasts are transmission and distribution losses in the range of 9 to 13 percent depending upon the generation scenario assumed. These forecasts, ranging from 2.71 to 4.76 percent average annual growth, were adjusted for use in generation planning studies.

The self-supplied industrial energy primarily involves drilling and offshore operations and other activities which are not likely to be connected into the Railbelt supply system. This component, which varies depending upon generation scenario, was therefore omitted from the forecasts used for planning purposes.

The military is likely to continue purchasing energy from the general market as long as it remains economic. However, much of their generating capacity is tied to district heating systems which would presumably continue operation. For study purposes, it was therefore assumed that 30 percent of the estimated military generation would be supplied from the grid system.

The adjustments made to power and energy forecasts for use in self-supplied industrial and military sectors are reflected in Table B.69 and in Figure B.78. The power and energy values given in Table B.70 are those developed by ISER and used in the development selection studies. Annual growth rates range from 1.99 to 5.96 percent for very low and high forecasts with a medium generation forecast of 3.96 percent.

(c) Battelle Load Forecasts

As part of its study of Alaska Railbelt Electric Energy Alternatives (6) Battelle did extensive work in reviewing the 1980 ISER forecasts, methodology, and data, and produced a new series of forecasts. These forecasts built on the base of information and modeling established by ISER's 1980 work and, with the assistance of ISER, developed new models for forecasting Railbelt economic activity and resulting electrical energy demands. The resulting forecasts were adopted directly for use in final generation planning studies under this feasibility study.

These revised forecasts included both an energy and peak capacity projection for each year of the study period (1982-2010). The projection left out portions of electrical demand which would be self-supplied, such as much of the military demand and some of the industrial demand. In addition, these forecasts took into account the conservation technology and market penetration likely to take place. Details of the Battelle forecasts and methodology are available in a report produced by Battelle in early 1982 (9). The demand forecasting process is summarized in the following three paragraphs.

Figure B.79 shows the electricity demand forecasting process used by Battelle. The forecasting process contains two steps. The first step combines sets of consistent economic and policy assumptions (scenarios) with economic models from the ISER to produce forecasts of future economic activity, population, and households in the Railbelt region and its three load centers. In the second step, these forecasts are combined with data on current end uses of electricity in the residential sector, data on the size of the Railbelt commercial building stock, data on the cost and performance of conservation, assumptions concerning the future prices of electricity and other fuels, and future uses of electricity to produce demand forecasts.

The economic and population forecasts, energy use data, and other assumptions are all entered into a computer-based electricity demand forecasting model called the Railbelt Electricity Demand (RED) Model (7). The RED model generates forecasts of housing stock and commercial building stock and the price-adjusted intensity of energy use in both the residential and commercial (including government) sectors. It also adds estimates of major industrial electrical energy demand and miscellaneous uses such as street lighting. These forecasts are adjusted for specific energy conservation policies, and then the major end-use sector forecasts are combined by the model into forecasts of future annual demand for electric energy for each of the Railbelt's load centers. The combined annual loads are adjusted by an annual load factor to estimate future annual peak demand by load center. Finally, the peak loads are added together and multiplied by a diversity factor (to adjust for the fact that peak loads for different load centers do not coincide) to derive peak demand for the Railbelt. More detail on the RED model can be found in Reference 7.

The projected cost of power affects these forecasts. Because the size of demand for power affects the size, number, and cost of generating facilities that may have to be built to meet the demand (which in turn affects the cost of power), several passes through the RED model with constant economic assumptions and varying costs of power are required to produce a final forecast.

The Battelle study produced numerous load forecasts which corresponded to different development plans. The plans varied due to different economic scenarios and costs of power. From these separate forecasts, a high, medium and low forecast were selected for project planning and economic and financial feasibility studies.

The Battelle forecasts are based on energy sales, and have therefore been adjusted by an addition of an estimated 8 percent for transmission losses to arrive at the supply forecast to be used in generation planning. Table B.71 and Figure B.80 present the three Battelle forecasts which were prepared to bracket the range of electrical demand for the future.

It should be noted that the load forecast figures vary in absolute values of peak demand and energy from those figures in the referenced Battelle studies. This minor variance (approximately 5-8 percent in the project development years) is due to the revision in the Battelle forecasts in 1982 after the feasibility work on Susitna proceeded using December 1981 numbers.

The Battelle forecasts were used in second stage generation planning studies. The second stage studies focused on the economic and financial feasibility of the selected Susitna project and the sensitivity of the analyses to variation of key study assumptions. The differences between the earlier ISER forecasts used in development selection studies and the revised Battelle forecasts are not considered to be significant enough to have altered the conclusions of the earlier studies. The Railbelt generation planning studies undertaken for Susitna feasibility assessment were based on the Battelle medium forecast. The high and low Battelle forecasts were used as a basis for sensitivity testing.

No additional information on load patterns relative to monthly and daily shifting of load shapes was developed in the Battelle forecasts. Thus, the historical data developed for use with the 1980 ISER forecasts were also used with the Battelle forecasts.

(d) Load Management and Conservation

The Alaska Power Authority as a developer of power projects has not instituted any conservation rate design programs to effect loads. However, both the ISER and Battelle forecasts included a consideration of these measures. In addition, the ISER low forecast (Tables B.69 and B.70) was modified to reflect a higher degree of load modifying measures.

(i) The resultant ISER forecasts in Table B.69 were made based on several projected conservation measures in place. These assumed measures resulted in lower forecasts than would be made if prevailing (1980) conditions were projected to continue.

For the residential sector, ISER assumed the federally-mandated efficiency standards for electrical home appliances would be enforced from 1981 to 1985 but that target efficiencies would be reduced by 10 percent. Energy saving due to retrofitting of homes was assumed to be confined to single family residences and to occur between 1980 and 1985. Heating energy consumption was assumed to be reduced by 4 percent in Fairbanks, 2 percent in Anchorage and between 2 and 4 percent in the Glennallen-Valdez area. Enforcement of mandatory construction or performance standards for new housing was assumed in 1981 with a reduction of the heat load for new permanent home construction by 5 percent.

In the commercial-industrial-government sector, it was assumed by ISER that electricity requirements for new construction would be reduced by 5 percent between 1985 and 1990 and by 10 percent during the period 1990 to 2000. It was assumed that retrofitting measures would have no impact.

Since the ISER forecasts incorporated the impacts of these expected energy conservation measures but did not include load management, a low load forecast with high emphasis on load reduction measures was made. The purpose of this forecast would be to test generation plans during the development selection phase. The basis for this forecast was the ISER forecast, further adjusted downward to account for load reduction measures.

The programs of energy conservation and load management measures that were assumed to be implemented in addition to those included in the ISER forecast are the following:

- Energy programs provided for in the Alaska state energy conservation legislation;

- Load management concepts not tested by utilities, including rate reform, to reflect incremental cost of service and load controls.

The impact of state energy conservation legislation has been evaluated in a study by Energy Probe (10) which indicated that it could reduce the amount of electricitiy needed for space heating by 47 percent. The total growth rate in electricity demand over the 1980-2010 period would drop from an average of 3.98 percent per annum (projected by ISER in the MES-GM forecast) to 3.49 percent annum. Energy Probe indicated that the electrical energy growth rate could be reduced even further to 2.70 percent per annum with a conservation program more stringent than that presently contemplated by the state legislature.

The ISER low forecast case incorporates an annual growth rate of 2.71 percent. This rate would be reduced with enforcement of energy conservation measures more intensive than those presently in the state legislature. An annual growth rate of 2.1 percent was judged to be a reasonable lower limit for electrical demand for purposes of this study. This represents a 23 percent reduction in growth rate which is similar to the reduction developed in the Energy Probe study.

The implementation of load management measures would result in an additional reduction in peak load demand. The residential sector demand is the most sensitive to a shift of load from the peak period to the off-peak period. Over the 1980-2010 period, an annual growth rate for peak load of 2.73 percent was used in the low forecast case. With load management measures such as rate reform and load controls, this growth rate could be reduced to an estimated 2.1 percent. The annual load factor for year 2010 would be increased from 62.2 percent in the low forecast to 64.4 in the lowest case. The resultant adjusted low-load management and conservation forecast is presented in Table B.70. The forecast was used to check the development selection plans discussed in Section 1. Results of that analysis are presented in Table B.12.

(ii) The Battelle Railbelt Electric Power Alternative Study (6) also reviewed in depth the impact of conservation impacts on load forecasts. The forecoasts made for the base plans, such as those produced in Table B.71 take into account substantial conservation of electricity because of the increase in price of electricity during the time horizon of the study. Since the forecasts are an end product of an iterative process of demand and price analysis, they include a market penetration of conservation technologies which improve the efficiency of end use of electricity. This would include a variety of techniques such as weatherstripping, set-back thermostats, water-heater jackets. These measures which are expected to be adopted as a matter of course are the low initial investment, quick-payback conservation methods.

The Battelle Study also studied a specific plan in which conservation alternatives received greater emphasis than the base plan. The plan also included a high use of renewable energy sources. To achieve the plan, a maximum technical contribution of conservation program was assumed which goes beyond the market-induced conservation included in the base plan.

In this conservation program, the State of Alaska is assumed to provide a grant program to residential consumers to offset the initial investment cost of four technologies with higher initial cost and high energy payoff. The four selected technologies are: super insulation of buildings, passive solar designs for space heating, active solar hot water heating, and wood-fired space heating. Because less information is available about specific end uses of electricity in the business sector, the conservation supply plans relied on estimates of maximum average electrical conservation of about 35 percent in the business sector and corresponding estimates of minimum life cycle energy costs. The initial capital cost of achieving this maximum technical saving was then reduced to zero by an assumed business sector grant program, resulting in full technical savings.

The resultant forecasts of peak demand and annual energy are presented in Table B.72. The table compares the Battelle base plan forecast to the high conservation and renewable resource forecast for low, medium and high conservation. As discussed in (c) of this subsection, these forecasts vary slightly from the forecasts used in Susitna project planning studies, due to adjustments made after completion of the latter. Additionally, the forecasts are for end use demand and should be increased by approximately eight percent for line losses and reserve requirements. These forecasts are those developed with the Susitna project part of the generation plan. They are slightly higher than those of similar economic scenarios which do not include Susitna due to the price elasticity of the forecast model.

5.2 - Market and Price for Watana Output in 1994

It has been planned that Watana energy will be supplied at a single wholesale rate on a free market basis. This requires, in effect, that Susitna energy be priced so that it is attractive even to utilities with the lowest cost alternative source of energy. On this basis it is estimated that for the marketable 3315 GWh of energy generated by Watana in 1994 to be attractive, a price of 145 mills per kWh in 1994 dollars is required. Justification for this price is illustrated in Figure B.81. Note that the assumption is made that the only capital costs which would be avoided in the early 1990s would be those due to the addition of new coal-fired generating plants (i.e., the alternative 2 x 200 MW coal-fired Beluga station).

The financing considerations under which it would be appropriate for Watana energy to be sold at approximately 145 mills/kWh price are presented in Exhibit D; however, it should be noted that some of the energy which would be displaced by Watana's 3315 GWh would have been generated at a lower cost than 145 mills, and utilities might wish to delay accepting it at this price until the escalating cost of natural gas or other fuels made it more attractive. A number of approaches to the resolution of this problem can be postulated, including pre-contract arrangements.

(a) Contractual Preconditions for Susitna Energy Sale

It will be necessary to contract with Railbelt utilities for the purchase of Susitna capacity and energy on a basis appropriate to support financing of the project.

Pricing policies for Susitna output are assumed to be constrained by both cost (as defined by State of Alaska Senate Bill 25) and by the price of energy from the best thermal option.

Marketing Susitna's output within these twin constraints would ensure that all state support for Susitna flowed through to consumers and under no circumstances were prices to consumers higher than they would have been under the best thermal option. In addition, consumers would also obtain the long-term economic benefits of Susitna's low cost energy.

(b) Market Price for Watana Output 1995-2001

After its initial entry into the system in 1994, the price and market for the 3315 Gwh of Watana output is consistently upheld over the years to 2001 by the projected 20 percent increase in total demand over this period.

There would, as a result, be a 70 percent increase in cost savings compared with the best thermal alternative. The increasing cost per unit of output from a system without Susitna is illustrated in Figure B.82.

(c) Market and Price for Watana and Devil Canyon Output in 2003

A diagramatic analysis of the total cost savings which the combined Watana and Devil Canyon output will confer on the system compared with the present thermal option in the year 2003 is shown in Figure B.83. These total savings are divided by the energy contributed by Susitna to indicate a price of 250 mills per kWh as the maximum price which can be charged for Susitna output. Here again, the problem of competing with lower cost combined cycle, gas turbines, etc., will have to be addressed; however, this problem is likely to be short term in nature, since by this time period these thermal power facilities will be approaching retirement.

Only about 90 percent of the total Susitna output will be absorbed by the system in 2002; the balance of the output will be progressively absorbed over the following decade. This will provide increasing total savings to the system from Susitna with no associated increase in costs.

(d) Potential Impact of State Appropriations

In the preceding paragraphs the maximum price at which Susitna energy could be sold has been identified. Sale of the energy at these prices will depend upon the magnitude of any proposed state appropriation designed to reduce the cost of Susitna energy in the earlier years. At significantly lower prices it is likely that the total system demand will be higher than assumed. This, combined with a state appropriation to reduce the energy cost of Watana energy, would make it correspondingly easier to market the output from the Susitna development; however, as the preceding analysis shows, a viable and strengthening market exists for the energy from the development that would make it possible to price the output up to the cost of the best thermal alternative.

(e) Conclusions

Based on the assessment of the market for power and energy output from the Susitna Hydroelectric Project, it has been concluded that, with the appropriate level of state appropriation and with pricing as defined in Senate Bill 25, an attractive basis exists, particularly in the long term, for the Railbelt utilities to derive benefit from the project. It should be recognized that contractual arrangements covering purchase of Susitna output will be an essential precondition for the actual commencement of project construction. These contractual arrangements will be pursued during the licensing and design phase of the project.

5.3 - Sale of Power

Electrical energy from the Susitna Hydroelectric Project will be sold to utilities serving the Anchorage/Fairbanks net.

The potential customers for Susitna power utilities in the Railbelt include:

- Fairbanks Municipal Utility System;
- Homer Electric Association;
- Anchorage Municipal Light & Power Department;
- Chugach Electric Association;
- Golden Valley Electric Association;
- Matanuska Electric Association; and
- Seward Electric System

A more detailed discussion of marketing can be found in Reference 8.

6 - FUTURE SUSITNA BASIN DEVELOPMENT

6 - FUTURE SUSITNA BASIN DEVELOPMENT

The Alaska Power Authority has no current plans for further development of the Watana/Devil Canyon system and no plans for further water power projects in the Susitna River Basin at this time.

Development of the proposed projects would preclude further major hydroelectric development in the Susitna basin, with the exception of major storage projects in the Susitna basin headwaters. Although these types of plans have been considered in the past, they are neither active nor anticipated to be so in the foreseeable future.

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4. Acres American Inc., Susitna Hydroelectric Project, Feasibility Report, Vol. 1, prepared for the Alaska Power Authority, March 1982.

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6. Battelle Pacific Northwest Laboratories, Railbelt Electric Power Alternatives Study: Evaluation of Railbelt Electric Energy Plans, prepared for the Office of the Governor, State of Alaska, August 1982.

7. Battelle Pacific Northwest Laboratories, The Railbelt Electricity Demand (RED) Model Specifications Report, prepared for the Office of the Governor, State of Alaska, August 1982.

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12. Acres American Inc. and Terrestrial Environmental Specialist, Inc., Transmission Line Selected Route, prepared for the Alaska Power Authority, March 1982.

13. R&M Consultants, Terrain Analysis of the North and South Intertie Power Transmission Corridors, prepared for Acres American Inc., November 1981.

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14. Acres American Inc, Susitna Hydroelectric Project, Feasibility Report, Vol. 4, prepared for the Alaska Power Authority, March 1982.

15. Acres American Inc., Susitna Hydroelectric Project, Access Route Selection Report, prepared for the Alaska Power Authority, March 1982.

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TABLE B.1: POTENTIAL HYDROELECTRIC DEVELOPMENT

Site	Dam Proposed Type	Dam Height Ft.	Upstream Regulation	Capital Cost $ million (1980)	Installed Capacity (MW)	Average Annual Energy Gwh	Economic Cost of Energy[1] $/1000 kWh	Source of Data
Gold Creek[2]	Fill	190	Yes	900	260	1,140	37	USBR 1953
Olson (Susitna II)	Concrete	160	Yes	600	200	915	31	USBR 1953 KAISER 1974 COE 1975
Devil Canyon	Concrete	675	No Yes	830 1,000	250 600	1,420 2,980	27 17	This Study "
High Devil Canyon (Susitna I)	Fill	855	No	1,500	800	3,540	21	" "
Devil Creek[2]	Fill	Approx 850	No	-	-	-	-	-
Watana	Fill	880	No	1,860	800	3,250	2	"
Susitna III	Fill	670	No	1,390	350	1,580	41	"
Vee	Fill	610	No	1,060	400	1,370	37	"
Maclaren[2]	Fill	185	No	530[4]	55	180	124	"
Denali	Fill	230	No	480[4]	60	245	81	"
Butte Creek[2]	Fill	Approx 150	No	-	40	130[3]	-	USBR 1953
Tyone[2]	Fill	Approx 60	No	-	6	22[3]	-	USBR 1953

Notes:

(1) Includes AFDC, Insurance, Amortization, and Operation and Maintenance Costs.
(2) No detailed engineering or energy studies undertaken as part of this study.
(3) These are approximate estimates and serve only to represent the potential of these two damsites in perspective.
(4) Include estimated costs of power generation facility.

TABLE B.2 - COST COMPARISONS

DAM		Capital Cost Estimate[2] (1980 $)				
		ACRES 1980		OTHERS		
Site	Type	Installed Capacity - MW	Capital Cost $ million	Installed Capacity - MW	Capital Cost $ million	Source and Date of Data
Gold Creek	Fill	-	-	260[1]	890	USRB 1968
Olson (Susitna II)	Concrete	-	—	190[1]	550	COE 1975
Devil Canyon	Fill	600	1,000	-	-	-
	Concrete Arch	-	-	776	630	COE 1975
	Concrete Gravity	-	-	776	910	COE 1978
High Devil Canyon (Susitna I)	Fill	800	1,500	700	1,480	COE 1975
Devil Creek	Fill	-	-	-	-	-
Watana	Fill	800	1,860	792	1,630	COE 1978
Susitna III	Fill	350	1,390	445	-	KAISER 1974
Vee	Fill	400	1,060	-	770	COE 1975
Maclaren	Fill	55	530	-		-
Denali	Fill	60	480	None	500	COE 1975

Notes:

(1) Dependable Capacity
(2) Excluding Anchorage/Fairbanks transmission intertie, but including local access and transmission.

TABLE B.3: DAM CREST AND FULL SUPPLY LEVELS

Site	Staged Dam Construction	Full Supply Level - Ft.	Dam Crest Level - Ft.	Average Tailwater Level - ft.	Dam Height[1] ft.
Gold Creek	No	870	880	680	290
Olson	No	1,020	1,030	810	310
Portage Creek	No	1,020	1,030	870	250
Devil Canyon - intermediate height	No	1,250	1,270	890	465
Devil Canyon - full height	No	1,450	1,470	890	675
High Devil Canyon	No	1,610	1,630	1,030	710
	No	1,750	1,775	1,030	855
Watana	Yes	2,000	2,060	1,465	680
	Stage 2	2,200	2,225	1,465	880
Susitna III	No	2,340	2,360	1,810	670
Vee	No	2,330	2,350	1,925	610
Maclaren	No	2,395	2,405	2,300	185
Denali	No	2,540	2,555	2,405	230

Notes:

(1) To foundation level.

TABLE B.4 - CAPITAL COST ESTIMATE SUMMARIES
SUSITNA BASIN DAM SCHEMES
COST IN $MILLION 1980

Item	Devil Canyon 1470 ft Crest 600 MW	High Devil Canyon 1775 ft Crest 800 MW	Watana 2225 ft Crest 800 MW	Susitna III 2360 ft Crest 330 MW	Vee 2350 ft Crest 400 MW	Maclaren 2405 ft Crest No power	Denali 2250 ft Crest No power
1) Lands, Damages & Reservoirs	26	11	46	13	22	25	38
2) Diversion Works	50	48	71	88	37	118	112
3) Main Dam	166	432	536	398	183	106	100
4) Auxiliary Dam	0	0	0	0	40	0	0
5) Power System	195	232	244	140	175	0	0
6) Spillway System	130	141	165	121	74	0	0
7) Roads and Bridges	45	68	96	70	80	57	14
8) Transmission Line	10	10	26	40	49	0	0
9) Camp Facilities and Support	97	140	160	130	100	53	50
10) Miscellaneous[1]	8	8	8	8	8	5	5
11) Mobilization and Preparation	30	47	57	45	35	15	14
Subtotal	757	1137	1409	1053	803	379	333
Contingency (20%)	152	227	282	211	161	76	67
Engineering and Owner's Administration (12%)	91	136	169	126	96	45	40
TOTAL	1000	1500	1860	1390	1060	500	440

Notes:

(1) Includes recreational facilities, buildings and grounds and permanent operating equipment.

TABLE B.5 - RESULTS OF SCREENING MODEL

	Total Demand		Optimal Solution				First Suboptimal Solution				Second Suboptimal Soultion			
Run	Cap. MW	Energy GWh	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million
1	400	1750	High Devil Canyon	1580	400	885	Devil Canyon	1450	400	970	Watana	1950	400	980
2	800	3500	High Devil Canyon	1750	800	1500	Watana	1900	450	1130	Watana	2200	800	1860
							Devil Canyon	1250	350	710				
							TOTAL		800	1840				
3	1200	5250	Watana	2110	700	1690	High Devil Canyon	1750	800	1500	High Devil Canyon	1750	820	1500
			Devil Canyon	1350	500	800	Vee	2350	400	1060	Susitna III	2300	380	1260
			TOTAL		1200	2490	TOTAL		1200	2560	TOTAL		1200	2760
4	1400	6150	Watana	2150	740	1770	NO SOLUTION				NO SOLUTION			
			Devil Canyon	1450	660	1000								

TABLE B.6: INFORMATION ON THE DEVIL CANYON DAM AND TUNNEL SCHEMES

Item	Devil Canyon Dam	Tunnel Scheme			
		1	2	3	4
Reservoir Area (Acres)	7,500	320	0	3,900	0
River Miles Flooded	31.6	2.0	0	15.8	0
Tunnel Length (Miles)	0	27	29	13.5	29
Tunnel Volume (1000 Yd^3)	0	11,976	12,863	3,732	5,131
Compensating Flow Release (cfs)	0	1,000	1,000	1,000	1,000
Reservoir Volume (1000 Acre-feet)	1,100	9.5	—	350	—
Dam Height (feet)	625	75	—	245	—
Typical Daily Range of Discharge From Devil Canyon Powerhouse (cfs)	6,000 to 13,000	4,000 to 14,000	4,000 to 14,000	8,300 to 8,900	3,900 to 4,200
Approximate Maximum Daily Fluctuations in Reservoir (feet)	2	15	—	4	—

Notes:

[3] Estimated, above existing rock elevation.

TABLE B.7 - DEVIL CANYON TUNNEL SCHEMES COSTS, POWER OUTPUT AND AVERAGE ANNUAL ENERGY

Stage	Installed Capacity (MW) Watana	Devil Canyon Tunnel	Increase[1] in Installed Capacity (MW)	Devil Canyon Average Annual Energy (Gwh)	Increase[1] in Average Annual Energy (Gwh)	Tunnel Scheme Total Project Costs $ Million	Cost[3] of Additional Energy[1] (mills/kWh)
STAGE 1:							
Watana Dam	800	---	---	---	---	---	---
STAGE 2:							
Tunnel:							
- Scheme 1	800	550	550	2,050	2,050	1980	42.6
- Scheme 2[2]	70	1,150	420	4,750	1,900	2320	52.9
- Scheme 3[2]	850	330	380	2,240	2,180	1220	24.9
- Scheme 4	800	365	365	2,490	890	1490	73.6

Note

(1) Increase over single Watana, 800 MW development 3250 Gwh/yr
(2) Includes power and energy produced at re-regulation dam
(3) Energy cost is based on an economic analysis (i.e. using 3 percent interest rate)

TABLE B.8 - CAPITAL COST ESTIMATE SUMMARIES
TUNNEL SCHEMES
COSTS IN $MILLION 1980

Item		Two 30 ft dia tunnels		One 40 ft dia tunnel
Land and damages, reservoir clearing		14		14
Diversion works		35		35
Re-regulation dam		102		102
Power system		680		576
(a) Main tunnels	557		453	
(b) Intake, powerhouse, tailrace and switchyard	123		123	
Secondary power station		21		21
Spillway system		42		42
Roads and bridges		42		42
Transmission lines		15		15
Camp facilities and support		131		117
Miscellaneous*		8		8
Mobilization and preparation		47		47
TOTAL CONSTRUCTION COST		1,137		1,015
Contingencies (20%)		227		203
Engineering, and Owner's Administration		136		122
TOTAL PROJECT COST		1,500		1,340

TABLE B.9. SUSITNA DEVELOPMENT PLANS

Plan	Stage	Construction	Stage/Incremental Data: Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft	Cumulative System Data: Annual Energy Production Firm GWH	Avg. GWH.	Plant Factor %
1.1	1	Watana 2225 ft 800MW	1860	1993	2200	150	2670	3250	46
	2	Devil Canyon 1470 ft 600 MW	1000	1996	1450	100	5500	6230	51
		TOTAL SYSTEM 1400 MW	2860						
1.2	1	Watana 2060 ft 400 MW	1570	1992	2000	100	1710	2110	60
	2	Watana raise to 2225 ft	360	1995	2200	150	2670	2990	85
	3	Watana add 400 MW capacity	130[2]	1995	2200	150	2670	3250	46
	4	Devil Canyon 1470 ft 600 MW	1000	1996	1450	100	5500	6230	51
		TOTAL SYSTEM 1400 MW	3060						
1.3	1	Watana 2225 ft 400 MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400 MW capacity	150	1993	2200	150	2670	3250	46
	3	Devil Canyon 1470 ft 600 MW	1000	1996	1450	100	5500	6230	51
		TOTAL SYSTEM 1400 MW	2890						

TABLE B.9 (Continued)

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Annual Energy Production Firm GWH	Annual Energy Production Avg. GWH	Plant Factor %
2.1	1	High Devil Canyon							
		1775 ft 800 MW	1500	1994[3]	1750	150	2460	3400	49
	2	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200 MW	2560						
2.2	1	High Devil Canyon							
		1630 ft 400 MW	1140	1993[3]	1610	100	1770	2020	58
	2	High Devil Canyon add 400 MW Capacity raise dam to 1775 ft	500	1996	1750	150	2460	3400	49
	3	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200 MW	2700						
2.3	1	High Devil Canyon							
		1775 ft 400 MW	1390	1994[3]	1750	150	2400	2760	79
	2	High Devil Canyon add 400 MW capacity	140	1994	1750	150	2460	3400	49
	3	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200 MW	2590						
3.1	1	Watana 2225 ft 800 MW	1860	1993	2200	150	2670	3250	46
	2	Watana add 50 MW tunnel 330 MW	1500	1995	1475	4	4890	5430	53
		TOTAL SYSTEM 1180 MW	3360						

TABLE B.9 (Continued)

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Annual Energy Production Firm GWH	Annual Energy Production Avg. GWH	Plant Factor %
3.2	1	Watana 2225 ft 400 MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400 MW capacity	150	1994	2200	150	2670	3250	46
	3	Tunnel 330 MW add 50 MW to Watana	1500	1995	1475	4	4890	5430	53
			3390						
4.1	1	Watana 2225 ft 400 MW	1740	1995[3]	2200	150	2670	2990	85
	2	Watana add 400 MW capacity	150	1996	2200	150	2670	3250	46
	3	High Devil Canyon 1470 ft 400 MW	860	1998	1450	100	4520	5280	50
	4	Portage Creek 1030 ft 150 MW	650	2000	1020	50	5110	6000	51
		TOTAL SYSTEM 1350 MW	3400						

NOTES:

(1) Allowing for a 3 year overlap construction period between major dams.
(2) Plan 1.2 Stage 3 is less expensive than Plan 1.3 Stage 2 due to lower mobilization costs.
(3) Assumes FERC license can be filed by June 1984, ie. 2 years later than for the Watana/Devil Canyon Plan 1.

TABLE B.10. SUSITNA ENVIRONMENTAL DEVELOPMENT PLANS

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft	Annual Energy Production Firm GWH	Annual Energy Production Avg. GWH.	Plant Factor %
E1.1	1	Watana 2225 ft 800MW and Re-Regulation Dam	1960	1993	2200	150	2670	3250	46
	2	Devil Canyon 1470 ft 400MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200MW	2860						
E1.2	1	Watana 2060 ft 400MW	1570	1992	2000	100	1710	2110	60
	2	Watana raise to 2225 ft	360	1995	2200	150	2670	2990	85
	3	Watana add 400MW capacity and Re-Regulation Dam	230[2]	1995	2200	150	2670	3250	46
	4	Devil Canyon 1470 ft 400MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200MW	3060						
E1.3	1	Watana 2225 ft 400MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400MW capacity and Re-Regulation Dam	250	1993	2200	150	2670	3250	46
	3	Devil Canyon 1470 ft 400 MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200MW	2890						

TABLE B.10 (Continued)

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Annual Energy Production Firm GWH	Avg. GWH	Plant Factor %
E1.4	1	Watana 2225 ft 400MW	1740	1993	2200	150	2670	2990	85
	2	Devil Canyon 1470 ft 400MW	900	1996	1450	100	5190	5670	81
		TOTAL SYSTEM 800MW	2640						
E2.1	1	High Devil Canyon 1775 ft 800MW and Re-Regulation Dam	1600	1994[3]	1750	150	2460	3400	49
	2	Vee 2350ft 400MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200MW	2660						
E2.2	1	High Devil Canyon 1630 ft 400MW	1140	1993[3]	1610	100	1770	2020	58
	2	High Devil Canyon raise dam to 1775 ft add 400MW and Re-Regulation Dam	600	1996	1750	150	2460	3400	49
	3	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200MW	2800						
E2.3	1	High Devil Canyon 1775 ft 400MW	1390	1994[3]	1750	150	2400	2760	79
	2	High Devil Canyon add 400MW capacity and Re-Regulation Dam	240	1995	1750	150	2460	3400	49
	3	Vee 2350 ft 400MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200	2690						

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TABLE B.10 (Continued)

Plan	Stage	Construction	Stage/Incremental Data: Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Cumulative System Data: Annual Energy Production Firm GWH	Avg. GWH	Plant Factor %
E2.4	1	High Devil Canyon 1755 ft 400MW	1390	1994[3]	1750	150	2400	2760	79
	2	High Devil Canyon add 400MW capacity and Portage Creek Dam 150 ft	790	1995	1750	150	3170	4080	49
	3	Vee 2350 ft 400MW	1060	1997	2330	150	4430	5540	47
		TOTAL SYSTEM	3240						
E3.2	1	Watana 2225 ft 400MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400 MW capacity and Re-Regulation Dam	250	1994	2200	150	2670	3250	46
	3	Watana add 50MW Tunnel Scheme 330MW	1500	1995	1475	4	4890	5430	53
		TOTAL SYSTEM 1180MW	3490						
E4.1	1	Watana 2225 ft 400MW	1740	1995[3]	2200	150	2670	2990	85
	2	Watana add 400MW capacity and Re-Regulation Dam	250	1996	2200	150	2670	3250	46
	3	High Devil Canyon 1470 ft 400MW	860	1998	1450	100	4520	5280	50
	4	Portage Creek 1030 ft 150MW	650	2000	1020	50	5110	6000	51
		TOTAL SYSTEM 1350 MW	3500						

NOTES:
(1) Allowing for a 3 year overlap construction period between major dams.
(2) Plan 1.2 Stage 3 is less expensive than Plan 1.3 Stage 2 due to lower mobilization costs.
(3) Assumes FERC license can be filed by June 1984, ie. 2 years later than for the Watana/Devil Canyon Plan 1.

TABLE B.11 - RESULTS OF ECONOMIC ANALYSES OF SUSITNA PLANS - MEDIUM LOAD FORECAST

Susitna Development Plan Inc.						Installed Capacity (MW) by Category in 2010					Total System Installed Capacity in 2010-MW	Total System Present Worth Cost $ Million	Remarks Pertaining to the Susitna Basin Development Plan
	Online Dates Stages					Thermal			Hydro				
Plan No.	1	2	3	4	OGP5 Run Id. No.	Coal	Gas	Oil	Other	Susitna			
E1.1	1993	2000	--	--	LXE7	300	426	0	144	1200	2070	5850	
E1.2	1992	1995	1997	2002	L5Y9	200	501	0	144	1200	2045	6030	
E1.3	1993	1996	2000	--	L8J9	300	426	0	144	1200	2070	5850	
	1993	1996	--	--	L7W7	500	651	0	144	800	2095	6960	Stage 3, Devil Canyon Dam not constructed
	1998	2001	2005	--	LAD7	400	276	30	144	1200	2050	6070	Delayed implementation schedule
E1.4	1993	2000	--	--	LCK5	200	726	50	144	800	1920	5890	Total development limited to 800 MW
Modified E2.1	1994	2000	--	--	LB25	400	651	60	144	800	2055	6620	High Devil Canyon limited to 400 MW
E2.3[1]	1993	1996	2000	--	L601	300	651	20	144	1200	2315	6370	
	1993	1996	--	--	LE07	500	651	30	144	800	2125	6720	Stage 3, Vee Dam, not constructed
Modified E2.3	1993	1996	2000		LEB3	300	726	220	144	1300	2690	6210	Vee dam replaced by Chakachamna dam
3.1	1993	1996	2000	--	L607	200	651	30	144	1180	2205	6530	
Special 3.1	1993	1996	2000	--	L615	200	651	30	144	1180	2205	6230	Capital cost of tunnel reduced by 50 percent
E4.1	1995	1996	1998	--	LTZ5	200	576	30	144	1200	2150	6050	Stage 4 not constructed

NOTES:

(1) Adjusted to incorporate cost of re-regulation dam

TABLE B.12 - RESULTS OF ECONOMIC ANALYSES OF SUSITNA PLANS - LOW AND HIGH LOAD FORECAST

Plan No.	Online Dates Stage 1	Stage 2	Stage 3	Stage 4	OGP5 Run Id. No.	Thermal: Coal	Thermal: Gas	Oil	Hydro: Other	Hydro: Susitna	Total System Installed Capacity in 2010-MW	Total System Present Worth Cost $ Million	Remarks Pertaining to the Susitna Basin Development Plan
VERY LOW FORECAST[1]													
E1.4	1997	2005	--	--	L7B7	0	651	50	144	800	1645	3650	
LOW LOAD FORECAST													
E1.3	1993	1996	2000	--	--	--	--	--	--	--	--	--	Low energy demand does not warrant plan capacities
E1.4	1993	2002	--	--	LC07	0	351	40	144	800	1335	4350	
	1993	--	--	--	LBK7	200	501	80	144	400	1325	4940	Stage 2, Devil Canyon Dam, not constructed
E2.1	1993	2002	--	--	LG09	100	426	30	144	800	1500	4560	High Devil Canyon limited to 400 MW
	1993	--	--	--	LBU1	400	501	0	144	400	1445	4850	Stage 2, Vee Dam, not constructed
E2.3	1993	1996	2000	--	--	--	--	--	--	--	--	--	Low energy demand does not warrant plan capacities
Special 3.1	1993	1996	2000	--	L613	0	576	20	144	780	1520	4730	Capital cost of tunnel reduced by 50 percent
3.2	1993	2002	--	--	L609	0	576	20	144	780	1520	5000	Stage 2, 400 MW addition to Watana, not constructed
HIGH LOAD FORECAST													
E1.3	1993	1996	2000	--	LA73	1000	951	0	144	1200	3295	10680	
Modified E1.3	1993	1996	2000	2005[2]	LBV7	800	651	60	144	1700	3355	10050	Chakachamna hydroelectric generating station (480 MW) brought on line as a fourth stage
E2.3	1993	1996	2000	--	LBV3	1300	951	90	144	1200	3685	11720	
Modified E2.3	1993	1996	2000	2003[2]	LBY1	1000	876	10	144	1700	3730	11040	Chakachamna hydroelectric generating station (480 MW) brought on line as a fourth stage

Installed Capacity (MW) by Category in 2010: Thermal (Coal, Gas, Oil); Hydro (Other, Susitna).

NOTE:
(1) Incorporating load management and conservation

TABLE B.13 - ANNUAL FIXED CARRYING CHARGES

Project Type		Economic Life - Years	Economic Parameters: Cost of Money %	Amortization %	Insurance %
Thermal	- Gas Turbine (Oil Fired)	20	3.00	3.72	0.25
	- Diesel, Gas Turbine (Gas Fired) and Large Steam Turbine	30	3.00	2.10	0.25
	- Small Steam Turbine	35	3.00	1.65	0.25
Hydropower		50	3.00	0.89	0.10

FUEL COSTS AND ESCALATION RATES

	Natural Gas	Coal	Distillate
Base Period (January 1980)			
- Prices ($/million Btu)			
Market Prices	$1.05	$1.15	$4.00
Shadow (Opportunity) Values	2.00	1.15	4.00
Real Escalation Rates (Percentage)			
- Change Compounded (Annually)			
1980 - 1985	1.79%	9.56%	3.38%
1986 - 1990	6.20	2.39	3.09
1991 - 1995	3.99	-2.87	4.27
Composite (average) 1980-1995	3.98	2.93	3.58
1996 - 2005	3.98	2.93	3.58
2006 - 2010	0	0	0

TABLE B.14 - SUMMARY OF THERMAL GENERATING RESOURCE PLANT PARAMETERS

Parameter	PLANT TYPE: COAL-FIRED STEAM 500 MW	COAL-FIRED STEAM 250 MW	COAL-FIRED STEAM 100 MW	COMBINED CYCLE 250 MW	GAS TURBINE 75 MW	DIESEL 10 MW
Heat Rate (Btu/kWh)	10,500	10,500	10,500	8,500	12,000	11,500
O&M Costs						
Fixed O&M ($/yr/kW)	0.50	1.05	1.30	2.75	2.75	0.50
Variable O&M ($/MWH)	1.40	1.80	2.20	0.30	0.30	5.00
Outages						
Planned Outages (%)	11	11	11	14	11	1
Forced Outages (%)	5	5	5	6	3.8	5
Construction Period (yrs)	6	6	5	3	2	1
Start-up Time (yrs)	6	6	6	4	4	1
Total Capital Cost ($ million)						
Railbelt:	-	-	-	175	26	7.7
Beluga:	1,130	630	290	-	-	-
Unit Capital Cost ($/kW)[1]						
Railbelt:	-	-	-	728	250	778
Beluga:	2473	2744	3102	-	-	-

Notes:

(1) Including AFDC at 0 percent escalation and 3 percent interest.

TABLE B.15 - ECONOMIC BACKUP DATA FOR EVALUATION OF PLANS

	Total Present Worth Cost for 1981 - 2040 Period $ Million (% Total)			
Parameter	Generation Plan With High Devil Canyon - Vee	Generation Plan With Watana - Devil Canyon Dam	Generation Plan With Watana - Tunnel	All Thermal Generation Plans
Capital Investment	2800 (44)	2740 (47)	3170 (49)	2520 (31)
Fuel	3220 (50)	2780 (47)	3020 (46)	5240 (64)
Operation and Maintenance	350 (6)	330 (6)	340 (5)	370 (5)
TOTAL:	6370 (100)	5850 (100)	6530 (100)	8130 (100)

TABLE B.16 - ECONOMIC EVALUATION OF DEVIL CANYON DAM AND TUNNEL SCHEMES AND WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE PLANS

		Present worth of Net Benefit ($ million) of total generation system costs for the: Devil Canyon Dam over the Tunnel Scheme	Watana/Devil Canyon Dams over the High Devil Canyon/Vee Dams	Remarks
ECONOMIC EVALUATION: - Base Case		680	520	Economic ranking: Devil Canyon dam scheme is superior to Tunnel scheme. Watana/Devil Canyon dam plan is superior to the High Devil Canyon dam/Vee dam plan.
SENSITIVITY ANALYSES: - Load Growth	Low High	650 N.A.	210 1040	The net benefit of the Watana/Devil Canyon plan remains positive for the range of load forecasts considered. No change in ranking.
- Capital Cost Estimate		Higher uncertainty associated with tunnel scheme.	Higher uncertainty associated with H.D.C./Vee plan.	Higher cost uncertainties associated with higher cost schemes/plans. Cost uncertainty therefore does not affect economic ranking.
- Period of Economic Analysis	Period shortened to (1980 - 2010)	230	160	Shorter period of evaluation decreases economic differences. Ranking remains unchanged.
- Discount Rate	5% 8% (interpolated) 9%	As both the capital and fuel costs associated with the tunnel scheme and H.D.C./Vee Plan are higher than for Watana/Devil Canyon plan any changes to these parameters cannot reduce the Devil Canyon or Watana/Devil Canyon net benefit to below zero.		Ranking remains unchanged.
- Fuel Cost	80% basic fuel cost			
- Fuel Cost Escalation	0% fuel escalation 0% coal escalation			
- Economic Thermal Plant Life	50% extension 0% extension			

TABLE B.17 - ENVIRONMENTAL EVALUATION OF DEVIL CANYON DAM AND TUNNEL SCHEME

Environmental Attribute	Concerns	Appraisal (Differences in impact of two schemes)	Identification of difference	Appraisal Judgement	Scheme judged to have the least potential impact: Tunnel	Scheme judged to have the least potential impact: DC
Ecological:						
- Downstream Fisheries and Wildlife	Effects resulting from changes in water quantity and quality.	No significant difference between schemes regarding effects downstream of Devil Canyon.	---	Not a factor in evaluation of scheme.		
		Difference in reach between Devil Canyon dam and tunnel re-regulation dam.	With the tunnel scheme controlled flows between regulation dam and downstream powerhouse offers potential for anadromous fisheries enhancement in this 11 mile reach of the river.	If fisheries enhancement opportunity can be realized the tunnel scheme offers a positive mitigation measure not available with the Devil Canyon dam scheme. This opportunity is considered moderate and favors the tunnel scheme. However, there are no current plans for such enhancement and feasibility is uncertain. Potential value is therefore not significant relative to additional cost of tunnel.	X	
Resident Fisheries:	Loss of resident fisheries habitat.	Minimal differences between schemes.	Devil Canyon dam would inundate 27 miles of the Susitna River and approximately 2 miles of Devil Creek. The tunnel scheme would inundate 16 miles of the Susitna River.	Loss of habitat with dam scheme is less than 5% of total for Susitna main stem. This reach of river is therefore not considered to be highly significant for resident fisheries and thus the difference between the schemes is minor and favors the tunnel scheme.	X	
Wildlife:	Loss of wildlife habitat.	Minimal differences between schemes.	The most sensitive wildlife habitat in this reach is upstream of the tunnel re-regulation dam where there is no significant difference between the schemes. The Devil Canyon dam scheme in addition inundates the river valley between the two dam sites resulting in a moderate increase in impacts to wildlife.	Moderate wildlife populations of moose, black bear, weasel, fox, wolverine, other small mammals and songbirds and some riparian cliff habitat for ravens and raptors, in 11 miles of river, would be lost with the dam scheme. Thus, the difference in loss of wildlife habitat is considered moderate and favors the tunnel scheme.	X	
Cultural:	Inundation of archeological sites.	Potential differences between schemes.	Due to the larger area inundated the probability of inundating archeological sites is increased.	Significant archeological sites, if identified, can probably be excavated. Additional costs could range from several hundreds to hundreds of thousands of dollars, but are still considerably less than the additional cost of the tunnel scheme. This concern is not considered a factor in scheme evaluation.	-	-
Land Use:	Inundation of Devil Canyon.	Significant difference between schemes.	The Devil Canyon is considered a unique resource, 80 percent of which would be inundated by the Devil Canyon dam scheme. This would result in a loss of both an aesthetic value plus the potential for white water recreation.	The aesthetic and to some extent the recreational losses associated with the development of the Devil Canyon dam is the main aspect favoring the tunnel scheme. However, current recreational uses of Devil Canyon are low due to limited access. Future possibilities include major recreational development with construction of restaurants, marinas, etc. Under such conditions, neither scheme would be more favorable.	X	

OVERALL EVALUATION: The tunnel scheme has overall a lower impact on the environment.

TABLE B.18 - SOCIAL EVALUATION OF SUSITNA BASIN DEVELOPMENT SCHEMES/PLANS

Social Aspect	Parameter	Tunnel Scheme	Devil Canyon Dam Scheme	High Devil Canyon/ Vee Plan	Watana/Devil Canyon Plan	Remarks
Potential non-renewable resource displacement	Million tons Beluga coal over 50 years	80	110	170	210	Devil Canyon dam scheme potential higher than tunnel scheme. Watana/ Devil Canyon plan higher than High Devil Canyon/ Vee plan.
Impact on state economy	--	All projects would have similar impacts on the state and local economy.				Essentially no difference between plans/schemes.
Impact on local economy	--	All projects would have similar impacts on the state and local economy.				Essentially no difference between plans/schemes.
Seismic exposure	Risk of major structural failure	All projects designed to similar levels of safety.				Essentially no difference between plans/schemes.
	Potential impact of failure on human life.	Any dam failures would effect the same downstream population.				Essentially no difference between plans/schemes.
Overall Evaluation	1. Devil Canyon dam superior to tunnel. 2. Watana/Devil Canyon superior to High Devil Canyon/Vee plan.					

TABLE B.19 - ENERGY CONTRIBUTION EVALUATION OF THE DEVIL CANYON DAM AND TUNNEL SCHEMES

Parameter	Dam	Tunnel	Remarks
Total Energy Production Capability			
Annual Average Energy GWH	2850	2240	Devil Canyon dam annually develops 610 GWH and 540 GWH more average and firm energy respectively than the Tunnel scheme.
Firm Annual Energy GWH	2590	2050	
% Basin Potential Developed	43	32	Devil Canyon schemes develops more of the basin potential.
Energy Potential Not Developed GWH	60	380	As currently envisaged, the Devil Canyon dam does not develop 15 ft gross head between the Watana site and the Devil Canyon reservsoir. The tunnel scheme incorporates additional friction losses in tunnels. Also the compensation flow released from re-regulation dam is not used in conjunction with head between re-regulation dam and Devil Canyon.

Notes:

(1) Based on annual average energy. Full potential based on USBR four dam scheme.

TABLE B.20 - OVERALL EVALUATION OF TUNNEL SCHEME AND DEVIL CANYON DAM SCHEME

ATTRIBUTE	SUPERIOR PLAN
Economic	Devil Canyon Dam
Energy Contribution	Devil Canyon Dam
Environmental	Tunnel
Social	Devil Canyon Dam (Marginal)
Overall Evaluation	Devil Canyon dam scheme is superior Tradeoffs made: Economic advantage of dam scheme is judged to outweigh the reduced environmental impact associated with the tunnel scheme.

TABLE B.21 - ENVIRONMENTAL EVALUATION OF WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE DEVELOPMENT PLANS

Environmental Attribute	Plan Comparison	Appraisal Judgement	Plan judged to have the least potential impact	
			HDC/V	W/DC
Ecological:				
1) Fisheries	No significant difference in effects on downstream anadromous fisheries. HDC/V would inundate approximately 95 miles of the Susitna River and 28 miles of tributary streams, including the Tyone River. W/DC would inundate approximately 84 miles of the Susitna River and 24 miles of tributary streams, including Watana Creek.	Due to the avoidance of the Tyone River, lesser inundation of resident fisheries habitat and no significant difference in the effects on anadromous fisheries, the W/DC plan is judged to have less impact.		X
2) Wildlife a) Moose	HDC/V would inundate 123 miles of critical winter river bottom habitat. W/DC would inundate 108 miles of this river bottom habitat. HDC/V would inundate a large area upstream of Vee utilized by three sub-populations of moose that range in the northeast section of the basin. W/DC would inundate the Watana Creek area utilized by moose. The condition of this sub-population of moose and the quality of the habitat they are using appears to be decreasing.	Due to the lower potential for direct impact on moose populations within the Susitna, the W/DC plan is judged superior.		X
b) Caribou	The increased length of river flooded, especially upstream from the Vee dam site, would result in the HDC/V plan creating a greater potential division of the Nelchina herd's range. In addition, an increase in range would be directly inundated by the Vee reservoir.	Due to the potential for a greater impact on the Nelchina caribou herd, the HDC/V scheme is considered inferior.		X
c) Furbearers	The area flooded by the Vee reservoir is considered important to some key furbearers, particularly red fox. This area is judged to be more important than the Watana Creek area that would be inundated by the W/DC plan.	Due to the lesser potential for impact on furbearers the W/DC is judged to be superior.		X
d) Birds and Bears	Forest habitat, important for birds and black bears, exist along the valley slopes. The loss of this habitat would be greater with the W/DC plan.	The HDC/V plan is judged superior.	X	
Cultural:	There is a high potential for discovery of archeological sites in the easterly region of the Upper Susitna Basin. The HDC/V plan has a greater potential of affecting these sites. For other reaches of the river the difference between plans is considered minimal.	The W/DC plan is judged to have a lower potential effect on archeological sites.		X

TABLE B.21 (Continued)

Environmental Attribute	Plan Comparison	Appraisal Judgement	Plan judged to have the least potential impact HDC/V	W/DC
Aesthetic/ Land Use	With either scheme, the aesthetic quality of both Devil Canyon and Vee Canyon would be impaired. The HDC/V plan would also inundate Tsusena Falls.	Both plans impact the valley aesthetics. The difference is considered minimal.	-	-
	Due to construction at Vee Dam site and the size of the Vee Reservoir, the HDC/V plan would inherently create access to more wilderness area than would the W/DC plan.	As it is easier to extend access than to limit it, inherent access requirements were considered detrimental and the W/DC plan is judged superior. The ecological sensitivity of the area opened by the HDC/V plan reinforces this judgement.		X

OVERALL EVALUATION: The W/DC plan is judged to be superior to the HDC/V plan. (The lower impact on birds and bears associated with HDC/V plan is considered to be outweighed by all the other impacts which favour the W/DC plan.)

NOTES:

W = Watana Dam
DC = Devil Canyon Dam
HDC = High Devil Canyon Dam
V = Vee Dam

TABLE B.22 - ENERGY CONTRIBUTION EVALUATION OF THE WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE PLANS

Parameter	Watana/ Devil Canyon	High Devil Canyon/Vee	Remarks
Total Energy Production Capability			
Annual Average Energy GWH	6070	4910	Watana/Devil Canyon plan annually develops 1160 GWH and 1650 GWH more average and firm energy respectively than the High Devil Canyon/Vee Plan.
Firm Annual Energy GWH	5520	3870	
% Basin Potential Developed (1)	91	81	Watana/Devil Canyon plan develops more of the basin potential
Energy Potential Not Developed GWH (2)	60	650	As currently conceived, the Watana/-Devil Canyon Plan does not develop 15 ft of gross head between the Watana site and the Devil Canyon reservoir. The High Devil Canyon/Vee Plan does not develop 175 ft gross head between Vee site and High Devil reservoir.

Notes:

(1) Based on annual average energy. Full potential based on USBR four dam schemes.
(2) Includes losses due to unutilized head.

TABLE B.23 - OVERALL EVALUATION OF THE HIGH DEVIL CANYON/VEE AND WATANA/DEVIL CANYON DAM PLANS

ATTRIBUTE	SUPERIOR PLAN
Economic	Watana/Devil Canyon
Energy Contribution	Watana/Devil Canyon
Environmental	Watana/Devil Canyon
Social	Watana/Devil Canyon (Marginal)
Overall Evaluation	Plan with Watana/Devil Canyon is superior Tradeoffs made: None

TABLE B.24: COMBINED WATANA AND DEVIL CANYON OPERATION

Watana Dam Crest Elevation (ft MSL)	Watana* Cost ($ x 10^6)	Devil Canyon* Cost ($ x 10^6)	Total Cost ($ x 10^6)	Average Annual Energy (GWh)
2240 (2215 reservoir elevation)	4,076	1,711	5,787	6,809
2190 (2165 reservoir elevation)	3,785	1,711	5,496	6,586
2140 (2115 reservoir elevation)	3,516	1,711	5,227	6,264

Watana Project alone (prior to year 2002)

Crest Elevation (ft MSL)	Average Annual Energy (GWh)
2240	3,542
2190	3,322
2140	3,071

* Estimated costs in January 1982 dollars, based on preliminary conceptual designs, including relict channel drainage blanket and 20 percent contingencies.

TABLE B.25: PRESENT WORTH OF PRODUCTION COSTS

Watana Dam Crest Elevation (ft MSL)	Present Worth of Production Costs ($ x 10^6)
2240 (reservoir elevation 2215)	7,123
2190 (reservoir elevation 2165)	7,052
2140 (reservoir elevation 2115)	7,084

* LTPW in January 1982 dollars.

TABLE B.26: DESIGN PARAMETERS FOR DEPENDABLE CAPACITY AND ENERGY PRODUCTION

	Watana	Devil Canyon
(a) Minimum stream flow (monthly average, cfs)	570 (March, 1950)	664 (March, 1964)
Mean stream flow	7,990	9,050
Maximum stream flow	42,840 (June, 1964)	47,816 (June, 1964)
Evaporation	Approximately cancels precipitation and is neglected. Section 4.1(f)	
Leakage	Negligible	Negligible
Minimum flow release	Table B.67	Table B.68
Flow duration curve	Figure B.69	Figure B.69
Critical streamflow for dependable capacity curve (Watana and Devil Canyon combined)	5,400 GWh annual potential recurrence frequency 1 in 70 years	
Area capacity curve	Figure B.67	Figure B.68
Rule curve	Figure B.62	Figure B.69
Hydraulic Capacity Flow (cfs) 1/2	1,775	1,895
full	3,550	3,790
best	2,900	3,100
Efficiency 1/2	87	87
full	91	91
best	94	94
Generator output (Kw) 1/2	91,000	82,000
full	183,000	164,000
best	156,000	139,000
Tailwater rating curves	Figure B.67	Figure B.68
Powerplant capability vs head	Figure B.70	Figure B.73

TABLE B.27: WATANA - MAXIMUM CAPACITY REQUIRED (MW)
OPTION 1 - THERMAL AS BASE

Hydrological Year	CAPACITY (MW) 1995	2000	2010***
1	743	762	838*
2	550	569	680
3	760	779	836*
4	749	768	836*
5	744	763	868*
6	763	782	832*
7	737	756	838*
8	771	790	836**
9	799**	818**	825*
10	563	582	683*
11	769	788	832*
12	784*	803	829*
13	773	792	832*
14	771	790	838*
15	745	764	844*
16	550	569	840*
17	745	764	836*
18	554	573	684*
19	771	790	832*
20	550	569	685*
21	550	569	678
22	550	569	672
23	784*	803	834*
24	747	766	838*
25	550	569	684
26	550	569	678
27	728	747	839*
28	550	569	675
29	785*	804	833*
30	550	569	678
31	787*	806	837*
32	754	773	839*

*Restricted by peak demand
**Maximum value
***Including Devil Canyon

TABLE B.28: WATANA - MAXIMUM CAPACITY REQUIRED (MW)
OPTION 2 - THERMAL AS PEAK

Hydrological Year	CAPACITY (MW)		
	1995	2000	2010*
1	575	575	838
2	382	382	389
3	592	592	839
4	581	581	836
5	576	576	868
6	595	595	832
7	569	569	838
8	603	603	836
9	631	631	825
10	395	365	391
11	601	601	832
12	616	616	829
13	605	605	832
14	603	603	838
15	577	577	844
16	382	382	840
17	577	577	836
18	386	386	392
19	603	603	832
20	382	382	393
21	382	382	386
22	382	382	380
23	616	626	834
24	579	579	838
25	382	382	392
26	382	382	386
27	560	560	839
28	382	382	383
29	617	617	833
30	382	382	387
31	619	619	837
32	586	586	839

*Including Devil Canyon

TABLE B.29: DESIGN DATA AND DESIGN CRITERIA FOR FINAL REVIEW OF LAYOUTS

River Flows	
Average flow (over 30 years of record):	7,860 cfs
Probable maximum flood (routed):	326,000 cfs
Maximum inflow with return period of 1:10,000 years:	156,000 cfs
Maximum 1:10,000-year routed discharge:	115,000 cfs
Maximum flood with return period of 1:500 years:	116,000 cfs
Maximum flood with return period of 1:50 years:	87,000 cfs
Reservoir normal maximum operating level:	2215 ft
Reservoir minimum operating level:	2030 ft
Dam	
Type:	Rockfill
Crest elevation at point of maximum super elevation:	2240 ft
Height:	890 ft above foundation
Cutoff and foundation treatment:	Core founded on rock; grout curtain and downstream drains
Upstream slope:	2.4H: 1V
Downstream slope:	2H: 1V
Crest width:	50 ft
Diversion	
Cofferdam type:	Rockfill
Cutoff and foundation:	Slurry trench to bedrock
Upstream cofferdam crest elevation:	1585 ft
Downstream cofferdam crest elevation:	1475 ft
Maximum pool level during construction:	1580 ft
Tunnels	Concrete lined,
Final closure:	Mass concrete plugs
Releases during impounding:	6,000 cfs maximum via bypass to outlet structure
Spillway	
Design floods:	Passes PMF, preserving integrity of dam with no loss of life
	Passes routed 1:10,000-year flood with no damage to structures
Main spillway - Capacity:	Routed 1:10,000-year flood with 5 ft surcharge
- Control structure:	Gated ogee crests
Emergency spillway - Capacity:	PMF minus 1:10,000 year flood
- Type:	Fuse plug
Power Intake	
Type:	Reinforced concrete
Number of intakes:	6
Draw-off requirements:	Multi-level corresponding to temperature strata
Drawdown:	185 feet

TABLE B.29: (Cont'd)

Penstocks

Type:	Concrete-lined tunnels with downstream steel liners
Number of penstocks:	6

Powerhouse

Type:	Underground
Transformer area:	Separate gallery
Control room and administration:	Surface
Access - Vehicle:	Rock tunnel
- Personnel:	Elevator from surface

Power Plant

Type of turbines:	Francis
Number and rating:	6 x 170 MW
Rated net head:	690 ft
Design flow:	3,500 cfs per unit
Normal maximum gross head:	745 ft
Type of generator:	Vertical synchronous
Rated output:	190 MVA
Power factor:	0.9
Frequency:	60 HZ
Transformers:	13.8-345 kV, 3-phase

Tailrace

Water passages:	2 concrete-lined tunnels
Surge:	Separate surge chambers
Average tailwater elevation (full generation):	1458 ft

TABLE B.30: EVALUATION CRITIERA

PRELIMINARY REVIEW	INTERMEDIATE REVIEW	FINAL REVIEW
Technical feasibility	Technical feasibility	Technical feasibility
Compatibility of layout with known geological and topographical site features	Compatibility of layout with known geological and topographical site features	Compatibility of layout with known geological and topographical site features
Ease of construction	Ease of construction	Ease of construction
Physical dimensions of component structures in certain locations	--	--
Obvious cost differences of comparable structures	Overall cost	Overall cost
Environmental acceptability	Environmental acceptability	Environmental impact
Operating characteristics	Operating characteristics	Mode of operation of spillways
--	Impact on construction schedule	Impact on construction schedule
--	--	Design and operating limitations for key structures

TABLE B.31: SUMMARY OF COMPARATIVE COST ESTIMATES

INTERMEDIATE REVIEW OF ALTERNATIVE ARRANGEMENTS
(January 1982 $ x 10^6)

	WP1	WP2	WP3	WP4
Diversion	101.4	112.6	101.4	103.1
Service Spillway	128.2	208.3	122.4	267.2
Emergency Spillway	-	46.9	46.9	-
Tailrace Tunnel	13.1	13.1	13.1	8.0
Credit for Use of Rock in Dam	(11.7)	(31.2)	(18.8)	(72.4)
Total Non-Common Items	231.0	349.7	265.0	305.9
Common Items	1643.0	1643.0	1643.0	1643.0
Subtotal	1874.0	1992.7	1908.0	1948.9
Camp & Support Costs (16%)	299.8	318.8	305.3	311.8
Subtotal	2173.8	2311.5	2213.3	2260.7
Contingency (20%)	434.8	462.3	442.7	452.1
Subtotal	2608.6	1773.8	2656.0	2712.8
Engineering and Administration (12.5%)	326.1	346.7	332.0	339.1
TOTAL	2934.7	3120.5	2988.0	3051.9

TABLE B.32: DEVIL CANYON - MAXIMUM CAPACITY REQUIRED (MW)

Hydrological Year	Capacity (MW) 2010 (Option 1 and 2)
1	544**
2	353
3	546
4	546
5	514
6	548
7	544
8	546
9	557
10	351
11	548
12	551
13	548
14	544
15	538
16	542
17	546
18	350
19	550
20	349
21	355
22	361
23	548
24	544
25	349
26	355
27	543
28	359
29	549
30	355
31	545
32	543

**Maximum Value

TABLE B.33: DESIGN DATA AND DESIGN CRITERIA FOR REVIEW OF ALTERNATIVE LAYOUTS

River Flows

Average flow (over 30 years of record):	8,960 cfs
Probable maximum flood:	346,000 cfs
Max. flood with return period of 1:10,000 years:	165,000 cfs (after routing through Watana
Maximum flood with return period of 1:500 years:	-
Maximum flood with return period of 1:50 years:	42,000 cfs (after routing through Watana

Reservoir

Normal maximum operating level:	1455 feet
Reservoir minimum operating level:	1430 feet
Area of reservoir at maximum operating level:	21,000 acres
Reservoir live storage:	180,000 acre feet
Reservoir full storage:	1,100,000 acre feet

Dam

Type:	Concrete arch
Crest elevation:	1455 feet
Crest length:	-
Maximum height above foundation:	635 feet
Crest width:	20 feet

Diversion

Cofferdam types:	Rockfill
Upstream cofferdam crest elevation:	960 feet
Downstream cofferdam crest elevation:	900 feet
Maximum pool level during construction:	955 feet
Tunnels:	Concrete lined
Outlet structures:	Low-level structure with slide closure gate
Final closure:	Mass concrete plugs in line with dam grout curtain
Releases during impounding:	2,000 cfs min. via fixed-cone valves

Spillway

Design floods:	Passes PMF, preserving integrity of dam with no loss of life
	Passes routed 1:10,000-year flood with no damage to structures
Service spillway - capacity:	45,000 cfs
- control structure:	Fixed-cone valves
- energy dissipation:	Five 108-inch diameter fixed-cone valves
Secondary spillway - capacity:	90,000 cfs
- control structure:	Gated, ogee crests
- energy dissipation:	Stilling basin
Emergency spillway - capacity:	pmf minus routed 1:10,000-year flood
- type:	Fuse plug

TABLE B.33: (Cont'd)

Power Intake

Type:	Underground
Transformer area:	Separate gallery
Access	Rock Tunnel
Type of turbines:	Francis
Number and rating:	4 x 140 MW
Rated net head:	550 feet
Maximum gross head:	565 feet approx.
Type of generator:	Vertical synchronous
Rated output:	155 MVA
Power factor:	0.9

TABLE B.34: SUMMARY OF COMPARATIVE COST ESTIMATES

PRELIMINARY REVIEW OF ALTERNATIVE ARRANGEMENTS
(January 1982 $ X 10^6)

Item	DC1	DC2	DC3	DC4
Land Acquisition	22.1	22.1	22.1	22.1
Reservoir	10.5	10.5	10.5	10.5
Main Dam	468.7	468.7	468.7	468.7
Emergency Spillway	25.2	25.2	25.2	25.2
Power Facilities	211.7	211.7	211.7	211.7
Switchyard	7.1	7.1	7.1	7.1
Miscellaneous Structures	9.5	9.5	9.5	9.5
Access Roads & Site Facilities	28.4	28.4	28.4	28.4
Common Items - Subtotal	783.2	783.2	783.2	783.2
Diversion	32.1	32.1	32.1	34.9
Service Spillway	46.8	53.3	50.1	85.2
Saddle Dam	19.9	18.6	18.6	19.9
Non-Common/Items Subtotal	98.8	104.0	100.8	140.0
Total	882.0	887.2	884.0	923.2
Camp & Support Costs (16%)	141.1	141.9	141.4	147.7
Subtotal	1023.1	1029.1	1025.4	1070.9
Contingency (20%)	204.6	205.8	205.1	214.2
Subtotal	1227.7	1234.9	1230.5	1285.1
Engineering & Administration (12.5%)	153.5	154.3	153.8	160.6
Total	1381.2	1389.2	1384.3	1445.7

TABLE B.35: POWER TRANSFER REQUIREMENTS (MW)

	INSTALLED CAPACITY			TRANSFER REQUIREMENT	
Year	Watana	Devil Canyon	Total Susitna	Susitna to Anchorage	Susitna to Fairbanks
1993	680	—	680	578	170
1994	1020	—	1020	867	255
2002	1020	600	1620	1377	405

TABLE B.36: SUMMARY OF LIFE CYCLE COSTS

TRANSMISSION ALTERNATIVE	1	2	3	4	5
Transmission Lines	1981 $ x 10^6				
Capital	$156.70	$159.51	$133.96	$140.94	$159.27
Land Acquisition	18.73	20.79	18.07	20.13	18.65
Capitalized Annual Charges	127.34	130.14	107.43	112.83	126.91
Capitalized Line Losses	53.07	54.50	64.51	65.82	42.82
Total Transmission Line Cost	$355.84	$364.94	$323.97	$339.72	$347.65
Switching Stations					
Capital	$114.09	$106.40	$128.32	$120.64	$154.75
Capitalized Annual Charges	121.02	113.30	135.94	128.22	165.02
Total Switching Station Cost	235.11	219.70	264.26	248.86	319.77
TOTAL	$590.95	$584.64	$588.23	$588.58	$667.42

TABLE B.37: TECHNICAL, ECONOMIC, AND ENVIRONMENTAL CRITERIA USED IN CORRIDOR SELECTION

Type	Criteria	Selection
1. Technical - Primary	General Location	Connect with Intertia 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 B.38

Environmental Inventory - Southern Study Area (Willow to Anchorage/Point MacKenzie)

Corridor Segment	Approx. Length (Miles)	Approx. # Road Crossings	Approx. # River/Creek Crossings	Topography	Soils [a]	Land Ownership/Status [b]	Existing/Proposed Developments	Existing Rights-of-Way
AB	38	2 hwy (Rt. 3, Glenn) 6 light duty roads 1 unimproved road 2 trails 1 railroad	1 river 17 creeks	Willow (100'), crosses Willow Ck, follows Deception Ck (1000') along ridge of Talkeetna Mts, s.e. into Palmer (200')	Willow to near Palmer-S04 Palmer E01	A to s. of Willow Ck Rd. crossing-mostly P, with some BAP and some SP;... to due n. of Wasilla-mainly SPTA;... to B-mostly P, with some BAP and SP	Ag. uses n. & w. of Palmer; ag/res. use near L. Susitna; proposed capital site; mixed res. area at Willow Ck.; Willow air strip; cabin near A	Follows no known right-of-way for appreciable distance
BC'	35	4 hwy (Glenn, 4x) 3+ light duty roads 7 unimproved roads 1 trail several railroads	4 rivers 11 creeks	Palmer (200'), crosses Knik River to base at Chugach Mts. (500'), along Knik Arm (200'- 300'), to Anchorage (200')	Palmer- E01 Knik Arm - EF1 S. of Eklutna to n. of Anchorage -S05 Anchorage - S04	B to Knik R. - P; ... to Birchwood-mainly VS with some SPTA, P and BAP; Birchwood area-P; s.w. of Birchwood to near C'-U.S. Army Military Wdl; C'-Data void	Urban uses in Anch.; passes through/near several communities: Eagle R, Birchwood Eklutna, Chugiak, Peters Ck.	Parallels trans. line Knik R. to Anch.; parallels Glenn Hwy from Knik R. to Birchwood; parallels RR-Eagle to C'
ADF	26	1 highway (Rt. 3) 3 tractor trails	1 river 6 creeks	Willow (100'), s. along Susitna River plains (flat, wet area, with drier, raised levees, 200'-400'), to F at 150'	Willow-S04 S. of Willow to to F-S01	Near A-P; route fairly even mix of BAP and SPTA; some P near Fish Ck; area surrounding L Susitna R - Susitna Flats Game Refuge; near F-SPTA	Red Shirt Lake-mixed residential use; near residential & recr. areas s.w. of Willow; Susitna Flats State Game Refuge	Generally parallels a tractor trail
AEF	27	1 highway (Parks) 1 tractor Trail	1 river 6 creeks	Willow (100'), s. along flat wet area (200'-400'), to F at about 150'	Near L. Susitna River - S05 Remainder-S04	A, s. to Rainbow L.-mostly P, small parcels BAP; State Selected Fed. Parcel w. of Willow L.; s. to L. Susitna R. - Nancy Lake State Rec. Area; to F - mix of SPTA and BAP	Mixed res. areas; lakes used to land float planes	No known
FC	12	2 tractor trails	2 creeks	F at 150' along flats to C near sea level	Near F - S04 Near C - S01	F to 1 mi. s.-SPTA;... s. to Horseshoe L.-Pt MacKenzie Agr. Sale;... s. to C-mainly SPTA, some BAP	Scattered residential/cabins on Horseshoe Lake; proposed ag. uses in area	Generally follows a tractor trail

a. Source: United States Department of Agriculture, Soil Conservation Service 1979. See Appendix Table B-1 for explanation of soil units.

b. Source: CIRI/Holmes and Narver. 1980. P=Private, SPTA=State Patented or Tentatively Approved, SP=State Patented, BAP=Borough Approved or Patented.

TABLE B.38 (CONT'D)

Environmental Inventory - Southern Study Area (Willow to Anchorage/Point MacKenzie)

Corridor Segment	Scenic Quality/ Recreation	Cultural Resources [a]	Vegetation [b]	Fish Resources [c]	Birds [d]	Furbearers [d]	Big Game [d]
AB	Gooding L. - bird-watching; rec. trails e. of Willow-hunting, hiking, x-c skiing, dog sledding, snow-mobiling, snowshoeing; rec. trail by Decep. Ck- snow-mobiling, dog sledding, fishing	Data void	Upland, mixed deciduous-conifer forests (birch-spruce)- open and closed mostly Tall shrub (alder); some woodland black spruce; bogs along Deception Ck.	Willow Ck. - chinook salmon, grayling, burbot, longnose sucker, round whitefish, Dolly Varden, slimy sculpin; lake trout & rainbow trout in lakes; L. Susitna R. - king salmon; Decep. Ck. - king, pink salmon	Data void	Data void	Except near Palmer-black bear summer range, moose winter/summer range, migrat corridors and calvir area; near A also brown bear summer range and feeding area
BC'	Passes near 2 camping grounds; parallels Iditarod racing trail (x-c skiing, sledding, snowmobiling); birdwatching at Eklutna Flats and Matunuska River	Data void	Deciduous forest (balsam poplar) along river, probably birch/spruce forests on uplands in most of area Data void	Sockeye, chinook, pink, chum, coho salmon in large rivers; grayling burbot, longnose sucker, round white-fish, Dolly Varden, slimy sculpin, lake and rainbow trout in lakes & stream; salmon of particular significance in the Matanuska and Knik Rivers	Waterfowl and shore bird nesting areas around Knik Arm and Eagle River Flats	Data void	Data void
ADF	X-c ski & snowmobile trails; recreation area s.w. of Willow	Data void	Higher grounds: Spruce-birch-poplar forests Wet sedge grass bogs and black spruce forests prevalent in lower half	Willow Ck.- chinook salmon; lake and rainbow trout posible in some lakes; also, in streams are grayling, burbot, longnose sucker, round whitefish, Dolly Varden, slimy sculpin; Red Skirt L. - lake trout, sockeye salmon	Waterfowl and shore bird nesting in Willow Creek/ Delta Islands	Data void	Brown and black bear feeding area, moose winter/summer range and calving area
AEF	Mixed rec. areas; Nancy Lake State Rec. area; trails and multiple uses; may cross Goose Bay St. Game Refuge	Data void	Upper half; mostly upland birch, spruce & aspen Lower half: wet sedge-grass bogs and black spruce; some birch, spruce; aspen on higher ground	Lakes may contain rainbow and lake trout; possibly grayling in the region	Same as ADF	"	Same as ADF
FC	May cross Susitna Flats State Wildlife Refuge	Data void	Spruce forests, spruce-birch forests, sedge-grass bogs and black spruce bogs	Lake may contain rainbow and lake trout; possibly grayling in the region	Waterfowl and shore bird migration route, feeding and nesting area	Furbearer and small mammal summer/ winter range	Black bear summer range and feeding area; moose winter/ summer range, feedin and calving area

a. Coastal area probably has many sites, available literature not yet reviewed.

b. Tall shrub=alder; low shrub=dwarf birch, and/or willow; open spruce=black (wet) or white spruce, 25%-60% cover; woodland spruce=white or black spruce, 10%-25% cover, mixed forest= spruce-birch.

d. Little data available. Source of information in this table: Alaska Department of Fish and Game 1978b.

c. Little data available. Source of information in this table: Alaska Department of Fish and Game 1978a.

TABLE B.39

Environmental Inventory - Central Study Area (Dam Sites to Intertie)

Corridor Segment	Approx. Length (Miles)	Approx. # Road Crossings	Approx. # River/Creek Crossings	Topography	Soils[a]	Land Ownership/ Status[b]
AB	7	0	5 creeks	Moderate sloping s. rim of Susitna R. Valley; crosses deep ravine at Fog Ck. at about 2000' contour	S015	VS
BC	18	0	8 creeks	2000' contour along s. rim of Susitna River; crosses 3 steep gorges	B westward- S015; near C - S010	VS
CD	15	1+	1 river 4 creeks	Moderately sloping terrain; crosses Susitna R. near Gold Creek (800')	OS10	C to 1 1/2 mi. e. of Susitna R. - VS; Susitna R. to 1 1/2 mi. e. - SPTA; ... to D-P
BEC	23	0	8 creeks	Crosses moderate slopes around Stephan Lake; w., then n. to avoid deep ravine at Cheechako Ck., then follows s. rim of Susitna at about 2000'	B, westward - OS15; between B & C - IU3; near C - S010	VS except where corridor skirts Cheechako Ck. ravine, which is classified SS Suspended
AJ	18	0	11 creeks	A (about 2000') to 3500'; crosses deep ravine at Devil Ck. (2000'); goes by several ponds	A, westward - OS15; remainder, except J - OS16; near J - S010	SS except at J ar at A westward across Tsusena Ck., which are VS
JC	8	0	1 creek	J (2000'), s.w. through gently sloping High Lake area, to C at Devil Canyon (2000')	OS10	SS except at J ar C which are VS
CF	15	0	2 creeks	Devil Canyon (<2000') west across 600' deep Portage Creek gorge; w. across gentle terrain to F (1200')	S010	C to 1 1/2 mi. e of Miami L. mainl VS with small parcel of SS; ... to F-P
AG	65	0	1 river 35 creeks	A (2000'), n. along Deadman Ck. to 3200'; crosses Brushkana drainage (at 3200'); drops to Nenana River (2400') and fairly flat terrain to G (2200')	Near A and along Denali Hwy - OS15; through mts.-S016	A - VS; n. of A t s.w. of Big L. - SS; ... to s. of Deadman L. - SPTA ... to Denali Hwy - Fed. D-1 Land; data void for 8 mi.; around G - Small Fed. Parce
AH	22	0	9 creeks	A (2000'), along Tsusena Ck.; past Tsusena Butte; through mt. pass at 3600'	Near A - S015; mt. base - S016; mts. - RM1	A - VS; ... to n. of Tsusena Butte SS; data void beyond here
HI	21	0	15 creeks	H (3400') through mts.; along Jack R. drainage and Caribou Pass; to I at 2400'	Mts. - RM1; along hwy - S015	I - VS; data voic to east
HJ	25	0	13 creeks	H (3400') through mts. along Portage Ck. drainage, through pass at 3600'; into Devil Creek drainage; to J at 2000'	Near J - S016; mid elevations- S017; mts. - RM1	J - VS; Devil Ck drainage - SS; data void beyond here

a. Source: United States Department of Agriculture, Soil Conservation Service 1979. See Appendix Table B-1 for explanation of soil units.

b. Source: CIRI/Holmes and Narver. 1980. P=Private, SPTA=State Patented or Tentatively Approved, SS=State Selection, VS=Village Selection.

TABLE B.39 (CONT'D)

Environmental Inventory - Central Study Area (Dam Sites to Intertie)

Corridor Segments	Fish Resources[a]	Birds	Furbearers	Big Game
AB	Fog Lakes - Dolly Varden, sculpin; Stephan Lake contains lake and rainbow trout, sockeye & coho salmon, whitefish, longnose sucker, grayling; burbot	Potential raptor nesting habitat in Fog Creek area	Excellent fox and marten habitat; Fog Lakes support numerous beavers and muskrat; otters common	Supports large pop. of moose; wolves, wolverine and bear, (especially brown) common; caribou regularly use area
BC	Several small tributaries crossed, perhaps used by grayling	Potential raptor nesting habitat along Devil Canyon	Excellent fox and marten habitat	Area around Stephan Lake & Prairie Ck. supports large pop. of moose; wolves, wolverines, and some bear (especially brown) common; caribou regular users
CD	Same as BC	Potential raptor nesting habitat along Devil Canyon	Area around Devil Canyon has excellent fox and marten habitat	Moose, caribou, and bear habitat
BEC	Several small tributaries crossed, perhaps used by grayling, burbot	Potential raptor nesting habitat along Devil Canyon and along drainages upstream; Stephan Lake area important to waterfowl and migrating swans	Excellent fox and marten habitat, particularly around Stephan Lake	Same as AB
AJ	Dolly Varden; grayling in Tsusena Creek	Data void	Red fox denning sites, numerous beaver, muskrat and mink, especially around High Lake	Mouth of Tsusena Ck. important moose habitat; heavily used by black and brown bear
JC	Burbot; no data for High Lake	Potential raptor hab. by Devil Canyon; golden eagle nest along Devil Ck. s. of confluence of ck. from High Lake	Same as AJ	Important moose and bear habitat; data void
CF	Portage Creek has king, chinook, chum and pink salmon, grayling, burbot	Potential raptor habitat along lower Portage Ck. and from Portage Ck. mouth through Devil Canyon	Area between Parks Hwy and Devil Canyon supports numerous beaver, muskrat, and mink	Probably important moose wintering area and black bear habitat; at least one wolf pack
AG	Dolly Varden; lakes - lake trout, grayling, white- fish; tributaries to Nenana River and Brushkana Creek n. of Deadman Mt. and Jack R. near Denali Hwy considered important fish habitat	Waterfowl numerous at Deadman Lake; impor- tant bald eagle habitat by Denali Hwy and Nenana R. just w. of Monahan Flat; unchecked bald eagle nest along Deadman Ck, s.e. of Tsusena Butte	Population relatively low, although beaver, mink, fox present; Deadman Mt. to Denali Hwy.- moderate pop. red fox	Probably important area for caribou, expecially in the north
AH	Dolly Varden; grayling	Known active bald eagle nest s.e. of Tsusena Butte	Population along Tsusena Ck. pro- bably relatively low; with beaver, mink, and fox probably present	Data void
HI	Lake trout, Caribou Pass area; Jack River s. of Caribou Pass considered important fish habitat; data void	Data void	Data void	Data void
HJ	Portage Creek - king, chinook, chum, and pink salmon, grayling, burbot	Data void	Numerous beaver, muskrat, and mink around High Lake	Data void

a. Little data available. Sources of information in this table: Alaska Department of Fish and Game 1978a, Friese 1975, and Morrow 1980.

TABLE B.39 (CONT'D)

Environmental Inventory - Central Study Area (Dam Sites to Intertie)

Corridor Segment	Existing/Proposed Developments	Existing Rights-of-Way	Scenic Quality/ Recreation	Cultural Resources	Vegetation [a]
AB	Follows general route of proposed Susitna access rds.; cabins on Fog Lakes; planes use lakes	No known	Fog Lakes - high aesthetic quality; fishing in Fog Lakes	Arch. sites identified near Watana Dam site and w. shore of Stephan Lake; potential for more sites around Fog Lakes and Stephan Lake	Mostly woodland black spruce (wet); some low shrub
BC	Follows general route of Susitna proposed access rds.; cabins and lodge on Stephan L.	No known	Stephan Lake - high aesthetic quality	Arch. sites near Stephan Lake	Open and woodland spruce forests, low shrub, open and closed mixed forest in about equal amounts
CD	Follows proposed Susitna access rd.- Devil Canyon to Susitna R.; scattered cabins in Canyon/Gold Creek area	Old Corps trail, Gold Ck. to Devil Canyon	Scenic area; possible fishing	Hist. sites near Gold Ck.; data void	Mostly closed mixed forests
BEC	Follows general route proposed Susitna access rd.; cabins and lodge on Stephan Lake	No known	Stephan Lake - high aesthetic quality; major recreation area for fishing/boating/ planes	See AB	Woodland spruce and bogs around Stephan Lake; low shrub, mat & cushion and sedge-grass tundra at upper end of Cheechako Ck. drain- age; tall shrub (alder) and mixed forest along Cheechako Ck. and towards Devil Canyon
AJ	Follows a proposed Susitna access rd. from Watana westward for approx. 8 mi.; lodge at High Lake	No known	High Lake and other lakes - high aesthetic quality; fishing/ hunting in High Lake area	Arch. sites at Portage Ck. and Susitna R. con- fluence and near Watana Dam site	Mostly low shrub, mat & cushion, sedge-grass tundra some tall shrub (alder)
JC	Generally follows proposed Susitna access rd.; lodge at High Lake	No known	Same as AJ	No known arch. sites	Tall shrub (alder), low shrub and open mixed forest
CF	Follows a proposed Susitna access rd. for about 3 mi. from Devil Canyon to Portage Ck.; mining, cabins	No known	Boating in Susitna; hunting, fishing, hiking	Arch. sites at Portage Ck.; hist. sites near Canyon	Open & closed mixed forest, tall shrub, low shrub.
AG	Follows a proposed Susitna access rd. - Watana to just n. of Deadman Mt.; occasional cabins; landing strip along Denali Hwy; airport near G	Parallels Denali Hwy beyond Brushkana Ck. drainage to G	Remote flat areas - high visibility; Deadman L. and Mt., Alaska Range - high aesthetic quality; fishing, float planes; major rec. areas by Brushkana and Nenana R., Drasher L.	Arch. sites along Deadman Ck.	Mostly low shrub in southern end; northern end - data void
AH	Cabins near Tsusena Butte	No known	Tsusena Butte - aesthetic quality; major sheep hunting area	Arch. site n. of Tsusena Butte along Tsusena Ck; data void	Low shrub, tall shrub, woodland spruce
HI	Cabins near Summit	No known	Major sheep hunting area; bird watching at Summit L.	Data void	Data void
HJ	Susitna access rd. along Devil Ck. for about 4 mi.; cabins along Devil Ck. drainage	No known	Scenic drainage; Sheep hunting in n.	Data void	Mat & cushion, sedge- grass tundra, tall shrub and open mixed forest in southern end

a. Tall shrub=alder; low shrub=dwarf birch, and/or willow; open spruce=black (wet) or white spruce, 25%-60% cover; woodland spruce=white or black spruce, 10%-25% cover, mixed forest= spruce-birch.

TABLE B-40

Environmental Inventory - Northern Study Area (Healy to Fairbanks)

Corridor Segment	Approx. Length (Miles)	Approx. # Road Crossings	Approx. # River/Creek Crossings	Topography	Soils [b]	Land Ownership/ Status [c]	Existing/Proposed Developments	Existing Rights-of-Way
AB	40	2 highway (Park) 3 trails (1 winter) 2 unimproved rds. 1 railroad	3 rivers 15 creeks	Follows Nenana River north at 1000' to Browne-crosses River; n.w. to Clear MEWS at 500'	IR10	A to e. of Dry Ck.-small Fed. Parcel; ...to s. of Clear MEWS and at B-mostly SPTA, small parcels of P, small Fed. Nat. A.lot. along Nenana R.; Clear MEWS area-parcel CIRI Selection, and U.S. Army Wdl. Land	Scattered residential and other uses along Parks Hwy; cabin near Browne; air strip at Healy	Generally paralle Parks Hwy, RR and trans. line- Heal to Browne
BC	50	Parks Highway 1 winter trail	1 river 25 creeks	Clear MEWS (500') north across plain (400'), n.e. across Tanana River Valley to Ester (600')	Near B - IR10; flats s. of Tanana River-IQ2; Tanana River-IQ3; Tanana R. to Ester-IR14	B to 1 1/2 mi n. - SPTA; ... to s. to Tanana R. - SS; ... to Tanana R. - P; ... to crossing L. Goldstream Ck. - mostly SPTA; ... to Bonanza Ck. Crossing - SS; ... to near C - SP; remainder - data void	Scattered residential and other uses along Parks Hwy; cabin at Tanana R. crossing	Follows w/in sever mi. Parks Hwy, RR, and trans. line; more closely follc Parks Hwy. and tra line and sled rd. of Tanana R.
BDC	40	1 winter trail	2 rivers 29 creek	Clear MEWS (500'), n.e. across plain to a point about 24 mi. due s. of Ester; n. across plain to Tanana R. (400') and n. to Ester	Near B - IR10 Remainder - IQ2	B area - SPTA; Fish Ck to Tanana R. - data void; remainder - SPTA, BAP with P at C and just n. of Tanana R.	Ft. Wainwright Mil. Reservation	No known
AE	65	1 hwy. (Parks) 1 trail	1 river [a] 50 creeks	Up Healy Ck. to pass at 4500'; down Wood R. drainage to Japan Hills (1100'); steep mts.; valleys	Near A - IR10; mt. base - IQ25; mt. area - RM1; near E - IR1	A to Nenana R. - small Fed. Parcel; ...to e. of Gold Run - SPTA... remainder - data void	Air strips - Healy and Cripple/Healy Cks. confluence; cabins-Cody Ck/ Wood R., Snow Mt. Gulch	Parallels small r near Healy to Coa Ck.; small RR - H to Suntrana; trai at pass between H and Cody Cks.
EDC	50	7 trails	2 rivers 22 creeks	Japan Hills (1100') n.w. on plain along Wood R.; through Wood R. Buttes area, n. across Tanana R.; n. to Ester	Near E - IR1; between E and open flats - IR10; open flats IQ2; Tanana R. -IQ3; Ester - IR14	Same as BDC north of the Tanana River	Ft. Wainwright Mil. Res.; Wood R. Butte VABM	No known
EF	40	Several roads in Fairbanks, depending upon exact route; 3 trails	2 rivers 10 creeks Salchaket Slough	Japan Hills (1100') n. across plain to Tanana R.(500'); n. to Fairbanks	Near E - IR1; s. section of flats-IR10; flats - IQ2; Fairbanks - IQ3	Data void	Ft. Wainwright Mil. Res.; cabin - Wood R. crossing s. of Clear Butte	Parallels Bonnifi Trail-Clear Ck. B to Fairbanks; tra line just s. of Fairbanks

a. Assumes corridor is located on n. side of Healy Ck. for most of its length, n. side of Cody Ck., and n.w. side of Wood R.

b. Source: United States Department of Agriculture, Soil Conservation Service 1979. See Appendix Table B-1 for explanation of soil units.

c. Source: CIRI/Holmes and Narver. 1980. P=Private, SPTA=State Patented or Tentatively Approved; SP=State Patened, SS=State Selection, BAP=Borough Approved or Patented.

TABLE B.40 (CONT'D)

Environmental Inventory - Northern Study Area (Healy to Fairbanks)

Corridor Segment	Scenic Quality/ Recreation	Cultural Resources	Vegetation[a]	Fish Resources[b]	Birds[c]	Furbearers[c]	Big Game[c]
AB	Parks Hwy-scenic area; rafting, kayaking on Nenana R.	Dry Ck. arch. site near Healy; good possibility for other sites; data void	Southern end - data void Northern end - low shrub, sedge-grass tundra	Grayling, burbot, longnose sucker, Dolly Varden, round whitefish, slimy sculpin	Important golden eagle habitat near A	Prime habitat - 15 mi. from Nenana to B	From Nenana R. to B- prime moose and important black bear habitat; from A northward about 10 mi.- prime moose habitat
BC	Parks Hwy - scenic area; hunting, fishing	Good possibility for arch. sites; data void	S. of Tanana River - wet old river floodplain, low shrub and sedge-grass bogs; Tanana R. crossing- willow and alder shrub types, white spruce, balsam poplar forests along river; n. of Tanana R. - open and closed deciduous (birch and aspen) forests on slopes, w/woodland spruce and bogs, low shrub, and wet sedge-grass on valley bottoms	Grayling, burbot, longnose sucker, Dolly Varden, round whitefish, slimy sculpin, salmon (coho, king, chum), sheefish; lake chub possible	Prime peregrine habitat at Tanana R.; prime waterfowl habitat along Tanana R. s. of corridor	Prime habitat - from Clear MEWS across the Tanana	Clear MEWS to across Tanana R - prime moose and important black bear habitat; n. of Bonanza Ck. Exp. Forest - prime black bear habitat
BDC	Wide open flat-high visibility; snowmobiling in flats s. of Fairbanks	Good possibility for arch. sites; data void	Probably wet, low shrub, bogs, wet sedge-grass, alder shrub, lowland spruce; n. of Tanana- upland deciduous forests	Same as BC	Near Totatlanika Ck. to Tanana R. - prime waterfowl habitat; near Wood R. - important raptor habitat; between D & C by Tanana R. - prime peregrine habitat	Prime habitat from B to across Tanana River	B to across Tanana R - prime moose, important black bear habitat; Wood R. to just s. of the Tanana R.- prime black bear habitat
AE	Scenic quality data void; Healy Ck - rafting area	Dry Ck. arch. site near Healy; few arch. sites in mountains; maybe near Japan Hills; data void	Data void	Same as AB	Important golden eagle habitat at A & along Healy Ck. s. of Usibelli Pk; prime peregrine habitat on Keevy Pk.	Prime habitat from E to the s. about 15 mi.	Usibelli to Japan Hills- prime moose & caribou habitat; between A & Mystic Mt.- prime sheep habitat; E to the s. - import. black bear hab.
EDC	Wide open flats - high visiblity; snowmobiling in flats s. of Fairbanks	High possibility for arch. sites; data void	Probably similar to BDC	Same as AB, lake chub possible	From Wood R. Buttes to n. of Tanana R.- prime waterfowl habitat; between D & C along the Tanana R.- prime peregrine habitat.	Prime habitat from E to just n. of Tanana River	E to just n. of Tanana R.- prime moose, important black bear habitat; Wood R. to just s. of Tanana R.- prime black bear habitat.
EF	Wide open flats - high visibility	Arch. sites have been identified for the Ft. Wainwright and Blair Lakes areas	Probably similar to EDC; wet	Same as BC with the exception of coho salmon, which is not recorded	N. of Blair Lake Air Force Range to the Tanana R. - prime waterfowl habitat; s. of Fairbanks along Tanana R.- prime bald eagle habitat	Prime habitat from E to Tanana River	E to Tanana R.- prime moose and important black bear habitat; Clear MEWS to Tanana R. - prime black bear habitat

a. Tall shrub=alder; low shrub=dwarf birch, and/or willow; open spruce=black (wet) or white spruce, 25%-60% cover; woodland spruce=white or black spruce, 10%-25% cover, mixed forest= spruce-birch.

b. Little data available. Sources of information in this table: Alaska Department of Fish and Game 1978a and Morrow 1980.

c. Source: VanBallenberghe personal communication. Prime habitat=minimum amount of land necessary to provide sustained yield for that species; based upon knowledge of that species' needs from experience of ADF&G personnel. Important habitat=land which the ADF&G considers not as critical to a species as is Prime habitat but is valuable.

TABLE B.41

SOIL ASSOCIATIONS WITHIN THE PROPOSED TRANSMISSION CORRIDORS - GENERAL DESCRIPTION, OFFROAD TRAFFICABILITY LIMITATIONS (ORTL), AND COMMON CROP SUITABILITY (CCS)[a]

EF1 - Typic Gyofluvents - Typic Cryaquepts, loamy, nearly level

- Dominant soils of this association consist of well-drained, stratified, waterlaid sediment of variable thickness over a substratum of gravel, sand, and cobblestones. Water table is high in other soils, including the scattered muskegs. ORTL: Slight - Severe (wet; subject to flooding); CCS: Good - Poor (low soil temperature throughout growing season).

EO1 - Typic Cryorthents, loamy, nearly level to rolling

- This association occupies broad terraces and moraines; most of the bedrock is under thick deposits of very gravelly and sandy glacial drift, capped with loess blown from barren areas of nearby floodplains. Well-drained, these soils are the most highly developed agricultural lands in Alaska. ORTL: Slight; CCS: Good - Poor.

IQ2 - Histic Pergelic Cryaquepts - loamy, nearly level to rolling

- The dominant soils in this association are poorly drained, developed in silty material of variable thickness over very gravelly glacial drift. Most soils have a shallow permafrost table, but in some of the very gravelly, well-drained soils, permafrost is deep or absent. ORTL: Severe - Wet; CCS: Poor

IQ3 - Histic Pergelic Cryaquepts - Typic Cryofluvents, loamy, nearly level

- Soils of this association located in low areas and meander scars of floodplains are poorly drained silt loam or sandy loam; these are usually saturated above a shallow permarfrost table. Soils on the natural levees along existing and former channels are well-drained, stratified silt loam and fine sand; permafrost may occur. ORTL: Severe (wet); CCS: Unsuitable (low temperature during growing season; wet) - Good (but subject to flooding).

IQ25 - Pergelic Cryaquepts - Pergelic Cryochrepts, very gravelly, hilly to steep

- Soils of this association occupying broad ridgetops, hillsides, and

a. Source: U.S. Department of Agriculture, Soil Conservation Service 1979. See Appendix Table B.2 for definitions for Offroad Trafficability Limitations and Common Crop Suitability.

TABLE B.41 (Cont'd)

valley bottoms at high elevation are poorly drained, consisting of a few inches of organic matter, a thin layer of silt loam, under which is very gravelly silt loam; permafrost table is at a depth greater than 2 feet. In locations of hills and ridges above tree line these soils are well-drained. ORTL: Severe (wet, steep slopes); CCS: Unsuitable (wet; low soil temperature; short, frost-free period).

IR1 - Typic Cryochrepts, loamy, nearly level to rolling

- On terraces and outwash plains, these soils are well-drained, having a thin mat of course organic matter over gray silt loam. In slight depressions and former drainage ways, these are moderately well-drained soils, having a thin organic mat over silt loam, with a sand or gravelly substratum. ORTL: Slight-Moderate; CCS: Good.

IR10 - Typic Cryochrepts, very gravelly, nearly level to rolling - Aeric Cryaquepts, loamy, nearly level to rolling

- Generally well- to moderately well-drained soils of terraces, outwash plains, and low moraines. Typically, these soils have a silt loam upper layer over gravelly soils. Pockets of poorly drained soils with a shallow permafrost table occupy irregular depressions. ORTL: Moderate - Severe (wet); CCS: Good - Poor (wet; low soil temperature throughout growing season; short, frost-free period).

IR14 - Alfic Cryochrepts, loamy, hilly to steep - Histic Pergelic Cryaquepts, loamy, nearly level to rolling

- On mid-slopes, these soils are well drained, of micaceous loess ranging to many feet thick over shattered bedrock of mica schist. Bottomland areas are poorly drained with a relatively thick surface of peatmoss. In these soils, permafrost ranges from 5-30 inches in depth. ORTL: Moderate - Severe (steep slope; wet); CCS: Poor (steep slopes; highly susceptible to erosion).

IU3 - Pergelic Cryumbrepts, very gravelly, hilly to steep - rough mountainous land

- On high alpine slopes and ridges close to mountain peaks, these soils have a thin surface mat of organic material beneath which is an 8 to 12-inch-thick, dark brown horizon formed in very gravelly or stony loam. This association also includes areas of bare rock and stony rubble on mountain peaks. ORTL: Severe (short, frost-free period) - Very Severe (steep slope); CCS: Unsuitable (short, frost-free period; shallow bedrock).

RM1 - Rough Mountainous Land

- Rough, mountainous land composed of steep, rocky slopes; icefields; and

TABLE B.41 (Cont'd)

glaciers. Soils on lower slopes are stony and shallow over bedrock. Unsuitable for agriculture. Roads feasible only in major valleys.

S01 - Typic Cryorthods, loamy, nearly level to rolling - Sphagnic Borofibrists, nearly level

- Low hills, terraces, and outwash plains have well-drained soils formed in silty loess or ash, over gravelly glacial till. Depressions have poorly drained, fibrous organic soils. ORTL: Slight - Very Severe; CCS: Good (on well-drained soils) - Unsuitable (wet organic soil).

S04 - Typic Cryorthods, very gravelly, nearly level to rolling - Sphagnic Borofibrists, nearly level

- Soils of nearly level to undulating outwash plains are well-drained to excessively well-drained, formed in a mantel of silty loess over very gravelly glacial till. Soils of the association located in depressions are very poorly drained, organic soils. ORTL: Slight - Very Severe; CCS: Good - Unsuitable (wet, organic).

S05 - Typic Cryorthods, very gravelly, hilly to steep - Sphagnic Borofibrists, nearly level

- On the hills and plains, these soils, formed in a thin metal of silty loess over very gravelly and stony glacial drift, are well drained and strongly acid. In muskegs, most of these soils consist of fibrous peat. ORTL: Severe (steep slope); CCS: Unsuitable (steep slopes; stones and boulders; short, frost-free season).

S010 - Humic Cryorthods, very gravelly, hilly to steep

- Generally, these are well-drained soils of foothills and deep mountain valleys, formed in very gravelly drift with a thin mantel of silty loess or mixture of loess and volcanic ash. These soils are characteristically free of permafrost except in the highest elevation. ORTL: Severe (steep slope); CCS: Poor - Unsuitable (low soil temperature throughout growing season; steep slopes).

S015 - Pergelic Cryorthods - Histic Pergelic Cryaquepts, very gravelly, nearly level to rolling

- On low moraine hills, these soils are well drained, formed in 10 to 20 inches of loamy material over very gravelly glacial drifts. On foot slopes and valleys, these soils tend to be poorly drained, with shallow permafrost table. ORTL: Slight - Severe (wet); CCS: Unsuitable (short, frost-free period; wet; stones and boulders).

TABLE B.41 (Cont'd)

S016 - Pergelic Cryorthods very gravelly, hilly to steep - Histic Pergelic Cryaquepts, loamy, nearly level

- On hilly moraines these soils are well-drained; beneath a thin surface of partially decomposed organic matter, the soils have spodic horizons developed in shallow silt loam over very gravelly or sandy loam. In valleys and long foot slopes, these are poorly drained soils, with a thick, peaty layer over a frost-churned loam or silt loam. Here, depth of permafrost is usually less than 20 inches below surface mat. ORTL: Severe (steep slope; wet); CCS: Unsuitable (short, frost-free period) - Poor (wet; low soil temperature).

TABLE B.42

DEFINITIONS FOR OFFROAD TRAFFICABILITY LIMITATIONS AND COMMON CROP SUITABILITY OF SOIL ASSOCIATIONS[a]

OFFROAD TRAFFICABILITY LIMITATIONS (ORTL)

Offroad Trafficability refers to cross-country movement of conventional wheeled and tracked vehicles, including construction equipment. Soil limitations for Offroad Trafficability (based on features of undisturbed soils) were rated Slight, Moderate, Severe, and Very Severe on the following bases:

- Slight

  Soil limitations, if any, do not restrict the movement of cross-country vehicles.

- Moderate

  Soil limitations need to be recognized but can generally be overcome with careful route planning. Some special equipment may be required.

- Severe

  Soil limitations are difficult to overcome, and special equipment and careful route planning are required. These soils should be avoided if possible.

- Very Severe

  Soil limitations are generally too difficult to overcome. Generally, these soils are unsuitable for conventional offroad vehicles.

Common Crop[b]
Suitability (CCS)

Soils were rated as Unsuitable, Good, Fair, and Poor for the production of common crops on the following bases:

- Unsuitable

  Soil or climate limitations are generally too severe to be overcome. None of the common crops can be grown successfully in most years, or there is danger of excessive damage to soils by erosion if cultivation is attempted.

a. Source: U.S. Department of Agriculture, Soil Conservation Service 1979.
b. The principal crops grown in Alaska--barley, oats, grasses for hay and silage, and potatoes--were considered in preparing ratings. Although only these crops were used, it is assumed that the ratings are also valid for vegetables and other crops suited to Alaskan soils.

TABLE B.42 (Cont'd)

- Good

Soil or climate limitations, if any, are easily overcome, and all of the common Alaskan crops can be grown under ordinary management practices. On soils of this group --

(a) Loamy texture extends to a depth of at least 18 inches (45 cm).

(b) Crop growth is not impeded by excessive soil moisture during the growing seasons.

(c) Damage by flooding occurs no more frequently than 1 year in 10.

(d) Slopes are dominantly less than 7 percent.

(e) Periods of soil moisture deficiency are rare, or irrigation is economically feasible.

(f) Damage to crops as a result of early frost can be expected no more frequently than 2 years in 10.

(g) The hazard of wind erosion is estimated to be slight.

- Fair

Soils or climate limitations need to be recognized but can be overcome. Common crops can be grown, but careful management and special practices may be required. On soils of this group --

(a) Loamy texture extends to a depth of at least 10 inches (25 cm).

(b) Periods of excessive soil moisture, which can impede crop growth during the growing season, do not exceed a total of 2 weeks.

(c) Damage by flooding occurs no more frequently than 2 years in 10.

(d) Slopes are dominantly less than 12 percent.

(e) Periods of soil moisture deficiency are infrequent.

(f) Damage to crops as a result of early frost can be expected no more frequently than 3 years in 10.

(g) There is no more than a moderate hazard of wind erosion.

- Poor

Soils or climate limitations are difficult to overcome and are severe enough

TABLE B.42 (Cont'd)

to make the use questionable. The choice of crops is narrow, and special treatment or managment practices are required. In some places, overcoming the limitations may not be feasible. On soils of this group --

(a) Loamy texture extends to a depth of at least 5 inches (12 cm).

(b) Periods of excessive soil moisture during the growing season do not exceed a total of 3 weeks.

(c) Damage by flooding occurs no more frequently than 3 years in 10.

(d) Slopes are dominantly less than 20 percent.

(e) Periods of soil moisture deficiency are frequent enough to severely damage crops.

(f) Climatic conditions permit at least one of the common crops, usually grasses, to be grown successfully in most years.

TABLE B.43: ECONOMICAL AND TECHNICAL SCREENING
SOUTHERN STUDY AREA (WILLOW TO ANCHORAGE/POINT MACKENZIE)

	(1) ABC'	(2) ADFC	(3) AEFC
- Length (miles)	73	38	39
- Max. Elev. (ft)	1400	400	400
- Clearing (miles) =			
Medium & Light	61	20	15
None	12	18	24
- Access (miles) =			
New Roads	20	0	12
4-Wheel	53	38	27
- Tower Construction*	329	180	176
- Rating:			
Economical	C	A	C
Technical	C	A	A

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

* Approximate number of towers required for this corridor, assuming single-circuit line.

TABLE B.44: ECONOMICAL AND TECHNICAL SCREENING
CENTRAL STUDY AREA (DAM SITES TO INTERTIE)

	(1) ABCD	(2) ABECD	(3) AJCF	(4) ABCJHI	(5) ABECJHI	(6) CBAHI	(7) CEBAHI	(8) CBAG	(9) CEBAG	(10) CJAG	(11) CJAHI	(12) JACJHI	(13) ABCF	(14) AJCD	(15) ABECF
- Length	40	45	41	77	82	68	75	90	95	91	69	70	41	41	45
- Max. Elevation, ft.	2500	3600	3500	4300	4300	4300	3500	3300	3600	3500	3800	3900	2500	3500	3600
- Clearing															
Medium & Light	38	30	26	18	30	20	27	45	37	40	55	17	39	26	35
None	2	15	15	59	50	48	46	45	60	51	14	53	2	15	10
- Access															
New Roads	28	33	41	66	57	47	56	60	70	63	50	50	41	29	45
4-Wheel	12	12	0	0	0	0	0	28	27	28	0	15	0	12	0
- Tower Construction*	180	203	185	347	369	306	329	405	428	410	311	315	180	185	203
- Rating:															
Economical	A	C	C	F	F	C	F	F	F	F	C	F	C	A	C
Technical	A	C	C	F	F	F	C	C	C	C	C	C	A	A	C

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

* Approximate number of towers required for this corridor, assuming single-circuit line.

TABLE B.45: ECONOMICAL AND TECHNICAL SCREENING
NORTHERN STUDY AREA (HEALY TO FAIRBANKS)

	(1) ABC	(2) ABDC	(3) AEDC	(4) AEF
- Length	90	86	115	105
- Max. Elevation	1600	1600	4500	4500
- Clearing				
Medium & Light	48	50	40	50
None	42	36	75	55
- Access				
New Roads	0	0	54	42
4-Wheel	90	43	42	16
- Tower Construction*	405	387	518	473
- Rating:				
Economical	A	A	C	C
Technical	A	C	F	F

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

* Approximate number of towers required for this corridor, assuming single-circuit line.

TABLE B.46: SUMMARY OF SCREENING RESULTS

Corridor	Env.	Econ.	Tech.	Summary
- Southern Study Area				
(1) ABC'	C	C	C	C
(2) ADFC	A	A	A	A
(3) AEFC	F	C	A	F
- Cental Study Area				
(1) ABCD	A	A	A	A
(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	A	C	A	C
(14) AJCD	C	A	A	C
(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

TABLE B.47

Environmental Constraints - Southern Study Area (Willow to Anchorage/Point MacKenzie)

Corridor	Length	Topography/Soils	Land Use	Aesthetics	Cultural Resources [a]	Vegetation	Fish Resources	Wildlife Resources	Environmental Rating [b]
1 (ABC')	73	Some soils with severe limitations to off road travel; some good agricultural soils	No existing ROW in AB; residential uses near Palmer; proposed capital site; much U.S. Military Wdl., Private, and Village Selection Land	Iditarod Trail; trail paralleling Deception Ck.; Gooding L. birdwatching area; 5 crossings of Glenn Hwy, 1 crossing of Parks Hwy	Archeologic sites-data void	Wetlands along Deception Ck. and at Matanuska River crossing; extensive clearing in upland, forested areas needed	5 river and 28 creek crossings; valuable spawning sites, especially salmon: Knik area Matanuska area data void	Passes through or near waterfowl and shorebird nesting and feeding areas, and areas used by brown bear	C
2 (ADFC)	38	Most of route potentially wet, with severe limitations to off road travel; some good agricultural soils	Trail is only existing ROW; residential and recreational areas; Susitna Flats Game Refuge; agricultural land sale	Susitna Flats Game Refuge; Iditarod Trail; 1 crossing of Parks Hwy	Archeologic sites-data void	Extensive wetlands; clearing needed in forested areas	1 river and 8 creek crossings; valuable spawning sites, especially salmon: L. Susitna R. data void	Passes through or near waterfowl and shorebird nesting, feeding, and migration areas, and areas used by furbearers and brown bear	A
3 (AEFC)	39	Same as Corridor 2	No known existing ROW; residential and recreational use areas, including Nancy Lakes; lakes used by float planes; agricultural land sale	Lake area south of Willow; Iditarod Trail; 1 crossing of Parks Hwy	Archeologic sites-data void	Extensive wetlands; clearing needed in forested areas	1 river and 8 creek crossings; valuable spawning sites, especially salmon: L. Susitna R. data void	Same as Corridor 2	F

a. Coastal area probably has many sites; available literature not yet reviewed.

b. A = recommended
C = acceptable but not recommended
F = unacceptable

TABLE B.48

Environmental Constraints - Central Study Area (Dam Sites to Intertie)

Corridor	Length (Miles)	Topography/Soils	Land Use	Aesthetics	Cultural Resources	Vegetation	Fish Resources	Wildlife Resources	Environmental Rating[a]
1 (ABCD)	40	Crosses several deep ravines; about 1000' change in elevation; some wet soils	Little existing ROW except Corps rd.; mostly Village Selection and Private Lands	Fog Lakes; Stephan Lake; proposed access road	Archeologic sites near Watana dam site, Stephan Lake and Fog Lakes; data void from Gold Creek to Devil Canyon; historic sites near the communities of Gold Creek and Canyon	Wetlands in eastern third of corridor; extensive forest-clearing needed	1 river and 17 creek crossings; valuable spawning areas, expecially grayling: data void	Unidentified raptor nest located on trib. to Susitna; passes through, habitat for: raptors, furbearers, wolves, wolverine, brown bear, caribou	A
2 (ABECD)	45	Crosses several deep ravines; about 2000' change in elev.; some steep slopes; some wet soils	Little existing ROW except Crops rd. and at D; rec. and resid. areas; float plane areas; mostly Village Selection and Private Lands	Fog Lakes; Stephan Lake; proposed access road; high country (Prairie & Chulitna Ck. drainages) and viewshed of Alaska Range	Same as Corridor 1	Wetlands in eastern half of corridor; extensive forest-clearing needed	1 river and 17 creek crossings; valuable spawning areas, especially grayling: data void	Passes through habitat for: raptors, waterfowl, migrating swans, furbearers, caribou, wolves, wolverine, brown bear	F
3 (AJCF)	41	Crosses several deep ravines; about 2000' change in elevation; some steep slopes; some wet soils	No existing ROW except at F; rec. areas; float plane areas; mostly Village Selection and Private Land; resid. & rec. development in area of Otter L. and old sled rd.	Viewshed of Alaska Range & High Lake; proposed access rd.	Archeologic sites by Watana dam site, & near Portage Ck./Susitna R. confluence; possible sites along Susitna R.; Historic sites near communities of Gold Ck. and Canyon	Forest-clearing needed in western half	14 creek crossing; valuable spawning areas, especially grayling and salmon: Indian River Portage Creek data void	Golden eagle nest along Devil Ck. near High L.; active raven nest on Devil Ck.; passes through habitat for: raptors, furbearers, wolves, brown bear	C
4 (ABCJHI)	77	Crosses several deep ravines; >2000' change in elevation; routing above 4000'; steep slopes; some wet soils; shallow bedrock in mts.	No existing ROW; rec. areas and isolated cabins; lakes used by float planes; much Village Selection Land	Fog Lakes; Stephan Lake; proposed access rd; viewshed of Alaska Range	Archeologic sites near Watana dam site, Stephan L. and Fog Lakes; possible sites along pass between drainages; data void between H and I	Small wetland areas in JA area; extensive forest-clearing needed; data void	1 river and 42 creek crossings; valuable spawning areas, especially grayling	Golden eagle nest along Devil Ck. near High L.; caribou movement area; passes through habitat for: raptors, waterfowl, furbearers, wolves, wolverine, brown bear	C

a. A = recommended
C = acceptable but not recommended
F = unacceptable

TABLE B.48 (CONT'D)

Environmental Constraints - Central Study Area (Dam Sites to Intertie)

Corridor	Length (Miles)	Topography/Soils	Land Use	Aesthetics	Cultural Resources	Vegetation	Fish Resources	Wildlife Resources	Environmental Rating
5 (ABECJHI)	82	Crosses several deep ravines; changes in elevation >2000'; routing above 4000'; steep slopes; some wet soils; shallow bedrock in mts	Same as Corridor 4	Fog Lakes; Stephan Lake; High Lake; proposed access rd; viewshed at Alaska Range	Same as Corridor 4	Wetlands in A and Stephan Lake areas; extensive forest-clearing needed	42 creek crossings; valuable spawning areas, especially grayling and salmon: data void	Same as Corridor 4 with important waterfowl and migrating swan habitat at Stephan Lake	F
6 (CBAHI)	68	Crosses several deep ravines; changes in elevation of about 1600'; routing above 4000'; steep slopes; some wet soils; shallow bedrock in mts.	No known existing ROW; rec. areas and isolated cabins; float plane area; Susitna area and near I are Village Selection Land	Fog Lakes and Stephan Lake; proposed access rd.; Tsusena Butte; viewshed of Alaska Range	Archeologic sites near Watana dam site, Fog Lakes and Stephan L.; data void between H and I	Extensive wet-lands from B to near Tsusena Butte; extensive forest-clearing needed	32 creek crossings; valuable spawning areas, especially grayling: data void	Bald eagle nest s.e. of Tsusena Butte; area of caribou movement; passes through habitat for: raptors, waterfowl, fur-bearers, wolves, wolverine, brown bear	C
7 (CEBAHI)	73	Crosses several deep ravines; change in elevation of about 1600'; routing above 3000'; steep slopes; some wet soils; shallow bedrock in mts.	Same as Corridor 6	Fog Lakes and Stephan Lake; proposed acess rd.; high country (Prairie-Chunilna Cks); Tsusena Butte; viewshed of Alaska Range	Same as Corridor 6	Extensive wet-lands in Stephan L., Fog Lakes, Tsusena Butte areas; extensive forest-clearing needed	45 creek crossing; valuable spawning areas, especially grayling: data void	Same as Corridor 6, with important waterfowl and migrating swan habitat at Stephan Lake	F
8 (CBAG)	90	Crosses several deep ravines; change in elevation of about 1600'; routing above 3000'; steep slopes; some wet soils; shallow bedrock in mts.	No existing ROW; rec. areas and isolated cabins; float plane areas; air strip and airport; much Village Selection and Federal Land	Fog Lakes; Stephan Lake; access rd; scenic area of Deadman Ck.; viewshed of Alaska Range	Archeologic sites near Watana dam site, Fog Lakes, Stephan Lake and along Deadman Ck.	Wetlands between B and mountains; extensive forest-clearing needed	1 river and 43 creek crossings; valuable spawning areas, expecially grayling: data void	Important bald eagle habitat by Denali Hwy. and Deadman L.; unchecked bald eagle nest near Tsusena Butte; passes through habitat for: raptors, furbearers, wolves, wolverine, brown bear	C

TABLE B.48 (CONT'D)

Environmental Constraints - Central Study Area (Dam Sites to Intertie)

Corridor	Length (Miles)	Topography/Soils	Land Use	Aesthetics	Cultural Resources	Vegetation	Fish Resources	Wildlife Resources	Environmental Rating
9 (CEBAG)	95	Crosses several deep ravines; changes in elevation of about 1600'; routing above 3000'; steep slopes; some wet soils; shallow bedrock in mts.	Same as Corridor 8	Fog Lakes; Stephan Lake; proposed access rd; high country (Prairie and Chunilna Cks.); Deadman Ck.; viewshed of Alaska Range	Same as Corridor 8	Wetlands in Stephan L./Fog Lakes areas; extensive forest-clearing needed	1 river and 48 creek crossings; valuable spawning areas, expecially grayling: data void	Same as Corridor 8, with important waterfowl and migrating swan habitat at Stephan Lake	F
10 (CJAG)	91	Same as Corridor 8	No existing ROW; rec. areas and isolated cabins; float plane areas; air strip and airport; mostly Village Selection and Federal Land	High Lakes area; proposed access rd.; Deadman Ck. drainage; view-shed at Alaska Range	Archeologic sites near Watana dam site. and along Deadman Ck.	Small wetlands in JA area; extensive forest-clearing needed	1 river and 47 creek crossings; valuable spawning areas, expecially grayling: data void	Golden eagle nest along Devil Ck. near High Lake; unchecked bald eagle nest near Tsusena Butte; area of caribou move-ment; passes through habitat for: raptors, waterfowl, furbearers, brown bear	C
11 (CJAHI)	69	Crosses several deep ravines; changes in elevation of 1000'; routing above 3000'; steep slopes; some wet soils; shallow bedrock in mts.	No existing ROW; rec. areas and isolated cabins; float plane areas; mostly Village Selection and Private Land	High Lakes area; proposed access rd.; viewshed of Alaska Range	Archeologic sites near Watana dam site	Small wetland areas in JA area; some forest-clearing needed	36 creek crossings; valuable spawning areas, especially grayling and salmon: data void	Golden eagle nest along Devil Ck. near High Lake; bald eagle nest s.e. of Tsusena Butte; passes through habitat for: raptors, furbearers, brown bear	C
12 (JA-CJHI)	70	Same as Corridor 11	No existing ROW; rec. areas and isolated cabins; float plane area; mostly Village Selection and Private Land	High Lakes area; proposed access rd.; Tsusena Butte; viewshed of Alaska Range	Archeologic site near Watana dam site; possible sites along pass between drainages	Small wetland areas in JA area; fairly extensive forest clearing needed	40 creek crossings; valuable spawning areas, especially grayling and salmon: data void	Golden eagle nest along Devil Ck. near High Lake; passes through habitat for: raptors, furbearers, wolves, brown bear	F

TABLE B.48 (CONT'D)

Environmental Constraints - Central Study Area (Dam Sites to Intertie)

Corridor	Length (Miles)	Topography/Soils	Land Use	Aesthetics	Cultural Resources	Vegetation	Fish Resources	Wildlife Resources	Environmental Rating
13 (ABCF)	41	Crosses several deep ravines; about 1000' change in elevation; some wet soils	No known existing ROW except at F; rec. areas; float plane areas; resid. and rec. use near Otter L. and old sled rd.; isolated cabins; mostly Village Selection Land; some Private Land	Fog Lakes, Stephan L.; proposed access rd.	Archeologic sites near Watana dam site, Portage Ck./Susitna R. confluence; Stephan L., and Fog Lakes; historic sites; near communities of Canyon and Gold Ck.	Wetlands in eastern third of corridor; extensive forest-clearing needed	15 creek crossings; valuable spawning areas, especially grayling and salmon: Indian River Portage Creek data void	Unidentified raptor nest on tributary to Susitna; passes through habitat for: raptors, furbearers, wolves, wolverine, brown bear, caribou	A
14 (AJCD)	41	Crosses deep ravine at Devil Ck.; about 2000' change in elevation; routing above 3000'; some steep slopes; some wet soils	Little existing ROW except old Corps rd. and at D; rec. areas; isolated cabins; much Village Selection land; some Private Land	Viewshed of Alaska Range and High Lake; proposed access road	Archeologic sites by Watana dam site, possible sites along Susitna R.; historic sites near communities of Canyon and Gold Ck.	Forest-clearing needed in western half	1 river and 16 creek crossings; valuable spawning areas, especially grayling: data void	Golden eagle nest in Devil Ck./High Lake area; active rap[illegible] nest on Devil Ck.; passes through habitat for: raptors, furbearers, wolves, brown bear, caribou	A
15 (ABECF)	45	Crosses several deep ravines; about 2000' change in elevation; some wet soils	No known existing ROW except at F; rec. areas; float plane areas; resid. and rec. use near Otter L. and old sled rd.; isolated cabins; mostly Village Selection land with some Private Land	Fog Lakes; Stephan Lake; proposed access road; high country (Prairie and Chunilna Cks. drainages); viewshed of Alaska Range	Same as Corridor 13	Wetlands in eastern half of corridor; extensive forest-clearing needed	15 creek crossings; valuable spawning areas, especially grayling and salmon: Indian River Portage Creek data void	Important waterfowl and migrating swan habitat at Stephan L.; passes through habitat for: raptors, waterfowl, furbearers, wolves, wolverine, brown bear, caribou	F

TABLE B.49

Environmental Constraints - Northern Study Area (Healy to Fairbanks)

Corridor	Length (Miles)	Topography/Soils	Land Use	Aesthetics	Cultural Resources	Vegetation	Fish Resources	Wildlife Resources[a]	Environmental Rating[b]
1 (ABC)	90	Some wet soils with severe limitations to off-road traffic	Air strip; residential areas and isolated cabins; some U.S. Military Withdrawl and Native land	3 crossings of Parks Hwy; Nenana R.- scenic area	Archeologic sites probable since there is a known site nearby; data void	Extensive wetlands; forest clearing needed mainly north of the Tanana River	4 river and 40 creek crossings; valuable spawning sites: Tanana River data void	Passes through or near prime habitat for: peregrines, waterfowl, furbearers, moose; passes through or near important habitat for: peregrines, golden eagles	A
2 (ABDC)	86	Severe limitations to off-road traffic in wet soils of the flats	No existing ROW n. of Browne; scattered residential and isolated cabins; airstrip; Fort Wainwright Military Reservation	3 crossings of Parks Hwy; high visibility in open flats	Dry Creek archeologic site near Healy; possible sites along river crossings; data void	Probably extensive wetlands between Wood and Tanana Rivers; extensive forest clearing needed n. of Tanana River	5 river and 44 creek crossings; valuable spawning sites: Wood River data void	Passes through or near prime habitat for: peregrines, waterfowl, furbearers; passes through or near important habitat for: golden eagles, other raptors	C
3 (AEDC)	115	Change in elevation of about 2500'; steep slopes; shallow bedrock in mts.; severe limitations to off-road traffic in the flats	No existing ROW beyond Healy/Cody Ck. confluence; isolated cabins; airstrips; Fort Wainwright Military Reservation	1 crossing of Parks Hwy; high visibility in open flats	Dry Creek archeologic site near Healy; possible sites near Japan Hills and in the mts.; data void	Probably extensive wetlands between Wood and Tanana Rivers; extensive forest clearing needed n. of Tanana River; data lacking for southern part	3 river and 72 creek crossings; valuable spawning sites: Wood River data void	Passes through or near prime habitat for: peregrines, waterfowl, furbearers, caribou, sheep; passes through or near important habitat for: golden eagles, brown bear	F
4 (AEF)	105	Same as Corridor 3	Airstrips; isolated cabins; Fort Wainwright Military Reservation	High visibility in open flats	Archeologic sites near Dry Creek and Fort Wainwright; possible sites near Tanana River; data void	Probably extensive wetlands between Wood and Tanana Rivers	3 river and 60 creek crossings; valuable spawning sites: Wood River data void	Passes through or near prime habitat for: peregrines, bald eagles, waterfowl, furbearers, caribou, sheep; passes through or near important habitat for: golden eagles, brown bear	C

a. Source: VanBallenberghe personal communication. Prime habitat = minimum amount of land necessary to provide a sustained yield for a species; based upon knowledge of that species' needs from experience of ADF&G personnel. Important habitat = land which ADF&G considers not as critical to a species as is Prime habitat, but is valuable.

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

TABLE B.50: 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 and Railroad Crossings

Environmental

Primary

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

Secondary

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

TABLE B.51: WATANA ESTIMATED NATURAL FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1950	4719.9[1]	2083.6	1168.9	815.1	641.7	569.1	680.1	8655.9	16432.1	19193.4	16913.6	7320.4	6599.5
1951	3299.1	1107.3	906.2	808.0	673.0	619.8	1302.2	11649.8	18517.9	19786.6	16478.0	17205.5	7696.1
1952	4592.9	2170.1	1501.0	1274.5	841.0	735.0	803.9	4216.5	25773.4	22110.9	17356.3	11571.0	7745.5
1953	6285.7	2756.8	1281.2	818.9	611.7	670.7	1382.0	15037.2	21469.8	17355.3	16681.6	11513.5	7988.7
1954	4218.9	1599.6	1183.8	1087.8	803.1	638.2	942.6	11696.8	19476.7	16983.6	20420.6	9165.5	7351.4
1955	3859.2	2051.1	1549.5	1388.3	1050.5	886.1	940.8	6718.1	24801.4	23787.9	23537.0	13447.8	8674.8
1956	4102.3	1588.1	1038.6	816.9	754.8	694.4	718.3	12953.3	27171.8	25831.3	19153.4	13194.4	9001.5
1957	4208.0	2276.6	1707.0	1373.0	1189.0	935.0	945.1	10176.2	25275.0	19948.9	17317.7	14841.1	8349.4
1958	6034.9	2935.9	2258.5	1480.6	1041.7	973.5	1265.4	9957.8	22097.8	19752.7	10843.4	5978.7	7718.4
1959	3668.0	1729.5	1115.1	1081.0	949.0	694.0	885.7	10140.6	18329.6	20493.1	23940.4	12466.9	7957.7
1960	5165.5	2213.5	1672.3	1400.4	1138.9	961.1	1069.9	13044.2	13233.4	19506.1	19323.1	16085.6	7901.2
1961	6049.3	2327.8	1973.2	1779.9	1304.8	1331.0	1965.0	13637.9	22784.1	19839.8	19480.2	10146.2	8551.6
1962	4637.6	2263.4	1760.4	1608.9	1257.4	1176.8	1457.4	11333.5	36017.1	23443.7	19887.1	12746.2	9799.1
1963	5560.1	2508.9	1708.9	1308.9	1184.7	883.6	776.6	15299.2	20663.4	28767.4	21011.4	10800.0	9206.1
1964	5187.1	1789.1	1194.7	852.0	781.6	575.2	609.2	3578.8	42841.9	20082.8	14048.2	7524.2	8255.4
1965	4759.4	2368.2	1070.3	863.0	772.7	807.3	1232.4	10966.0	21213.0	23235.9	17394.1	16225.6	8409.0
1966	5221.2	1565.3	1203.6	1060.4	984.7	984.7	1338.4	7094.1	25939.6	16153.5	17390.9	9214.1	7345.9
1967	3269.8	1202.2	1121.6	1102.2	1031.3	889.5	849.7	12555.5	24711.9	21987.3	26104.5	13672.9	9041.5
1968	4019.0	1934.3	1704.2	1617.6	1560.4	1560.4	1576.7	12826.7	25704.0	22082.8	14147.5	7163.6	7991.4
1969	3135.0	1354.9	753.9	619.2	607.5	686.0	1261.6	9313.7	13962.1	14843.5	7771.9	4260.0	4880.8
1970	2403.1	1020.9	709.3	636.2	602.1	624.1	986.4	9536.4	14399.0	18410.1	16263.8	7224.1	6068.0
1971	3768.0	2496.4	1687.4	1097.1	777.4	717.1	813.7	2857.2	27612.8	21126.4	27446.6	12188.9	8549.1
1972	4979.1	2587.0	1957.4	1670.9	1491.4	1366.0	1305.4	15973.1	27429.3	19820.3	17509.5	10955.7	8920.4
1973	4301.2	1977.9	1246.5	1031.5	1000.2	873.9	914.1	7287.0	23859.3	16351.1	18016.7	8099.7	7079.9
1974	3056.5	1354.7	931.6	786.4	689.9	627.3	871.9	12889.0	14780.6	15971.9	13523.7	9786.2	6272.5
1975	3088.8	1474.4	1276.7	1215.8	1110.3	1041.4	1211.2	11672.2	26689.2	23430.4	15126.6	13075.3	8367.7
1976	5679.1	1601.1	876.2	757.8	743.2	690.7	1059.8	8938.8	19994.0	17015.3	18393.5	5711.5	6788.4
1977	2973.5	1926.7	1687.5	1348.7	1202.9	1110.8	1203.4	8569.4	31352.8	19707.3	16807.3	10613.1	8208.6
1978	5793.9	2645.3	1979.7	1577.9	1267.7	1256.7	1408.4	11231.5	17277.2	18385.2	13412.1	7132.6	6947.4
1979	3773.9	1944.9	1312.6	1136.8	1055.4	1101.2	1317.9	12369.3	22904.8	24911.7	16670.7	9096.7	8133.0
1980	6150.0[3]	3525.0[3]	2032.0[3]	1470.0[3]	1233.0[3]	1177.0[3]	1404.0[3]	10140.0[3]	23400.0	26740.0	18000.0	11000.0	8855.9
1981	6458.0[2]	3297.0[2]	1385.0[4]	1147.0[4]	971.0[4]	889.0[4]	1103.0[4]	10406.0[4]	17323.0[2]	27840.0[2]	31435.0[2]	12026.0[2]	9523.3
AVE	4513.1	2052.4	1404.8	1157.3	978.9	898.3	1112.6	10397.6	22922.4	20778.0	18431.4	10670.4	7943.1

Notes: (1) Discharges based on Cantwell and Gold Creek flows unless specified
(2) Watana observed flows
(3) Flows based on Gold Creek
(4) Watana long-term average flows assumed

TABLE B.52: DEVIL CANYON ESTIMATED NATURAL FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1950	5758.2	2404.7	1342.5	951.3	735.7	670.0	802.2	10490.7	18468.6	21383.4	18820.6	7950.8	7481.6
1951	3652.0	1231.2	1030.8	905.7	767.5	697.1	1504.6	13218.5	19978.5	21575.9	18530.0	19799.1	8574.2
1952	5221.7	2539.0	1757.5	1483.7	943.2	828.2	878.5	4989.5	30014.2	24861.7	19647.2	13441.1	8883.8
1953	7517.6	3232.6	1550.4	999.6	745.6	766.7	1531.8	17758.3	25230.7	17184.0	19207.0	13928.4	9304.4
1954	5109.3	1921.3	1387.1	1224.2	929.7	729.4	1130.6	15286.0	23188.1	19154.1	24071.6	11579.1	8809.2
1955	4830.4	2506.8	1868.0	1649.1	1275.2	1023.6	1107.4	8390.1	28081.9	26212.8	24959.6	13989.2	9657.8
1956	4647.9	1788.6	1206.6	921.7	893.1	852.3	867.3	15979.0	31137.1	29212.0	22609.8	16495.8	10550.9
1957	5235.3	2773.8	1986.6	1583.2	1388.9	1105.4	1109.0	12473.6	28415.4	22109.6	19389.2	18029.0	9633.3
1958	7434.5	3590.4	2904.9	1792.0	1212.2	1085.7	1437.4	11849.2	24413.5	21763.1	21219.8	6988.8	8807.6
1959	4402.8	1999.8	1370.9	1316.9	1179.1	877.9	1119.9	13900.9	21537.7	23390.4	28594.4	15329.6	9585.0
1960	6060.7	2622.7	2011.5	1686.2	1340.2	1112.8	1217.8	14802.9	14709.8	21739.3	22066.1	18929.9	9025.0
1961	7170.9	2759.9	2436.6	2212.0	1593.6	1638.9	2405.4	16030.7	27069.3	22880.6	21164.4	12218.6	9965.1
1962	5459.4	2544.1	1978.7	1796.0	1413.4	1320.3	1613.4	12141.2	40679.7	24990.6	22241.8	14767.2	10912.2
1963	6307.7	2696.0	1896.0	1496.0	1387.4	958.4	810.9	17697.6	24094.1	32388.4	22720.5	11777.2	10352.5
1964	5998.3	2085.4	1387.1	978.0	900.2	663.8	696.5	4046.9	47816.4	21926.0	15585.8	8840.0	9243.7
1965	5744.0	2645.1	1160.8	925.3	828.8	866.9	1314.4	12267.1	24110.3	26195.7	19789.3	18234.2	9506.8
1966	6496.5	1907.8	1478.4	1278.7	1187.4	1187.4	1619.1	8734.0	30446.3	18536.2	20244.6	10844.3	8663.4
1967	3844.0	1457.9	1364.9	1357.9	1268.3	1089.1	1053.7	14435.5	27796.4	25081.2	30293.0	15728.2	10397.5
1968	4585.3	2203.5	1929.7	1651.2	1778.7	1778.7	1791.0	14982.4	29462.1	24871.0	16090.5	8225.9	9129.2
1969	3576.7	1531.8	836.3	686.6	681.8	769.6	1421.3	10429.9	14950.7	15651.2	8483.6	4795.5	5317.9
1970	2866.5	1145.7	810.0	756.9	708.7	721.8	1046.6	10721.6	17118.9	21142.2	18652.8	8443.5	7011.3
1971	4745.2	3081.8	2074.8	1318.8	943.6	866.8	986.2	3427.9	31031.0	22941.6	30315.9	13636.0	9614.1
1972	5537.0	2912.3	2312.6	2036.1	1836.4	1659.8	1565.5	19776.8	31929.8	21716.5	18654.1	11884.2	10151.8
1973	4638.6	2154.8	1387.0	1139.8	1128.6	955.0	986.7	7896.4	26392.6	17571.8	19478.1	8726.0	7704.6
1974	3491.4	1462.9	997.4	842.7	745.9	689.5	949.1	15004.6	16766.7	17790.0	15257.0	11370.1	7113.9
1975	3506.8	1619.4	1486.5	1408.8	1342.2	1271.9	1456.7	14036.5	30302.6	26108.0	17031.6	15154.7	9567.1
1976	7003.3	1853.0	1007.9	896.8	876.2	825.2	1261.2	11305.3	22813.6	18252.6	19297.7	6463.3	7654.7
1977	3552.4	2391.7	2147.5	1657.4	1469.7	1361.0	1509.8	11211.9	35606.7	21740.5	18371.2	11916.1	9411.3
1978	6936.3	3210.8	2371.4	1867.9	1525.0	1480.6	1597.1	11693.4	18416.8	20079.0	15326.5	8080.4	7715.4
1979	4502.3	2324.3	1549.4	1304.1	1203.6	1164.7	1402.8	[illegible]	24052.4	27462.8	19106.7	10172.4	8965.0
1980*	6900.0	3955.0	2279.0	1649.0	1383.0	1321.0	1575.0	11377.0	26255.0	30002.0	20196.0	12342.0	9936.2
1981*	7246.0	3699.0	1554.0	1287.0	1089.0	997.0	1238.0	11676.0	19436.0	31236.0	35270.0	13493.0	10685.1
AVE	5311.8	2382.9	1652.0	1351.9	1146.9	1041.8	1281.5	12230.2	25991.3	23100.9	20709.0	12299.2	9041.6

* Discharges based on Watana flows

TABLE B.53: MONTHLY FLOW REQUIREMENTS AT GOLD CREEK

MTH	A	A1	A2	C	C1	C2	D
O	2000	2000	2000	2000	2000	2000	2000
N	1000	1000	1000	1000	1000	1000	1000
D	1000	1000	1000	1000	1000	1000	1000
J	1000	1000	1000	1000	1000	1000	1000
F	1000	1000	1000	1000	1000	1000	1000
M	1000	1000	1000	1000	1000	1000	1000
A	1000	1000	1000	1000	1000	1000	1000
M	2000	4000	5000	6000	6000	6000	6000
J	2000	4000	5000	6000	6000	6000	6000
J[1]	2000	4320	5400	6480	6650	6810	7050
A	2000	8000	10000	12000	14000	16000	19000
S[2]	2000	6200	7750	9300	10400	11500	13150

Notes:

Derivation of transitional flows.

1 $\text{July} = \left(\text{June} \times 26 + 5\left[\frac{\text{June} + \text{August}}{2}\right]\right)\frac{1}{31}$

2 $\text{Sept} = \left(\text{August} \times 14 + 5\left[\frac{\text{June} + \text{August}}{2}\right] + \text{June} \times 11\right)\frac{1}{30}$

TABLE B.54: ENERGY POTENTIAL OF WATANA - DEVIL CANYON DEVELOPMENTS FOR DIFFERENT DOWNSTREAM FLOW REQUIREMENTS

MONTH	ENERGY POTENTIAL GWH											
	WATANA ONLY						WATANA & DEVIL CANYON					
	FIRM ENERGY			AVERAGE ENERGY			FIRM ENERGY			AVERAGE ENERGY		
	CASE A	C	D	A	C	D	A	C	D	A	C	D
OCT	244	221	180	296	263	185	482	610	590	548	610	587
NOV	269	243	197	340	322	321	528	472	410	678	635	473
DEC	315	285	231	407	388	323	617	551	480	801	770	645
JAN	288	260	211	356	346	316	564	504	439	742	717	646
FEB	224	202	164	291	283	266	438	392	341	638	616	513
MAR	250	226	278	290	286	276	490	438	381	628	614	527
APR	209	189	267	253	250	248	409	366	319	516	507	483
MAY	200	182	211	266	258	251	423	401	338	484	445	425
JUN	183	165	152	236	227	215	363	324	282	440	429	441
JUL	187	169	209	216	205	196	371	332	288	424	405	398
AUG	196	303	324	286	373	588	390	479	1543	495	581	855
SEP	200	266	179	239	274	354	394	459	569	536	579	777
TOTAL	2765	2711	2603	3476	3475	3449	5469	5338	4980	6930	6908	6771

NOTE: Cases B and C were similar and only Case C was analyzed in detail.

TABLE B.55: NET BENEFITS FOR SUSITNA HYDROELECTRIC PROJECT OPERATING SCENARIOS

	LTPWC* (1982 dollars x 10^6)	NET BENEFIT (1982 dollars x 10^6)	PERCENT Decrease Relative to Case A
Thermal Option	8238	-	-
Case A	7023	1215	-
Case A_1	7037	1201	1
Case A_2	7049	1189	2
Case C	7097	1141	6
Case C_1	7180	1058	13
Case C_2	7329	909	25
Case D	7574	664	45

*Long-Term Present Worth Costs

TABLE B.56: AVERAGE ANNUAL AND MONTHLY FLOW AT GAGE IN THE SUSITNA BASIN*

MONTH	STATION (USGS Reference Number)							
	Susitna River at Gold Creek (2920)		Susitna River Near Cantwell (2915)		Susitna River Near Denali (2910)		Maclaren River Near Paxson (2912)	
Drainage Area sq. mi.	6160		4140		950		280	
	%	Mean(cfs)	%	Mean(cfs)	%	Mean(cfs)	%	Mean(cfs)
JANUARY	1	1,474	1	824	1	244	1	96
FEBRUARY	1	1,249	1	722	1	206	1	84
MARCH	1	1,124	1	692	1	188	1	76
APRIL	1	1,362	1	853	1	233	1	87
MAY	12	13,240	10	7,701	6	2,036	7	803
JUNE	24	27,815	26	19,326	22	7,285	25	2,920
JULY	21	24,445	23	16,892	28	9,350	27	3,181
AUGUST	19	22,228	20	14,658	24	8,050	22	2,573
SEPTEMBER	12	13,321	10	7,800	10	3,350	10	1,149
OCTOBER	5	5,771	4	3,033	3	1,122	3	409
NOVEMBER	2	2,577	2	1,449	2	490	1	177
DECEMBER	2	1,807	1	998	1	314	1	118
ANNUAL - cfs	100	9,753	100	6,246	100	2,739	100	973

Period of Record - Gold Creek - 1950-81
Cantwell - 1961-72
Denali - 1957-79
Maclaren - 1957-79

* Ref. USGS Streamflow Data

TABLE B.57: PEAK FLOWS OF RECORD

Gold Creek		Cantwell		Denali		Maclaren	
Date	Peak ft^3/s	Date	Peak ft^3/s	Date	Peak ft^3/s	Date	Peak ft^3/s
8/25/59	62,300	6/23/61	30,500	8/18/63	17,000	9/13/60	8,900
6/15/62	80,600	6/15/62	47,000	6/07/64	16,000	6/14/62	6,650
6/07/64	90,700	6/07/64	50,500	9/09/65	15,800	7/18/65	7,350
6/06/66	63,600	8/11/70	20,500	8/14/67	28,200	8/14/67	7,600
8/15/67	80,200	8/10/71	60,000	7/27/68	19,000	8/10/71	9,300
8/10/71	87,400	6/22/72	45,000	8/08/71	38,200	6/17/72	7,100

TABLE B.58: ESTIMATED FLOOD PEAKS IN SUSITNA RIVER

Location	Peak Inflow in Cfs for Recurrence Interval in Years				
	1:2	1:50	1:100	1:10,000	PMF
Gold Creek	49,500	106,000	118,000	190,000	408,000
Watana Damsite	40,800	87,000	97,000	156,000	326,000
Devil Canyon Damsite (Routed Peak Inflow with Watana)	12,600	39,000	61,000	165,000	345,000

TABLE B.59: WATANA FLOOD ROUTING - MAXIMUM FLOWS (cfs)

WATANA FLOOD ROUTING

Flood	Powerhouse	Outlet	Spillway Main	Spillway Emergency	Total	Maximum Reservior Level (ft)
1:50	7000	24,000	0	0	3100	2193
1:10,000	7000	24,000	119,000	0	150,000	2193.5
PMF	7000[a]	24,000	150,000	119,000	293,000	2201.0

Maximum Flows During Flood (cfs)

DEVIL CANYON FLOOD ROUTING[b]

Flood	Powerhouse	Outlet	Spillway Main	Spillway Emergency	Total	Maximum Reservoir Level (ft)
1:50	3500	35,500	0	0	39,000	1455
1:10,000	3500	38,500	123,000	0	165,000	1455
PMF	3500[c]	38,500	156,000	150,000	345,000	1466

Maximum Flow During Flood (cfs)

Notes:

a Powerhouse closes when reservoir level exceeds 2193 ft MSL
b Assumes Watana Reservoir upstream
c Powerhouse closes when reservoir level exceeds 1456 MSL

TABLE B.60: ESTIMATED EVAPORATION LOSSES - WATANA AND DEVIL CANYON RESERVOIRS

Month	WATANA Pan Evaporation (Inches)	WATANA Reservoir Evaporation (Inches)	DEVIL CANYON Pan Evaporation (Inches)	DEVIL CANYON Reservoir Evaporation (Inches)	Average Monthly Air Temperature (°C) Watana[1]	Average Monthly Air Temperature (°C) Devil Canyon[2]	Average Monthly Air Temperature (°C) Talkeetna[3]
January	0.0	0.0	0.0	0.0	-2.5	-4.5	-13.0
February	0.0	0.0	0.0	0.0	-7.3	-5.0	-9.3
March	0.0	0.0	0.0	0.0	-1.8	-4.3	-6.7
April	0.0	0.0	0.0	0.0	-1.8	-2.5	0.7
May	3.6	2.5	3.9	2.7	8.7	6.1	7.0
June	3.4	2.4	3.8	2.7	10.0	9.2	12.6
July	3.3	2.3	3.7	2.6	13.7	11.9	14.4
August	2.5	1.8	2.7	1.9	12.5	N/A	12.7
September	1.5	1.0	1.7	1.2	N/A	4.8	7.8
October	0.0	0.0	0.0	0.0	0.2	-1.8	0.2
November	0.0	0.0	0.0	0.0	-5.1	-7.2	-7.8
December	0.0	0.0	0.0	0.0	-17.9	-21.1	-12.7
Annual Evap.	14.3	10.0	15.8	11.1			

1 Based on data - April 1980-June 1981
2 Based on data - July 1980-June 1981
3 Based on data - January 1941-December 1980

TABLE B.61: FLOW RELEASE (CFS) AT WATANA FOR WATANA ONLY - CASE C

	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	5258.9	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	7756.1	9595.1	10992.6	9648.3	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	11305.1	12148.4	10360.5	9549.5	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
AVE	6766.1	8667.7	10300.9	9399.2	8685.4	8098.3	7478.1	7519.6	6628.3	5549.6	9778.8	7310.7

TABLE B.62: FLOW RELEASE (CFS) AT DEVIL CANYON FOR WATANA/DEVIL CANYON - CASE C

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	6602.4	10756.1	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	7069.0	11783.4	11239.8	10909.5	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	16495.8
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	11646.1	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	16223.3	14767.2
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	15728.2
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	6448.9	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	17878.2	12762.0
AVE	7318.4	9444.5	11128.2	10484.6	10094.3	9204.0	8005.7	7656.6	8146.1	7094.4	11333.6	9603.0

TABLE B.63: WATER APPROPRIATIONS WITHIN ONE MILE OF THE SUSITNA RIVER

LOCATION*	ADDITIONAL NUMBER	TYPE	SOURCE (DEPTH)	AMOUNT	DAYS OF USE
CERTIFICATE					
T19N R5W	45156	Single-family dwelling	well (?)	650 gpd	365
		general crops	same source	0.5 ac-ft/yr	91
T25N R5W	43981	Single-family dwelling	well (90 ft)	500 gpd	365
T26N R5W	78895	Single-family dwelling	well (20 ft)	500 gpd	365
	200540	Grade school	well (27 ft)	910 gpd	334
	209233	Fire station	well (34 ft)	500 gpd	365
T27N R5W	200180	Single-family dwelling	unnamed stream	200 gpd	365
		Lawn & garden irrigation	same source	100 gpd	153
	200515	Single-family dwelling	unnamed lake	500 gpd	365
	206633	Single-family dwelling	unnamed lake	75 gpd	365
	206930	Single-family dwelling	unnamed lake	250 gpd	365
	206931	Single-family dwelling	unnamed lake	250 gpd	365
PERMIT					
	206929	General crops	unnamed creek	1 ac-ft/yr	153
T30N R3W	206735	Single-family dwelling	unnamed stream	250 gpd	365
PENDING					
	209866	Single-family dwelling	Sherman Creek	75 gpd	365
		Lawn & garden irrigation	same source	50 gpd	183

*All locations are within the Seward Meridian.

TABLE B.64: TURBINE OPERATING CONDITIONS

	Watana	Devil Canyon
Maximum net head	728 feet	600 feet
Minimum net head	604 feet	542 feet
Design head	680 feet	575 feet
Rated head	680 feet	575 feet
Turbine flow at rated head, cfs	3550 cfs	3800 cfs
Turbine efficiency at design head	91%	91%
Turbine-generating rating at rated head	186,500 kW	168,000 kW

TABLE B.65: HISTORICAL ANNUAL GROWTH RATES OF ELECTRIC UTILITY SALES

Period	U.S.	Anchorage and Fairbanks Areas
1940 - 1950	8.8%	20.5%
1950 - 1960	8.7%	15.3%
1960 - 1970	7.3%	12.9%
1970 - 1978	4.6%	11.7%
1970 - 1973	6.7%	13.1%
1973 - 1978	3.5%	10.9%
1940 - 1978	7.3%	15.2%

TABLE B.66: ANNUAL GROWTH RATES IN UTILITY CUSTOMERS AND CONSUMPTION PER CUSTOMER

	Greater Anchorage		Greater Fairbanks		U.S.	
	Customers (Thousands)	Consumption per Customer (MWh)	Customers (Thousands)	Consumption per Customer (MWh)	Customers (Millions)	Consumption per Customer (MWh)
Residential						
1965	27	6.4	8.2	4.8	57.6	4.9
1978	77	10.9	17.5	10.2	77.8	8.8
Annual Growth Rate (%)	8.4	4.2	6.0	6.0	2.3	4.6
Commercial						
1965	4.0	-	1.3	-	7.4	-
1978	10.2	-	2.9	-	9.1	
Annual Growth Rate (%)	7.5	-	6.4	-	1.6	-

TABLE B.67: UTILITY SALES BY RAILBELT REGIONS

	Greater Anchorage			Greater Fairbanks			Glennallen-Valdez			Railbelt Total	
	Sales		No. of Customers (Thousands)[1]	Sales		No. of Customers (Thousands)[1]	Sales		No. of Customers (Thousands)[1]	Sales	No. of Customers (Thousands)[1]
Year	GWh	Regional Share		GWh	Regional Share		GWh	Regional Share		GWh	
1965	369	78%	31.0	98	21%	9.5	6	1%	.6	473	41.1
1966	415		32.2	108		9.6	NA		NA	523	41.8
1967	461		34.4	66		NA	NA		NA	527	34.4
1968	519		39.2	141		10.8	NA		NA	661	30.0
1969	587		42.8	170		11.6	NA		NA	758	54.4
1970	684	75%	46.9	213	24%	12.6	9	1%	.8	907	60.3
1971	797		49.5	251		13.1	10		.9	1059	63.5
1972	906		54.1	262		13.5	6		.4	1174	68.0
1973	1010		56.1	290		13.9	11		1.0	1311	71.0
1974	1086		61.8	322		15.5	14		1.3	1422	78.6
1975	1270	75%	66.1	413	24%	16.2	24	1%	1.9	1707	84.2
1976	1463		71.2	423		17.9	33		2.2	1920	91.3
1977	1603		81.1	447		20.0	42		2.1	2092	103.2
1978	1747	79%	87.2	432	19%	20.4	38	2%	2.0	2217	109.6
Annual Growth	12.7%		8.2%	12.1%		6.1%	13.9%		9.7%	12.6%	7.8%

NOTES:

(1) Includes residential and commercial users only, but not miscellaneous users.
Source: Federal Energy Regulatory Commission, Power System Statement.
NA: Not Available.

TABLE B.68: SUMMARY OF ISER RAILBELT ELECTRICITY PROJECTIONS

Year	Utility Sales to All Consuming Sectors (GWh): LES-GL Bound[1]	LES-GM	MES-GM (Base Case)	MES-GM with Price Induced Shift	HES-GM	HES-GH Bound[1]	Military Net Generation (GWh): MES-GM (Base Case)	Self-Supplied Industry Net Generation (GWh): LES-GM	MES-GM (Base Case)	MES-GM with Price Induced Shift	HES-GM
1980	2390	2390	2390	2390	2390	2390	334	414	414	414	414
1985	2798	2921	3171	3171	3561	3707	334	414	571	571	847
1990	3041	3236	3599	3599	4282	4443	334	414	571	571	981
1995	3640	3976	4601	4617	5789	6317	334	414	571	571	981
2000	4468	5101	5730	6525	7192	8010	334	414	571	571	981
2005	4912	5617	6742	8219	9177	10596	334	414	571	571	981
2010	5442	6179	7952	10142	11736	14009	334	414	571	571	981
Average Annual Growth Rate (%)											
1980-1990	2.44	3.08	4.18	4.18	6.00	6.40	0.0	0.0	3.27	3.27	9.0
1990-2000	3.92	4.66	4.76	6.13	5.32	6.07	0.0	0.0	0.0	0.0	0.0
2000-2010	1.99	1.94	3.33	4.51	5.02	5.75	0.0	0.0	0.0	0.0	0.0
1980-2010	2.78	3.22	4.09	4.94	5.45	6.07	0.0	0.0	1.08	1.08	2.92

NOTES:

Lower Bound = Estimates for LES-GL
Upper Bound = Estimates for HES-GH

LES = Low Economic Growth
MES = Medium Economic Growth
HES = High Economic Growth
GL = Low Government Expenditure
GM = Moderate Government Expenditure
GH = High Government Expenditure

(1) Results generated by Acres, all others by ISER.

TABLE B.69: FORECAST TOTAL GENERATION AND PEAK LOADS - TOTAL RAILBELT REGION[1]

Year	ISER Low (LES-GM)[2]		ISER Medium (MES-GM)		ISER High (HES-GM)	
	Generation (GWh)	Peak Load (MW)	Generation (GWh)	Peak Load (MW)	Generation (GWh)	Peak Load (MW)
1978	3323	606	3323	606	3323	606
1980	3522	643	3522	643	4135	753
1985	4141	757	4429	808	5528	995
1990	4503	824	4922	898	6336	1146
1995	5331	977	6050	1105	8013	1456
2000	6599	1210	7327	1341	9598	1750
2005	7188	1319	8471	1551	11843	2158
2010	7822	1435	9838	1800	14730	2683
Percent Growth/Yr. 1978-2010	2.71	2.73	3.45	3.46	4.76	4.76

NOTES:

(1) Includes net generation from military and self-supplied industry sources.

(2) All forecasts assume moderate government expenditure.

TABLE B. 70: ISER 1980 RAILBELT REGION LOAD AND ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES FOR DEVELOPMENT SELECTION[5]

	LOAD CASE											
	Low Plus Load Management and Conservation (LES-GL Adjusted)[1]			Low (LES-GL)[2]			Medium (MES-GM)[3]			High (HES-GH)[4]		
Year	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor
1980	510	2790	62.5	510	2790	62.4	510	2790	62.4	510	2790	62.4
1985	560	3090	62.8	580	3160	62.4	650	3570	62.6	695	3860	63.4
1990	620	3430	63.2	640	3505	62.4	735	4030	62.6	920	5090	63.1
1995	685	3810	63.5	795	4350	62.3	945	5170	62.5	1295	7120	62.8
2000	755	4240	63.8	950	5210	62.3	1175	6430	62.4	1670	9170	62.6
2005	835	4690	64.1	1045	5700	62.2	1380	7530	62.3	2285	12540	62.6
2010	920	5200	64.4	1140	6220	62.2	1635	8940	62.4	2900	15930	62.7

Notes:

(1) LES-GL: Low economic growth/low government expenditure with load management and conservation.
(2) LES-GL: Low economic growth/low government expenditure.
(3) MES-GM: Medium economic growth/moderate government expenditure.
(4) HES-GH: High economic growth/high government expenditure.
(5) Excludes reserve requirements. Energy figures are for net generation.

TABLE B.71: DECEMBER 1981 BATTELLE PNL RAILBELT REGION LOAD AND ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES

	LOAD CASE								
	Medium			Low			High		
Year	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor
1981	574	2893	57.5	568	2853	57.3	598	3053	58.3
1985	687	3431	57.8	642	3234	57.5	794	4231	60.8
1990	892	4456	57.0	802	3999	56.9	1098	5703	59.3
1995	983	4922	57.1	849	4240	57.0	1248	6464	59.1
2000	1084	5469	57.4	921	4641	57.4	1439	7457	59.0
2005	1270	6428	57.8	1066	5358	57.4	1769	9148	59.0
2010	1537	7791	57.9	1245	6303	57.8	2165	11,435	60.3
Average Annual Growth Rate(%)									
1981-1990	5.0	4.9		3.9	3.8		7.0	7.2	
1990-2000	2.0	2.1		1.4	1.5		2.7	2.7	
2001-2010	3.6	3.6		3.1	3.1		4.2	4.4	
1981-2010	3.5	3.5		2.7	2.8		4.5	4.6	

Note: Excludes reserve requirements. Energy figures are for net generation.

TABLE B.72: BATTELLE DEMAND FORECASTS -- TOTAL RAILBELT

Base Plan

Medium Economic Scenario

Year	Peak (MW)	Sales (GWh)
1980	521	2551
1985	647	3160
1990	924	4482
1995	996	4894
2000	955	4728
2005	1073	5327
2010	1347	6686

Low Economic Scenario

Year	Peak (MW)	Sales (GWh)
1980	522	2554
1985	626	3052
1990	841	4083
1995	854	4150
2000	767	3756
2005	812	3991
2010	991	4878

High Economic Scenario

Year	Peak (MW)	Sales (GWh)
1980	521	2550
1985	667	3259
1990	1102	5639
1995	1198	6168
2000	1174	6092
2005	1391	7175
2010	1888	9627

High Conservation and Renewable Resource Use

Medium Seasonal Scenario

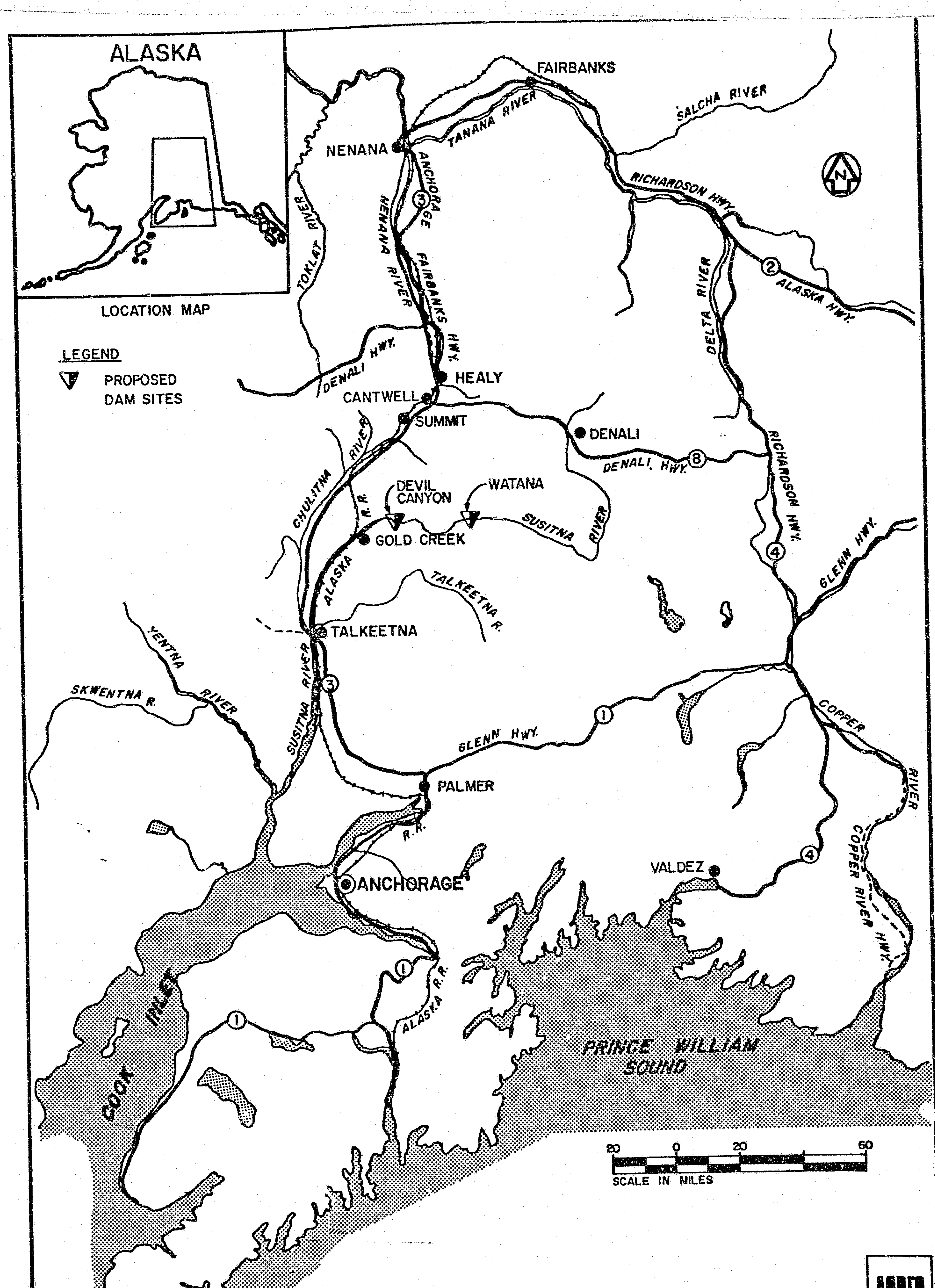
Peak (MW)	Sales (GWh)
521	2551
577	2746
832	3937
966	4692
936	4576
1038	5085
1245	6101

Low Economic Scenario

Peak (MW)	Sales (GWh)
522	2554
557	2651
751	3554
816	3922
750	3627
796	3859
979	4758

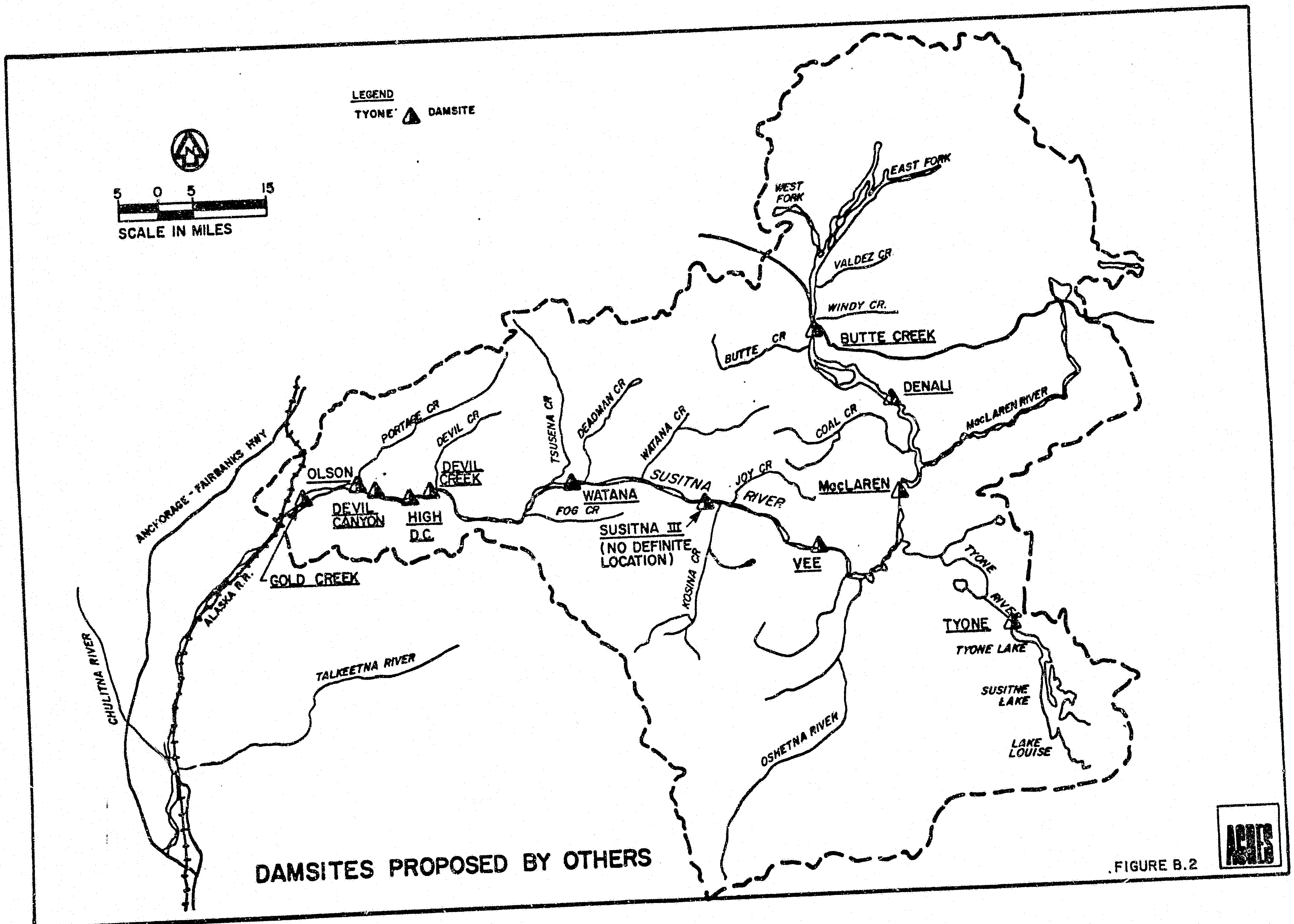
High Economic Scenario

Peak (MW)	Sales (GWh)
521	2550
596	2835
1002	5043
1164	5937
1148	5888
1352	6892
1816	9156



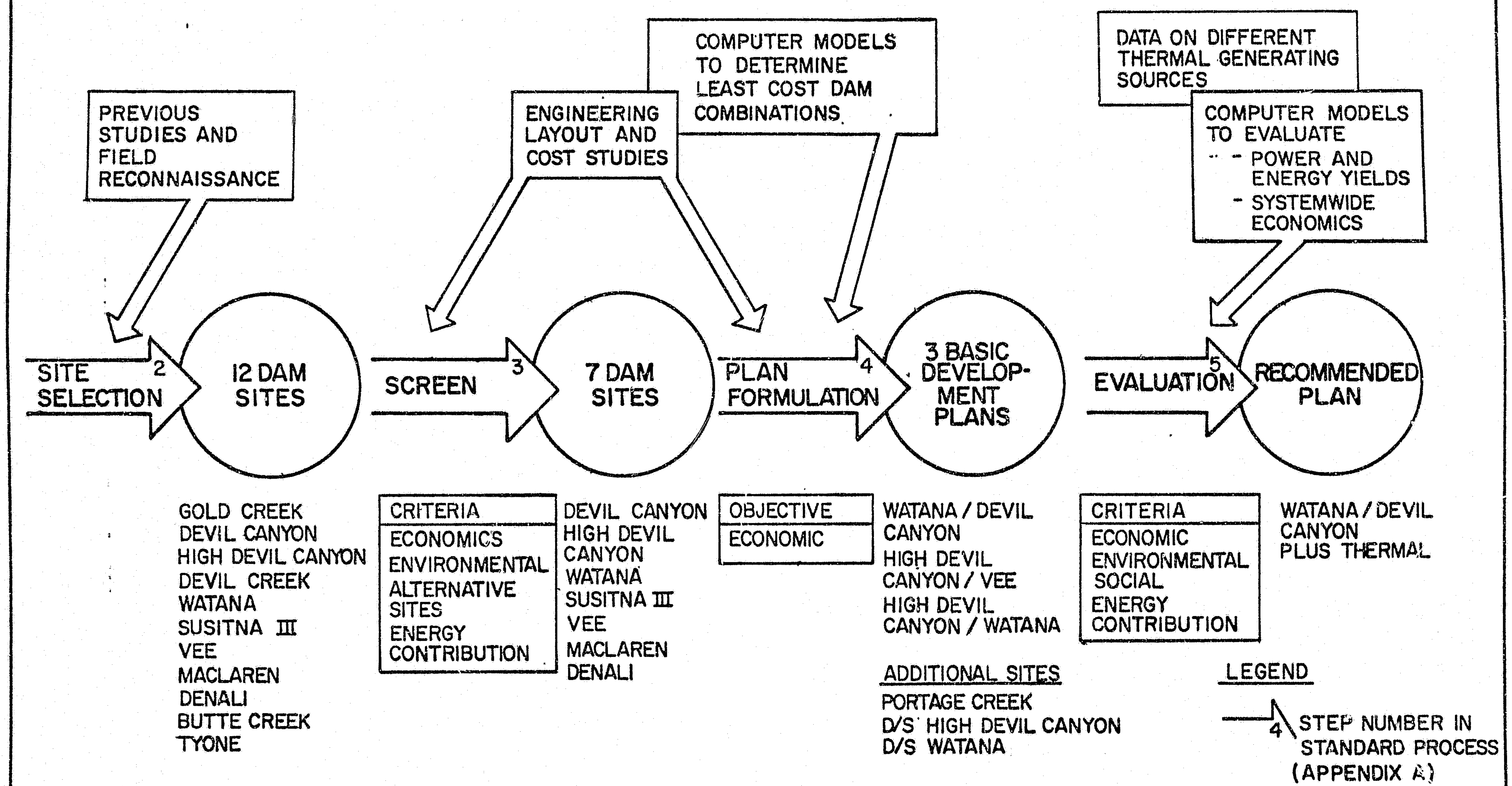
LOCATION MAP

FIGURE B.I



DAMSITES PROPOSED BY OTHERS

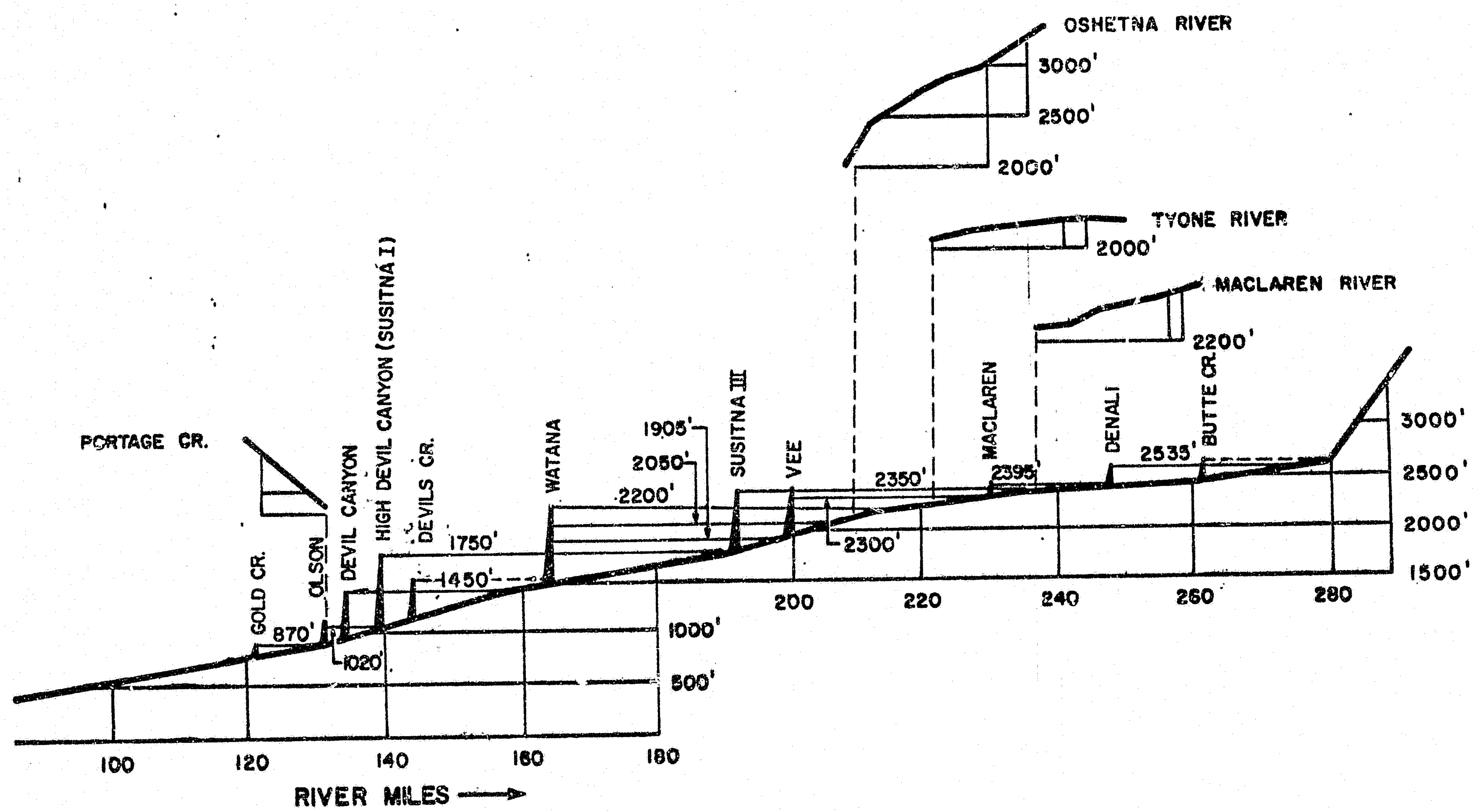
FIGURE B.2



SUSITNA BASIN PLAN FORMULATION AND SELECTION PROCESS

FIGURE B.3

00163



PROFILE THROUGH ALTERNATIVE SITES

FIGURE B.4

ACRES

	GOLD CREEK	OLSON	DEVIL CANYON	HIGH DEVIL CANYON	DEVIL CREEK	WATANA	SUSITNA III	VEE	MACLAREN	DENALI	BUTTE CREEK	TYONE
GOLD CREEK												
OLSON			890 (30)									
DEVIL CANYON				1030 (160)	1070 (200)							
HIGH DEVIL CANYON						1465 (445)						
DEVIL CREEK						1465 (405)						
WATANA							1810 (355)	1925 (470)				
SUSITNA III								1925 (125)	2320 (520)			
VEE									2320 (405)			
MACLAREN												
DENALI												
BUTTE CREEK												
TYONE												

LEGEND

COMPATIBLE ALTERNATIVES

MUTUALLY EXCLUSIVE ALTERNATIVES

1465 (405) — DAM IN COLUMN IS MUTUALLY EXCLUSIVE IF FULL SUPPLY LEVEL OF DAM IN ROW EXCEEDS THIS VALUE - FT.

VALUE IN BRACKET REFERS TO APPROXIMATE DAM HEIGHT.

MUTUALLY EXCLUSIVE DEVELOPMENT ALTERNATIVES

ACRES

FIGURE B.5

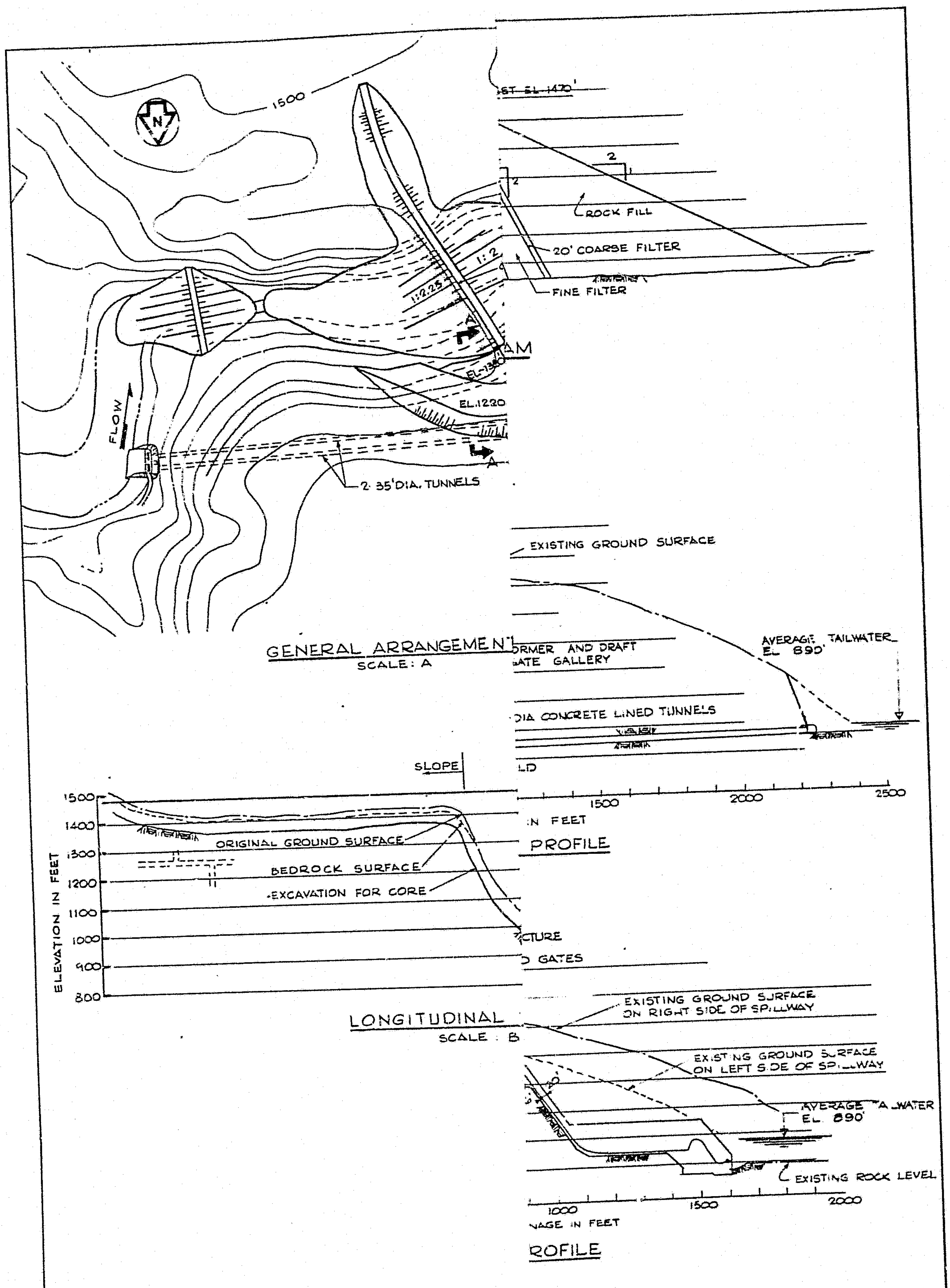


FIGURE B.6

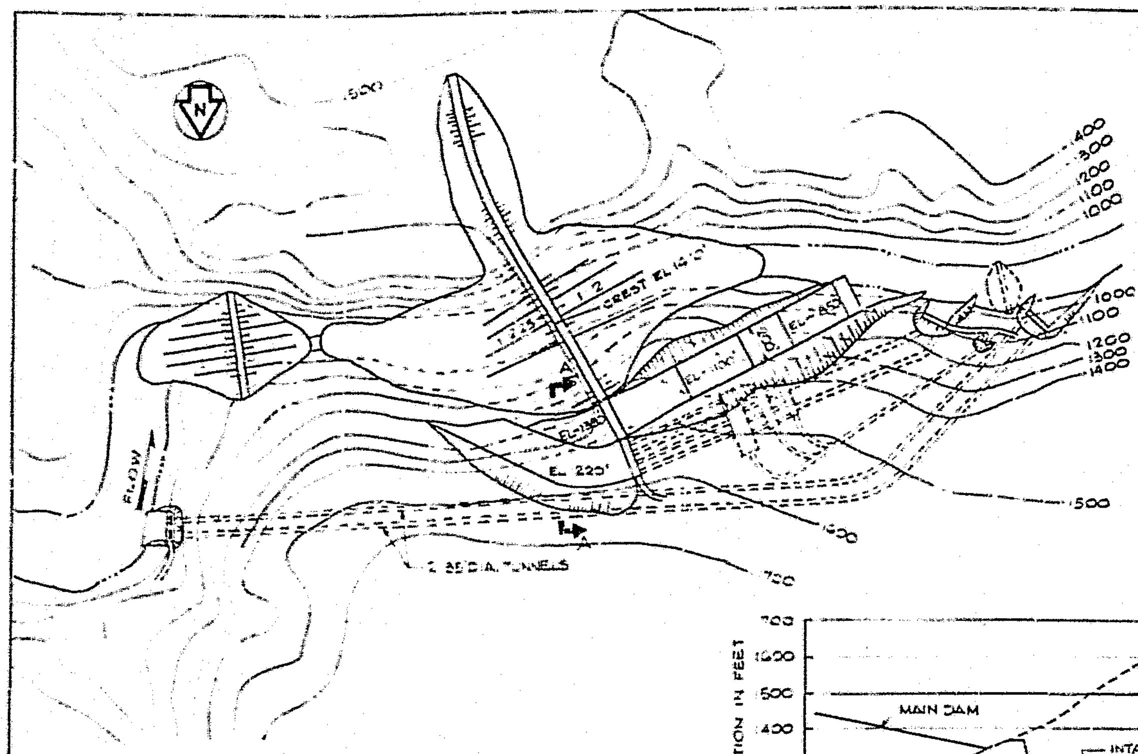
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

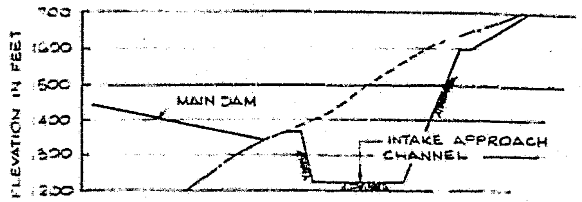
DEVIL CANYON
HYDRO DEVELOPMENT
FILL DAM

DATE DEC 1981 | SCALE AS SHOWN | DRAWING NO SK-5700-C6-102

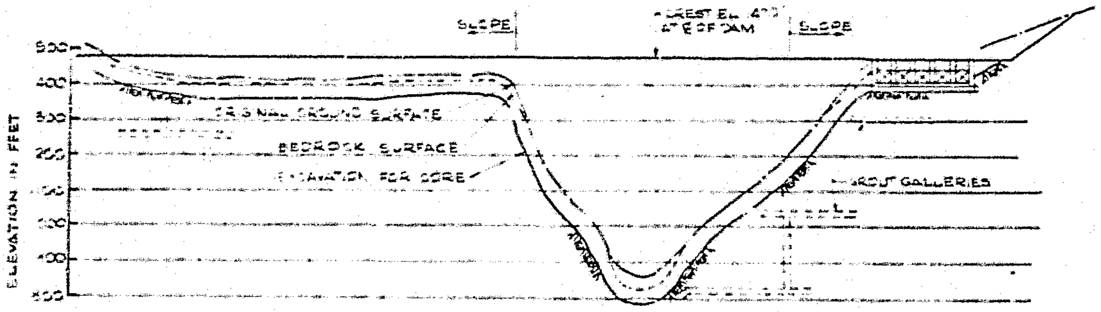
ACRES AMERICAN INCORPORATED



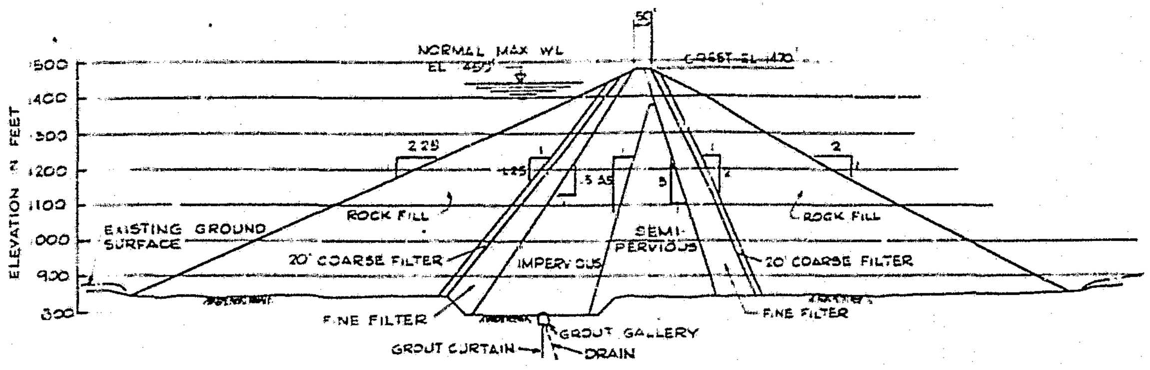
GENERAL ARRANGEMENT
SCALE A



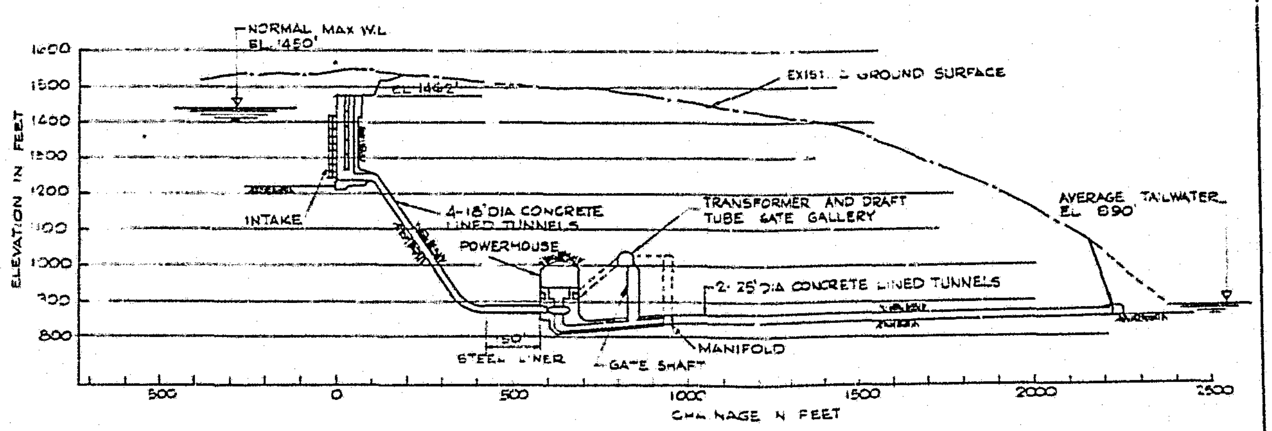
SECTION A-A
SCALE B



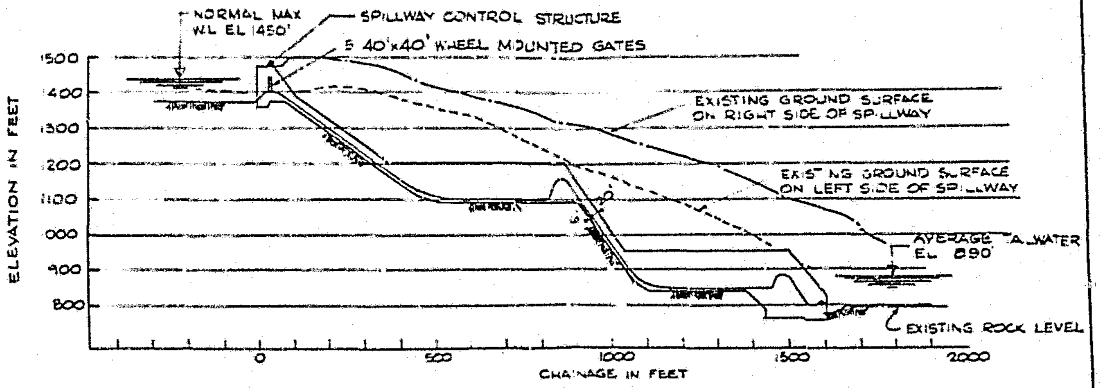
LONGITUDINAL SECTION THRU ℄ OF DAM
SCALE B



SECTION THRU DAM
SCALE: B



POWER FACILITIES PROFILE
SCALE: B



SPILLWAY PROFILE
SCALE: B

SCALE A 0 400 800 FEET

SCALE B 0 200 400 FEET

FIGURE B.6

ALASKA POWER AUTHORITY

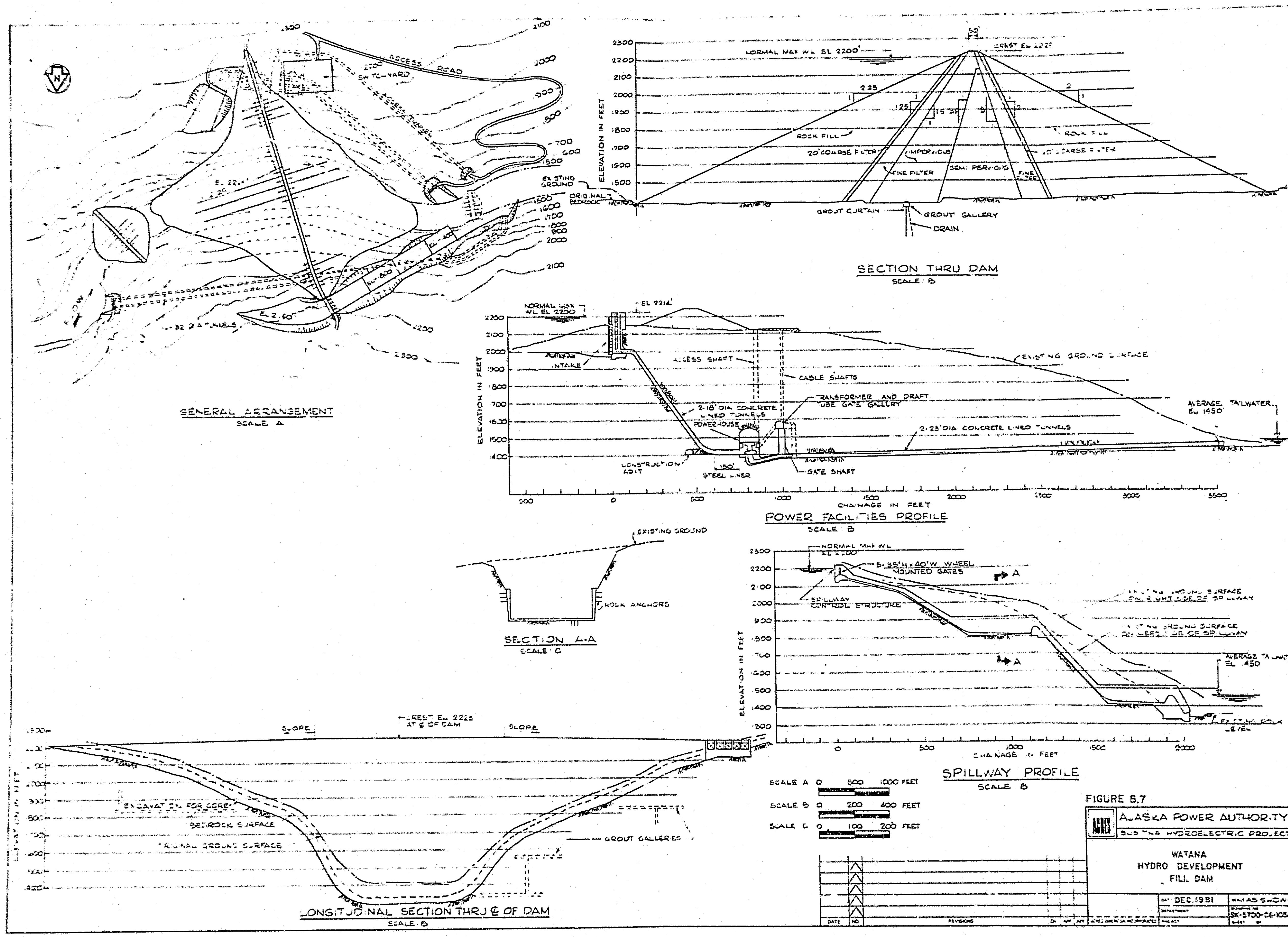
SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
HYDRO DEVELOPMENT
FILL DAM

DATE	NO	REVISIONS	CH	APP	APP

ACRES AMERICAN INCORPORATED

DATE DEC 1981 | SCALE AS SHOWN | DRAWING NO SK-5700-C6-102


GENERAL ARRANGEMENT
SCALE A
ACCESS ROAD
SWITCHYARD
ACCESS TUNNEL
FLOW
2-32' DIA TUNNELS
EXISTING GROUND
ORIGINAL BEDROCK
SECTION THRU DAM
SCALE: B
NORMAL MAX WL EL 2200'
CREST EL 2225
ELEVATION IN FEET
ROCK FILL
20' COARSE FILTER
IMPERVIOUS
FINE FILTER
SEMI PERVIOUS
GROUT CURTAIN
GROUT GALLERY
DRAIN
NORMAL MAX WL EL 2200
EL 2214'
INTAKE
ACCESS SHAFT
CABLE SHAFTS
EXISTING GROUND SURFACE
2-18' DIA CONCRETE LINED TUNNELS
TRANSFORMER AND DRAFT TUBE GATE GALLERY
POWERHOUSE
2-23' DIA CONCRETE LINED TUNNELS
AVERAGE TAILWATER EL 1450'
CONSTRUCTION ADIT
150'
STEEL LINER
GATE SHAFT
CHAINAGE IN FEET
POWER FACILITIES PROFILE
SCALE B
EXISTING GROUND
ROCK ANCHORS
SECTION A-A
SCALE C
NORMAL MAX WL EL 2200
5-35'H x 40'W WHEEL MOUNTED GATES
SPILLWAY CONTROL STRUCTURE
AVERAGE TAILWATER EL 1450
SPILLWAY PROFILE
SCALE B
CREST EL 2225 AT ℄ OF DAM
SLOPE
EXCAVATION FOR CORE
BEDROCK SURFACE
ORIGINAL GROUND SURFACE
GROUT GALLERIES
LONGITUDINAL SECTION THRU ℄ OF DAM
SCALE B
SCALE A 0 500 1000 FEET
SCALE B 0 200 400 FEET
SCALE C 0 100 200 FEET
FIGURE B.7
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
HYDRO DEVELOPMENT
FILL DAM
DEC. 1981
AS SHOWN
SK-5700-CE-105

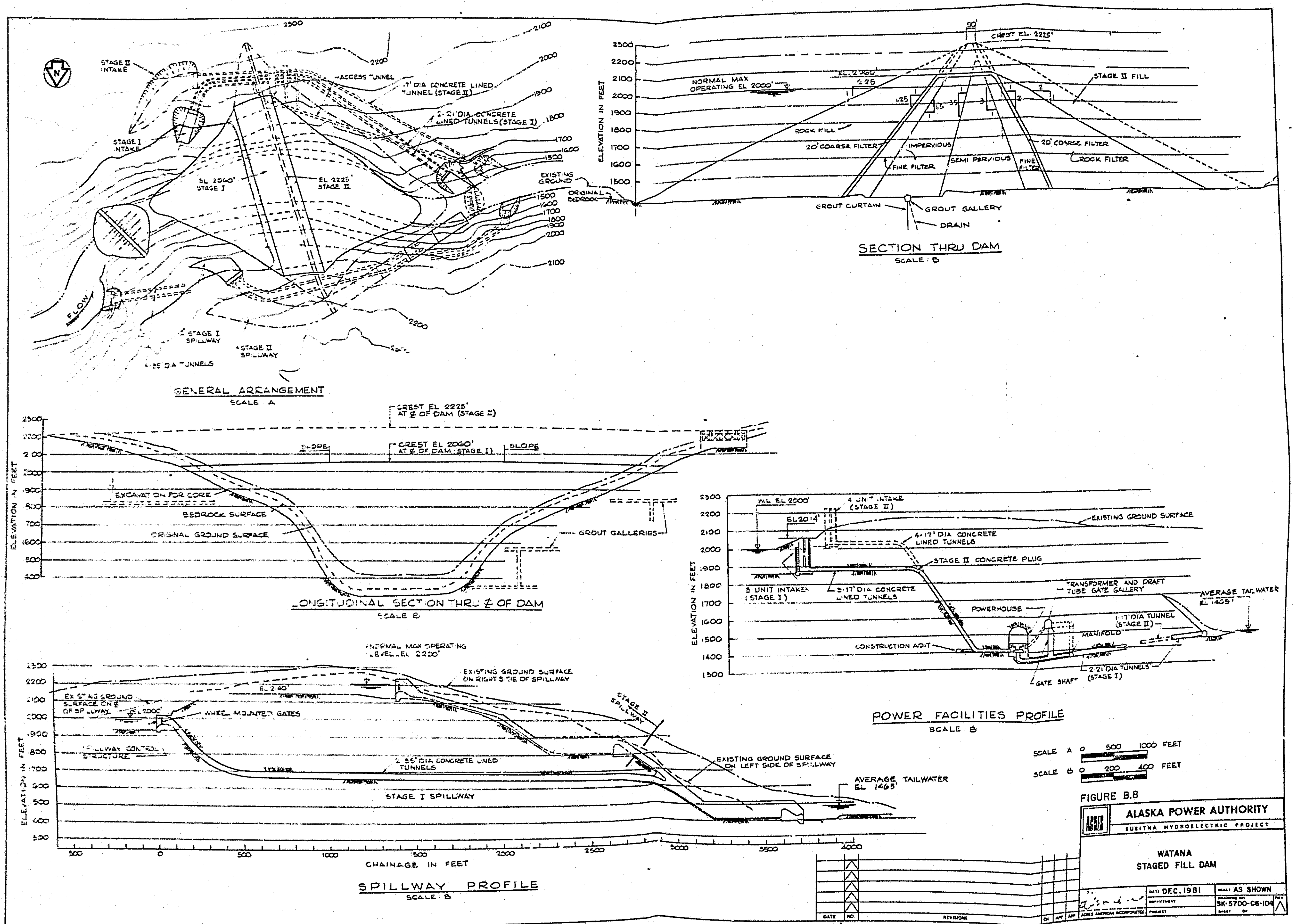


FIGURE B.8

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

WATANA
STAGED FILL DAM

DATE DEC. 1981
SCALE AS SHOWN
ACRES AMERICAN INCORPORATED
DRAWING NO. SK-5700-C6-104

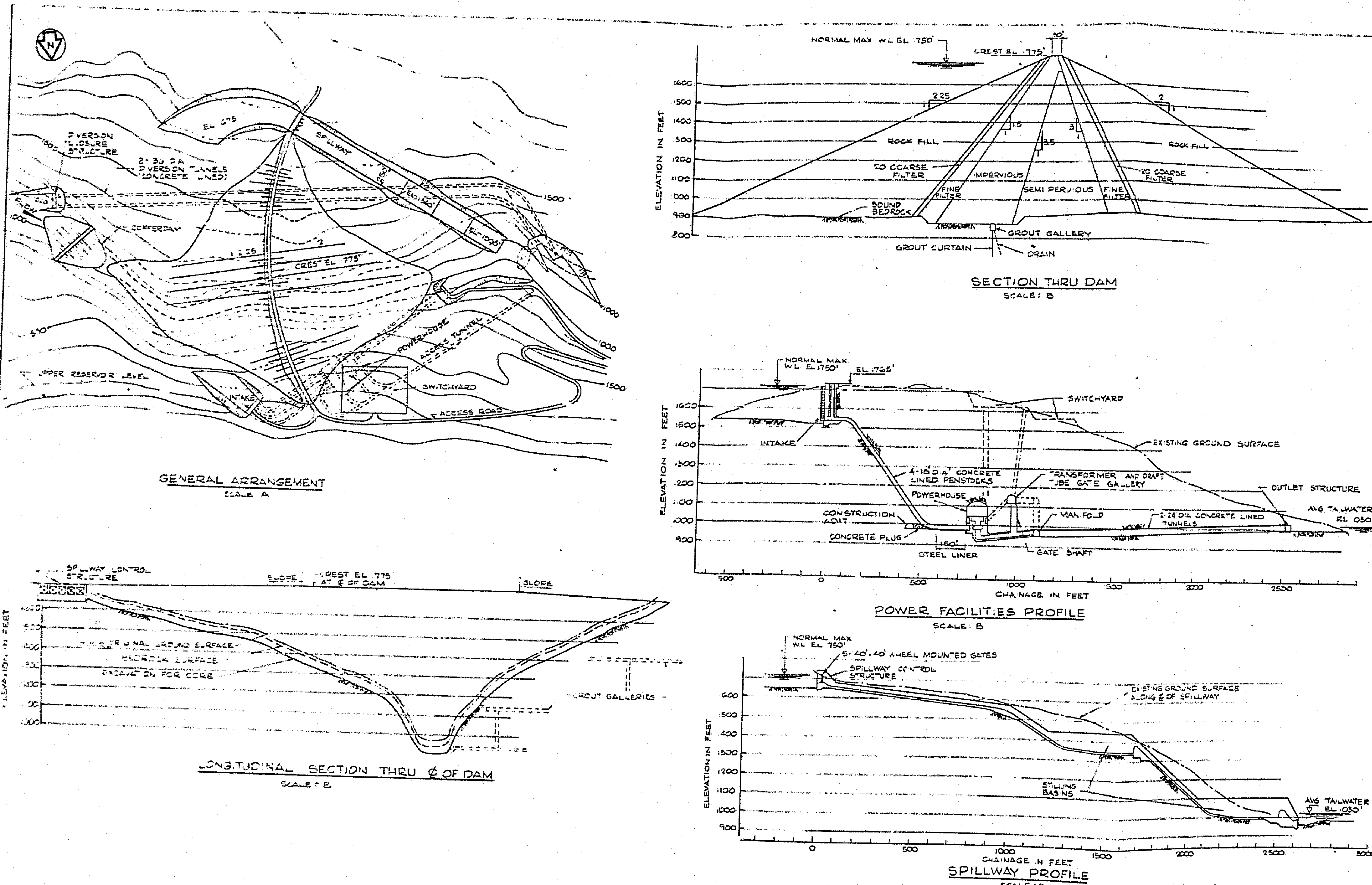


FIGURE B.9

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

HIGH DEVIL CANYON
HYDRO DEVELOPMENT

DATE DEC. 1981 | SCALE AS SHOWN | SI-5700-C6-101

DATE | NO | REVISIONS

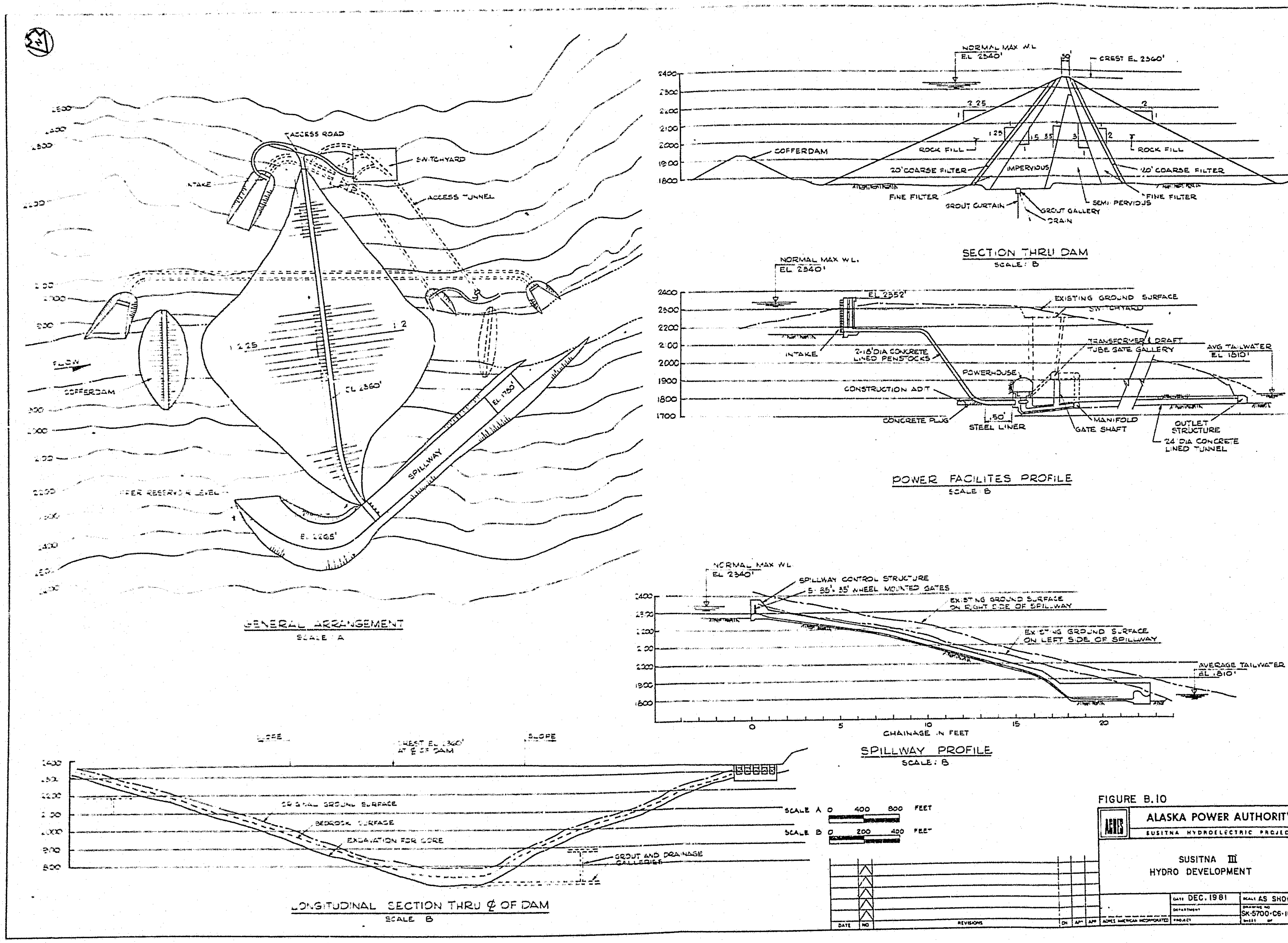


FIGURE B.10

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SUSITNA III HYDRO DEVELOPMENT

DATE DEC. 1981 SCALE AS SHOWN

SK-5700-C6-109

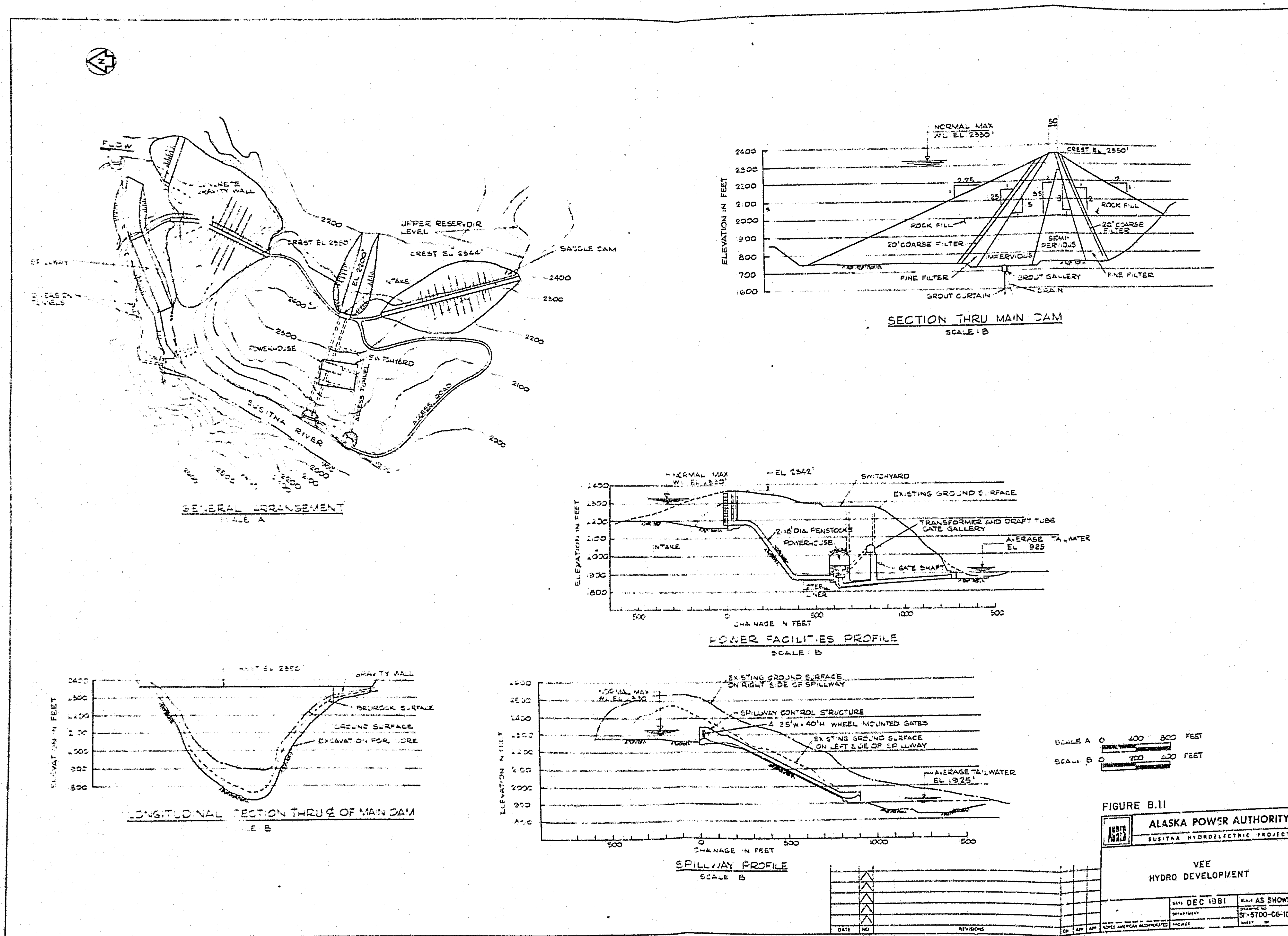
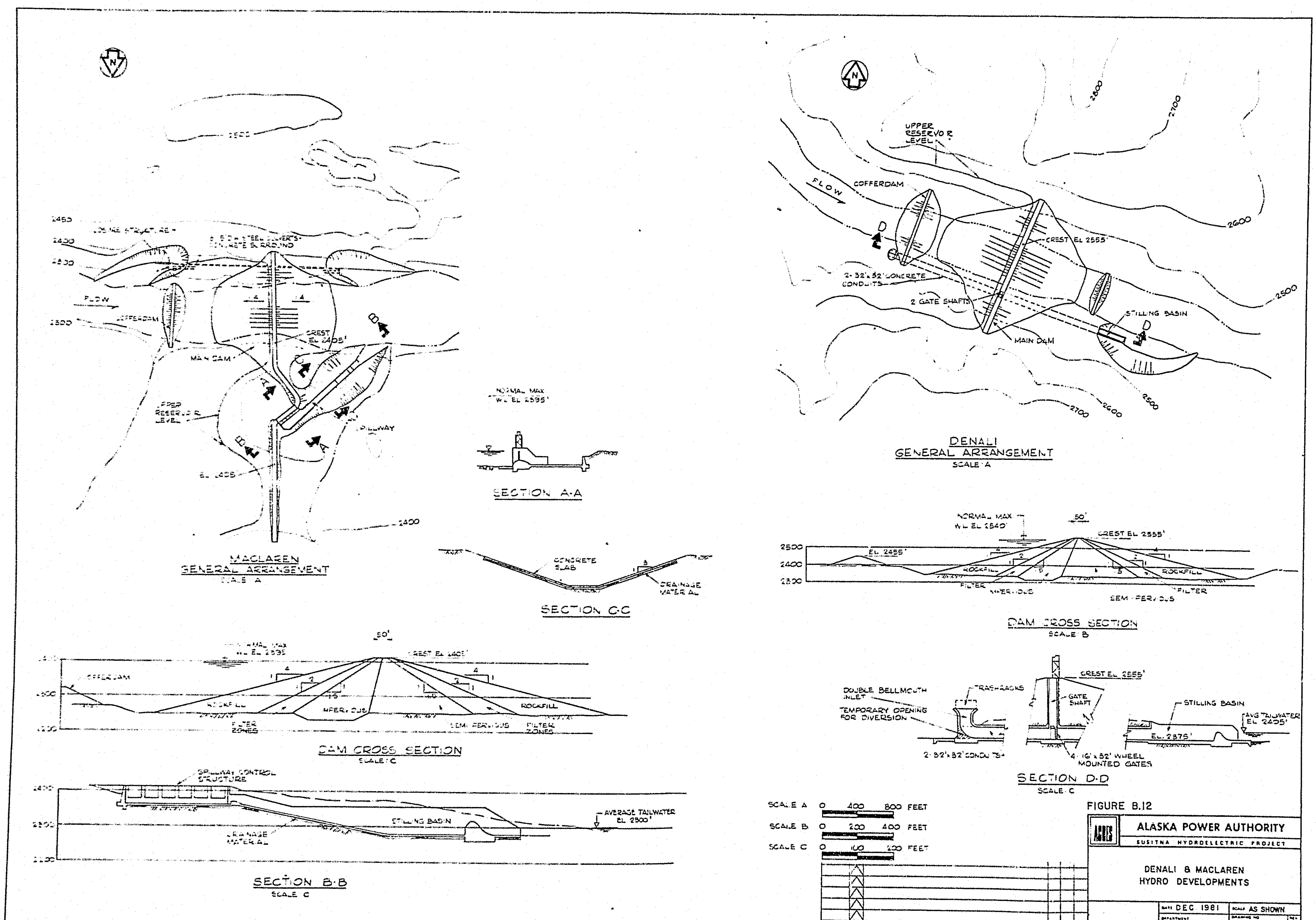


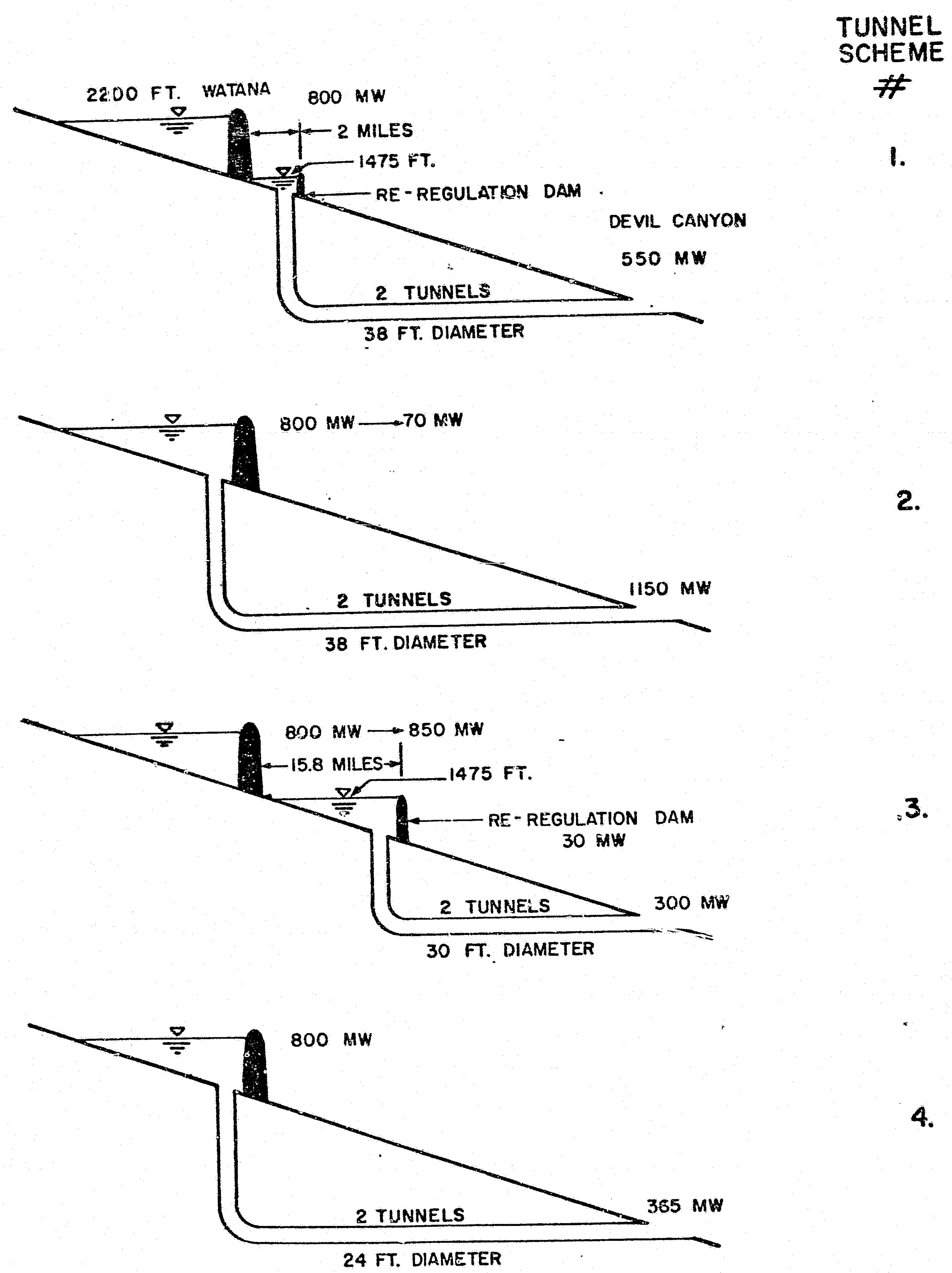
FIGURE B.11

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

VEE
HYDRO DEVELOPMENT

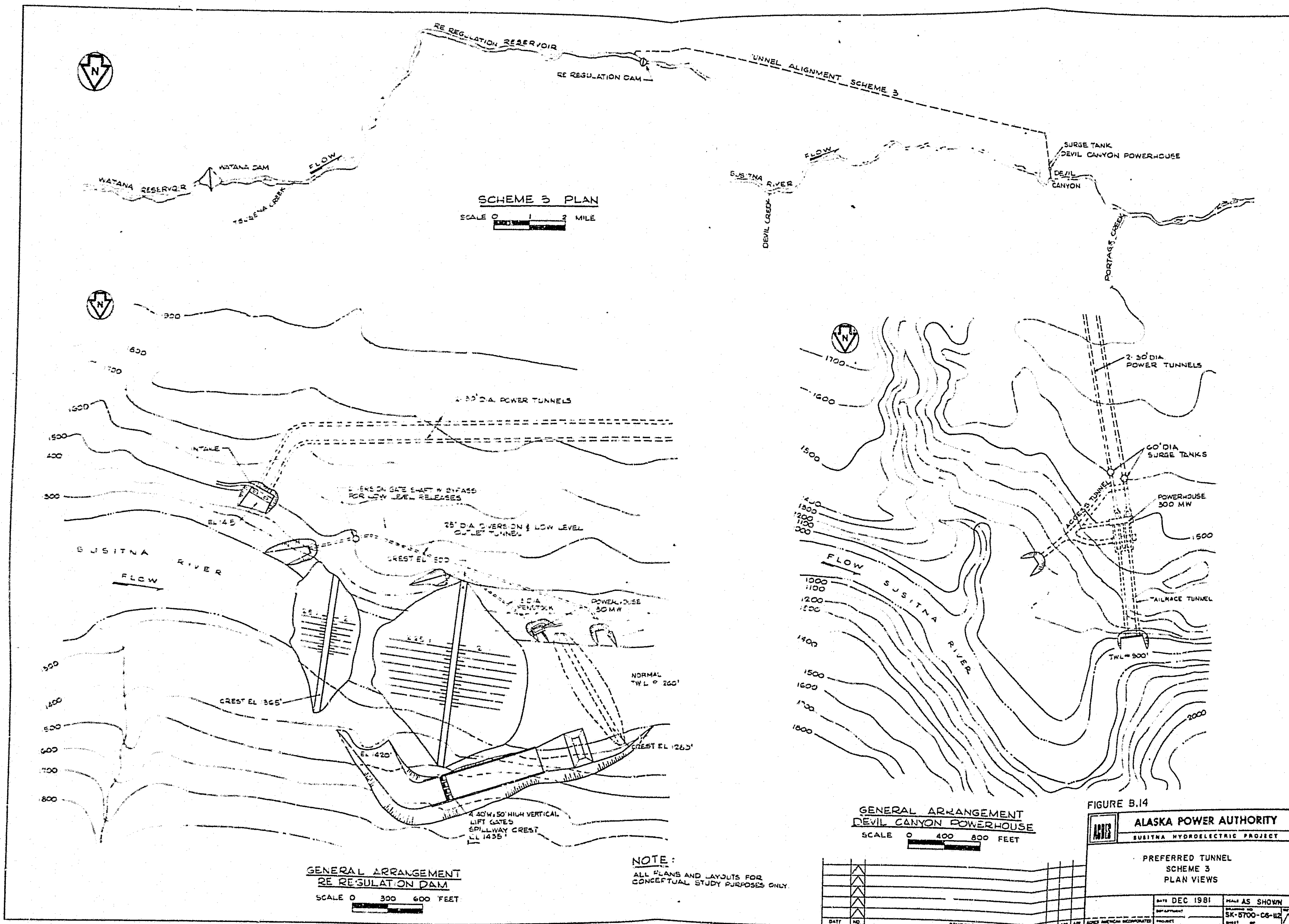
DATE DEC 1981 | SCALE AS SHOWN | DRAWING NO. SP-5700-C6-107

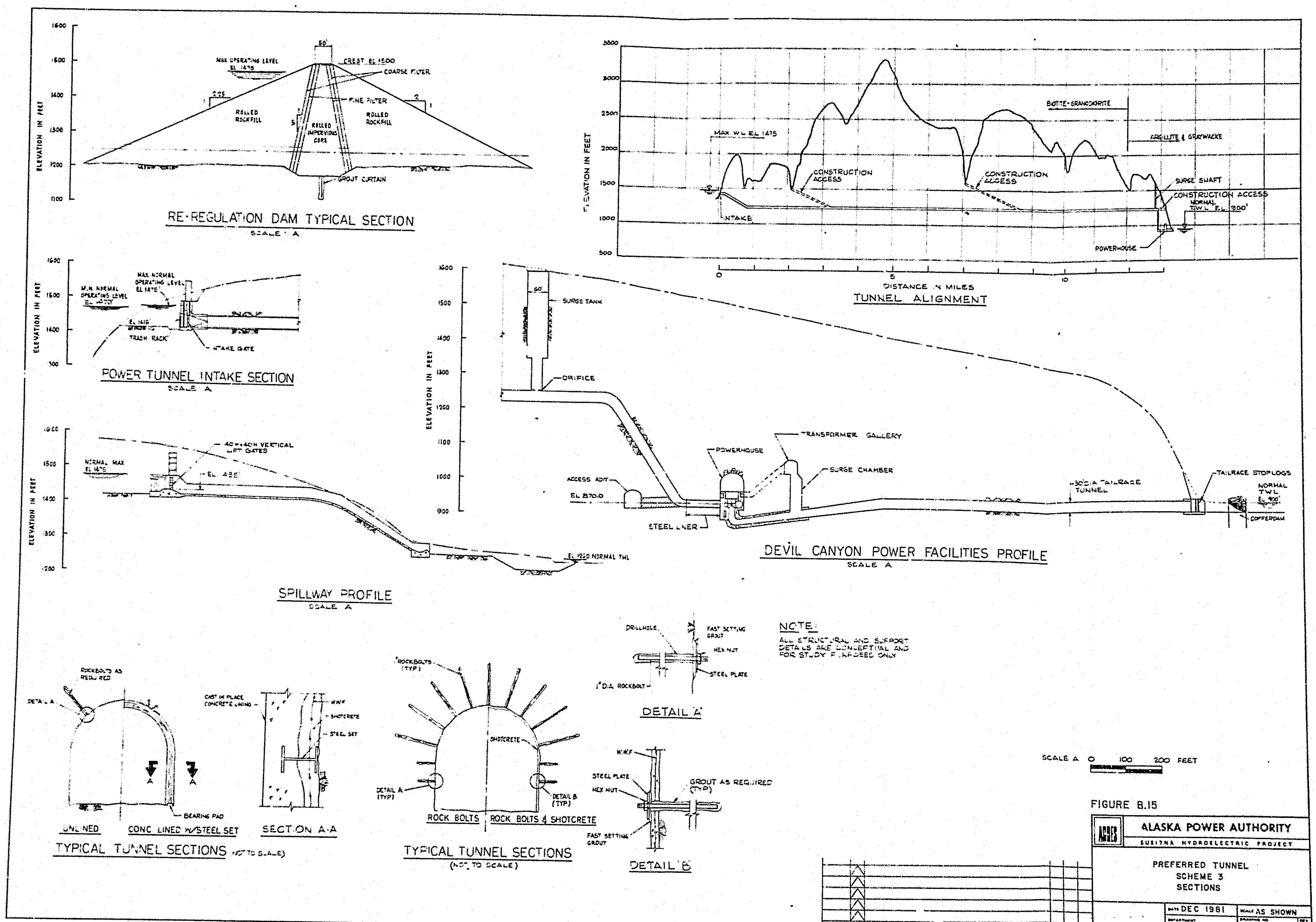

MACLAREN
GENERAL ARRANGEMENT
SCALE A
FLOW
COFFERDAM
MAIN DAM
CREST EL 2405'
UPPER RESERVOIR LEVEL
SPILLWAY
EL 2405
SECTION A-A
SECTION C-C
CONCRETE SLAB
DRAINAGE MATERIAL
DAM CROSS SECTION
SCALE C
CREST EL 2405'
ROCKFILL
IMPERVIOUS
SEMI PERVIOUS
FILTER ZONES
SPILLWAY CONTROL STRUCTURE
STILLING BASIN
AVERAGE TAILWATER EL 2300'
DRAINAGE MATERIAL
SECTION B-B
SCALE C
UPPER RESERVOIR LEVEL
FLOW
COFFERDAM
CREST EL 2555'
2-32'x32' CONCRETE CONDUITS
2 GATE SHAFTS
STILLING BASIN
MAIN DAM
DENALI
GENERAL ARRANGEMENT
SCALE A
NORMAL MAX W.L. EL 2540'
50'
CREST EL 2555'
EL 2455'
ROCKFILL
FILTER
IMPERVIOUS
SEMI-PERVIOUS
DAM CROSS SECTION
SCALE B
CREST EL 2555'
DOUBLE BELLMOUTH INLET
TRASHRACKS
TEMPORARY OPENING FOR DIVERSION
GATE SHAFT
STILLING BASIN
AVG TAILWATER EL 2405'
EL 2375'
2-32'x32' CONDUITS
4-16'x32' WHEEL MOUNTED GATES
SECTION D-D
SCALE C
SCALE A 0 400 800 FEET
SCALE B 0 200 400 FEET
SCALE C 0 100 200 FEET
FIGURE B.12
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
DENALI & MACLAREN
HYDRO DEVELOPMENTS
DEC 1981
AS SHOWN
SK-5700-C6-106

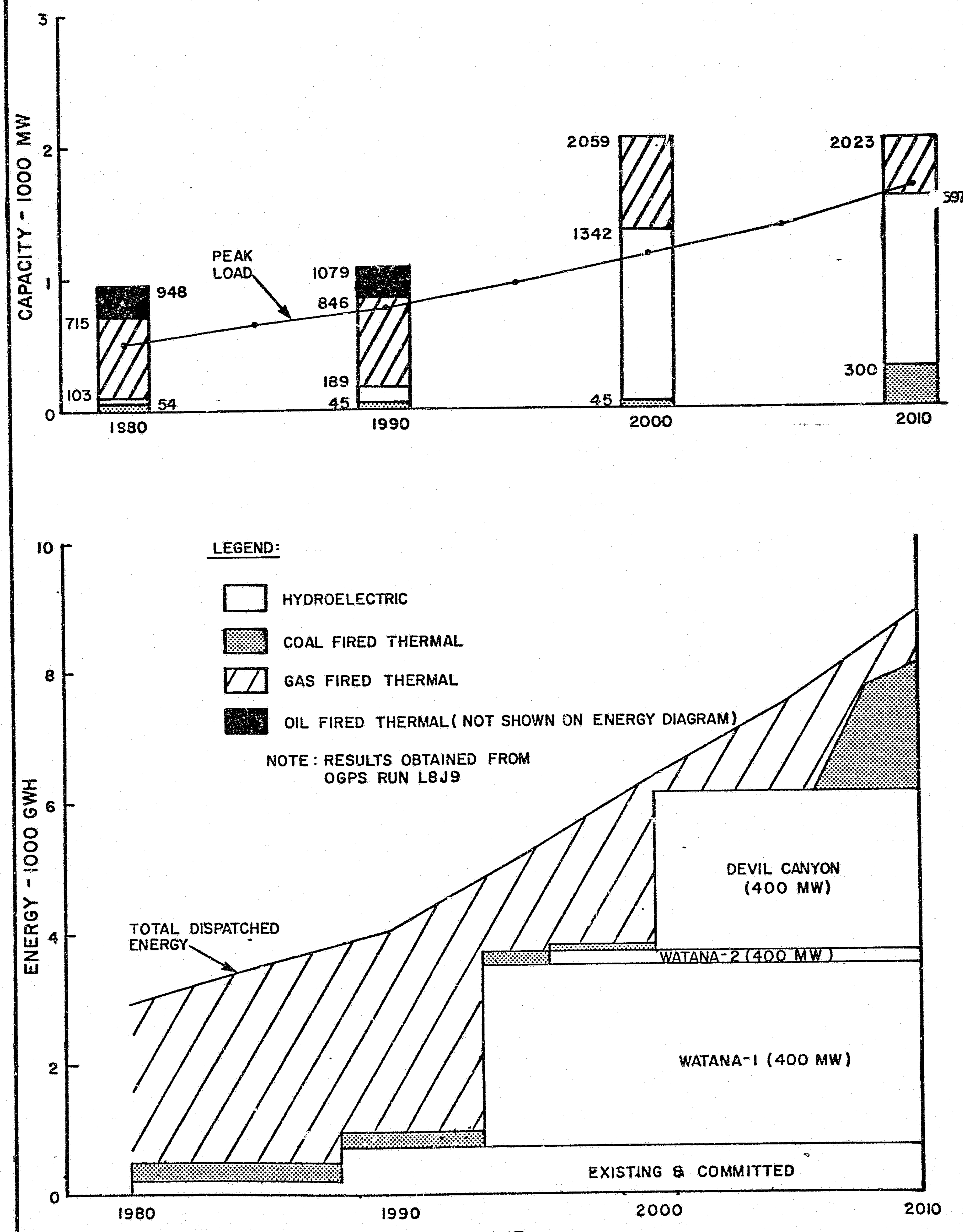


SCHEMATIC REPRESENTATION
OF CONCEPTUAL TUNNEL SCHEMES

FIGURE B.13


RE REGULATION RESERVOIR
RE REGULATION DAM
TUNNEL ALIGNMENT SCHEME 3
SURGE TANK
DEVIL CANYON POWERHOUSE
DEVIL CANYON
WATANA DAM
WATANA RESERVOIR
TSUSENA CREEK
FLOW
SUSITNA RIVER
DEVIL CREEK
PORTAGE CREEK
SCHEME 3 PLAN
SCALE 0 1 2 MILE
2-30' DIA POWER TUNNELS
INTAKE
DIVERSION GATE SHAFT W BYPASS FOR LOW LEVEL RELEASES
25' DIA DIVERSION & LOW LEVEL OUTLET TUNNEL
CREST EL 1500
SUSITNA RIVER
FLOW
POWERHOUSE 30 MW
NORMAL TWL ± 1260'
CREST EL 1365'
EL 1420'
CREST EL 1263'
4-40'W x 50' HIGH VERTICAL LIFT GATES
SPILLWAY CREST EL 1435'
GENERAL ARRANGEMENT RE REGULATION DAM
SCALE 0 300 600 FEET
NOTE:
ALL PLANS AND LAYOUTS FOR CONCEPTUAL STUDY PURPOSES ONLY.
2-30' DIA POWER TUNNELS
60' DIA SURGE TANKS
ACCESS TUNNEL
POWERHOUSE 300 MW
TAILRACE TUNNEL
TWL = 900'
FLOW
SUSITNA RIVER
GENERAL ARRANGEMENT DEVIL CANYON POWERHOUSE
SCALE 0 400 800 FEET
FIGURE B.14
ACRES
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
PREFERRED TUNNEL
SCHEME 3
PLAN VIEWS
DATE DEC 1981
SCALE AS SHOWN
SK-5700-C6-112
ACRES AMERICAN INCORPORATED
DATE
NO.
REVISIONS

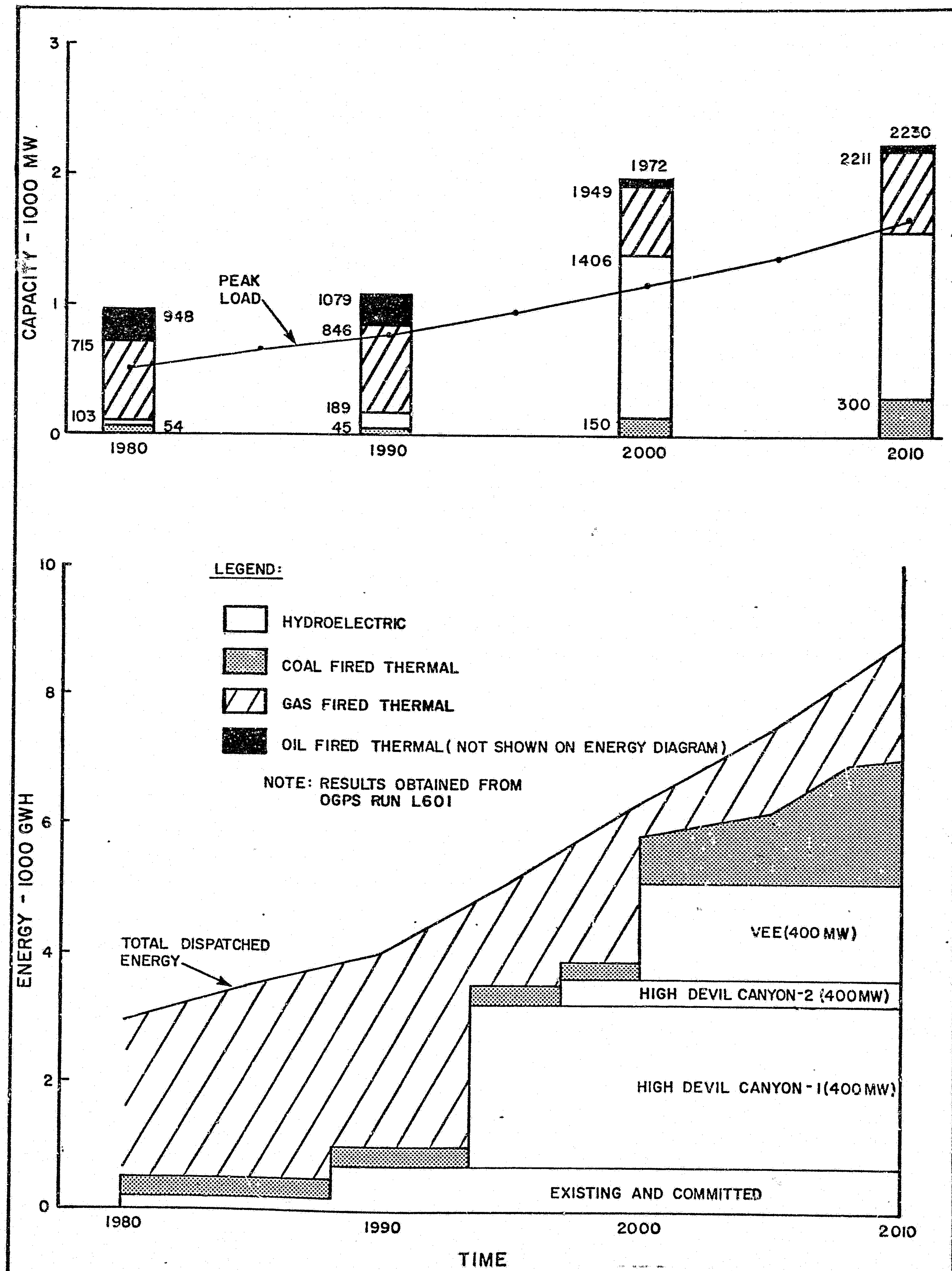

RE-REGULATION DAM TYPICAL SECTION
SCALE A
MAX OPERATING LEVEL EL 1475
CREST EL 1500
COARSE FILTER
FINE FILTER
ROLLED ROCKFILL
ROLLED IMPERVIOUS CORE
GROUT CURTAIN
ELEVATION IN FEET
TUNNEL ALIGNMENT
DISTANCE IN MILES
MAX W.L. EL 1475
CONSTRUCTION ACCESS
INTAKE
SURGE SHAFT
POWERHOUSE
BIOTITE-GRANODIORITE
ARGILLITE & GRAYWACKE
POWER TUNNEL INTAKE SECTION
SCALE A
TRASH RACK
INTAKE GATE
DEVIL CANYON POWER FACILITIES PROFILE
SCALE A
SURGE TANK
ORIFICE
TRANSFORMER GALLERY
SURGE CHAMBER
ACCESS ADIT
STEEL LINER
TAILRACE STOPLOGS
COFFERDAM
SPILLWAY PROFILE
SCALE A
40'W x 40'H VERTICAL LIFT GATES
EL 1920 NORMAL TWL
NOTE:
ALL STRUCTURAL AND SUPPORT DETAILS ARE CONCEPTUAL AND FOR STUDY PURPOSES ONLY
DETAIL 'A'
DETAIL 'B'
ROCKBOLTS AS REQUIRED
UNLINED
CONC LINED W/STEEL SET
SECTION A-A
TYPICAL TUNNEL SECTIONS (NOT TO SCALE)
ROCK BOLTS
ROCK BOLTS & SHOTCRETE
TYPICAL TUNNEL SECTIONS (NOT TO SCALE)
SCALE A 0 100 200 FEET
FIGURE B.15
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
PREFERRED TUNNEL SCHEME 3 SECTIONS
DEC 1981
AS SHOWN
SK-5700-C6-113



GENERATION SCENARIO WITH SUSITNA PLAN E1.3 -MEDIUM LOAD FORECAST-

ACRES

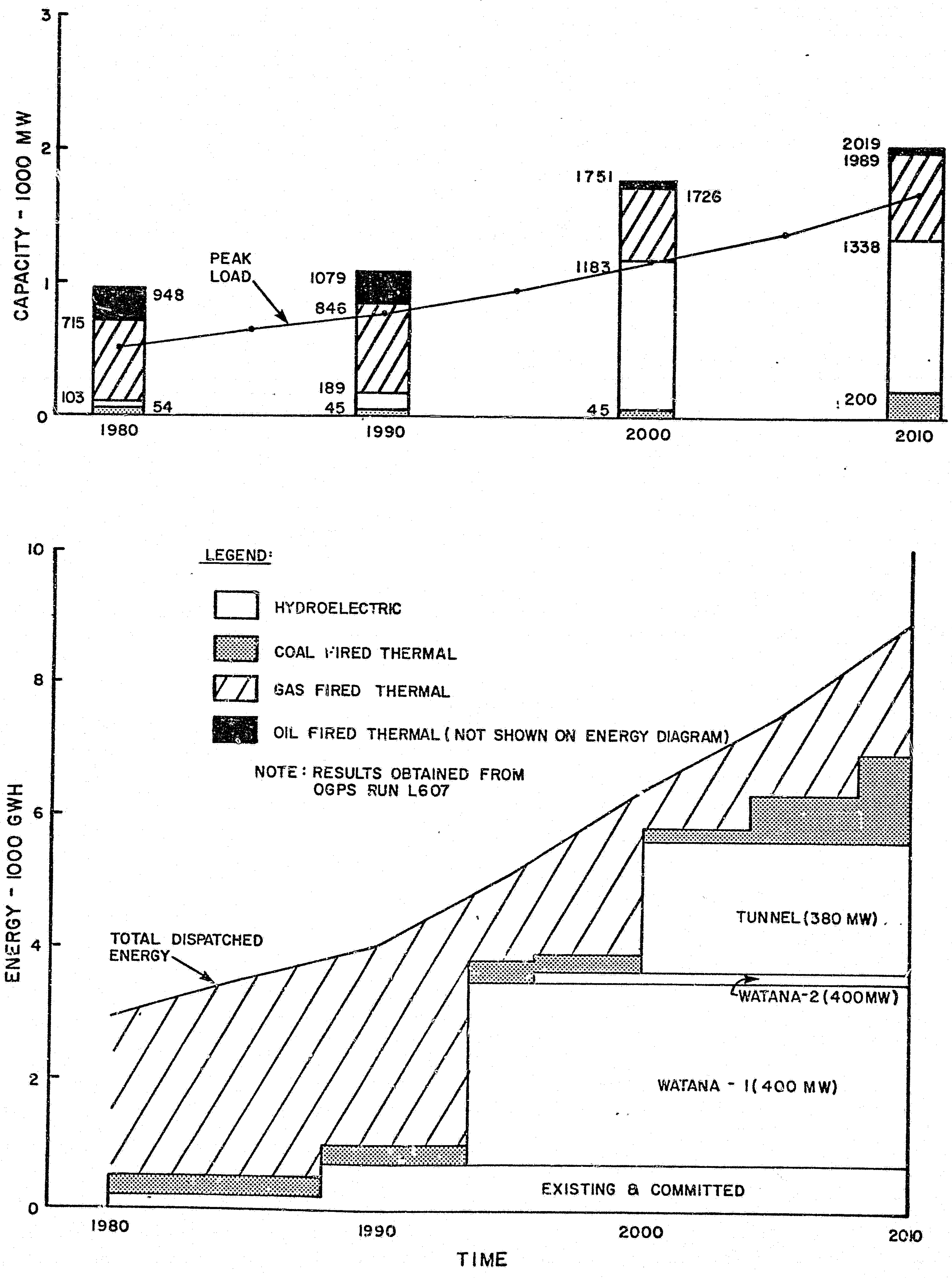
FIGURE B.16



GENERATION SCENARIO WITH SUSITNA PLAN E 2.3
- MEDIUM LOAD FORECAST -

FIGURE B.17

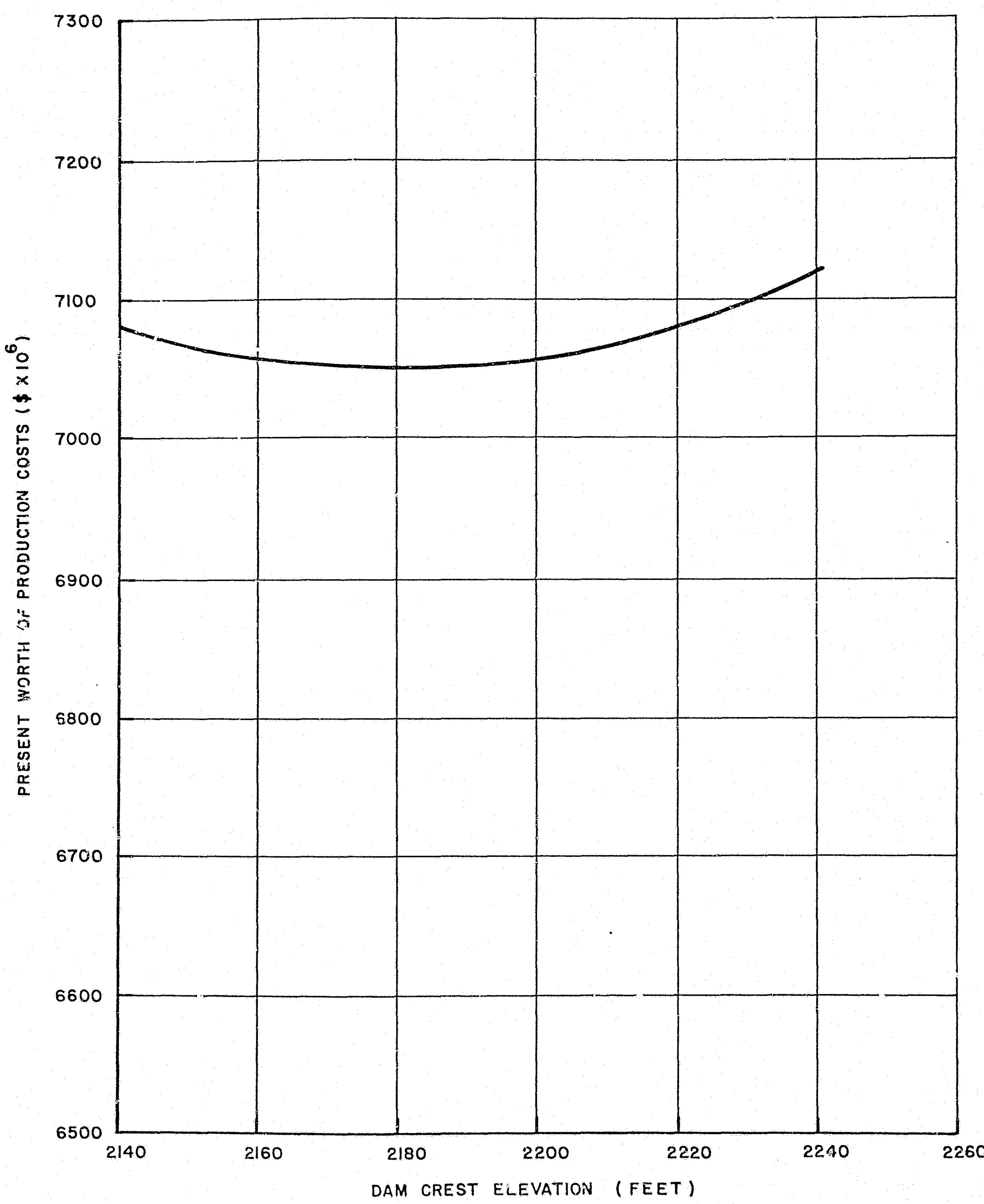
ACRES



GENERATION SCENARIO WITH SUSITNA PLAN E3.1
- MEDIUM LOAD FORECAST -

FIGURE B.18

ACRES



WATANA RESERVOIR

DAM CREST ELEVATION / PRESENT WORTH OF PRODUCTION COSTS

ACRES

FIGURE B.19

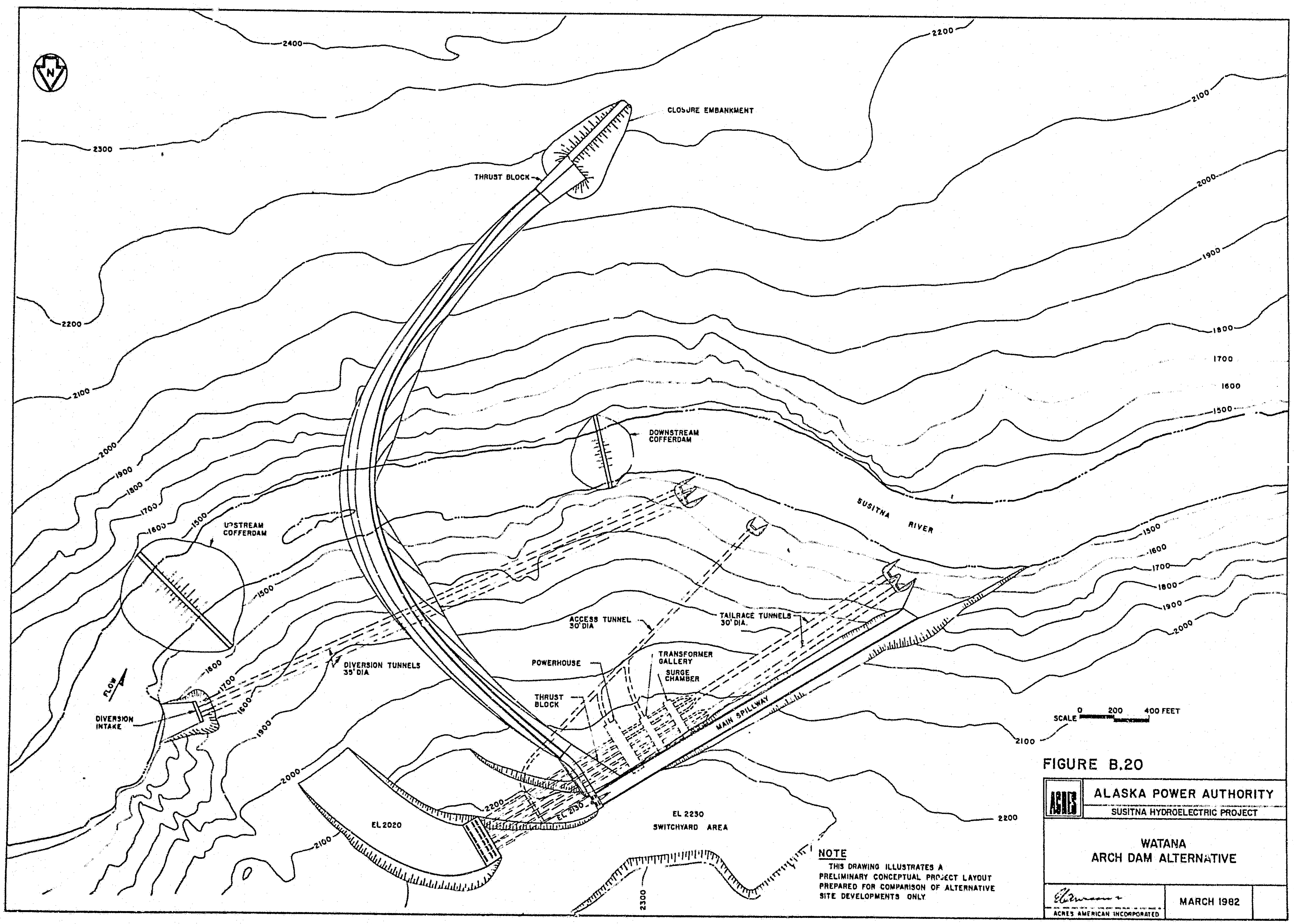

CLOSURE EMBANKMENT
THRUST BLOCK
DOWNSTREAM COFFERDAM
UPSTREAM COFFERDAM
SUSITNA RIVER
FLOW
DIVERSION INTAKE
DIVERSION TUNNELS 35' DIA
ACCESS TUNNEL 30' DIA
TAILRACE TUNNELS 30' DIA.
POWERHOUSE
TRANSFORMER GALLERY
SURGE CHAMBER
THRUST BLOCK
MAIN SPILLWAY
EL 2020
EL 2130
EL 2230
SWITCHYARD AREA
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
SCALE 0 200 400 FEET
NOTE
THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY
ACRES
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
ARCH DAM ALTERNATIVE
ACRES AMERICAN INCORPORATED
MARCH 1982

FIGURE B.20

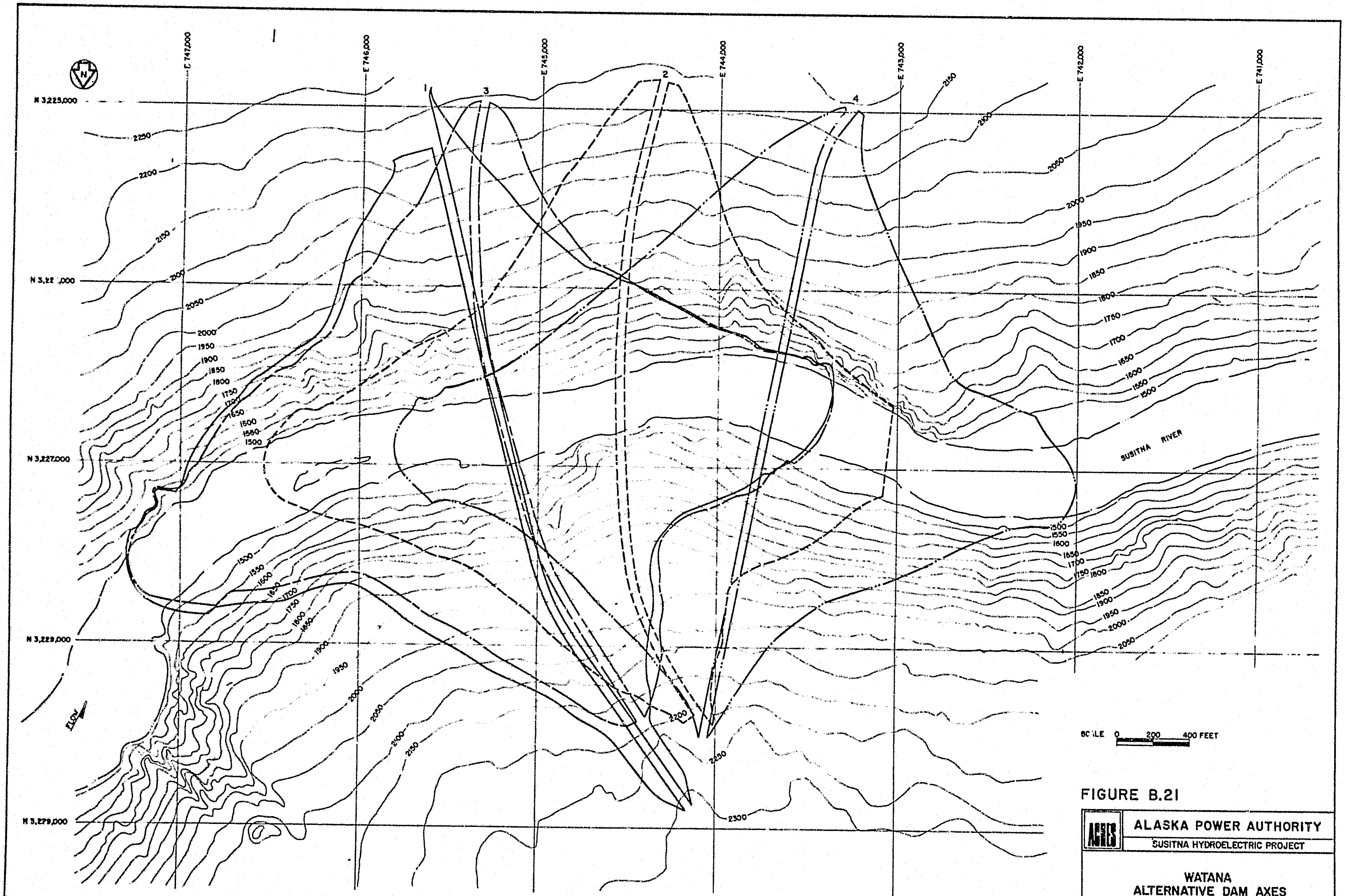


FIGURE B.21

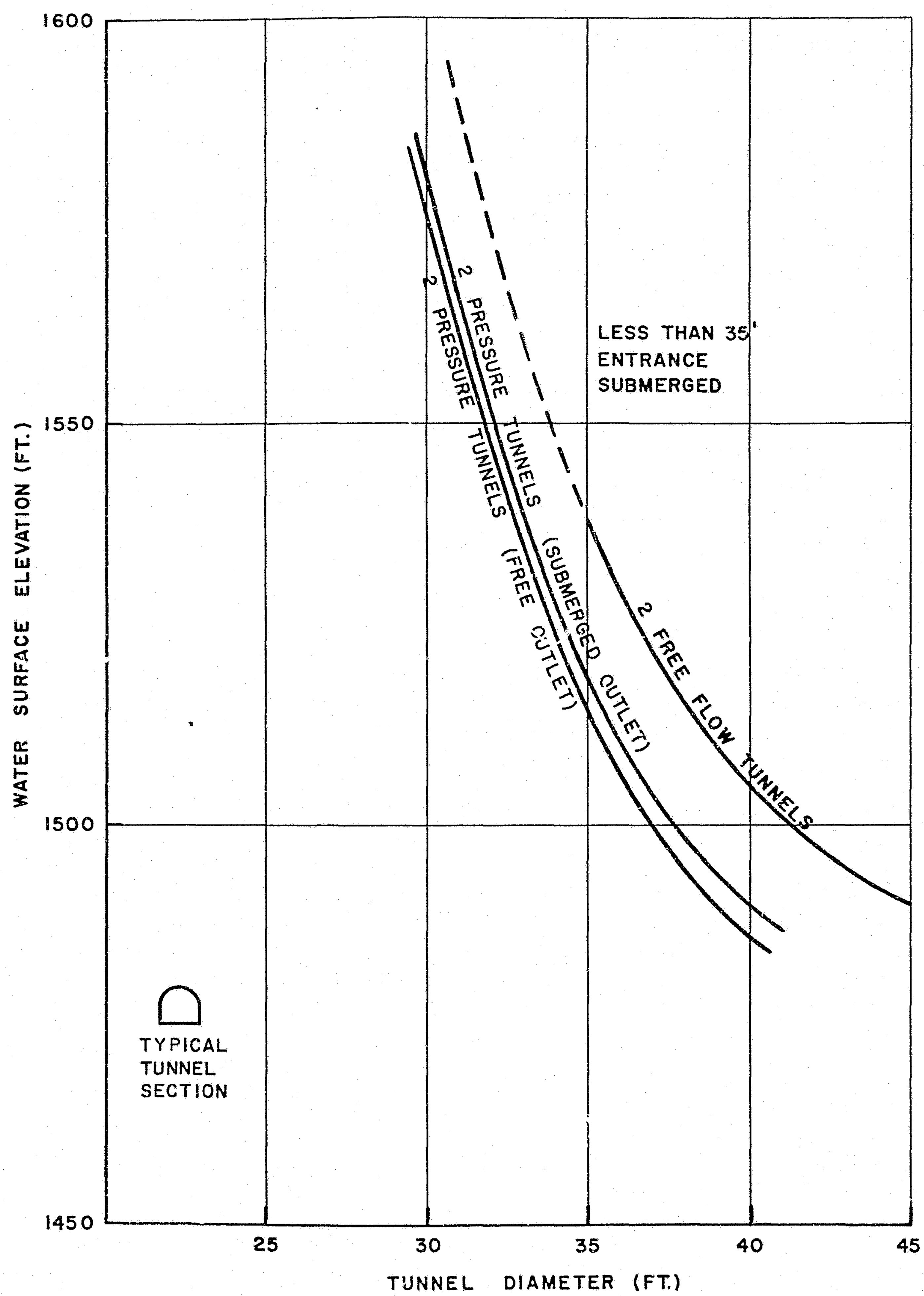
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA
ALTERNATIVE DAM AXES

ACRES AMERICAN INCORPORATED

MARCH 1982

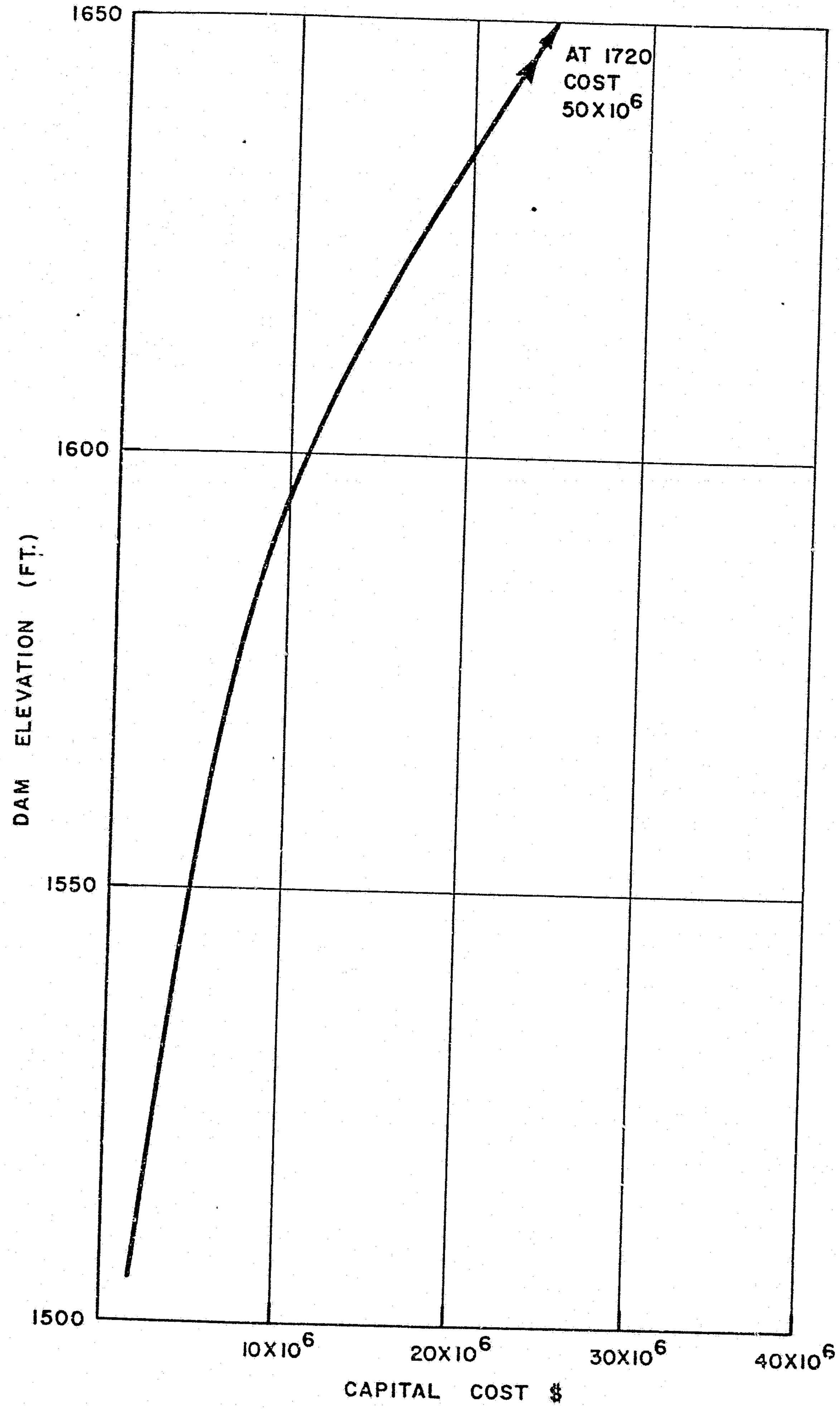


NOTE
FOR 80,000 CFS

WATANA DIVERSION
HEADWATER ELEVATION / TUNNEL DIAMETER

ACRES

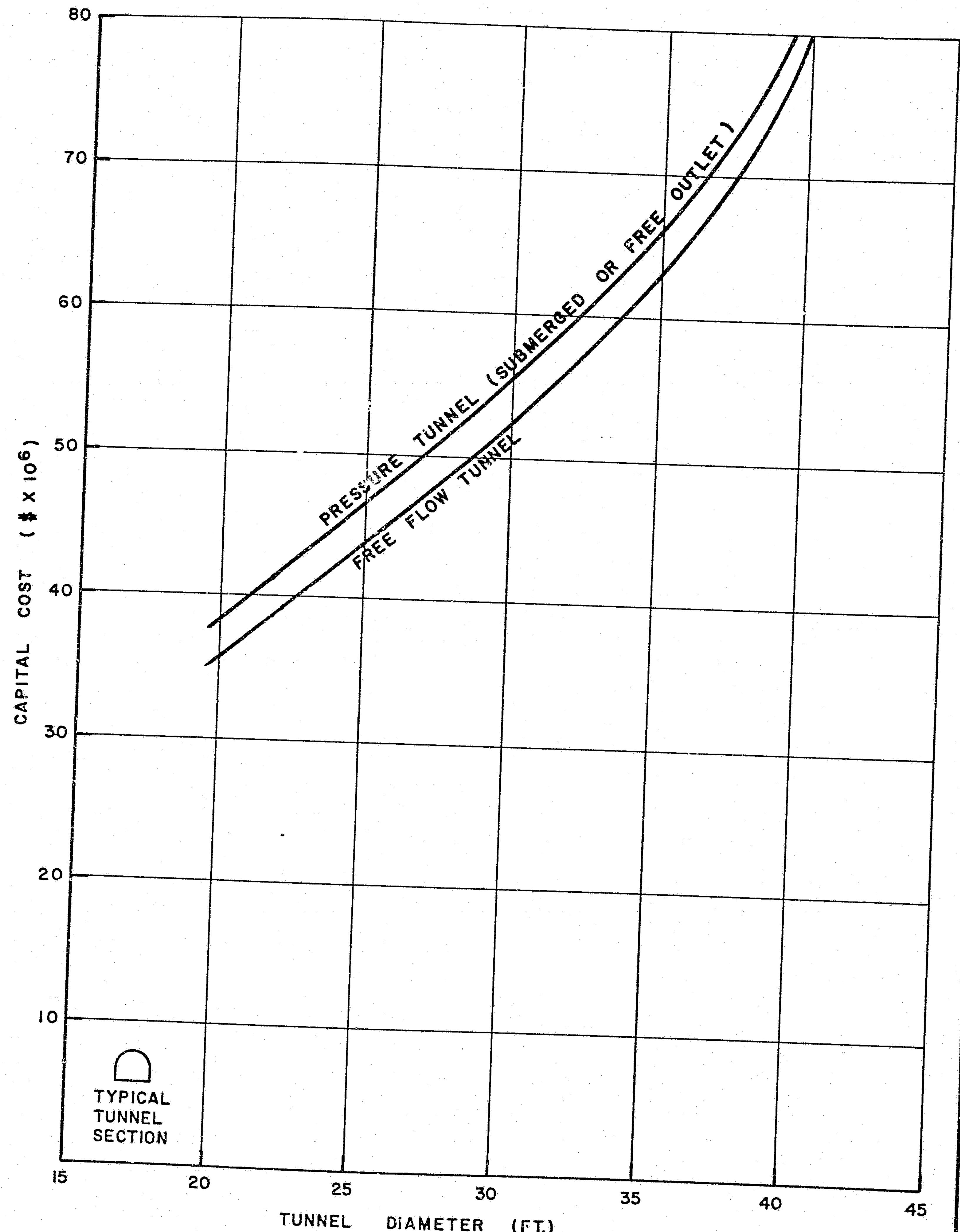
FIGURE B.22



WATANA DIVERSION
UPSTREAM COFFERDAM COSTS

ACRES

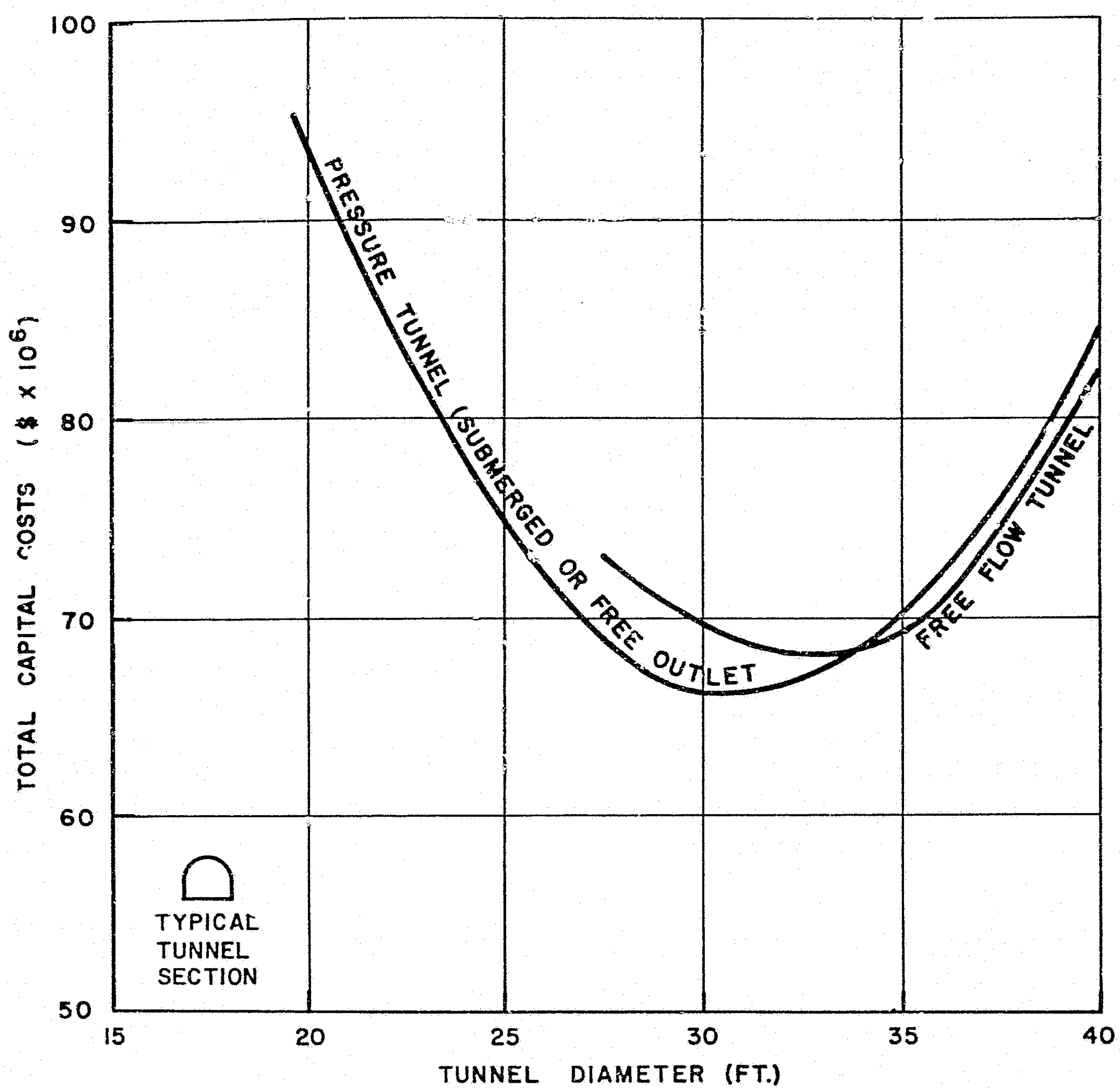
FIGURE B.23



WATANA DIVERSION
TUNNEL COST / TUNNEL DIAMETER

ACRES

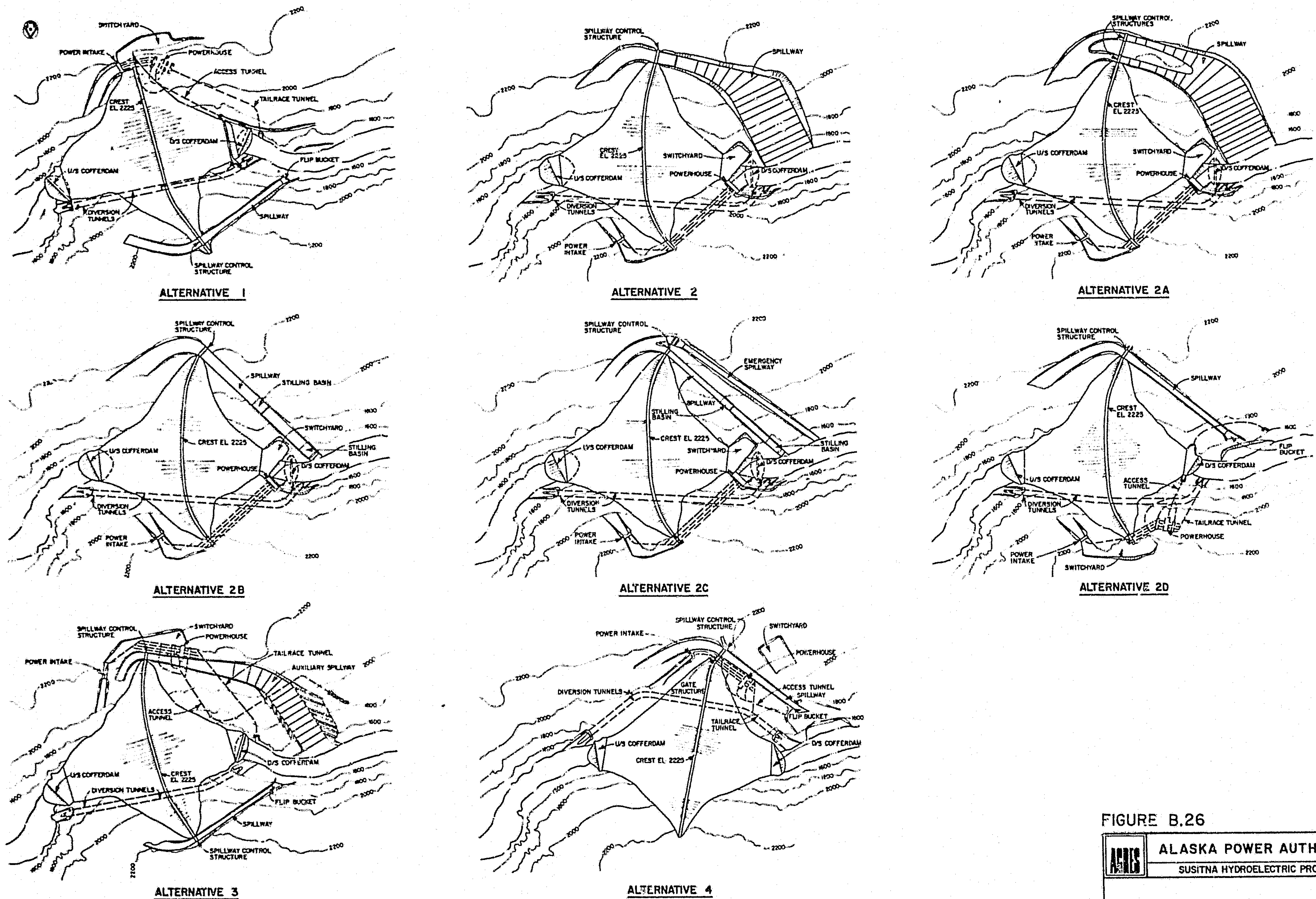
FIGURE B.24



WATANA DIVERSION
TOTAL COST / TUNNEL DIAMETER

FIGURE B.25

ACRES



WATANA
PRELIMINARY SCHEMES

FIGURE B.26

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

WATANA
PRELIMINARY SCHEMES

ACRES AMERICAN INCORPORATED

MARCH 1982

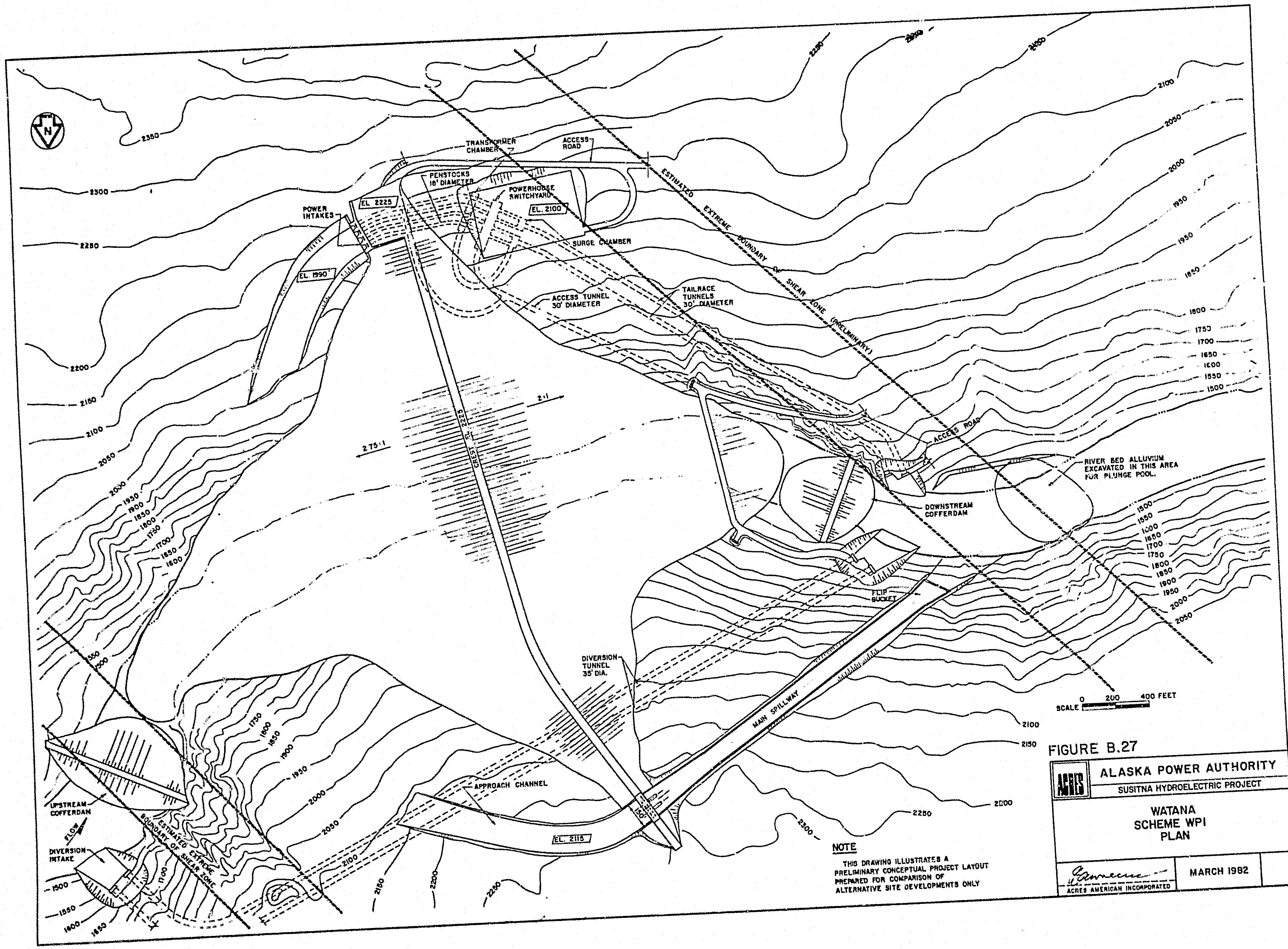


FIGURE B.27

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA
SCHEME WP1
PLAN

ACRES AMERICAN INCORPORATED

MARCH 1982

NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

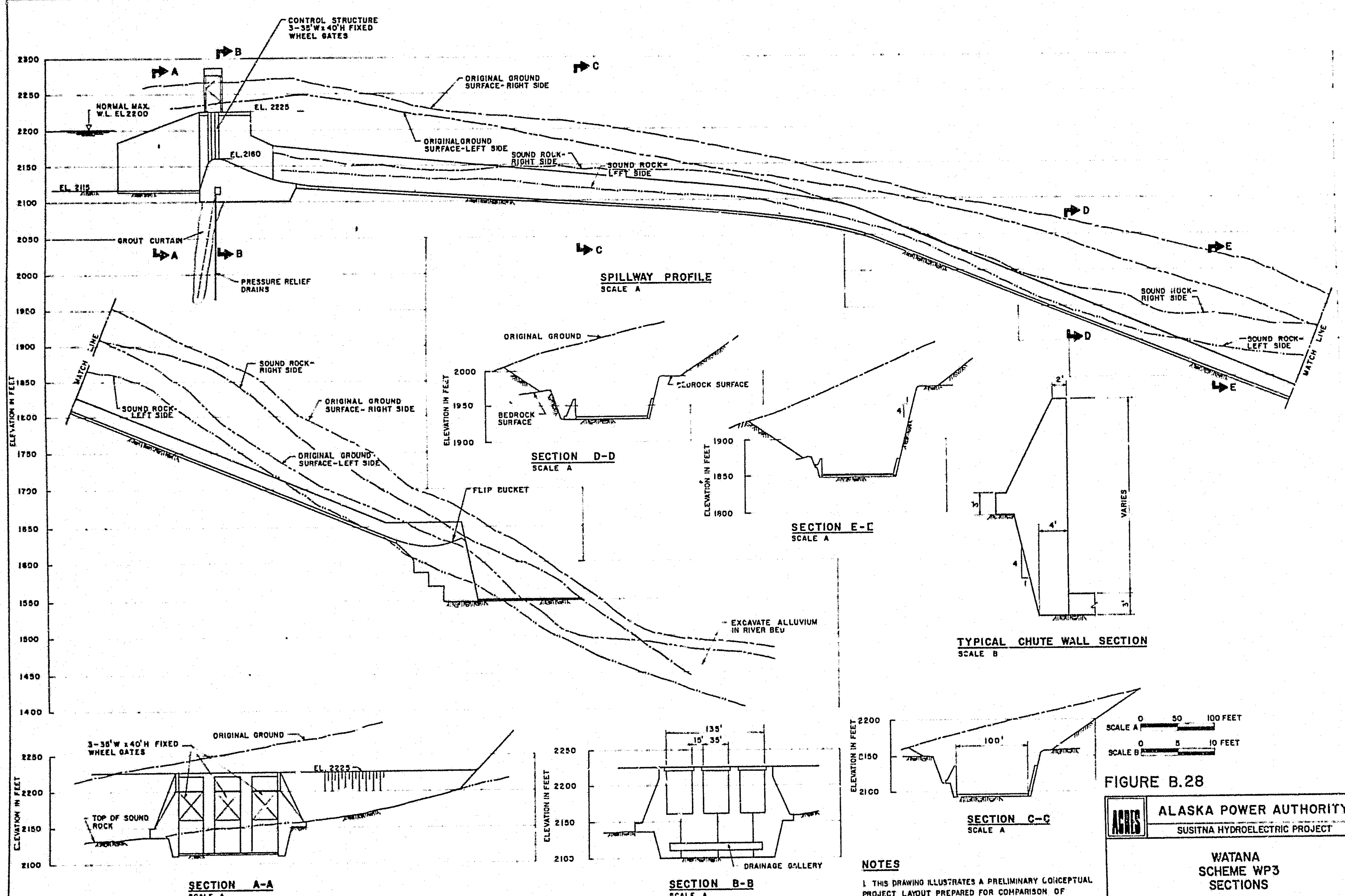


FIGURE B.28

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

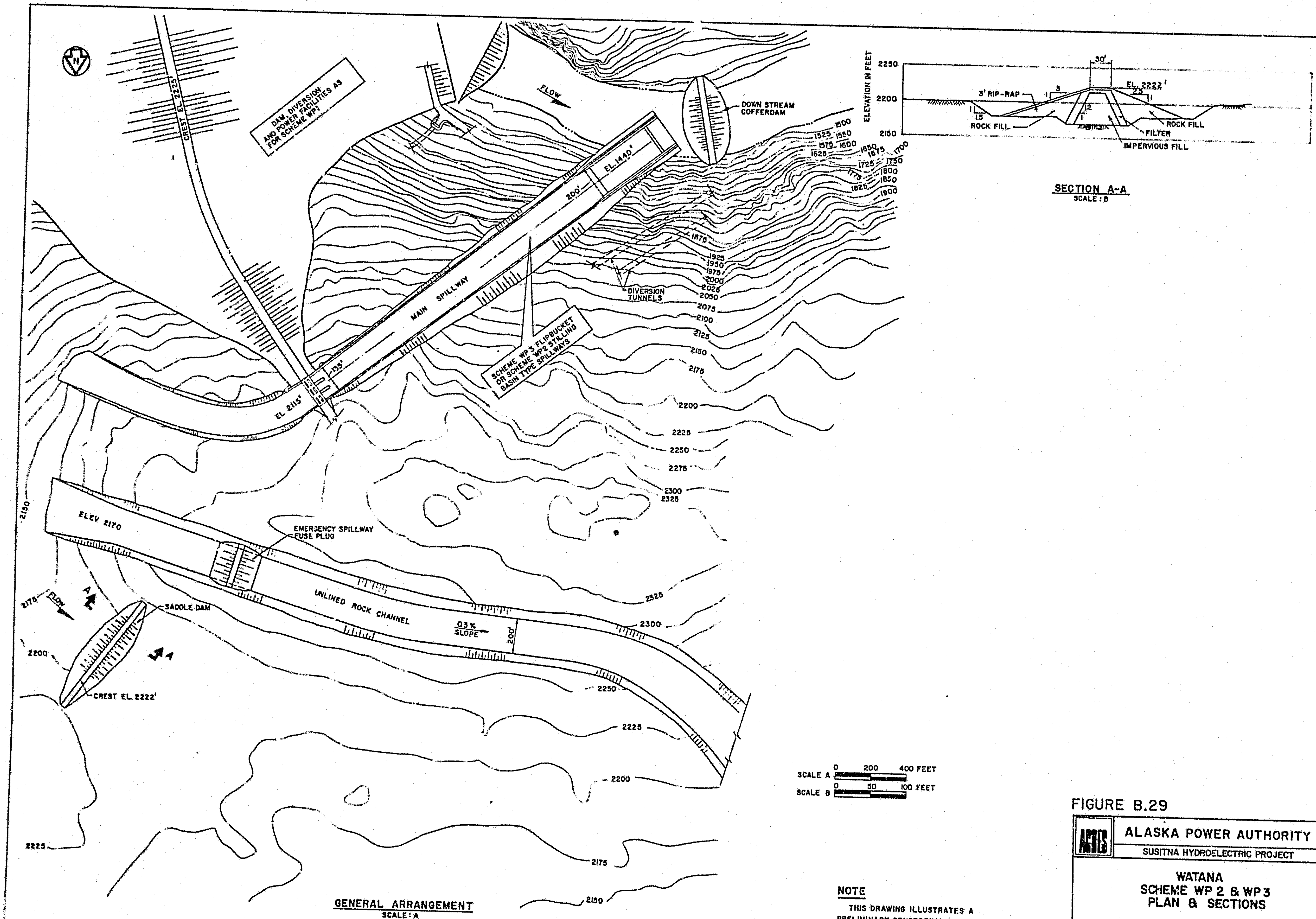
WATANA
SCHEME WP3
SECTIONS

ACRES AMERICAN INCORPORATED

MARCH 1982

NOTES

1. THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY
2. SECTIONS FOR SCHEME WP1 ARE SIMILAR EXCEPT THAT GATE STRUCTURE IS 130' WIDE WITH CREST EL 2150 AND 3-40' WIDE x 53' HIGH GATES



NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

FIGURE B.29

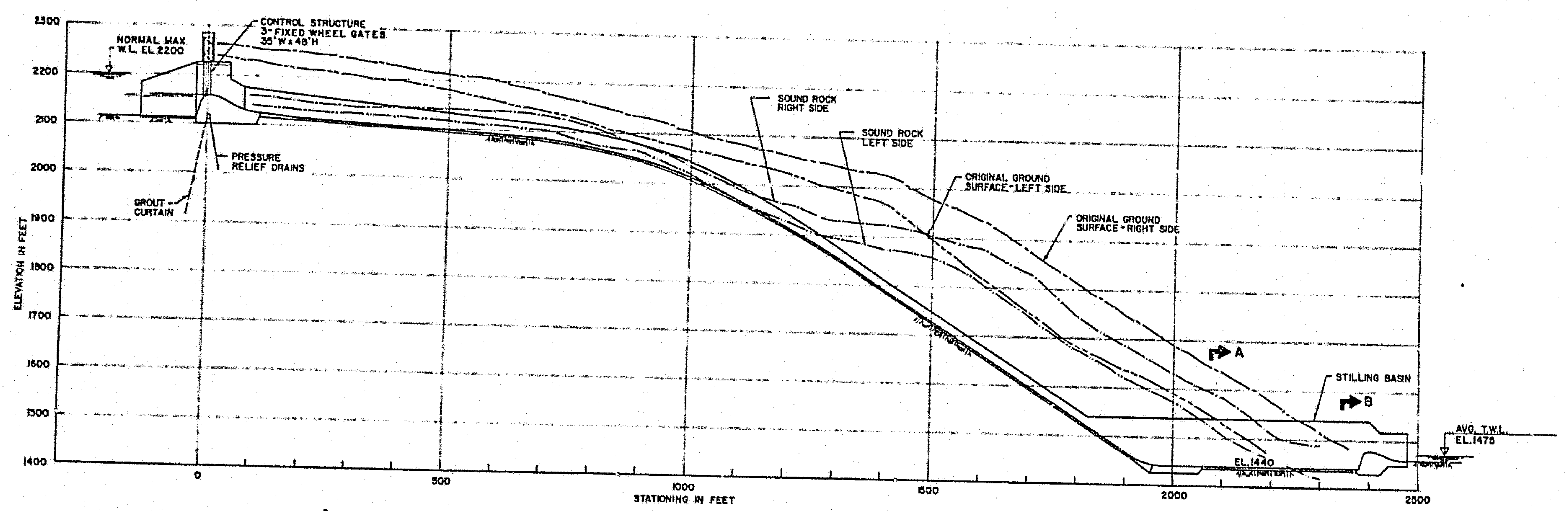
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

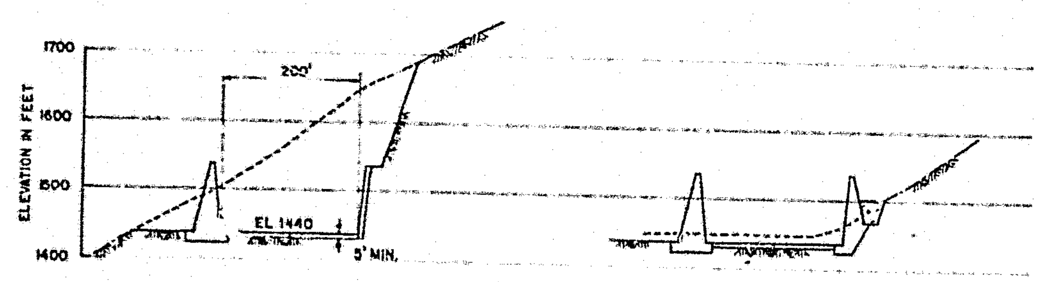
WATANA
SCHEME WP 2 & WP 3
PLAN & SECTIONS

ACRES AMERICAN INCORPORATED

MARCH 1982



SPILLWAY PROFILE



SECTION A-A

SECTION B-B

SCALE 0 100 200 FEET

NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

FIGURE B.30

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

WATANA
SCHEME WP 2
SECTIONS

ACRES AMERICAN INCORPORATED

MARCH 1982

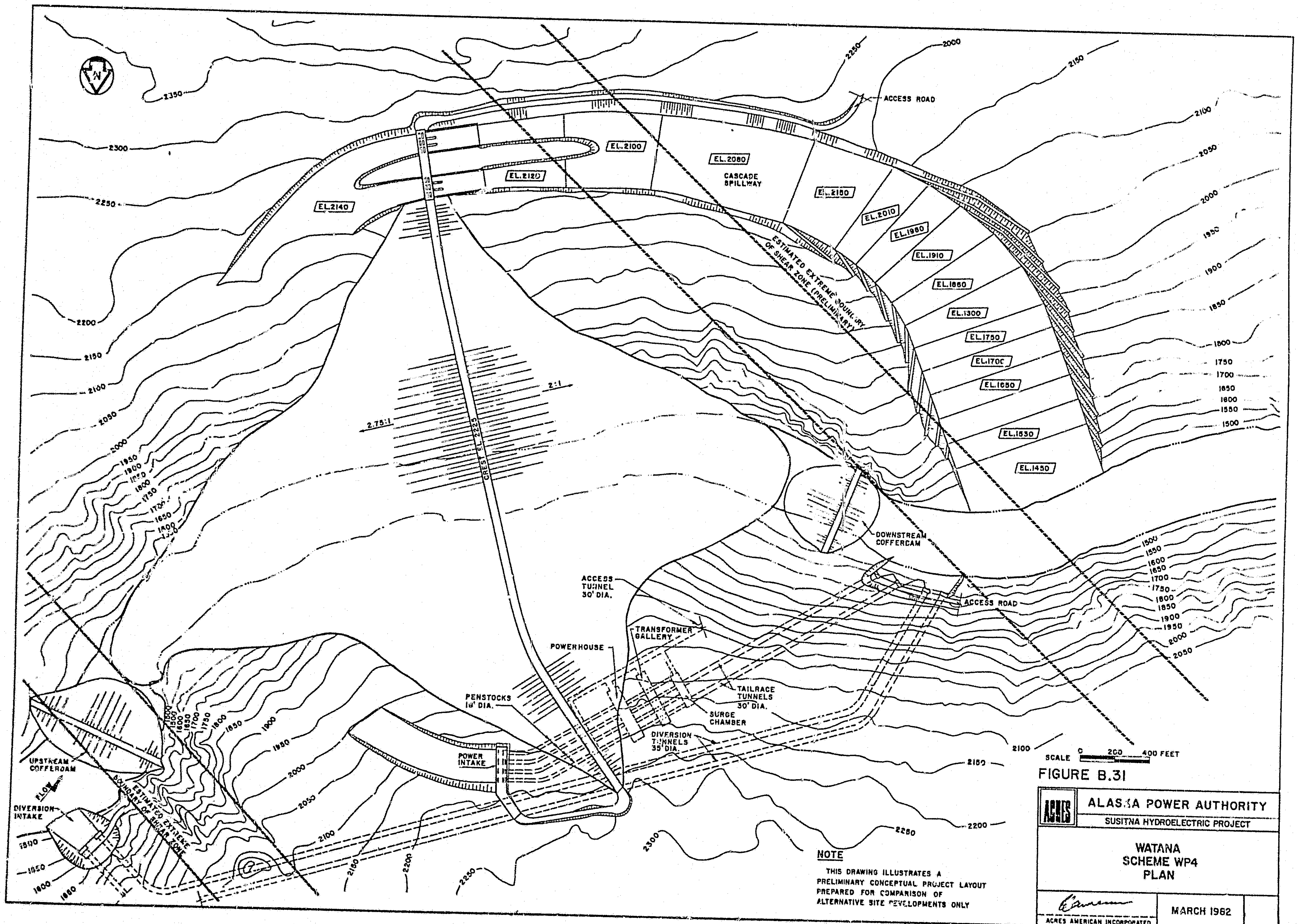
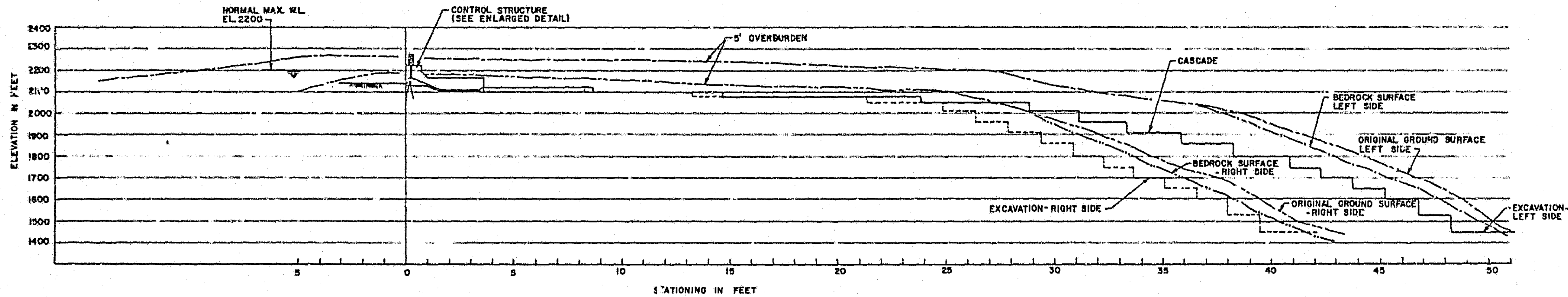
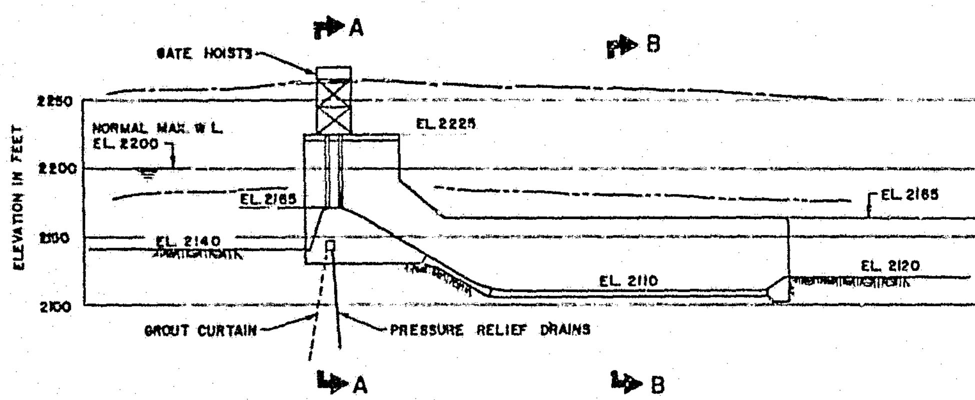

ACCESS ROAD
EL.2100
EL.2080
CASCADE SPILLWAY
EL.2120
EL.2140
EL.2150
EL.2010
EL.1960
EL.1910
EL.1860
EL.1800
EL.1750
EL.1700
EL.1650
EL.1530
EL.1450
ESTIMATED EXTREME BOUNDARY OF SHEAR ZONE (PRELIMINARY)
2:1
2.75:1
CREST EL. 2225
DOWNSTREAM COFFERDAM
ACCESS TUNNEL 30' DIA.
ACCESS ROAD
TRANSFORMER GALLERY
POWERHOUSE
TAILRACE TUNNELS 30' DIA.
SURGE CHAMBER
PENSTOCKS 18' DIA.
DIVERSION TUNNELS 35' DIA.
POWER INTAKE
UPSTREAM COFFERDAM
FLOW
DIVERSION INTAKE
ESTIMATED EXTREME BOUNDARY OF SHEAR ZONE
SCALE 0 200 400 FEET
NOTE
THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
SCHEME WP4
PLAN
ACRES AMERICAN INCORPORATED
MARCH 1982

FIGURE B.31



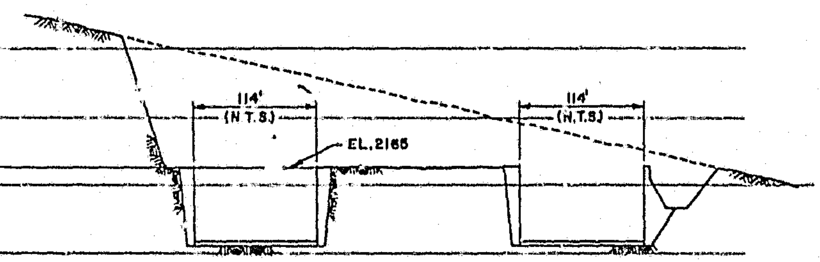
SPILLWAY PROFILE

SCALE: A



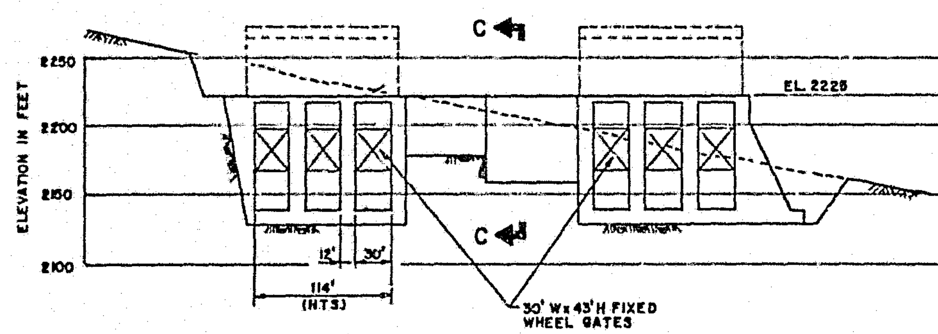
SPILLWAY CONTROL STRUCTURE

SCALE: B



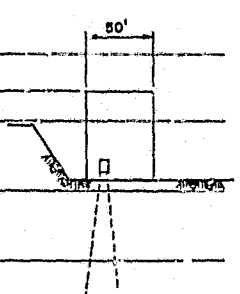
SECTION B-B

SCALE: B



SECTION A-A

SCALE: B



SECTION C-C

SCALE: B

SCALE A 0 200 400 FEET

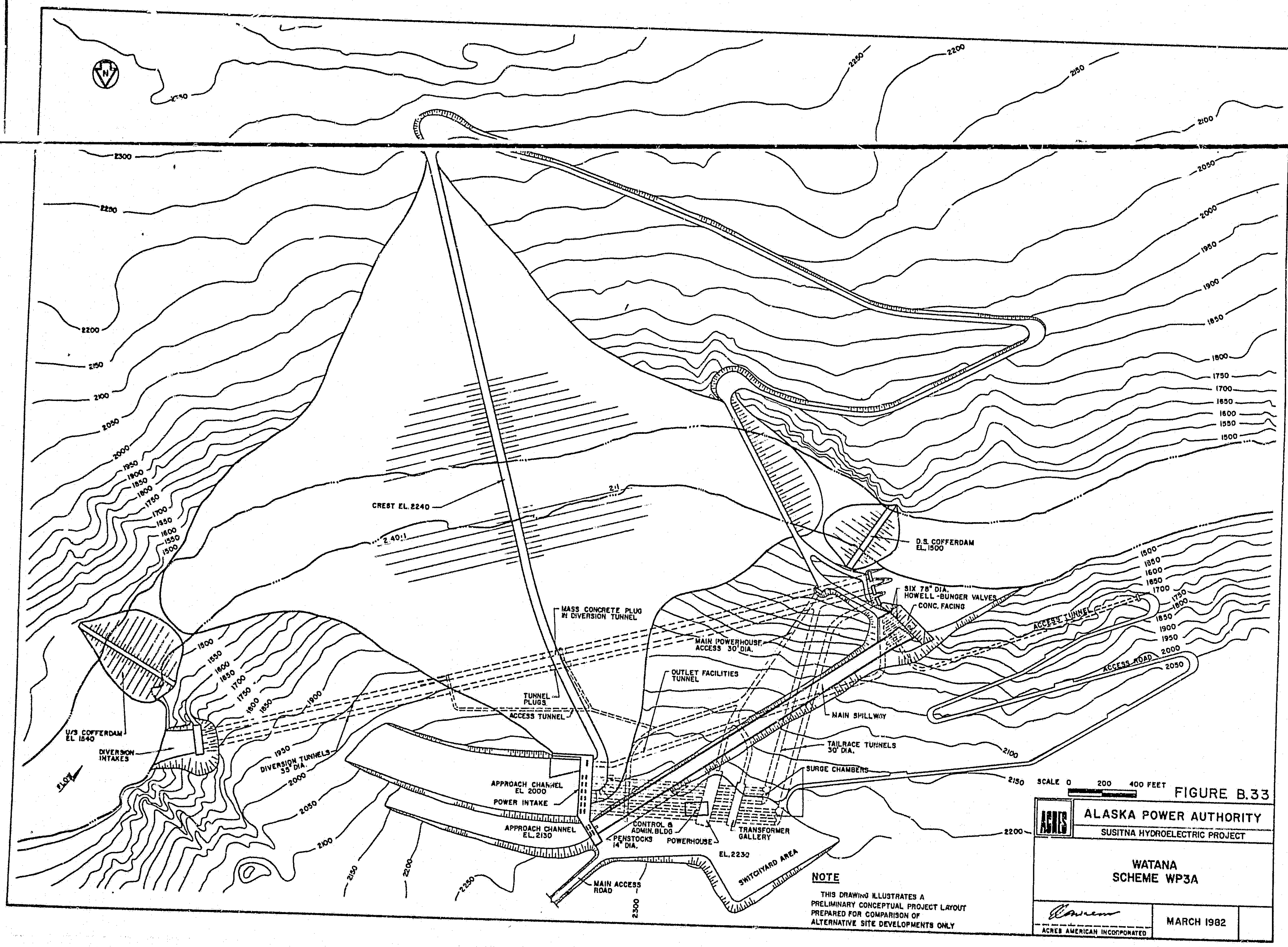
SCALE B 0 50 100 FEET

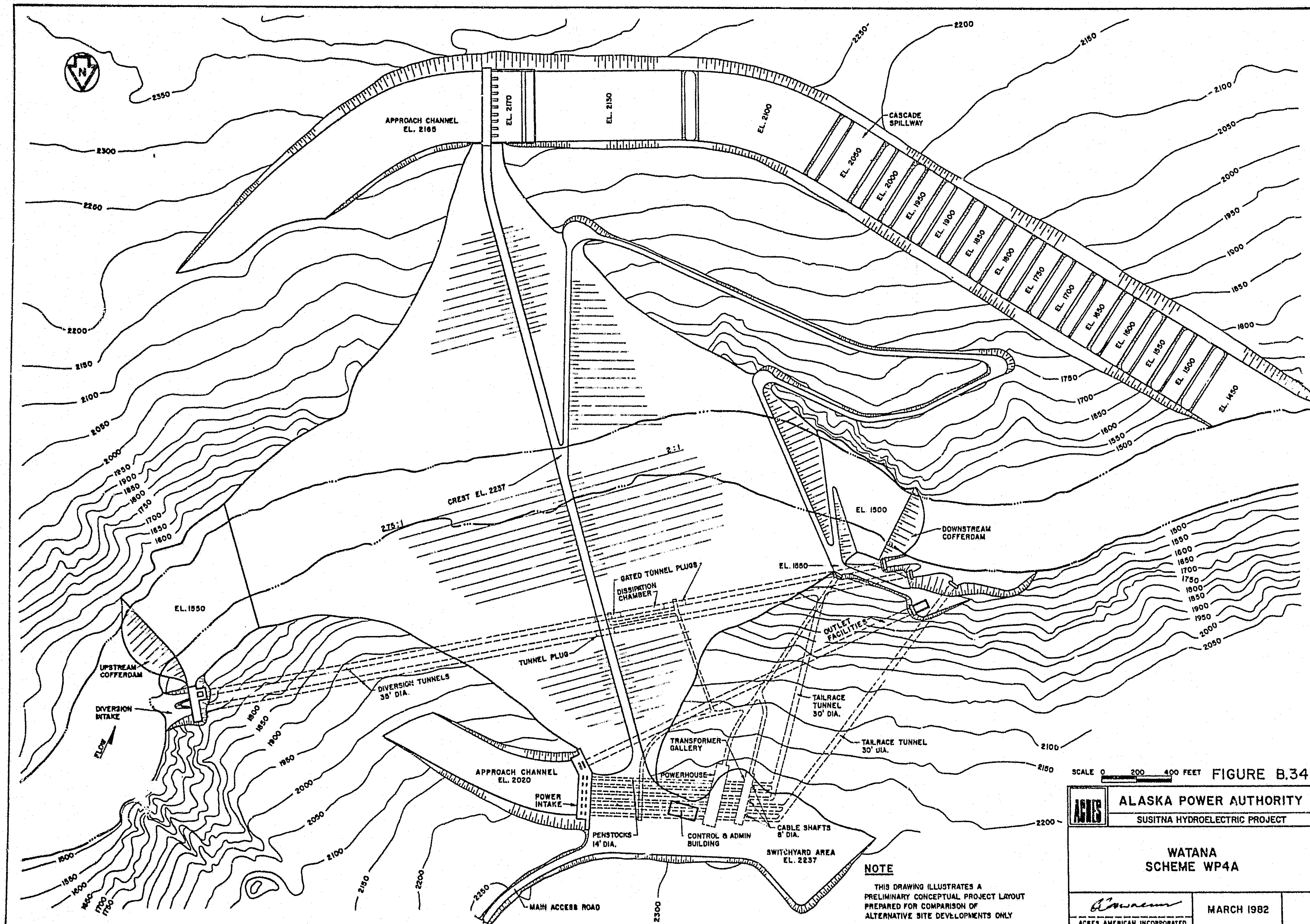
NOTE

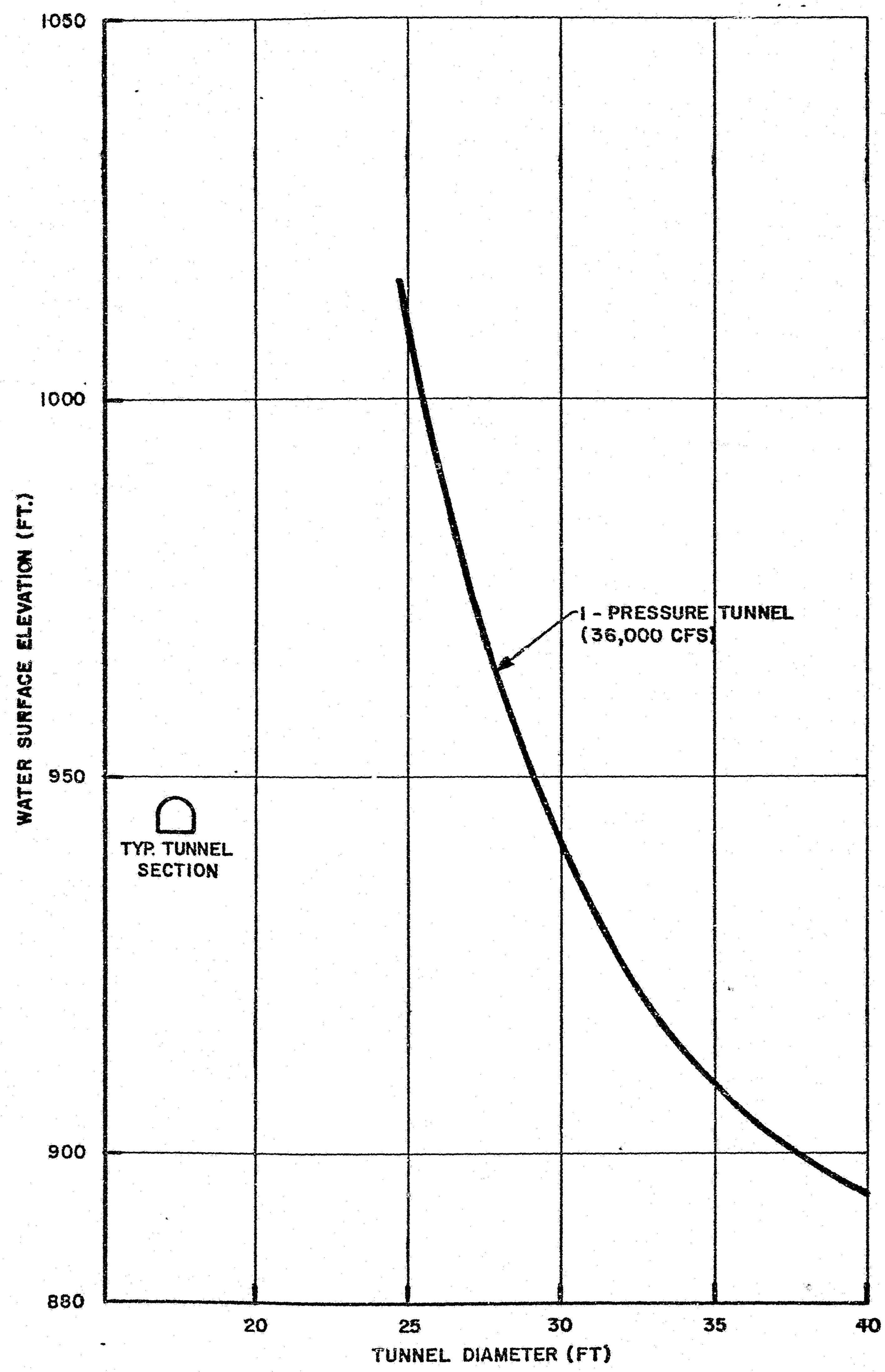
THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

FIGURE B.32

ACRES	ALASKA POWER AUTHORITY
	SUSITNA HYDROELECTRIC PROJECT
	WATANA SCHEME WP4 SECTIONS
ACRES AMERICAN INCORPORATED	MARCH 1982


CREST EL. 2240
2.40:1
2:1
MASS CONCRETE PLUG IN DIVERSION TUNNEL
TUNNEL PLUGS
ACCESS TUNNEL
U/S COFFERDAM EL 1540
DIVERSION INTAKES
FLOW
DIVERSION TUNNELS 35' DIA.
APPROACH CHANNEL EL. 2000
POWER INTAKE
APPROACH CHANNEL EL. 2130
PENSTOCKS 14' DIA.
CONTROL & ADMIN. BLDG
POWERHOUSE
TRANSFORMER GALLERY
EL. 2230
SWITCHYARD AREA
MAIN ACCESS ROAD
MAIN POWERHOUSE ACCESS 30' DIA.
OUTLET FACILITIES TUNNEL
MAIN SPILLWAY
TAILRACE TUNNELS 30' DIA.
SURGE CHAMBERS
D.S. COFFERDAM EL. 1500
SIX 78" DIA. HOWELL-BUNGER VALVES
CONC. FACING
ACCESS TUNNEL
ACCESS ROAD
SCALE 0 200 400 FEET
NOTE
THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY
FIGURE B.33
ACRES
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
SCHEME WP3A
ACRES AMERICAN INCORPORATED
MARCH 1982

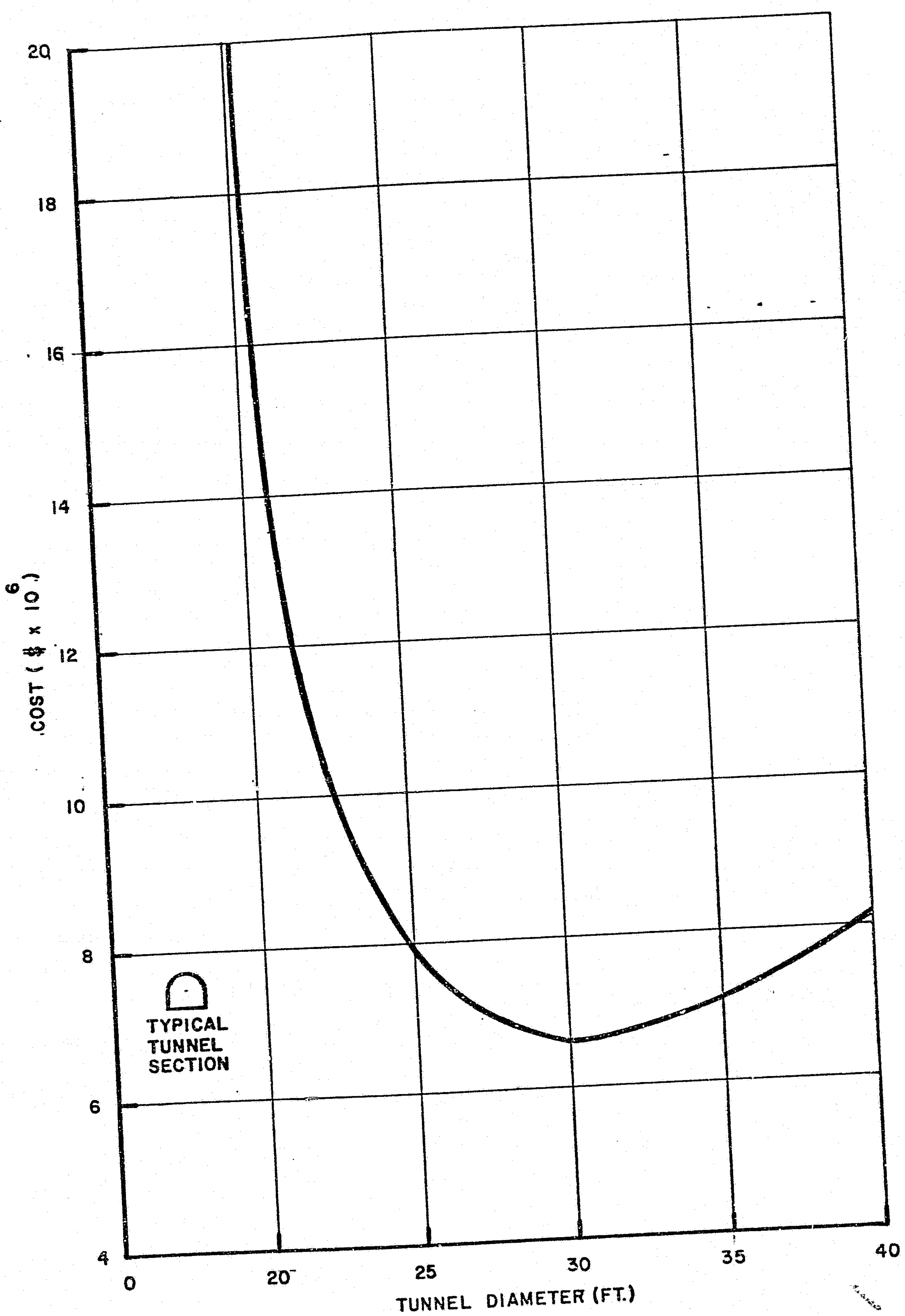

N
APPROACH CHANNEL EL. 2165
EL. 2170
EL. 2130
EL. 2100
CASCADE SPILLWAY
EL. 2050
EL. 2000
EL. 1950
EL. 1900
EL. 1850
EL. 1800
EL. 1750
EL. 1700
EL. 1650
EL. 1600
EL. 1550
EL. 1500
EL. 1450
CREST EL. 2237
2.75:1
2:1
EL. 1500
DOWNSTREAM COFFERDAM
EL. 1550
EL. 1550
GATED TUNNEL PLUGS
DISSIPATION CHAMBER
OUTLET FACILITIES
TUNNEL PLUG
UPSTREAM COFFERDAM
DIVERSION INTAKE
DIVERSION TUNNELS 35' DIA.
FLOW
TAILRACE TUNNEL 30' DIA.
TAILRACE TUNNEL 30' DIA.
TRANSFORMER GALLERY
POWERHOUSE
APPROACH CHANNEL EL. 2020
POWER INTAKE
PENSTOCKS 14' DIA.
CONTROL & ADMIN BUILDING
CABLE SHAFTS 8' DIA.
SWITCHYARD AREA EL. 2237
MAIN ACCESS ROAD
NOTE
THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY
SCALE 0 200 400 FEET
ACRES
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
SCHEME WP4A
ACRES AMERICAN INCORPORATED
MARCH 1982
FIGURE B.34



DEVIL CANYON DIVERSION
HEADWATER ELEVATION / TUNNEL DIAMETER

ACRES

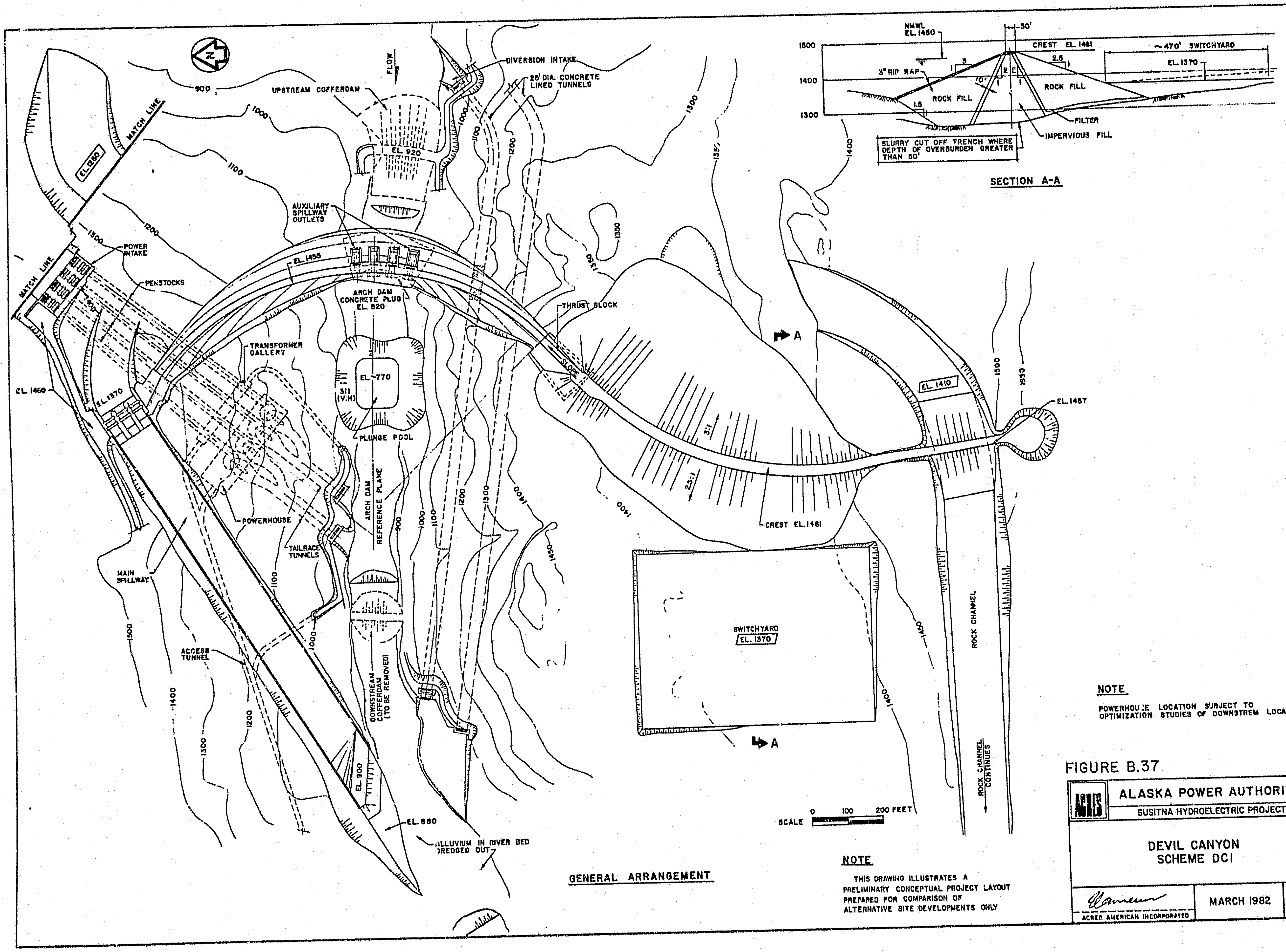
FIGURE B.35



DEVIL CANYON DIVERSION
TOTAL COST / TUNNEL DIAMETER

ACRES

FIGURE B.36



NOTE

POWERHOUSE LOCATION SUBJECT TO OPTIMIZATION STUDIES OF DOWNSTREAM LOCATIONS.

NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

FIGURE B.37

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
SCHEME DCI

ACRES AMERICAN INCORPORATED

MARCH 1982

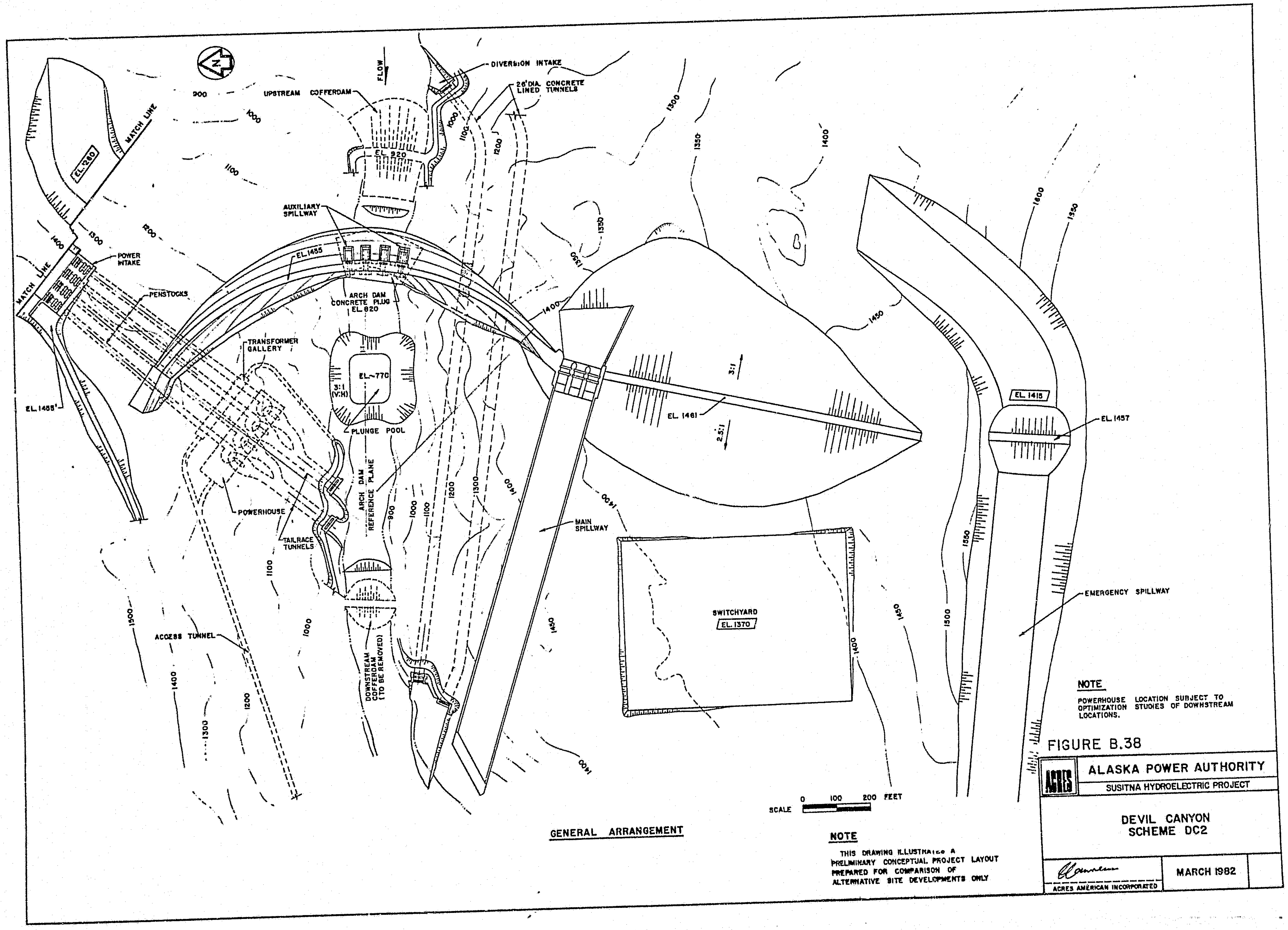


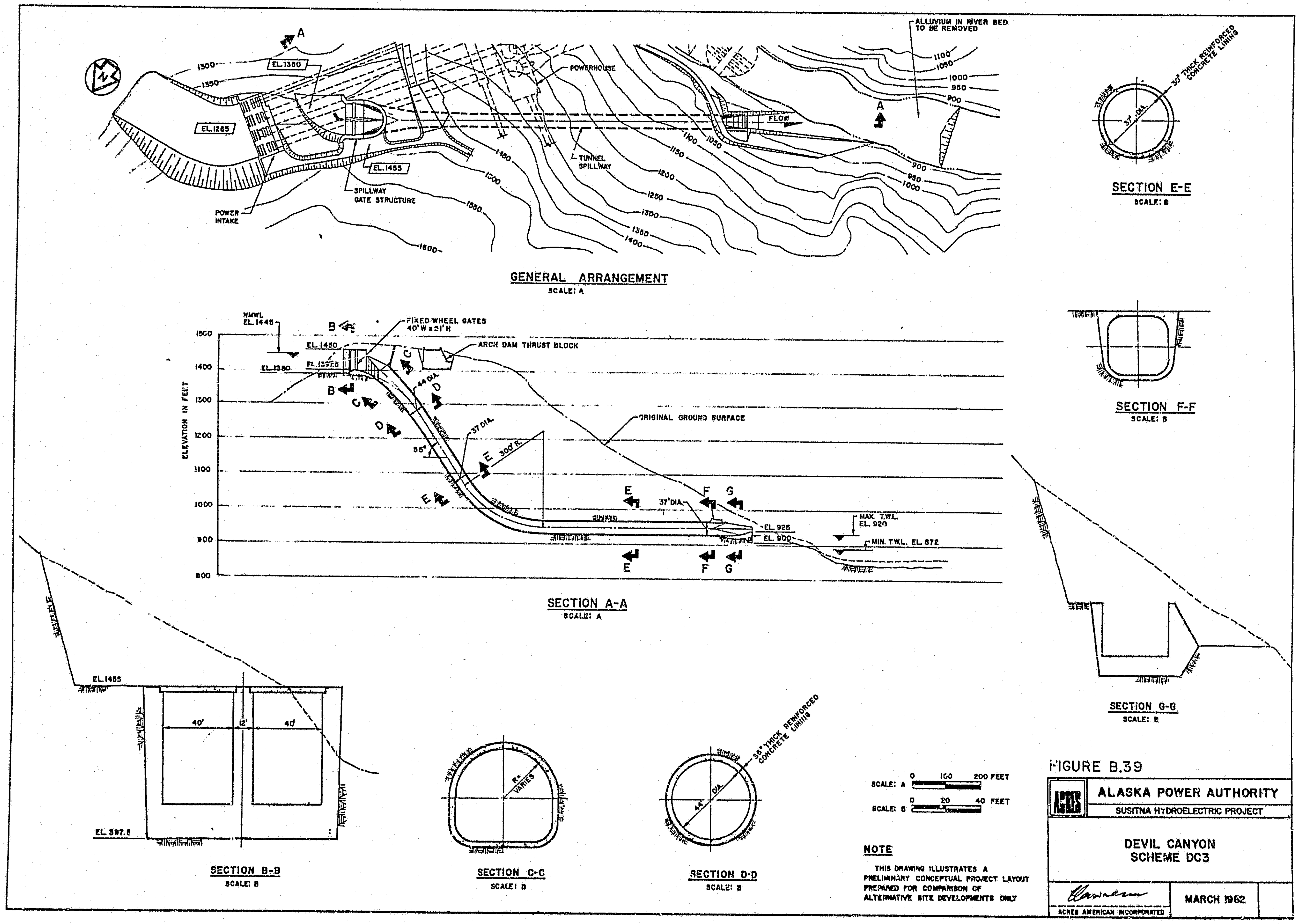
FIGURE B.38

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON SCHEME DC2

MARCH 1982



ALLUVIUM IN RIVER BED TO BE REMOVED
POWERHOUSE
EL.1380
EL.1265
EL.1455
TUNNEL SPILLWAY
SPILLWAY GATE STRUCTURE
POWER INTAKE
FLOW
30" THICK REINFORCED CONCRETE LINING
37' DIA.
SECTION E-E
SCALE: B
GENERAL ARRANGEMENT
SCALE: A
NMWL EL.1445
FIXED WHEEL GATES 40'W x 21'H
ARCH DAM THRUST BLOCK
EL.1450
EL.1380
44' DIA.
37' DIA.
300' R.
55°
ORIGINAL GROUND SURFACE
ELEVATION IN FEET
37' DIA.
EL.925
EL.900
MAX. T.W.L. EL.920
MIN. T.W.L. EL.872
SECTION A-A
SCALE: A
SECTION F-F
SCALE: B
SECTION G-G
SCALE: B
EL.1455
EL.397.5
40'
12'
40'
SECTION B-B
SCALE: B
R= VARIES
SECTION C-C
SCALE: B
36" THICK REINFORCED CONCRETE LINING
44' DIA.
SECTION D-D
SCALE: B
SCALE: A 0 100 200 FEET
SCALE: B 0 20 40 FEET
NOTE
THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY
FIGURE B.39
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
DEVIL CANYON SCHEME DC3
ACRES AMERICAN INCORPORATED
MARCH 1982

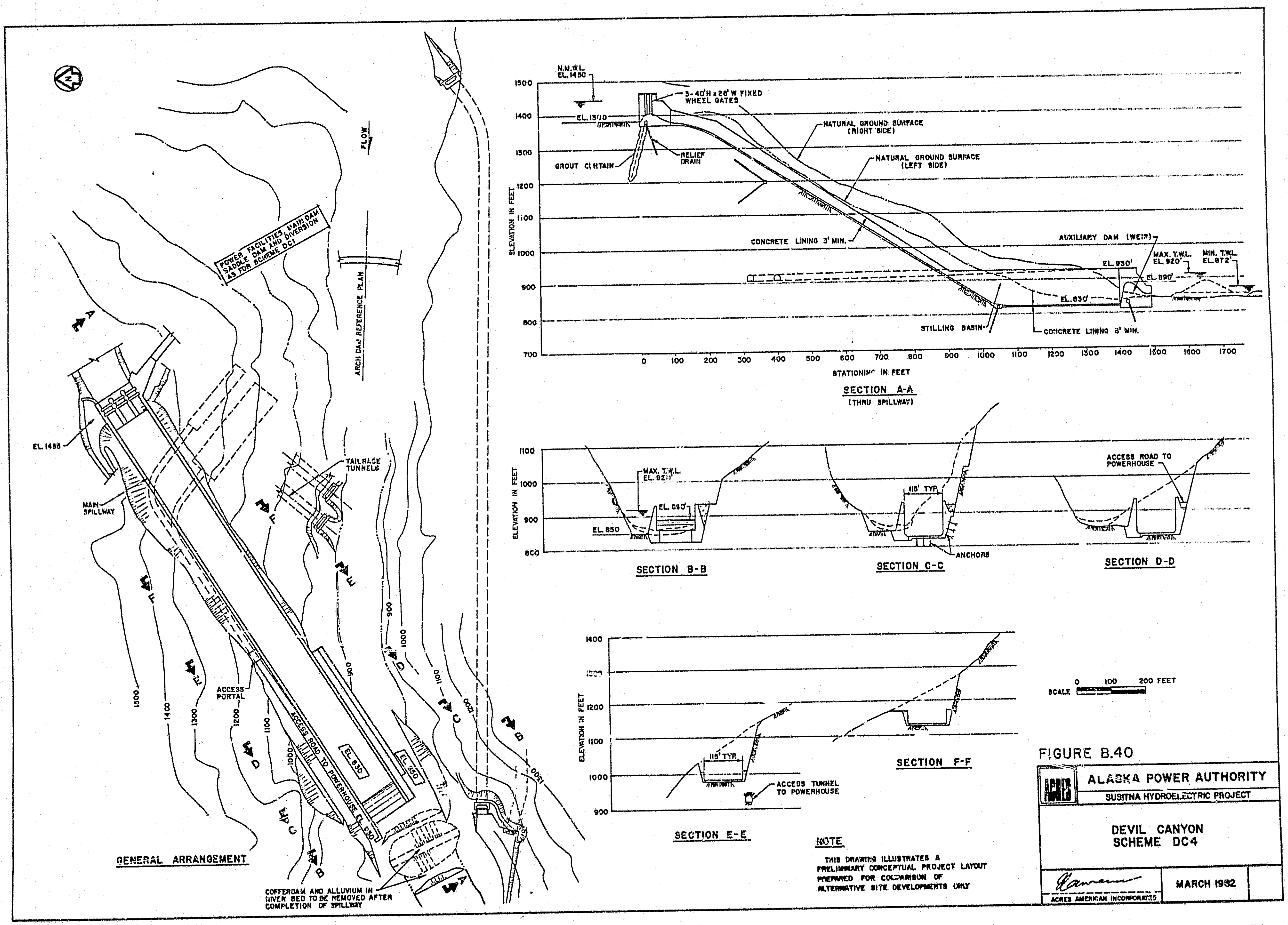


FIGURE B.40

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON SCHEME DC4

ACRES AMERICAN INCORPORATED

MARCH 1982

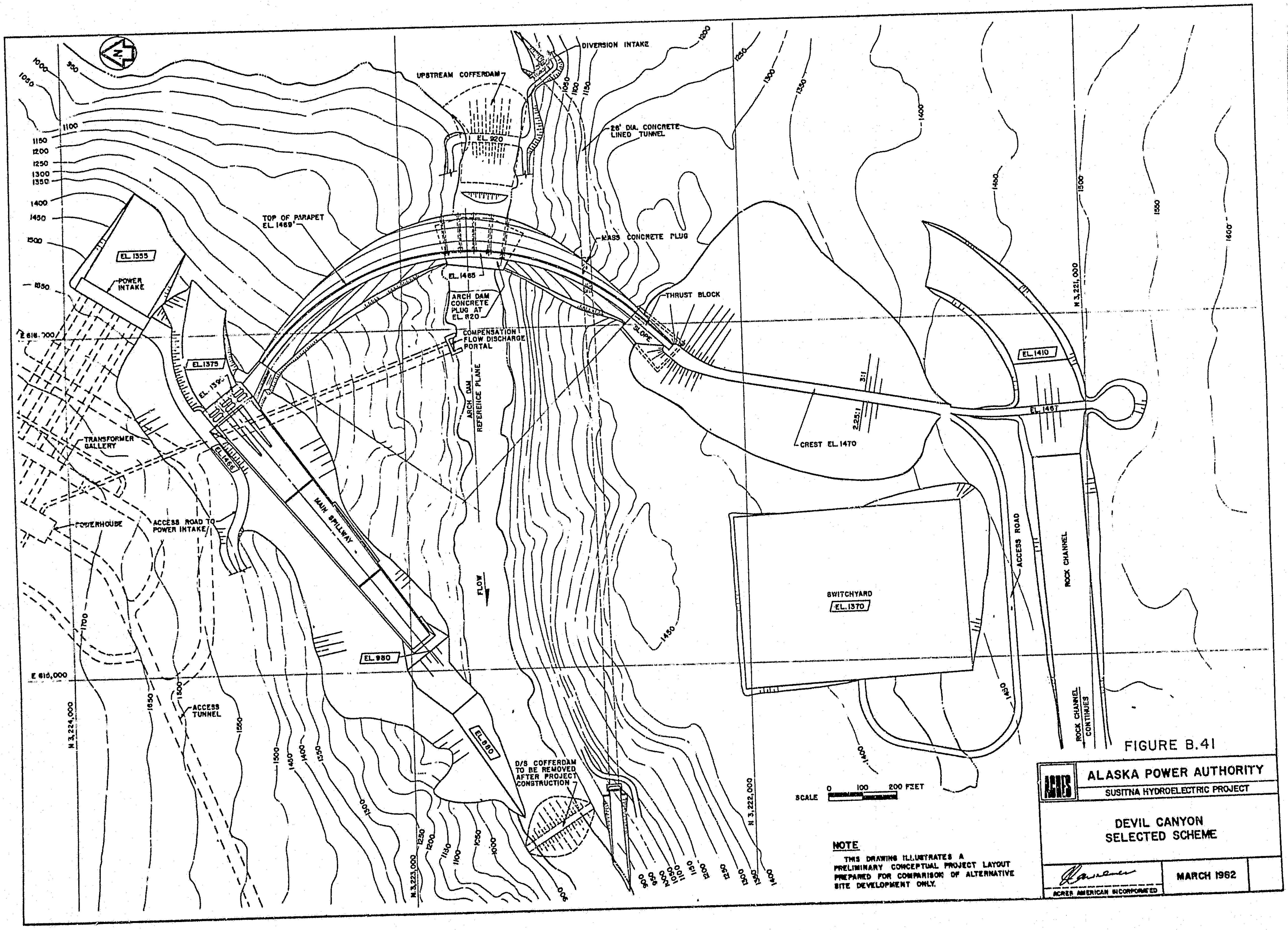
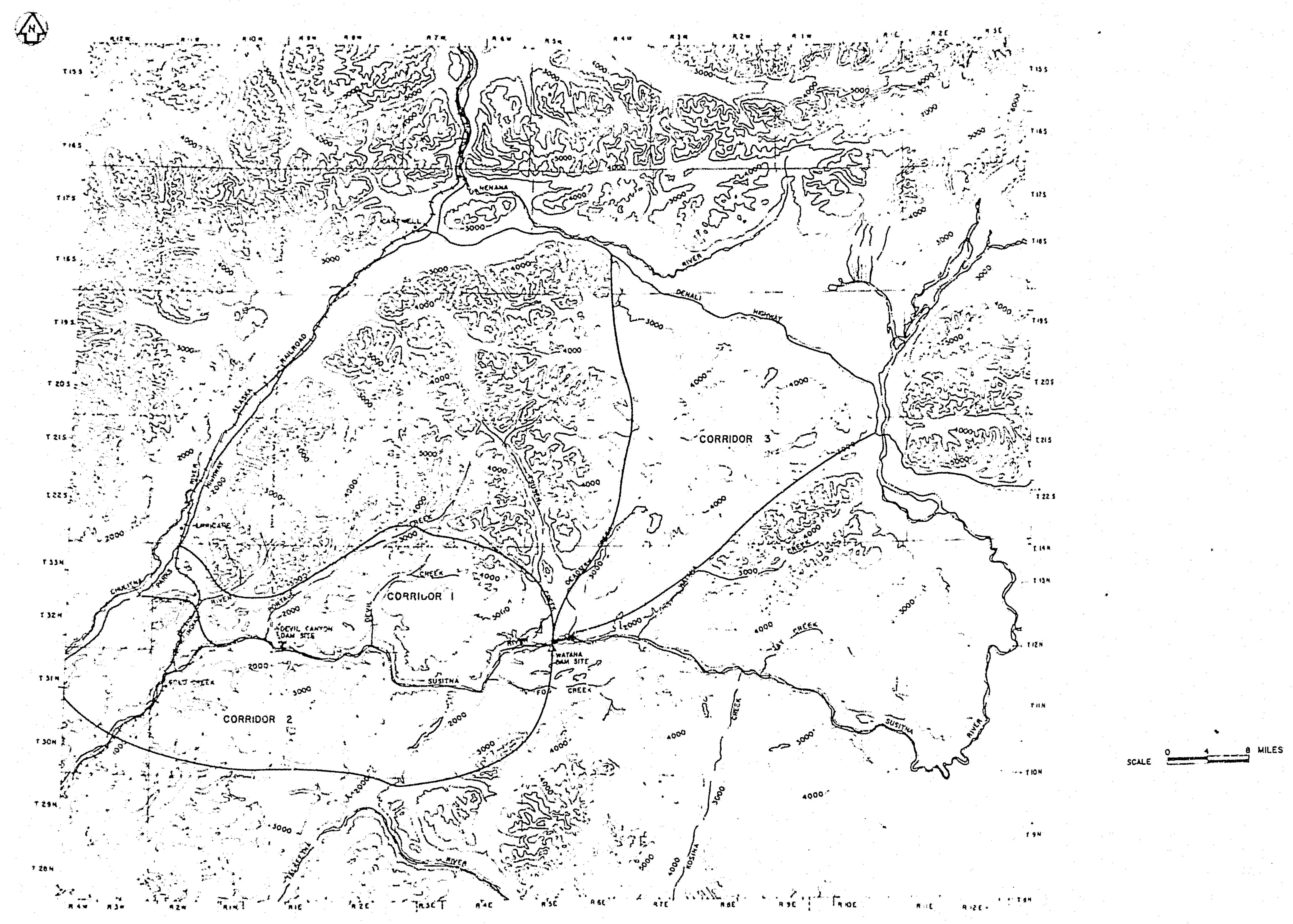

DIVERSION INTAKE
UPSTREAM COFFERDAM
EL. 920
28' DIA. CONCRETE LINED TUNNEL
TOP OF PARAPET EL. 1469'
MASS CONCRETE PLUG
EL. 1355
POWER INTAKE
EL. 1465
ARCH DAM CONCRETE PLUG AT EL. 820
THRUST BLOCK
SLOPE
COMPENSATION FLOW DISCHARGE PORTAL
EL. 1375
ARCH DAM REFERENCE PLANE
EL. 1410
EL. 1467
CREST EL. 1470
TRANSFORMER GALLERY
EL. 1466
MAIN SPILLWAY
POWERHOUSE
ACCESS ROAD TO POWER INTAKE
FLOW
SWITCHYARD
EL. 1370
ACCESS ROAD
ROCK CHANNEL
EL. 980
E 616,000
E 615,000
N 3,224,000
N 3,223,000
N 3,222,000
N 3,221,000
ACCESS TUNNEL
EL. 880
D/S COFFERDAM TO BE REMOVED AFTER PROJECT CONSTRUCTION
ROCK CHANNEL CONTINUES
SCALE 0 100 200 FEET
NOTE
THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENT ONLY.
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
DEVIL CANYON
SELECTED SCHEME
ACRES AMERICAN INCORPORATED
MARCH 1982

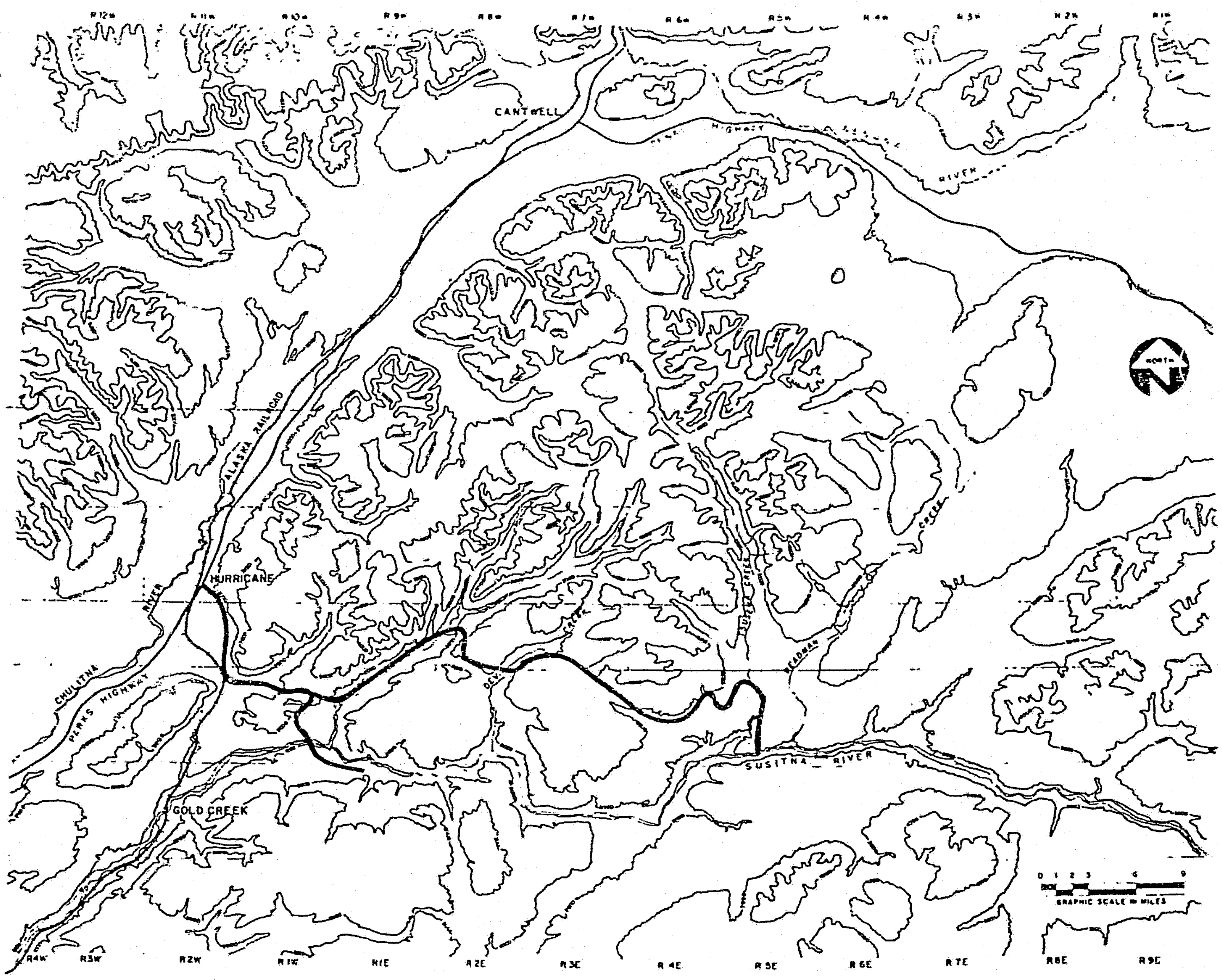
FIGURE B.41



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

ALTERNATIVE ACCESS CORRIDORS

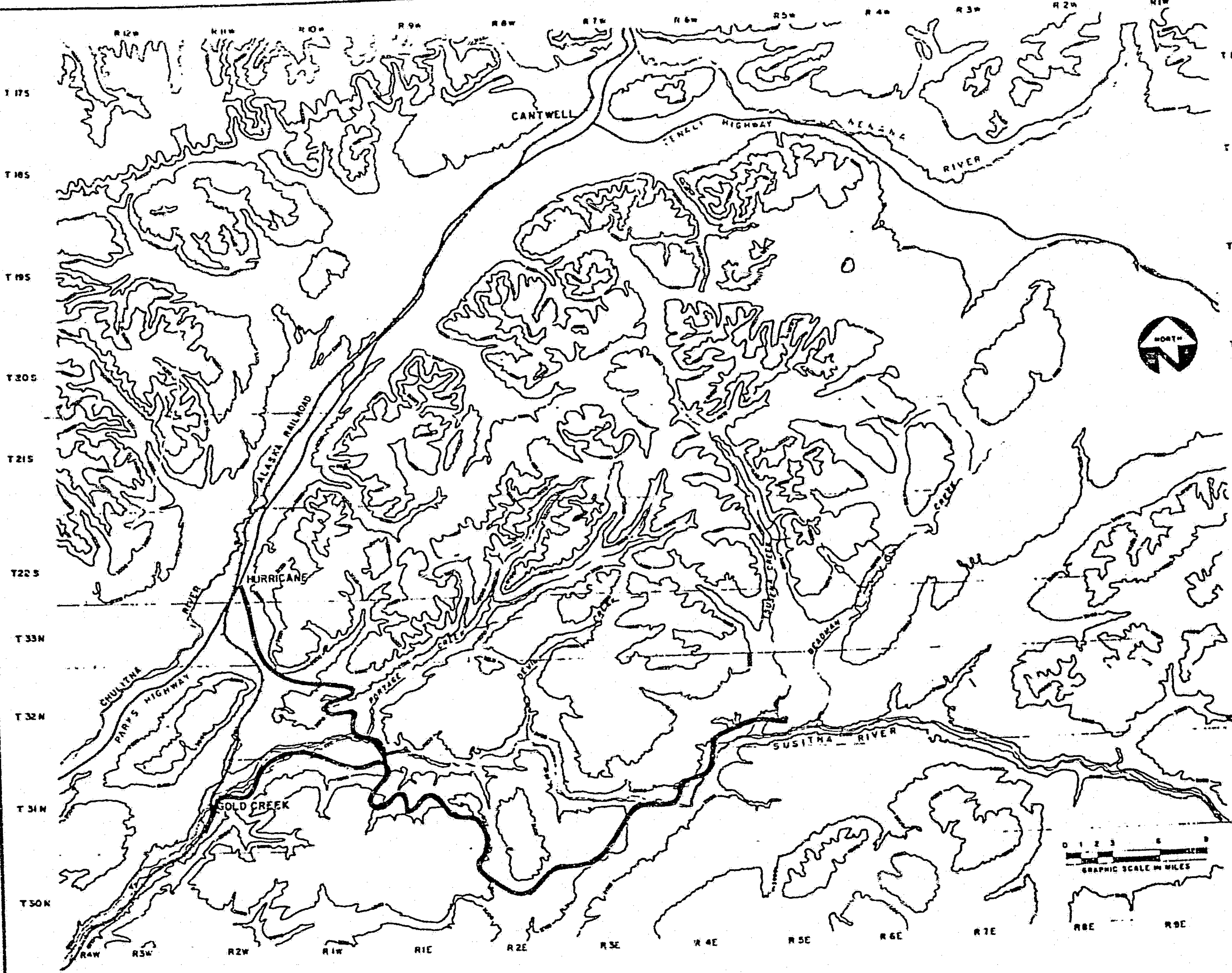
ACRES



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

ACRES

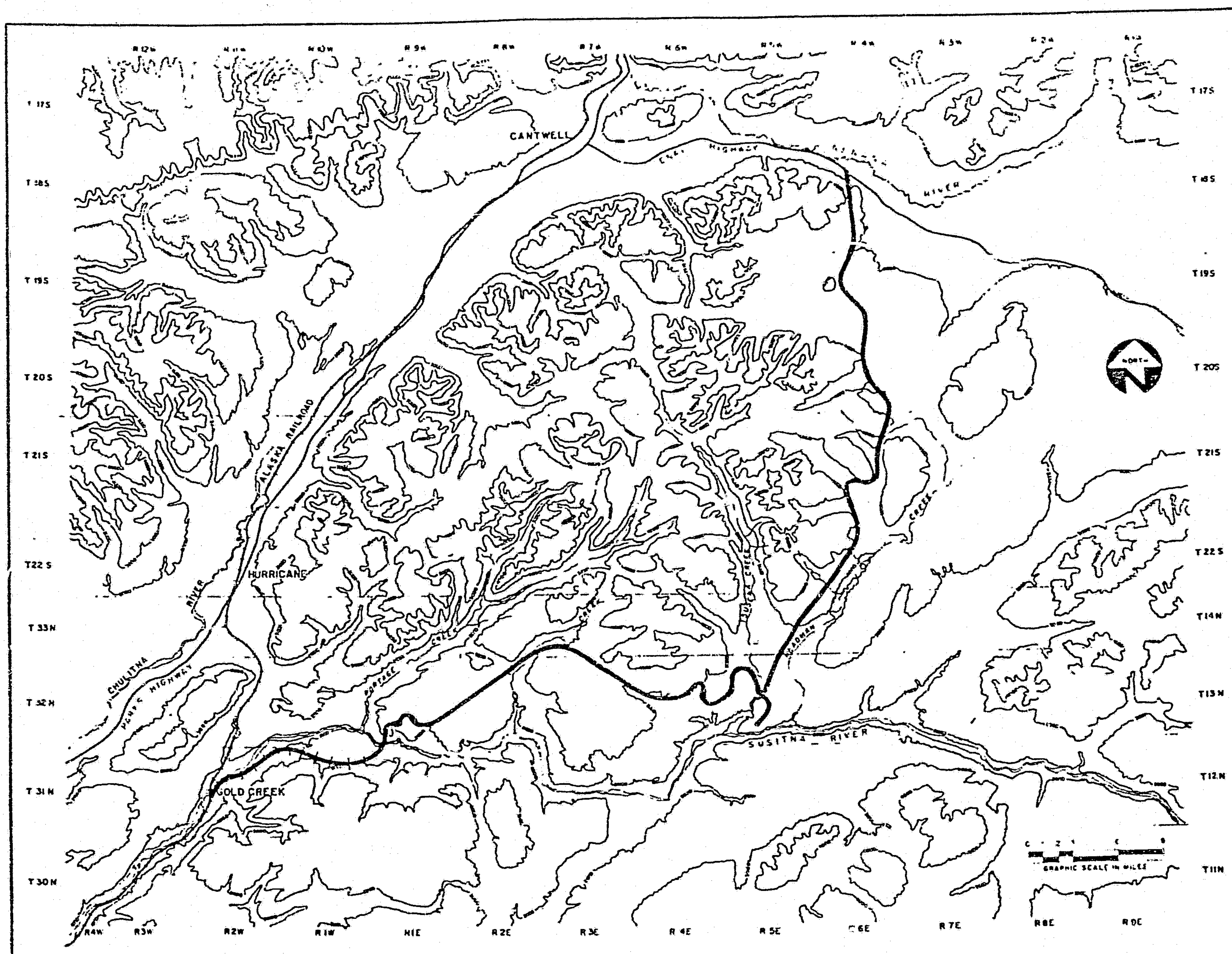
FIGURE B.43



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

ACRES

FIGURE B.44

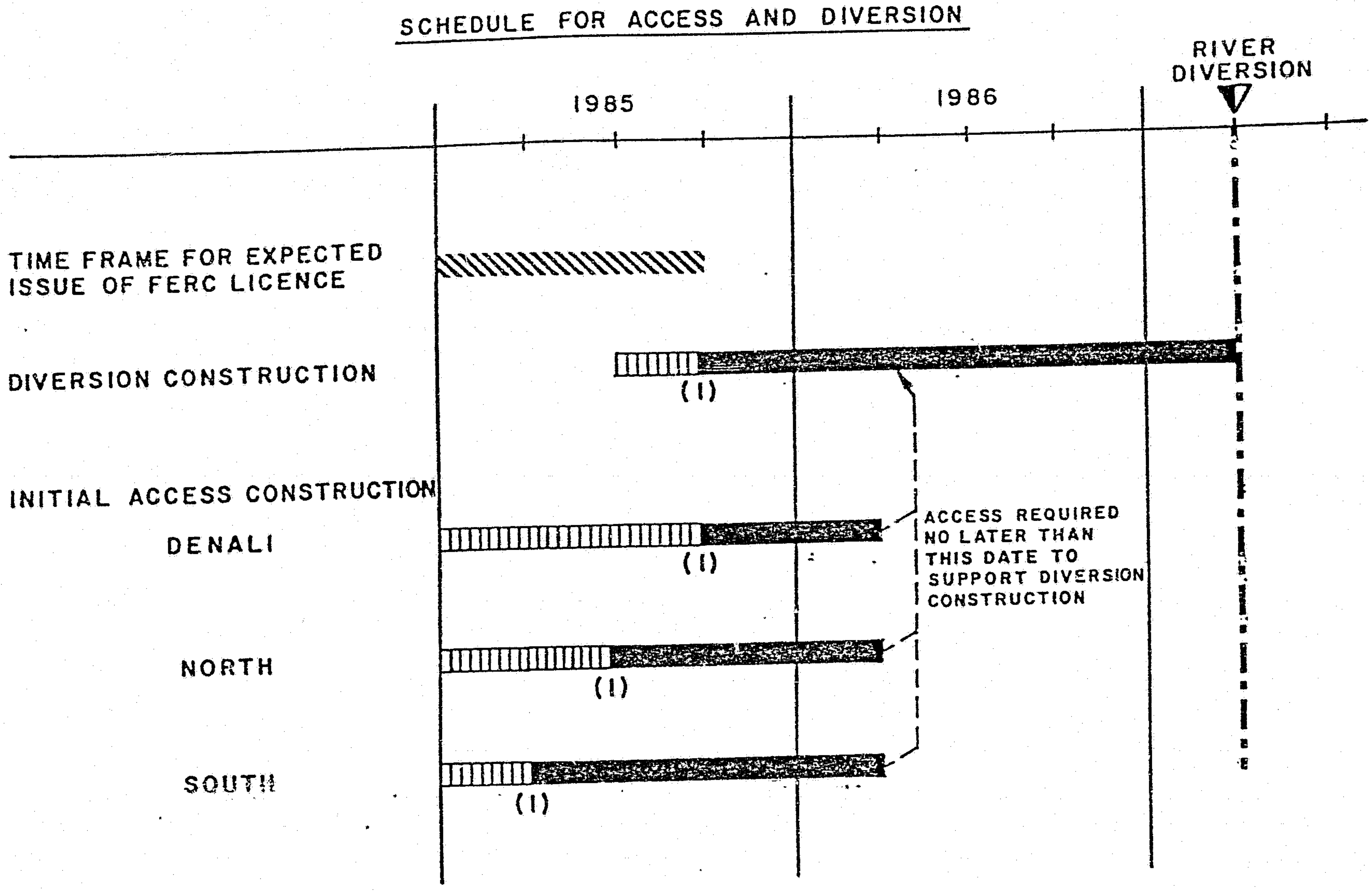


**ACCESS PLAN 18 (PROPOSED)
"SUSITNA HYDROELECTRIC PROJECT
ALTERNATIVE ACCESS PLAN"**

FIGURE B.45

ACRES

SCHEDULE FOR ACCESS AND DIVERSION



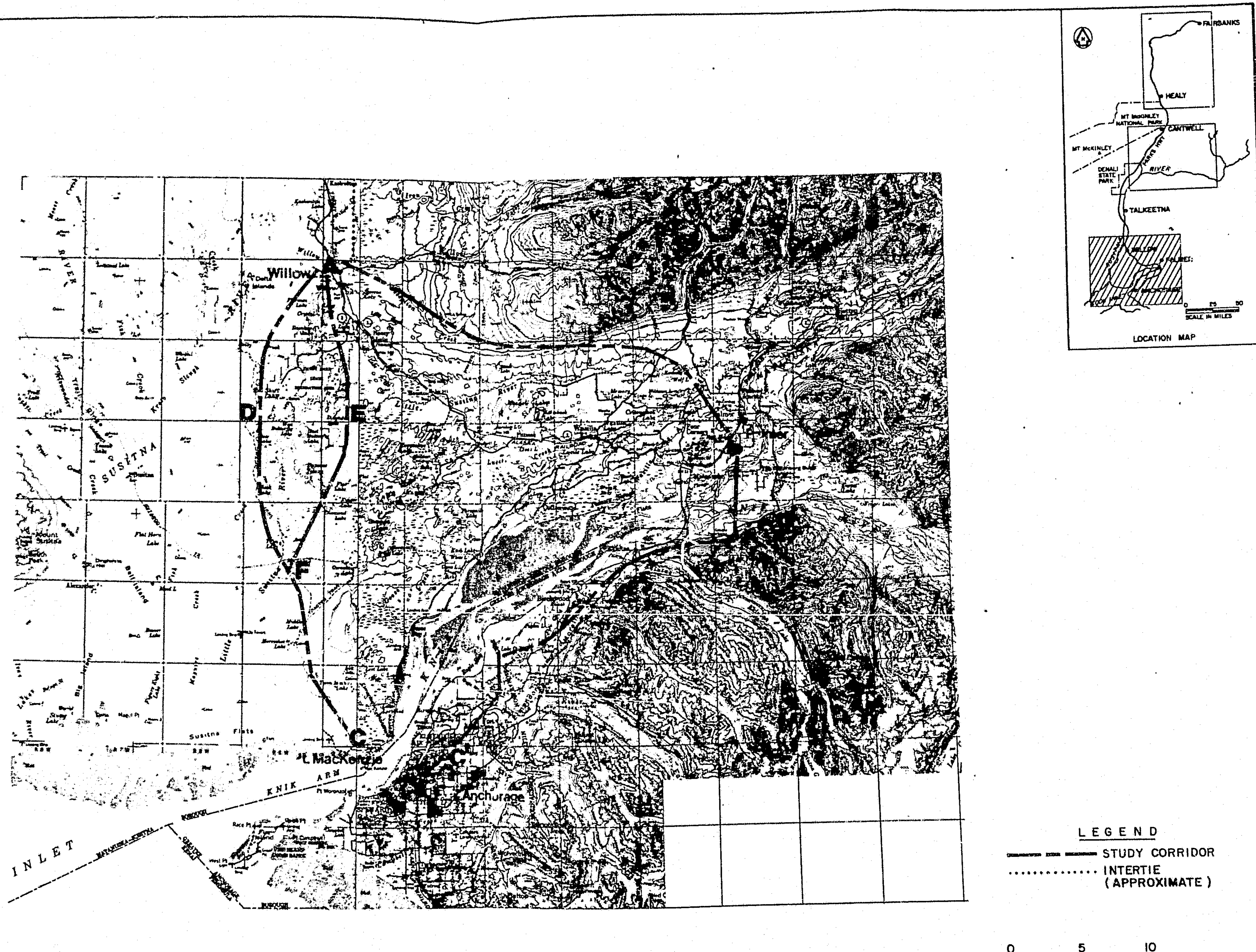
NOTES:

[hatched bar] ACTIVITY START COULD BE DELAYED AND DIVERSION STILL MET.

(1) LATEST START DATE OF CONSTRUCTION ACTIVITY.

FIGURE B.46

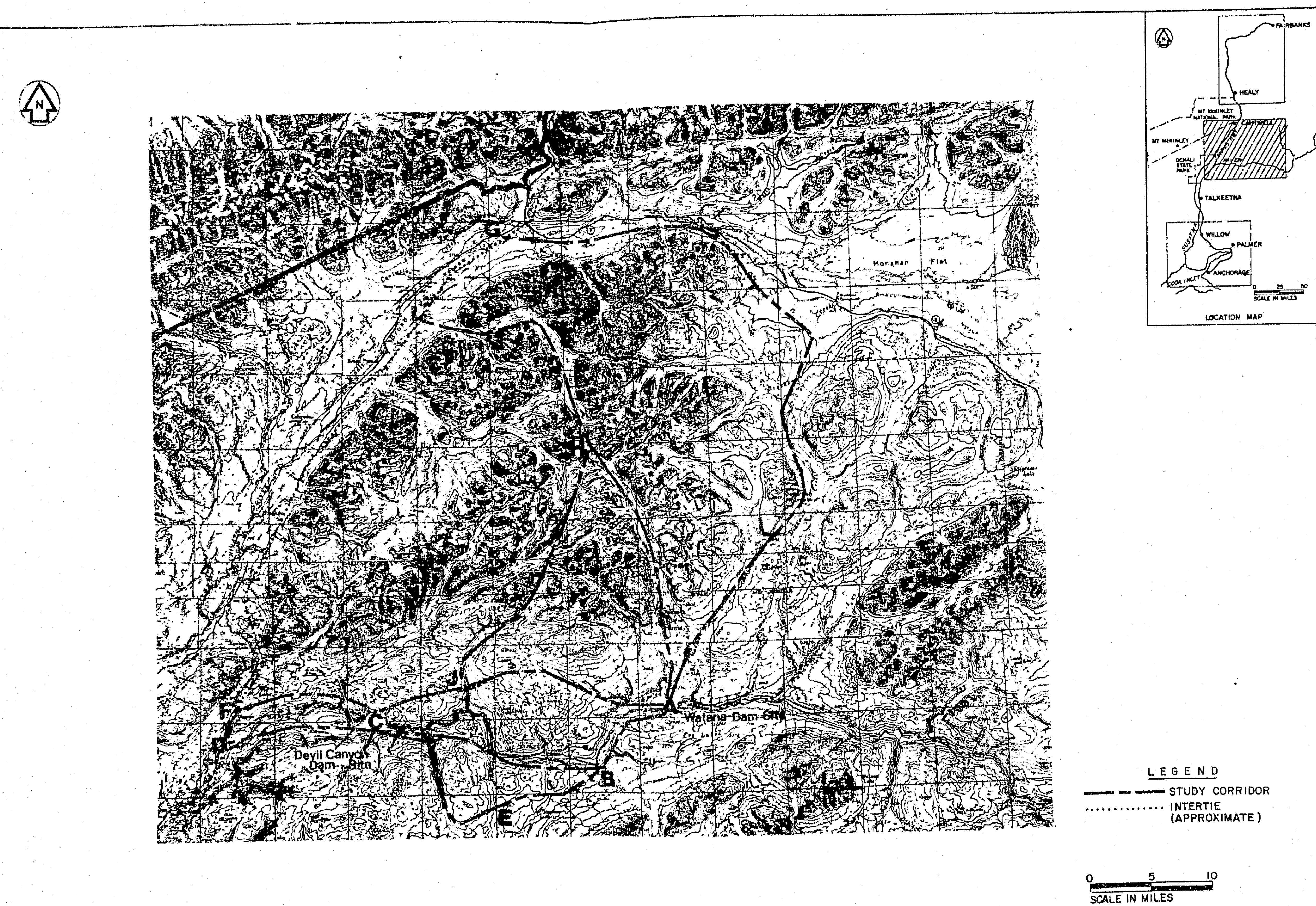
ACRES



ALTERNATIVE TRANSMISSION LINE CORRIDORS
SOUTHERN STUDY AREA

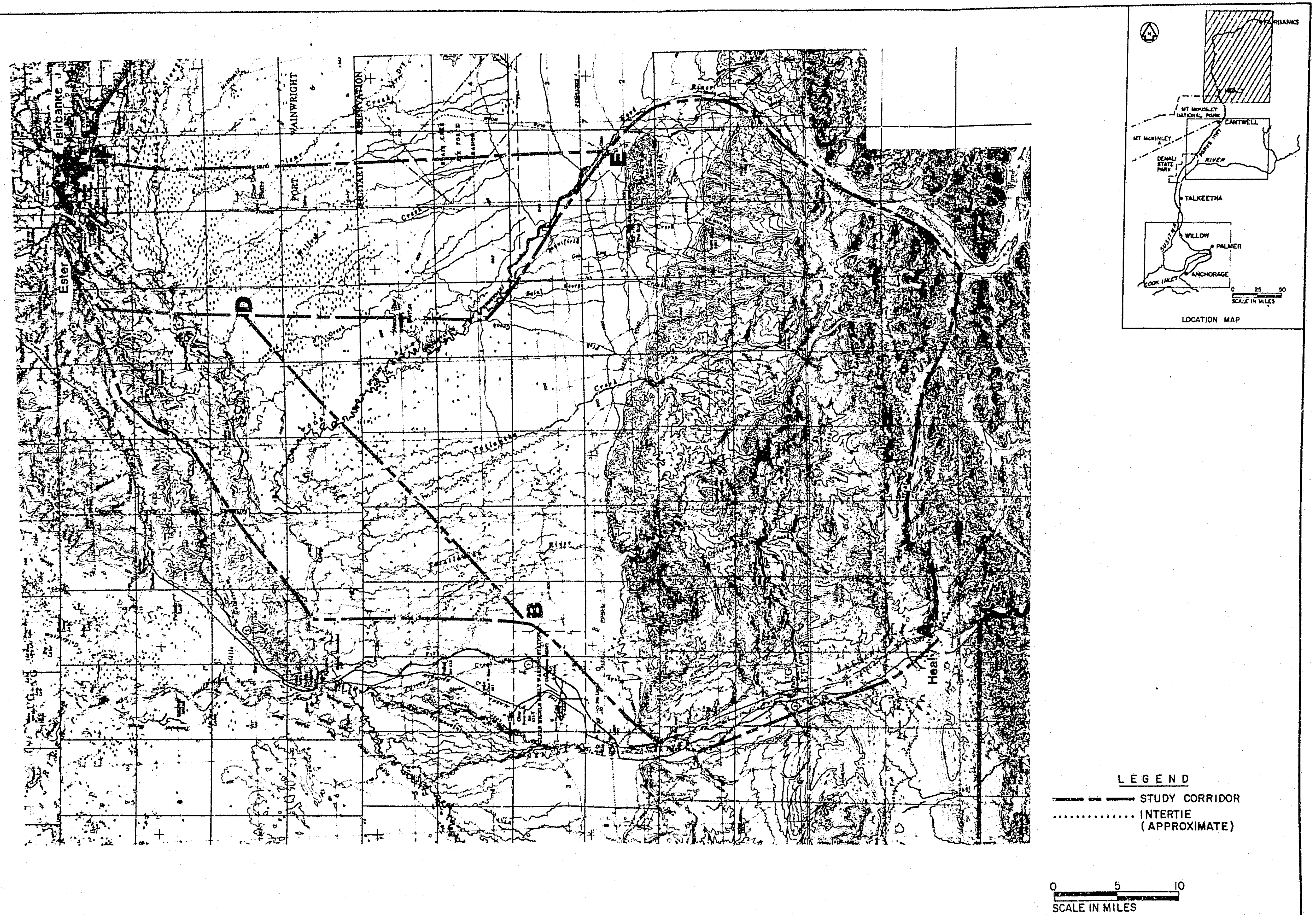
FIGURE B.47

ACRES



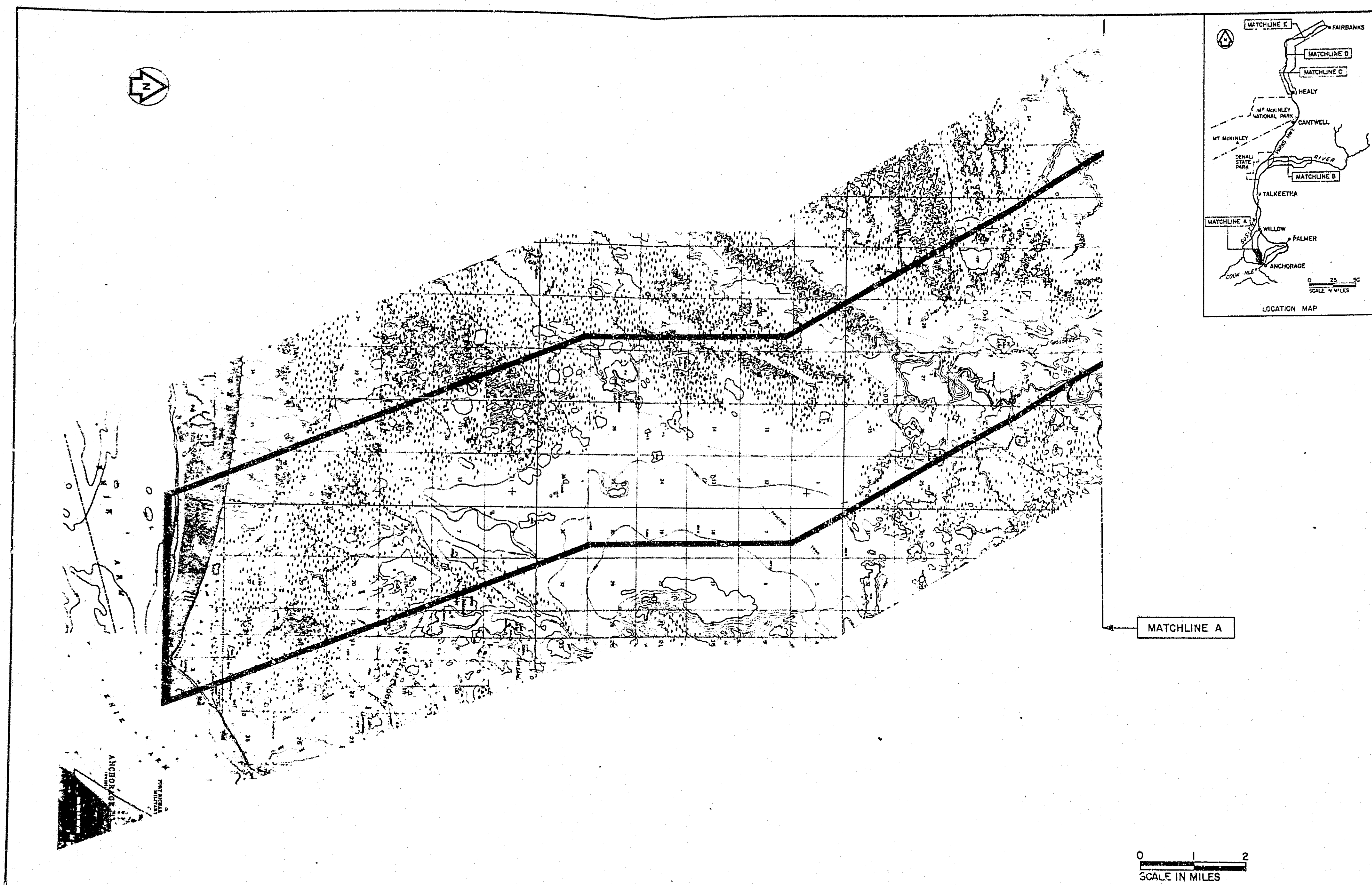
ALTERNATIVE TRANSMISSION LINE CORRIDORS
CENTRAL STUDY AREA

FIGURE B.48



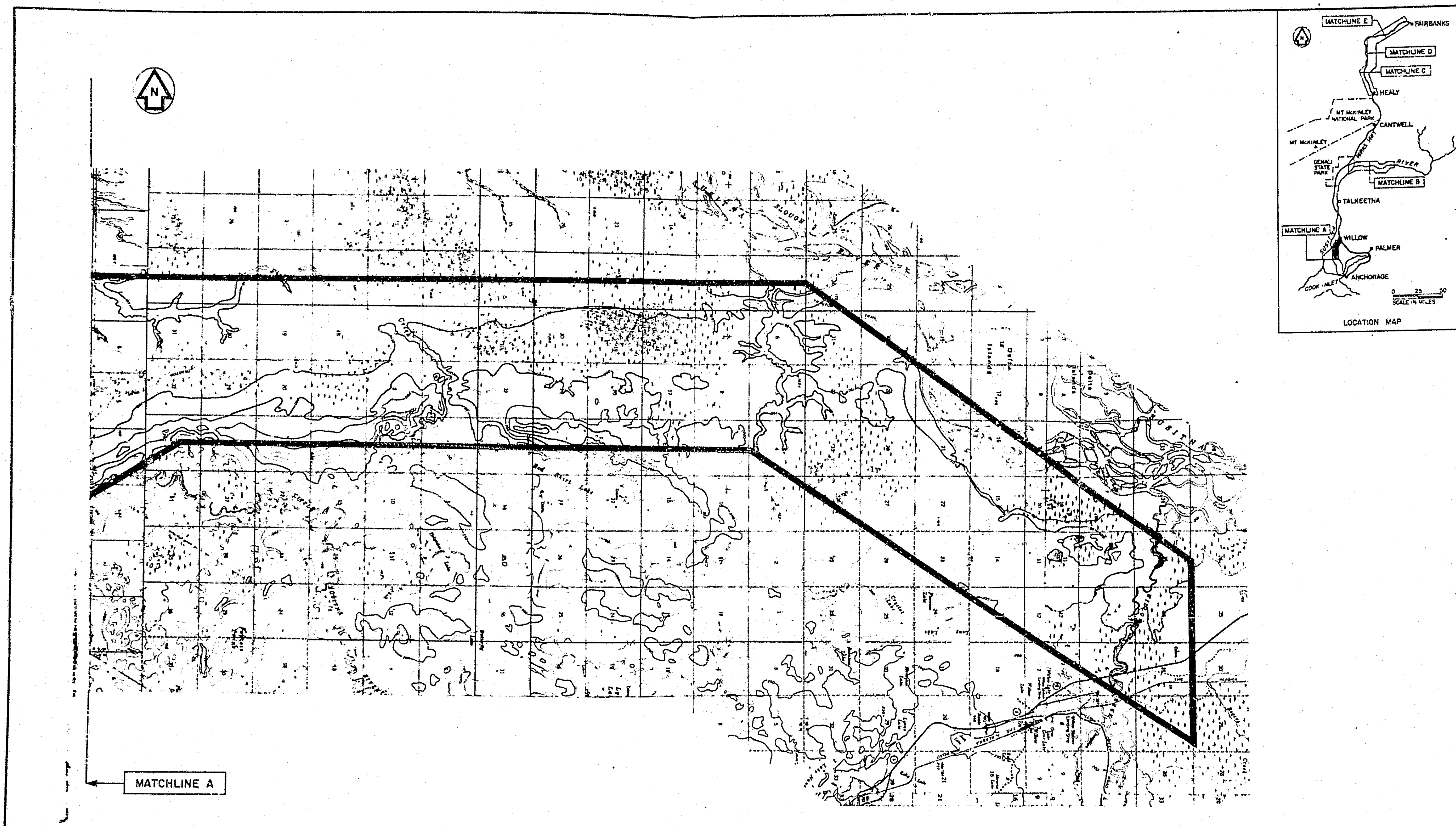
ALTERNATIVE TRANSMISSION LINE CORRIDORS
NORTHERN STUDY AREA

FIGURE B.49



RECOMMENDED TRANSMISSION CORRIDOR
SOUTHERN STUDY AREA

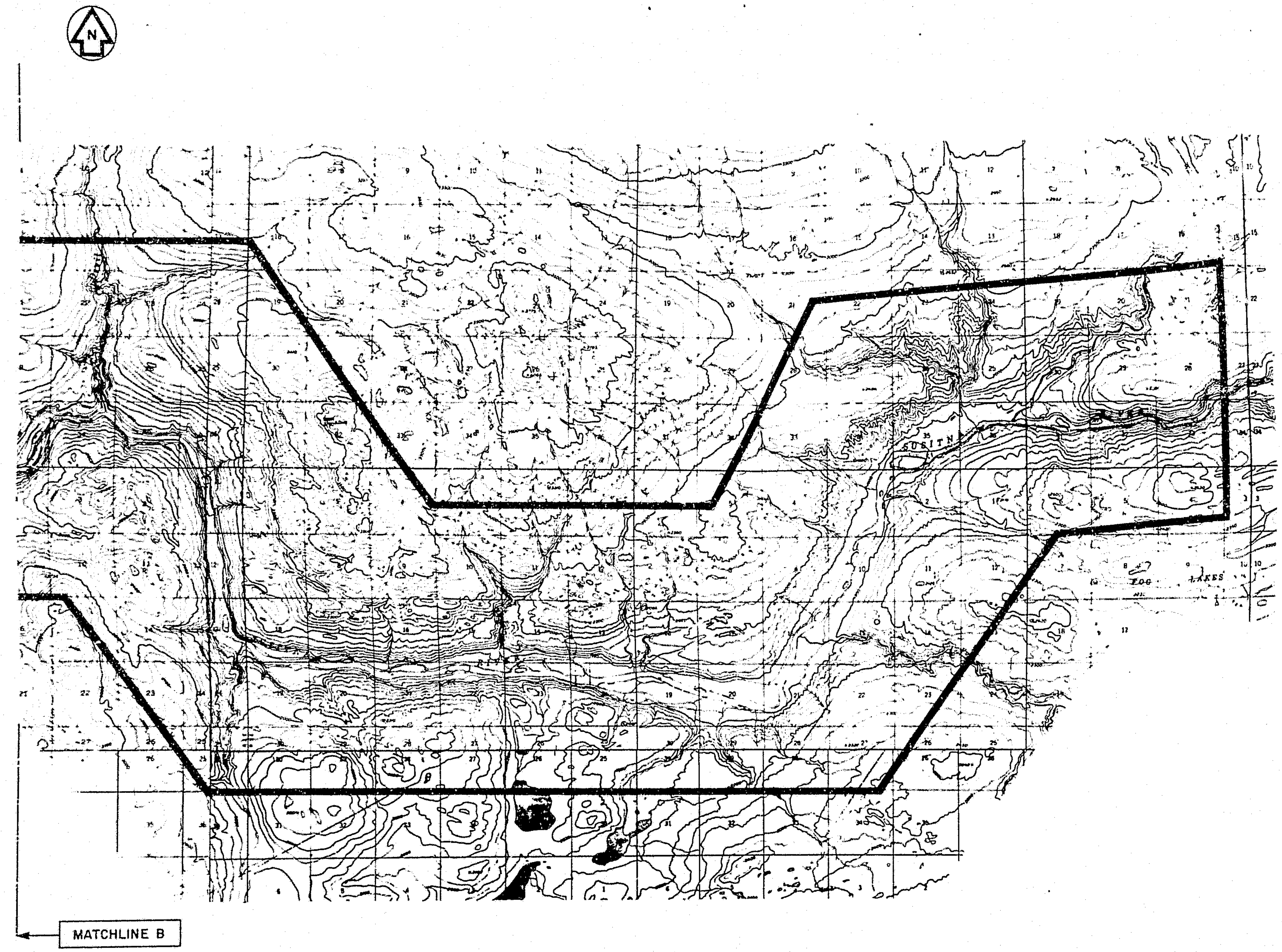
FIGURE B.50

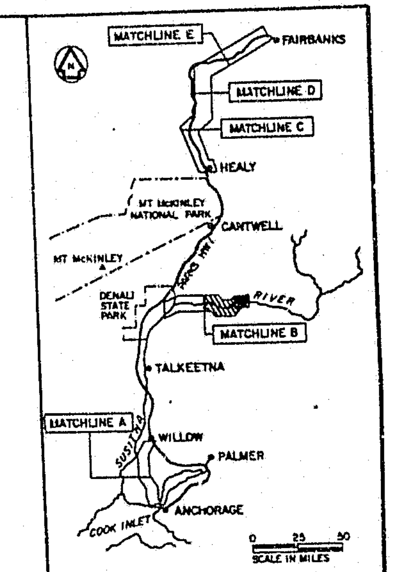


RECOMMENDED TRANSMISSION CORRIDOR
SOUTHERN STUDY AREA

FIGURE B.51

ACRES





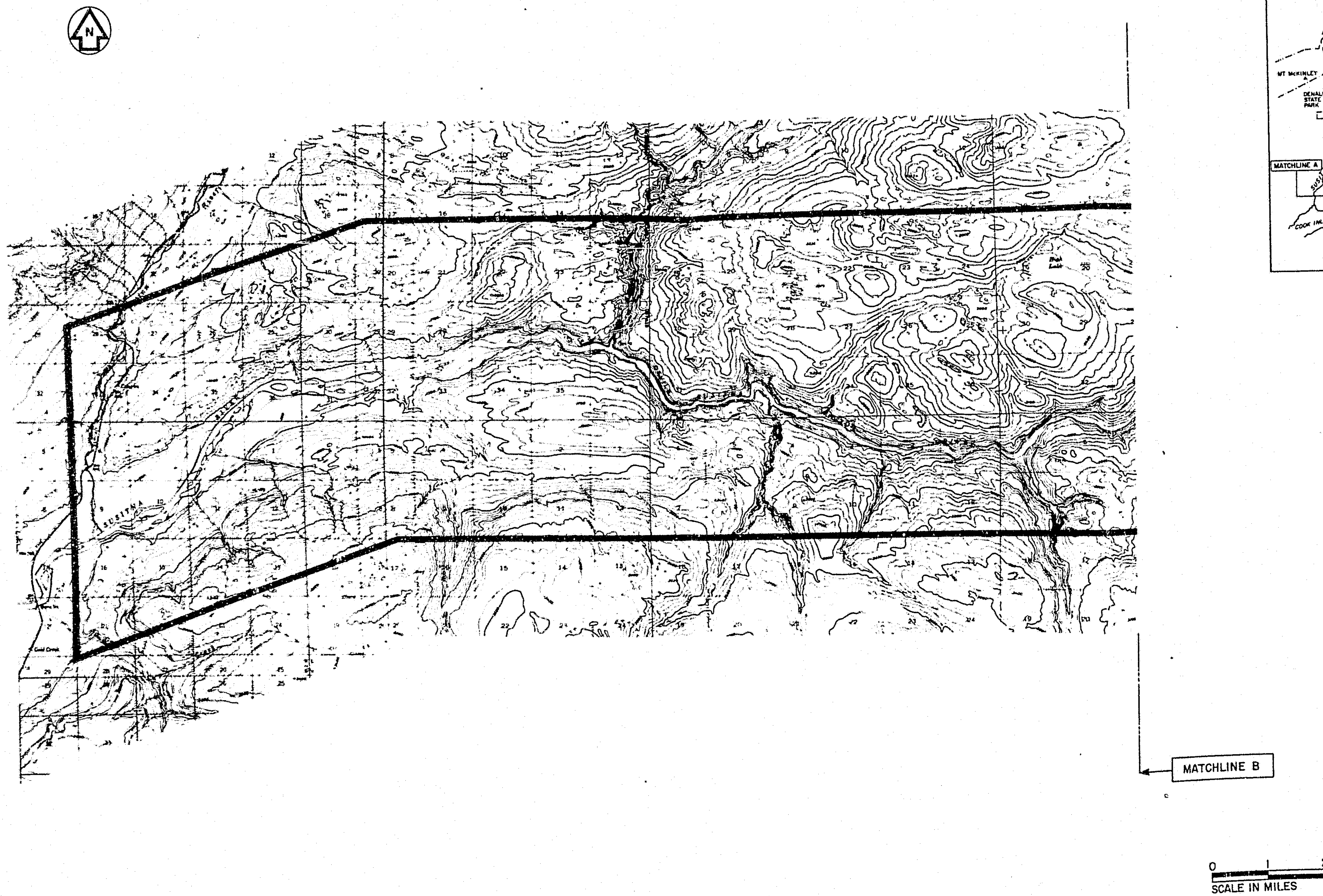
LOCATION MAP

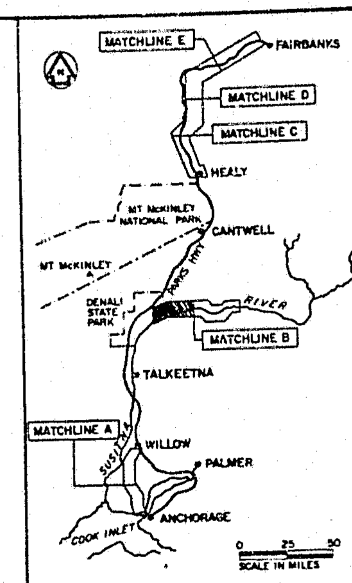
0 1 2
SCALE IN MILES

RECOMMENDED TRANSMISSION CORRIDOR
CENTRAL STUDY AREA

FIGURE B.52

ACRES

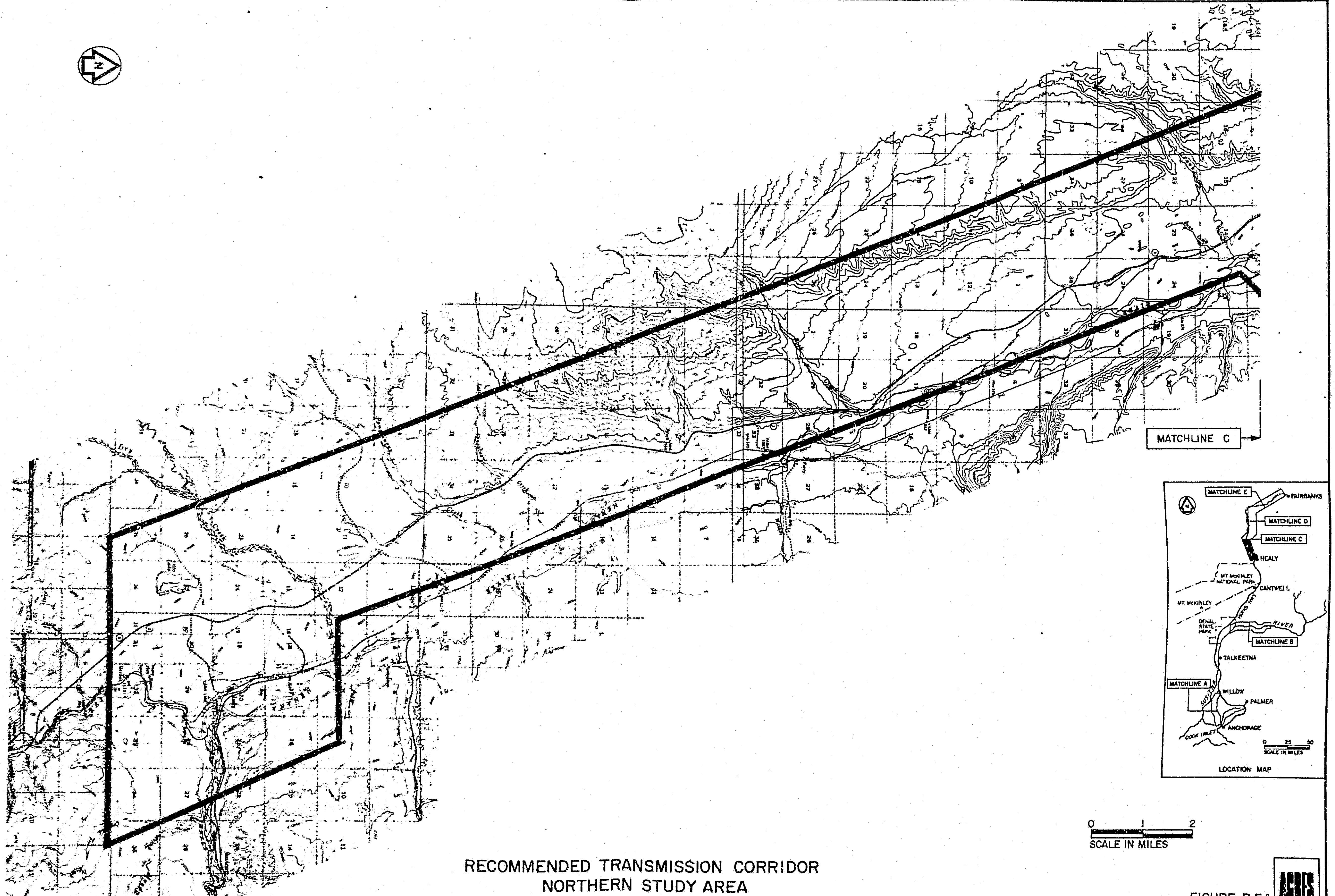




LOCATION MAP

RECOMMENDED TRANSMISSION CORRIDOR
CENTRAL STUDY AREA

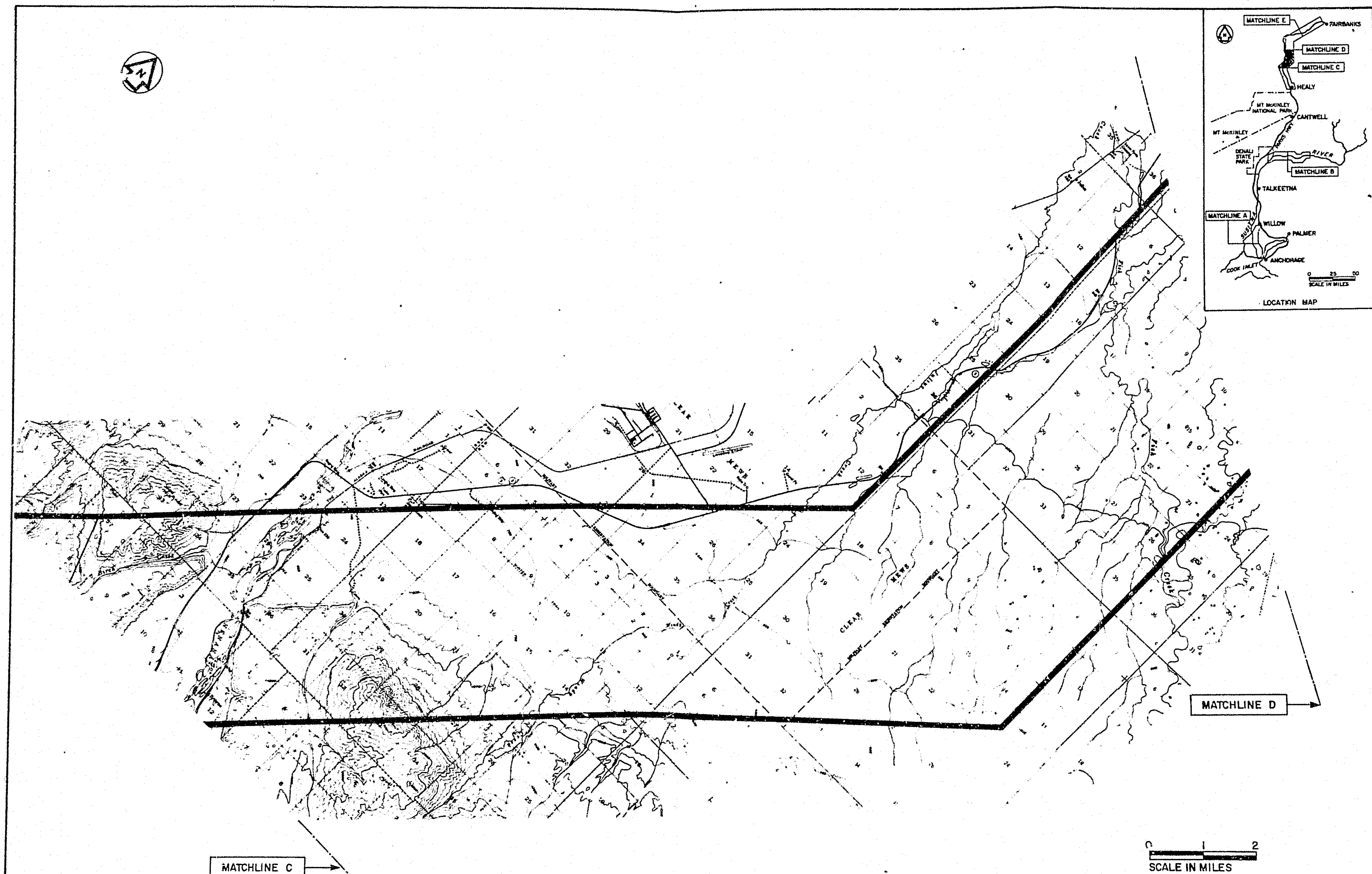
FIGURE B.53



RECOMMENDED TRANSMISSION CORRIDOR
NORTHERN STUDY AREA

FIGURE B.54

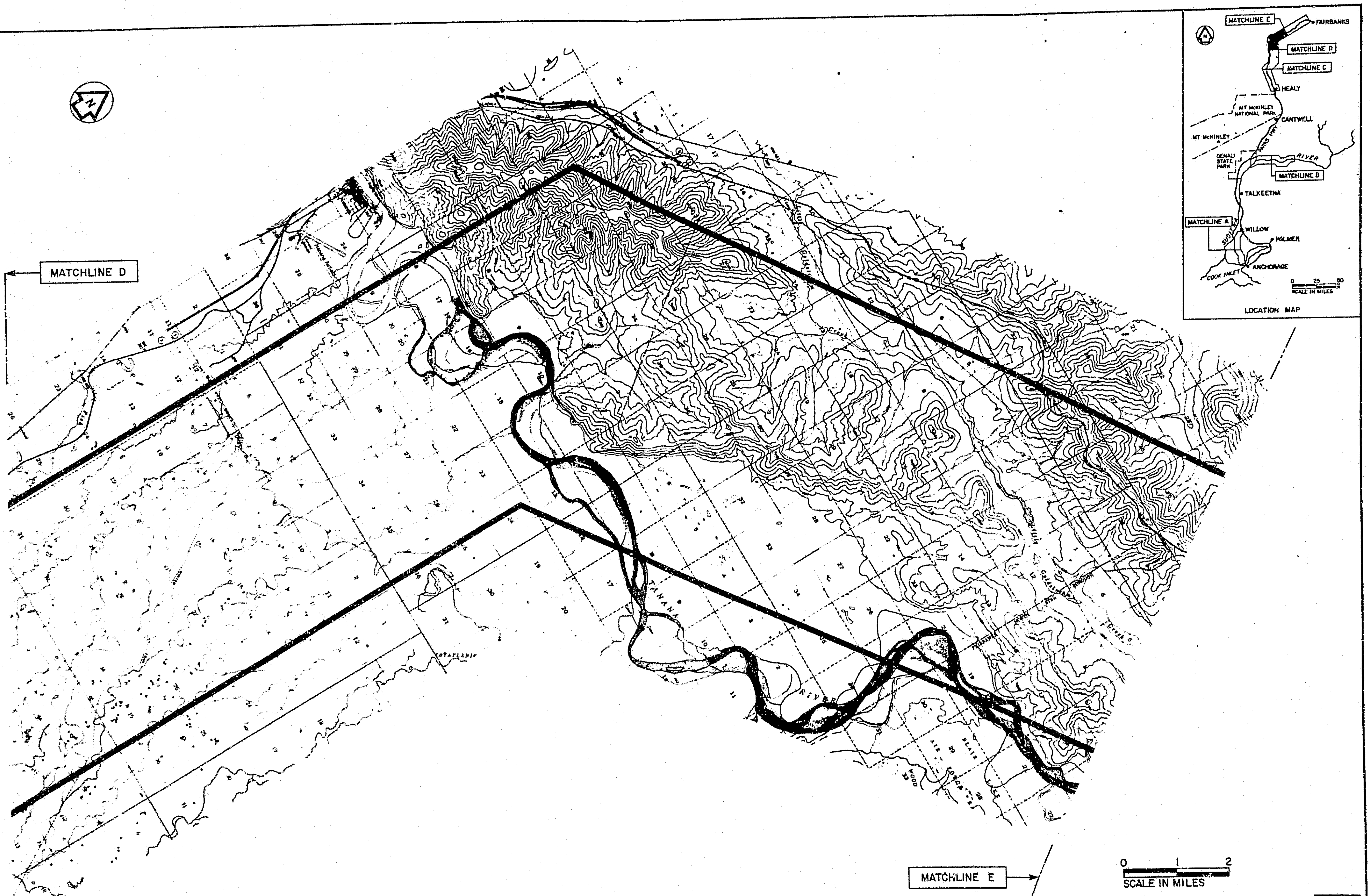
ACRES



RECOMMENDED TRANSMISSION CORRIDOR
NORTHERN STUDY AREA

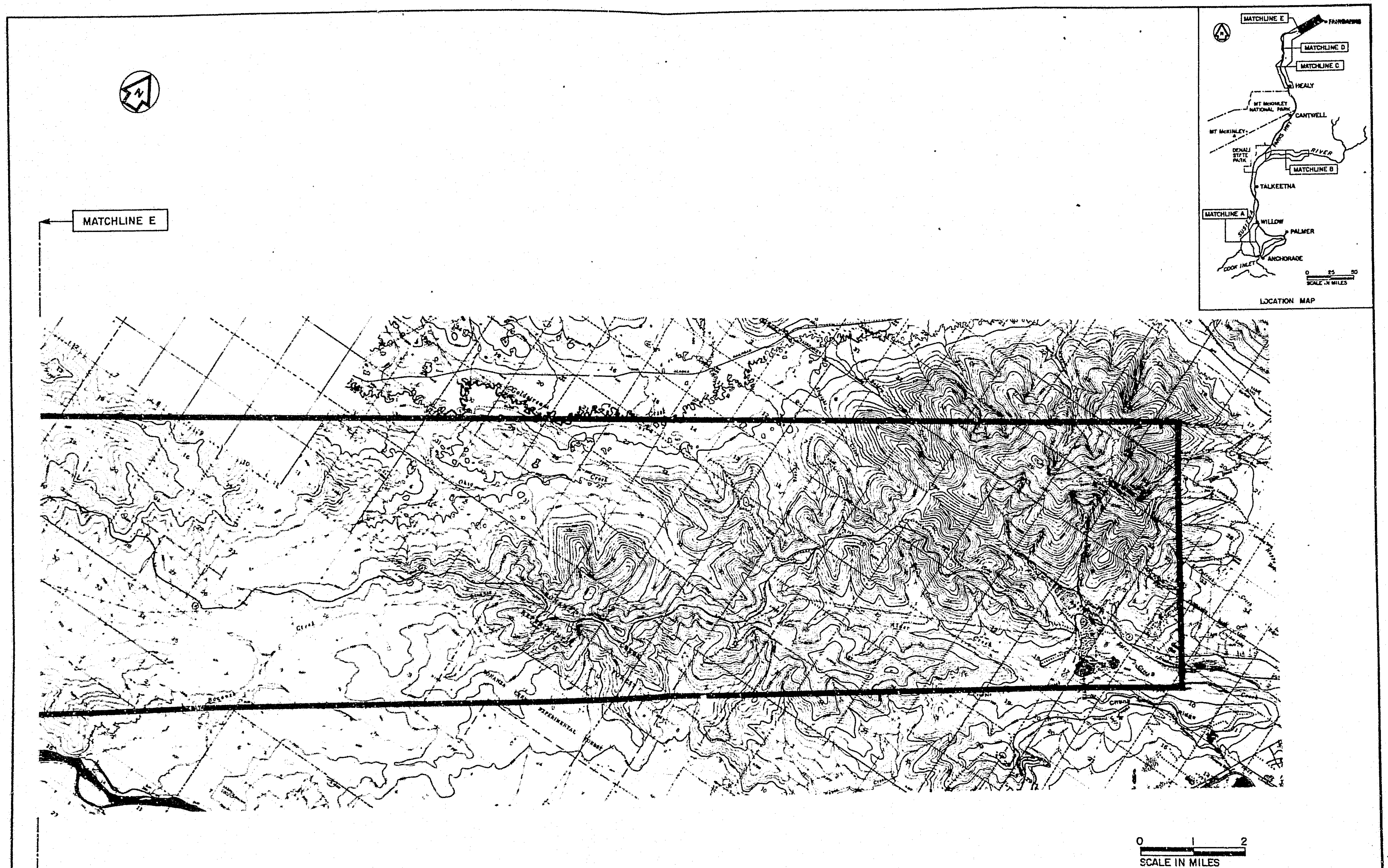
FIGURE B.55

ACRES



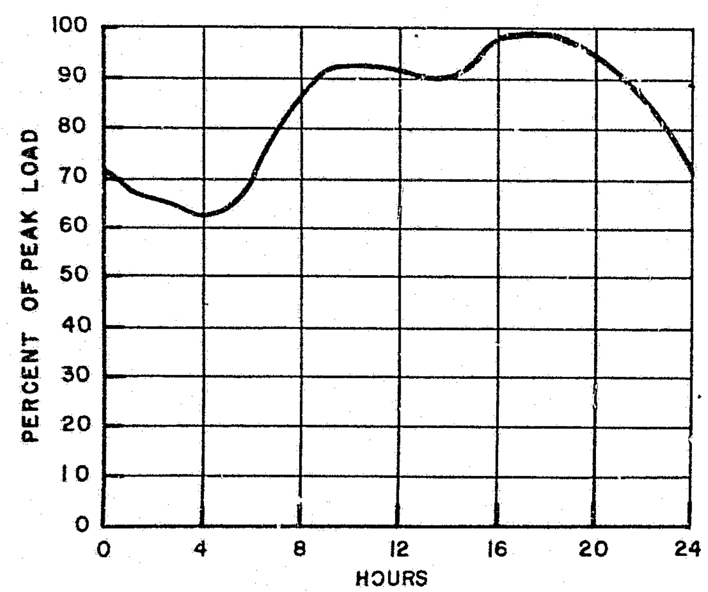
RECOMMENDED TRANSMISSION CORRIDOR
NORTHERN STUDY AREA

FIGURE B.56



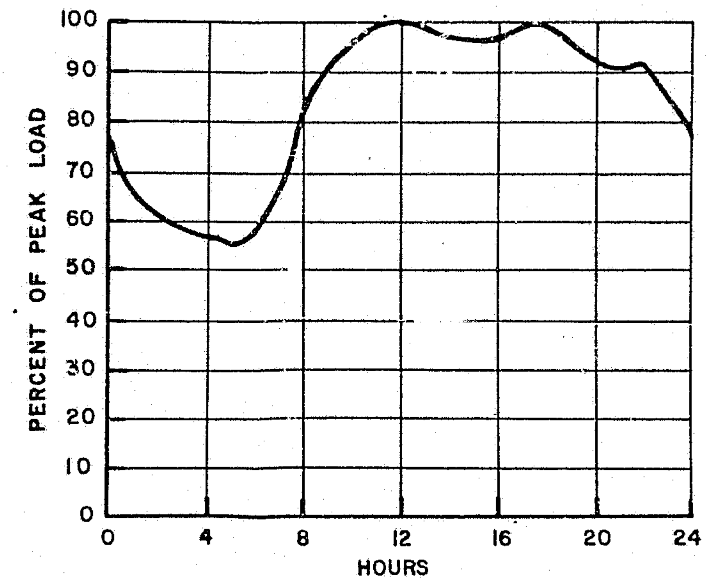
RECOMMENDED TRANSMISSION CORRIDOR
NORTHERN STUDY AREA

FIGURE B.57



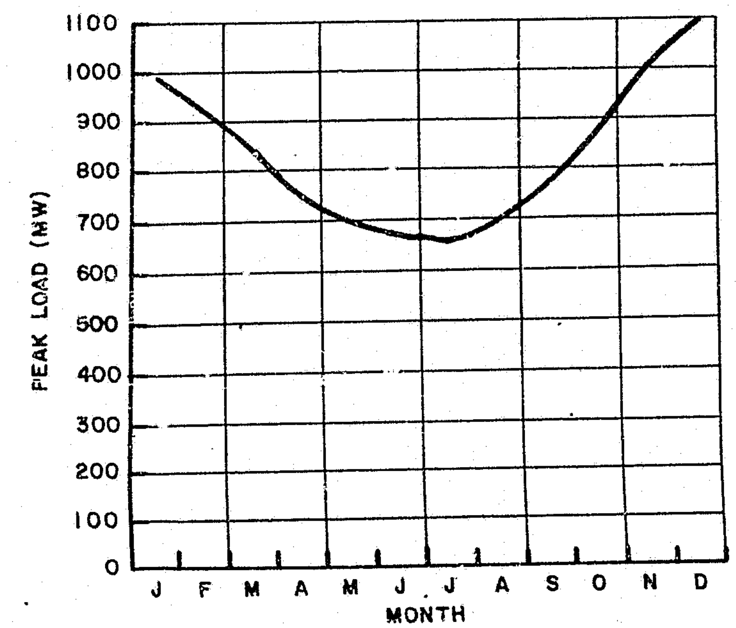
WINTER WEEKDAY
HOURLY LOAD VARIATION

NOTE: PEAK MW DECEMBER 2000 AD = 1084 MW



SUMMER WEEKDAY
HOURLY LOAD VARIATION

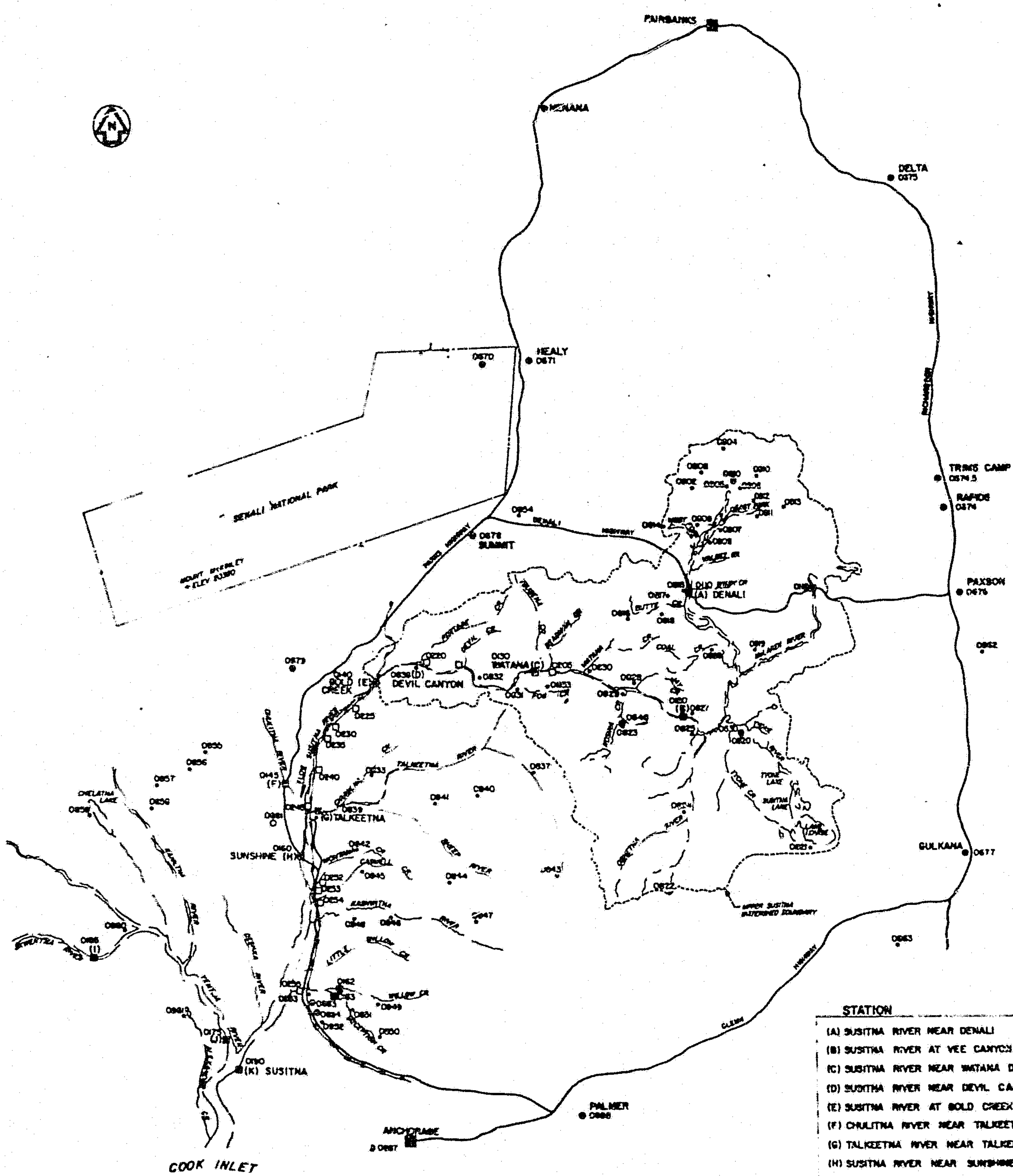
NOTE: PEAK MW JULY 2000 AD = 658 MW



LOAD VARIATION
IN YEAR 2000

TYPICAL LOAD VARIATION
IN ALASKA RAILBELT SYSTEM

FIGURE B.58



DATA COLLECTION STATIONS
USED IN PMF STUDY

DATA COLLECTED

		INDEX NUMBERING
■	STREAMFLOW - CONTINUOUS RECORD	0100
□	STREAMFLOW - PARTIAL RECORD	0200
●	WATER QUALITY	0300
T	WATER TEMPERATURE	0400
★	SEDIMENT DISCHARGE	0500
⊖	CLIMATE	0600
⊢	FREEZING RAIN AND INCLOUD ICING	0700
•	SNOW COURSE	0800
^	SNOW CREEP	0900

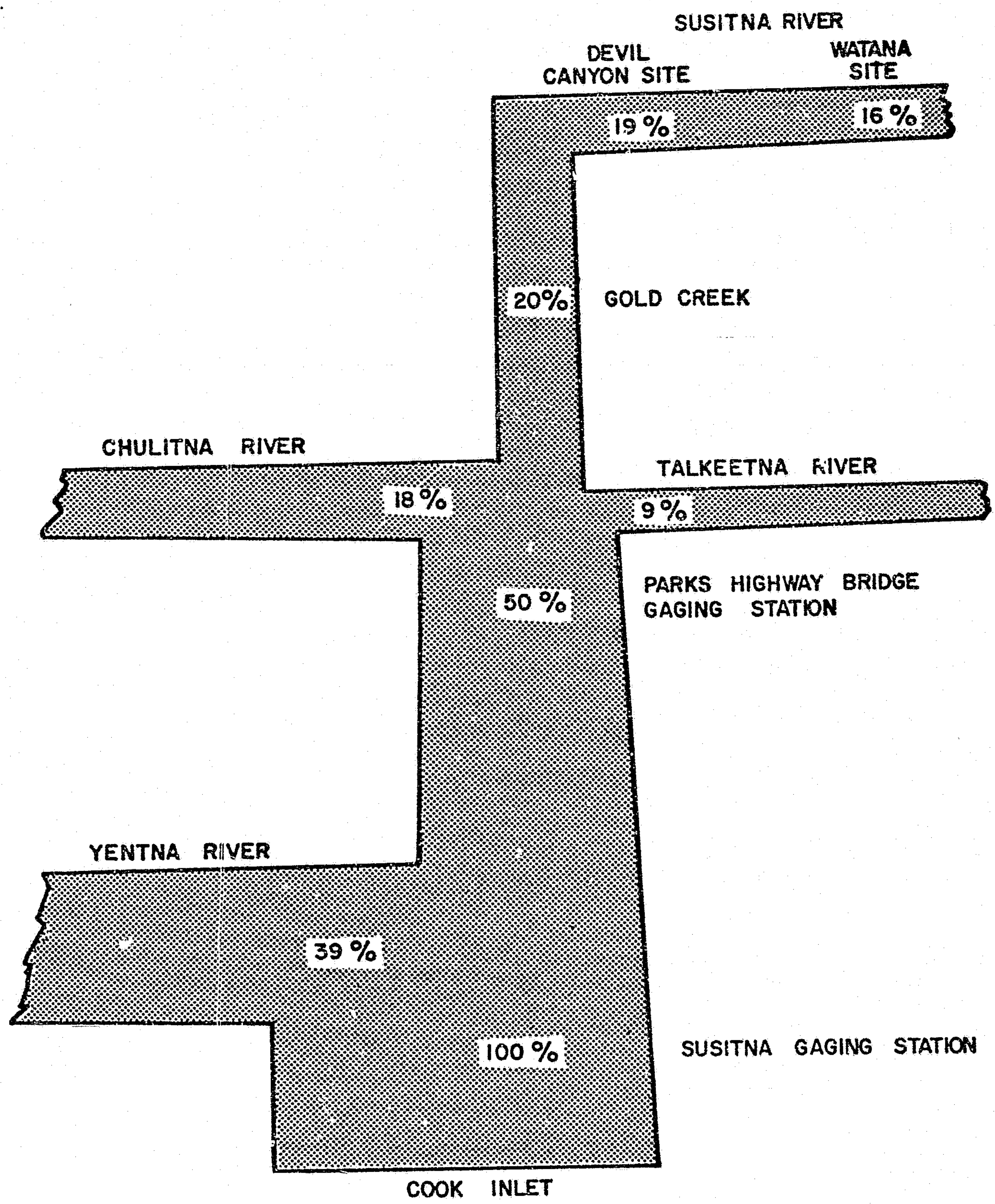
NOTES

1. PARAMETERS MEASURED LISTED IN APPENDIX B1
2. CONTINUOUS WATER QUALITY MONITOR INSTALLED
3. DATA COLLECTION 1981 SEASON
4. THE LETTER BEFORE EACH STATION NAME IN THE TABLE IS USED ON THE MAP TO MARK THE APPROXIMATE LOCATION OF THE STATIONS.

STATION	STREAMFLOW GAGING	CREST STAGE GAGE	STAFF GAGE	WATER QUALITY (1)	WATER TEMPERATURE	SEDIMENT DISCHARGE	BEDLOAD SAMPLING (3)	CLIMATE	IN-CLOUD ICING	FREEZING RAIN	SNOW CREEP	PERIOD OF RECORD OF STREAMFLOW
(A) SUSITNA RIVER NEAR DENALI	X		X		X	X		X	X	X		1957 – PRESENT
(B) SUSITNA RIVER AT VEE CANYON	X		X	X	X	X						1961 – 1972 & 1980 – PRESENT
(C) SUSITNA RIVER NEAR WATANA DAMSITE	X	X		X[2]	X			X	X	X	X	1980 – PRESENT
(D) SUSITNA RIVER NEAR DEVIL CANYON		X	X					X			X	
(E) SUSITNA RIVER AT GOLD CREEK	X			X	X	X	X					1949 – PRESENT
(F) CHULITNA RIVER NEAR TALKEETNA	X				X	X	X					1958 – 1972 & 1980 – PRESENT
(G) TALKEETNA RIVER NEAR TALKEETNA	X			X	X	X	X					1964 – PRESENT
(H) SUSITNA RIVER NEAR SUNSHINE	X				X	X	X					1981 – PRESENT
(I) SKWENTNA RIVER NEAR SKWENTNA	X			X	X	X		X				1959 – 1980
(J) YENTNA RIVER NEAR SUSITNA STATION	X				X	X						1980 – PRESENT
(K) SUSITNA RIVER AT SUSITNA STATION	X			X	X	X						1974 – PRESENT

SCALE 0 10 20 MILES (APPROX.)

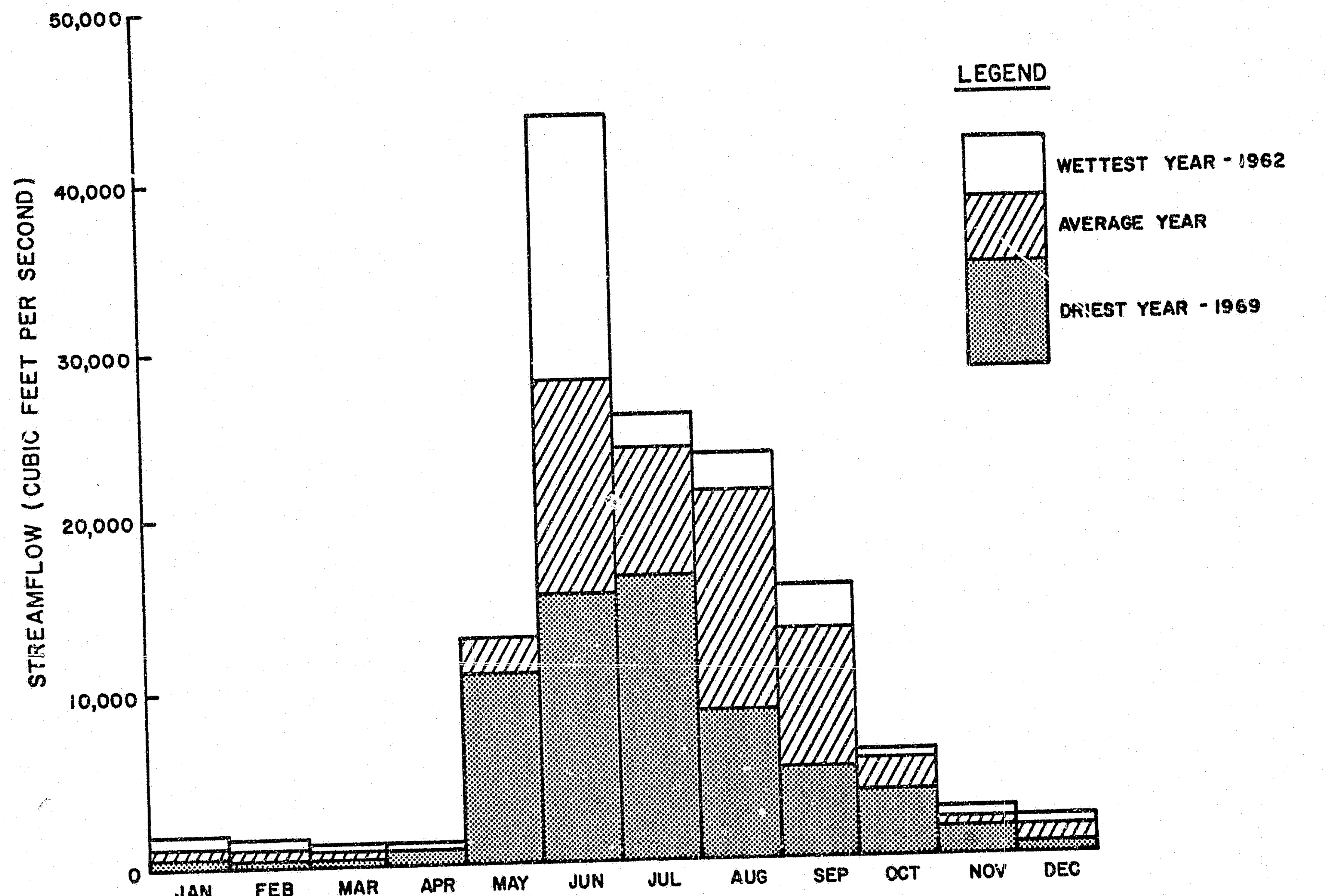
FIGURE B.59



AVERAGE ANNUAL FLOW DISTRIBUTION WITHIN THE SUSITNA RIVER BASIN

ACRES

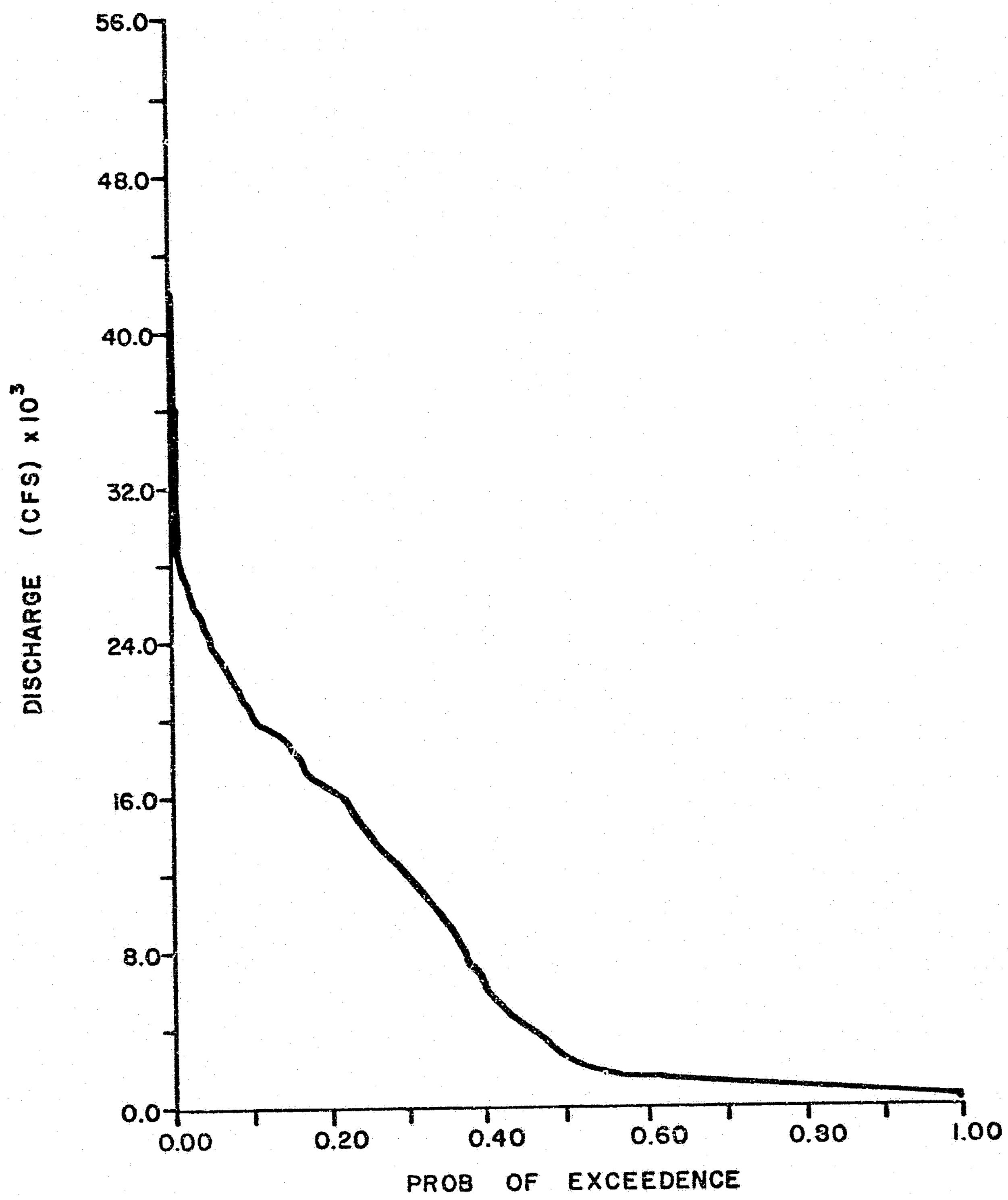
FIGURE B.60



MONTHLY AVERAGE FLOWS IN
THE SUSITNA RIVER AT GOLD CREEK

FIGURE B.61

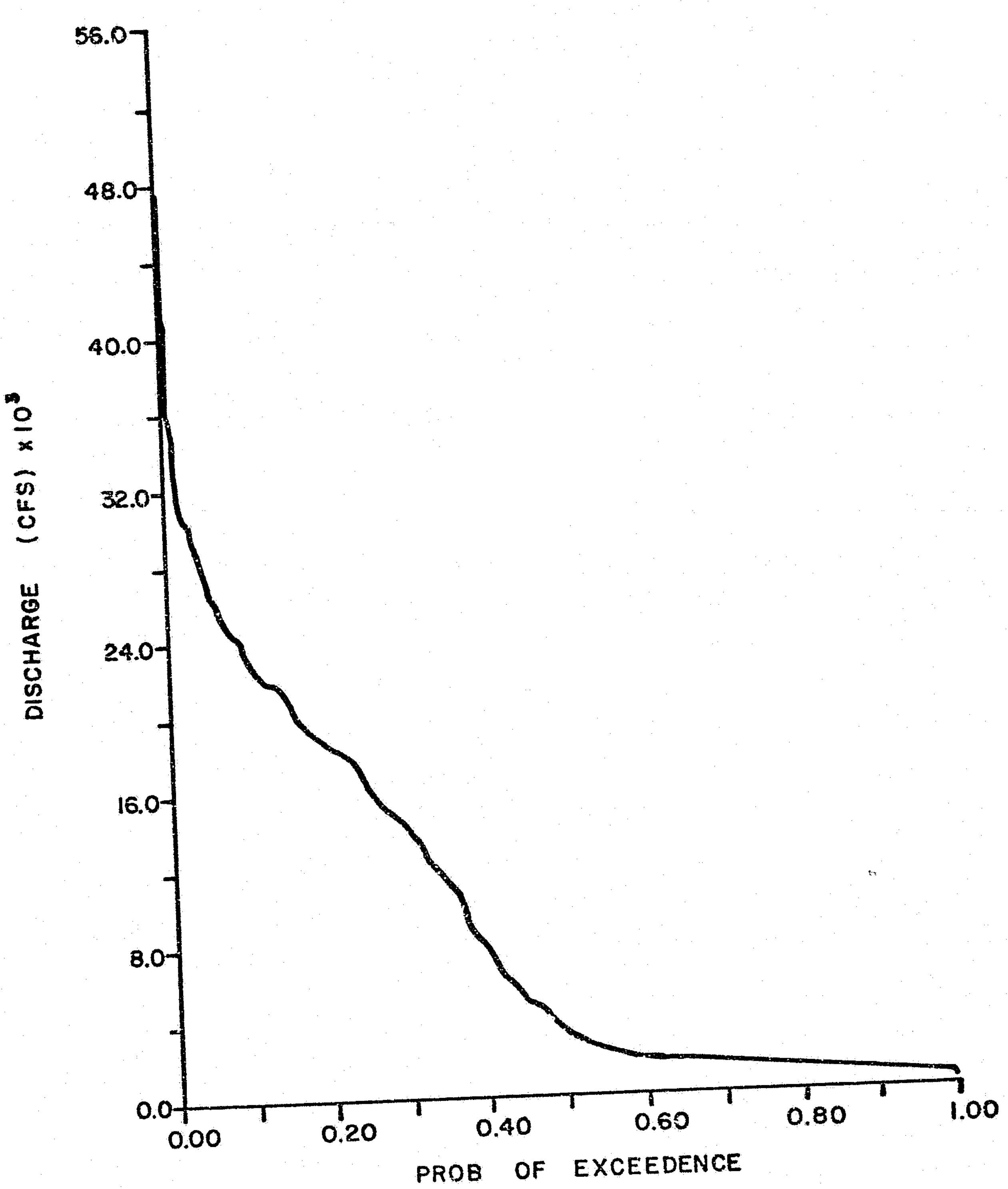
ACRES



FLOW DURATION CURVE
MEAN MONTHLY INFLOW
AT WATANA
PRE-PROJECT

ACRES

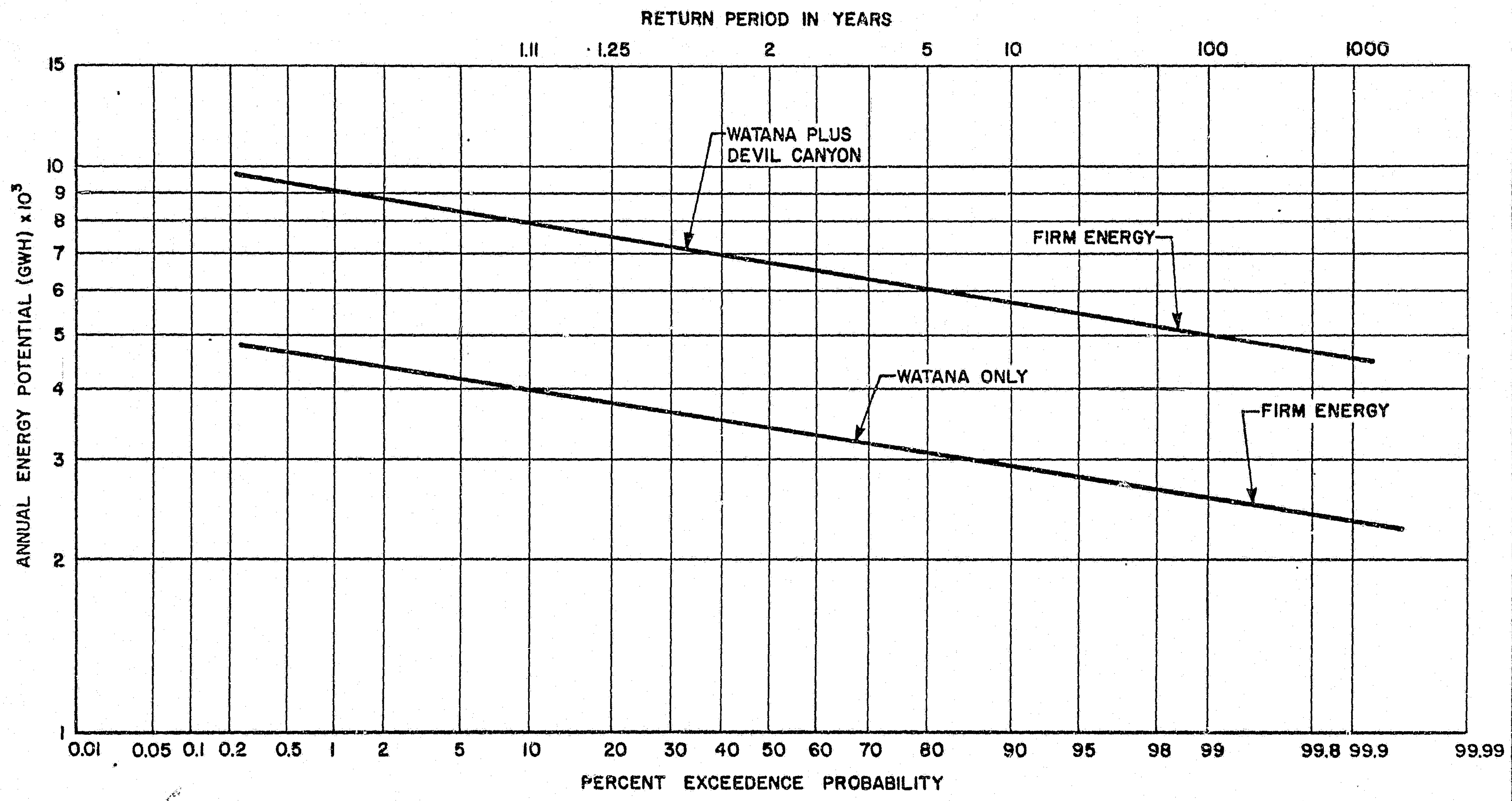
FIGURE B.62



FLOW DURATION CURVE
MEAN MONTHLY INFLOW
AT DEVIL CANYON
PRE-PROJECT

ACRES

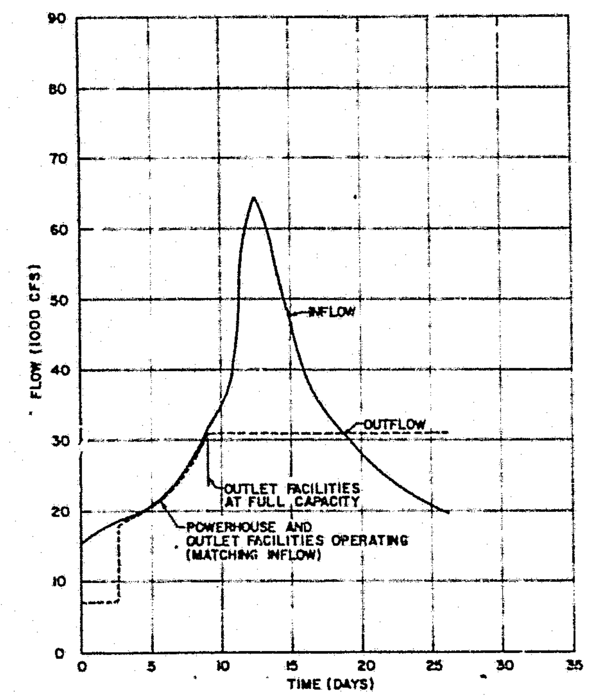
FIGURE B.63



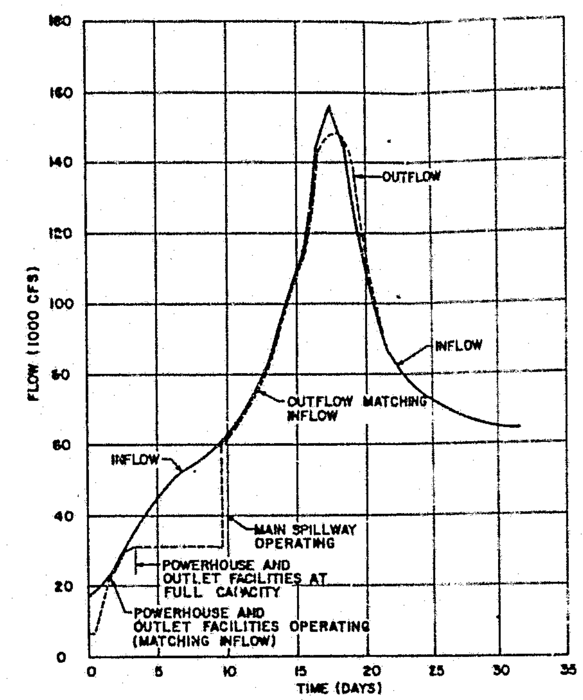
FREQUENCY ANALYSIS OF
AVERAGE ANNUAL ENERGY FOR SUSITNA DEVELOPMENTS

ACRES

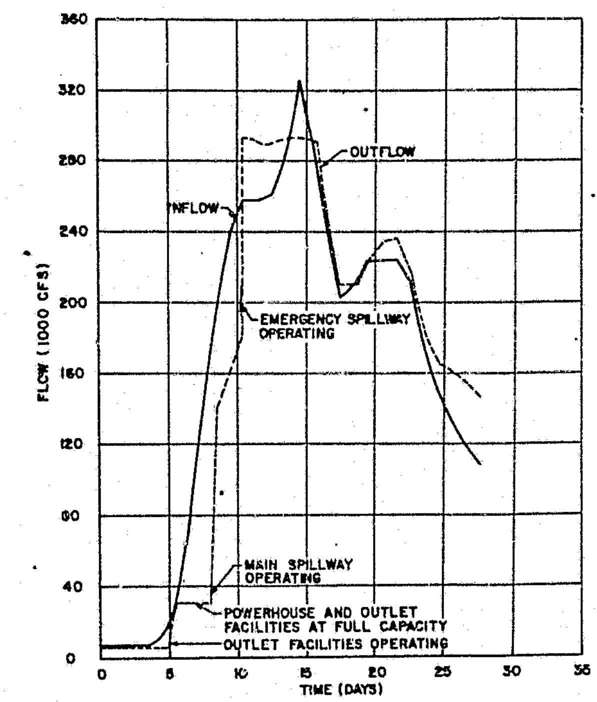
FIGURE B.64



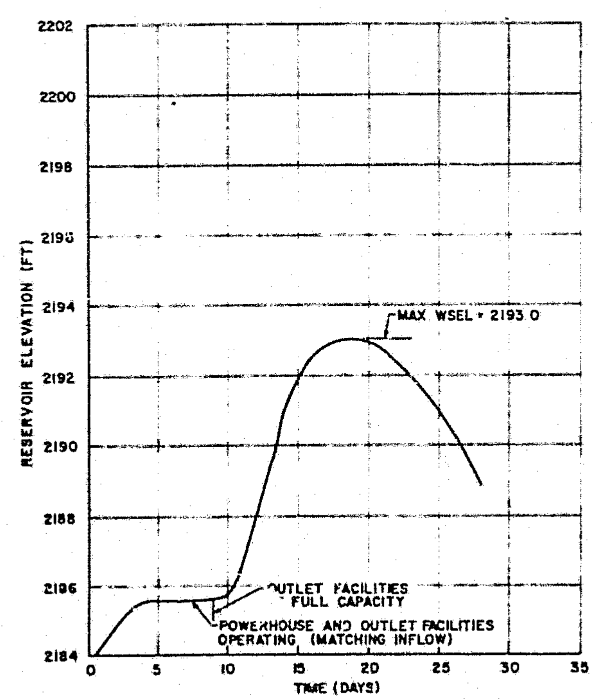
1:50 YEAR FLOOD
(SUMMER)



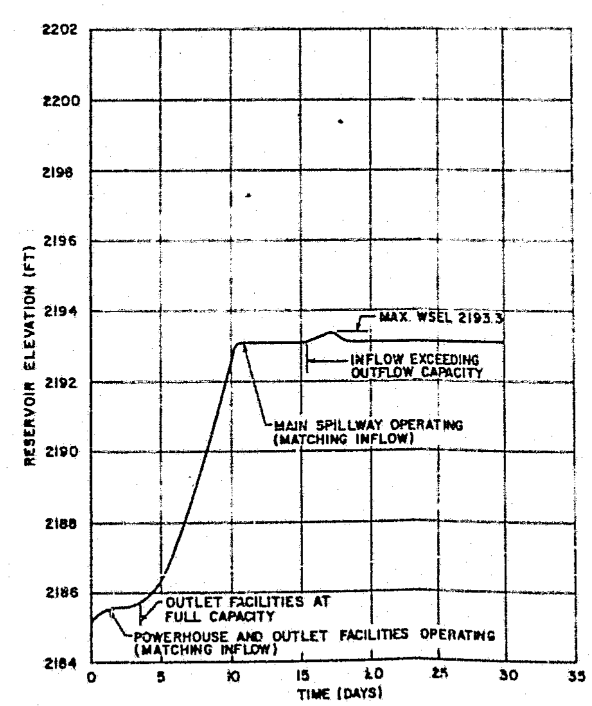
1:10,000 YEAR FLOOD



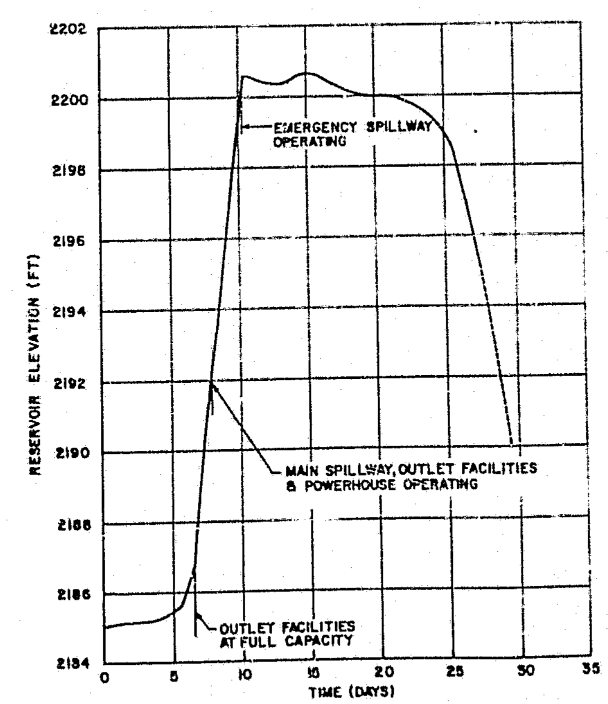
PROBABLE MAXIMUM FLOOD



1:50 YEAR FLOOD
(SUMMER)



1:10,000 YEAR FLOOD



PROBABLE MAXIMUM FLOOD

FIGURE B.65

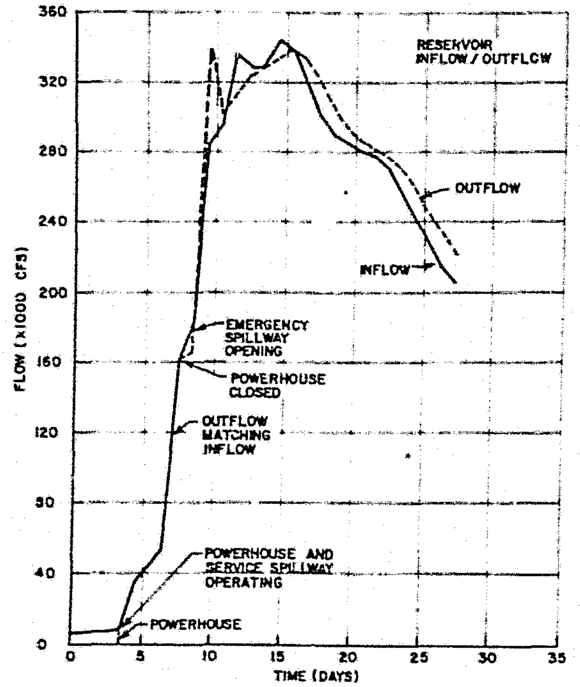
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

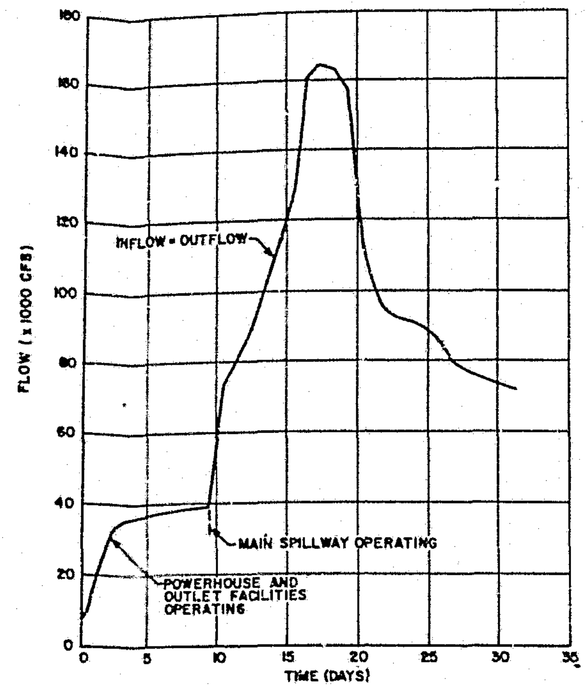
WATANA
HYDROLOGICAL DATA
SHEET 2

ACRES AMERICAN INCORPORATED

MARCH 1982

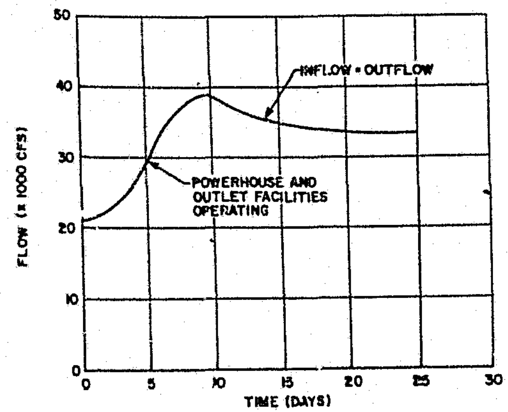


PROBABLE MAXIMUM FLOOD



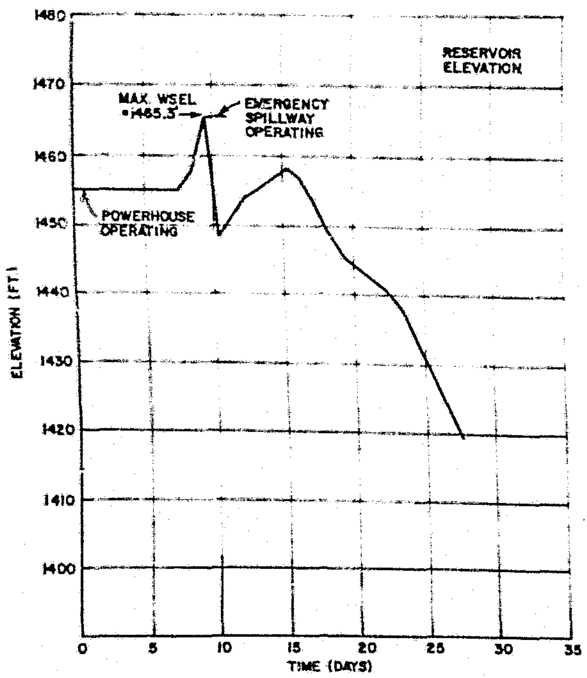
RESERVOIR ROUTING

1:10,000 YR. FLOOD

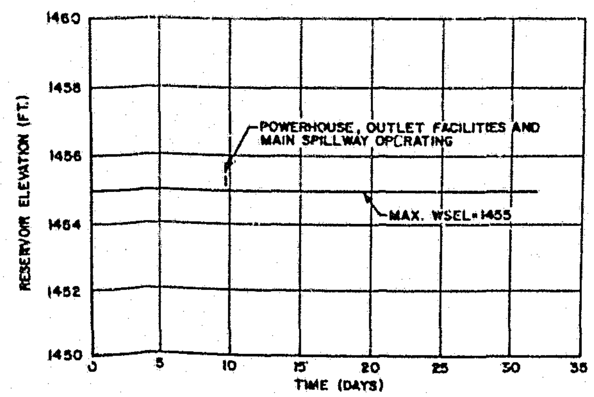


RESERVOIR ROUTING

1:50 YR. SUMMER FLOOD

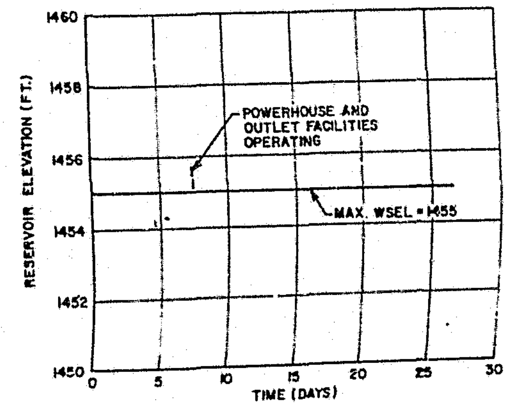


PROBABLE MAXIMUM FLOOD



RESERVOIR ROUTING

1:10,000 YR. FLOOD



RESERVOIR ROUTING

1:50 YR. SUMMER FLOOD

FIGURE B.66

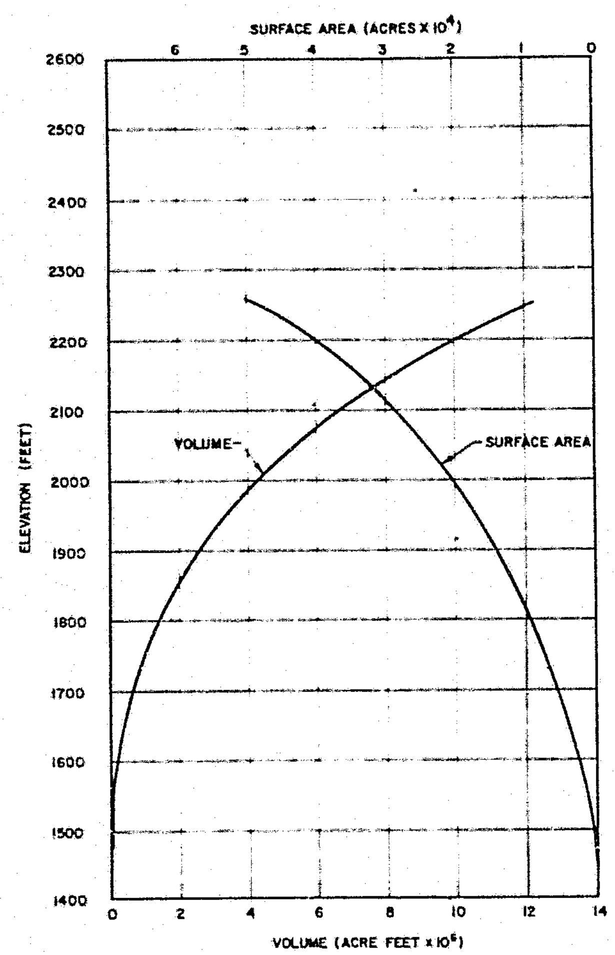
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

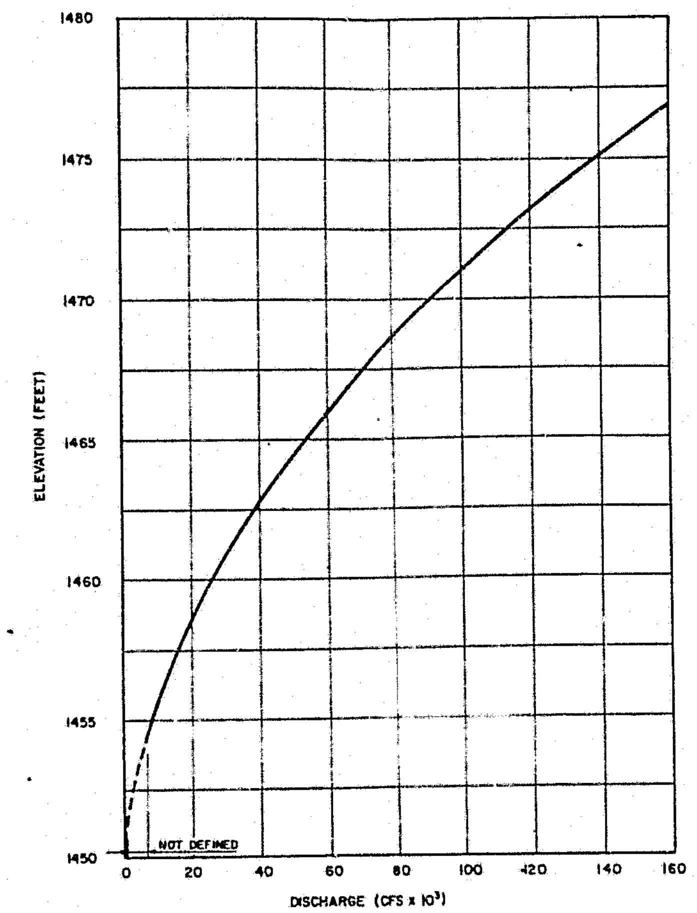
DEVIL CANYON HYDROLOGICAL DATA SHEET 2

ACRES AMERICAN INCORPORATED

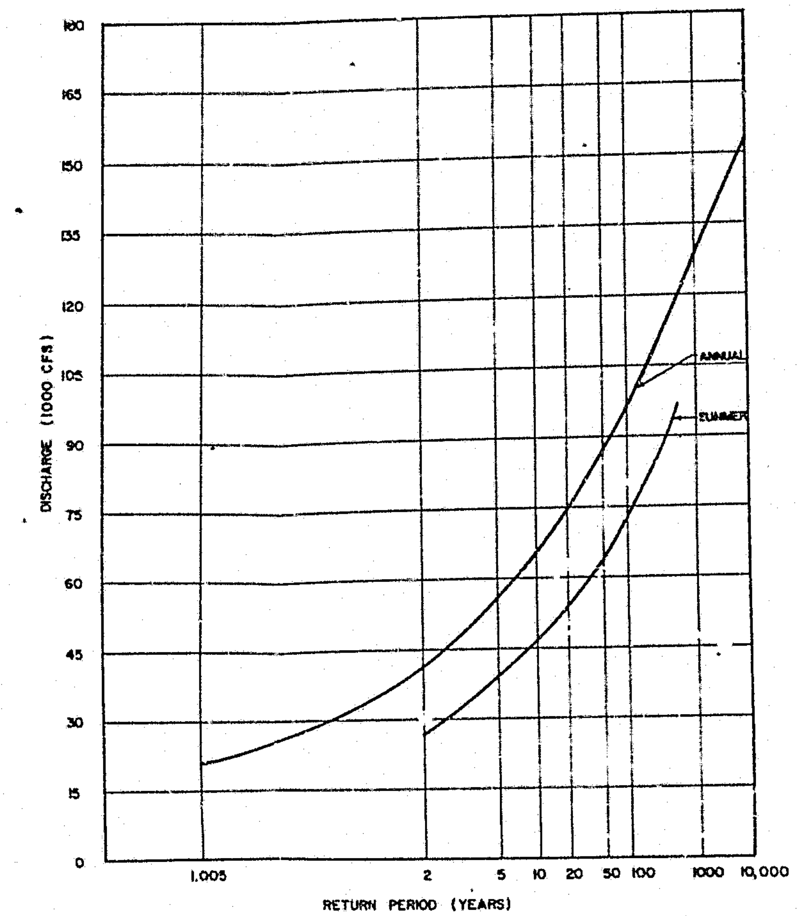
MARCH 1982



RESERVOIR VOLUME AND SURFACE AREA



TAILWATER RATING



INFLOW FLOOD FREQUENCY

FIGURE B.67

ALASKA POWER AUTHORITY

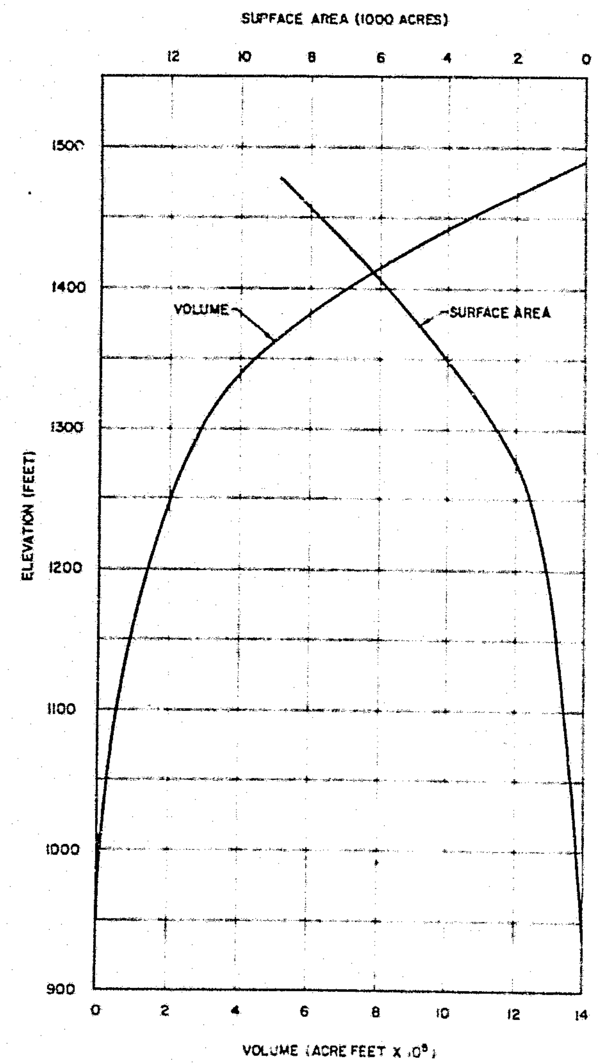
SUSITNA HYDROELECTRIC PROJECT

WATANA
HYDROLOGICAL DATA
SHEET 1

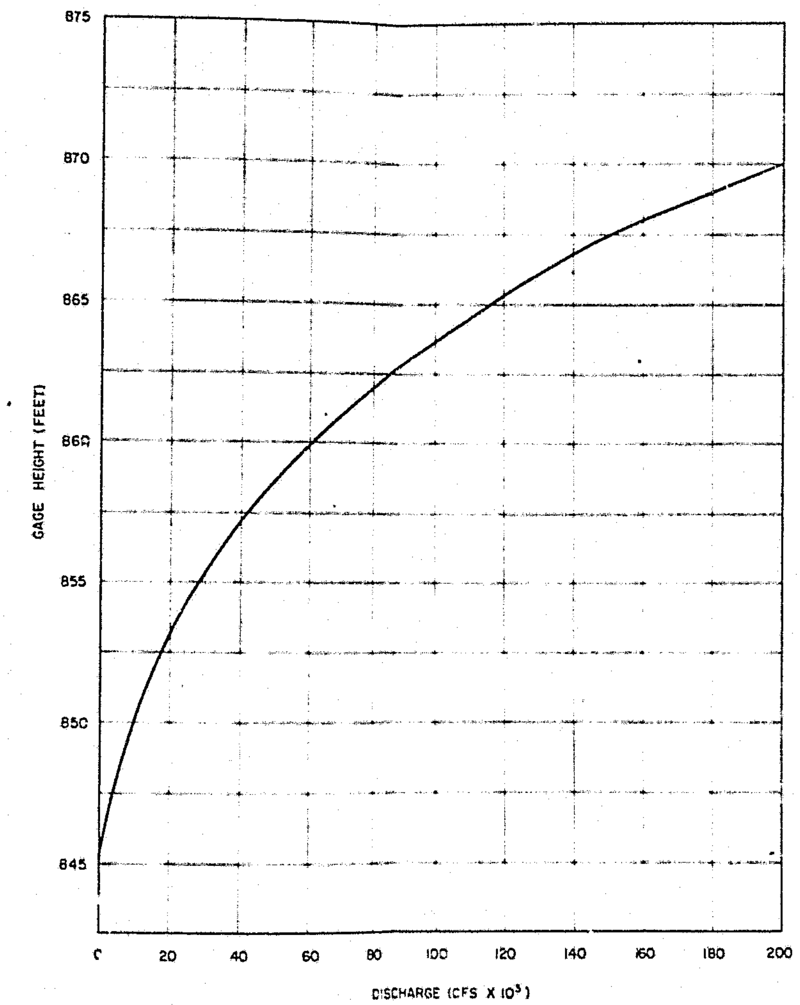
ACRES AMERICAN INCORPORATED

MARCH 1982

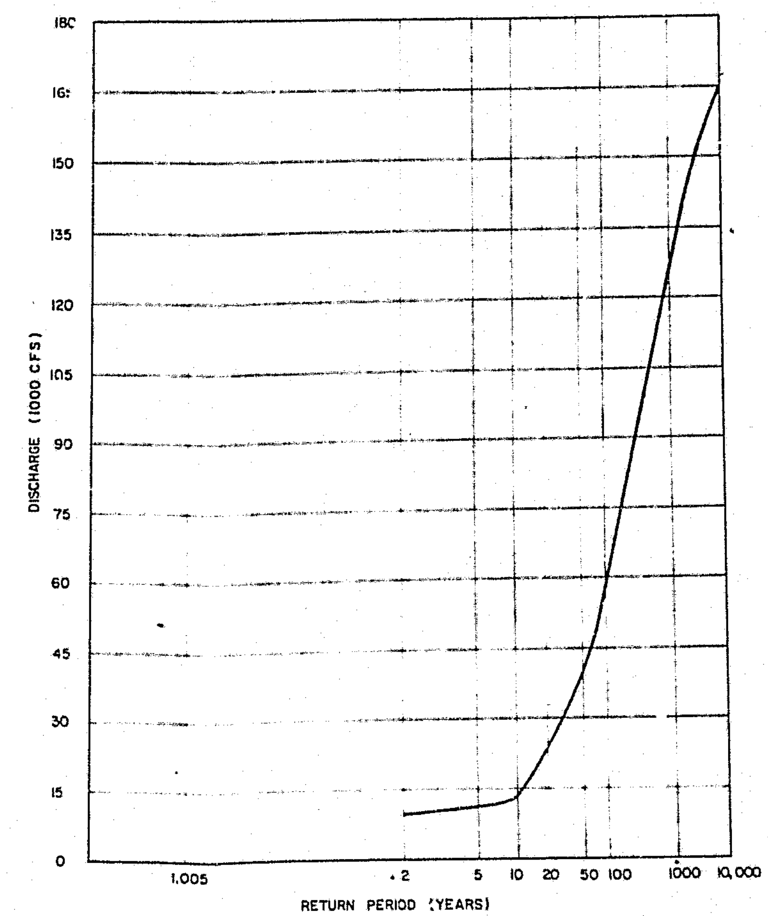
SK-5700-C6-50I



RESERVOIR VOLUME AND SURFACE AREA



TAILWATER RATING CURVE



FLOOD FREQUENCY CURVE
(INFLOW AFTER ROUTING THROUGH WATANA)

FIGURE B. 68

ACRES

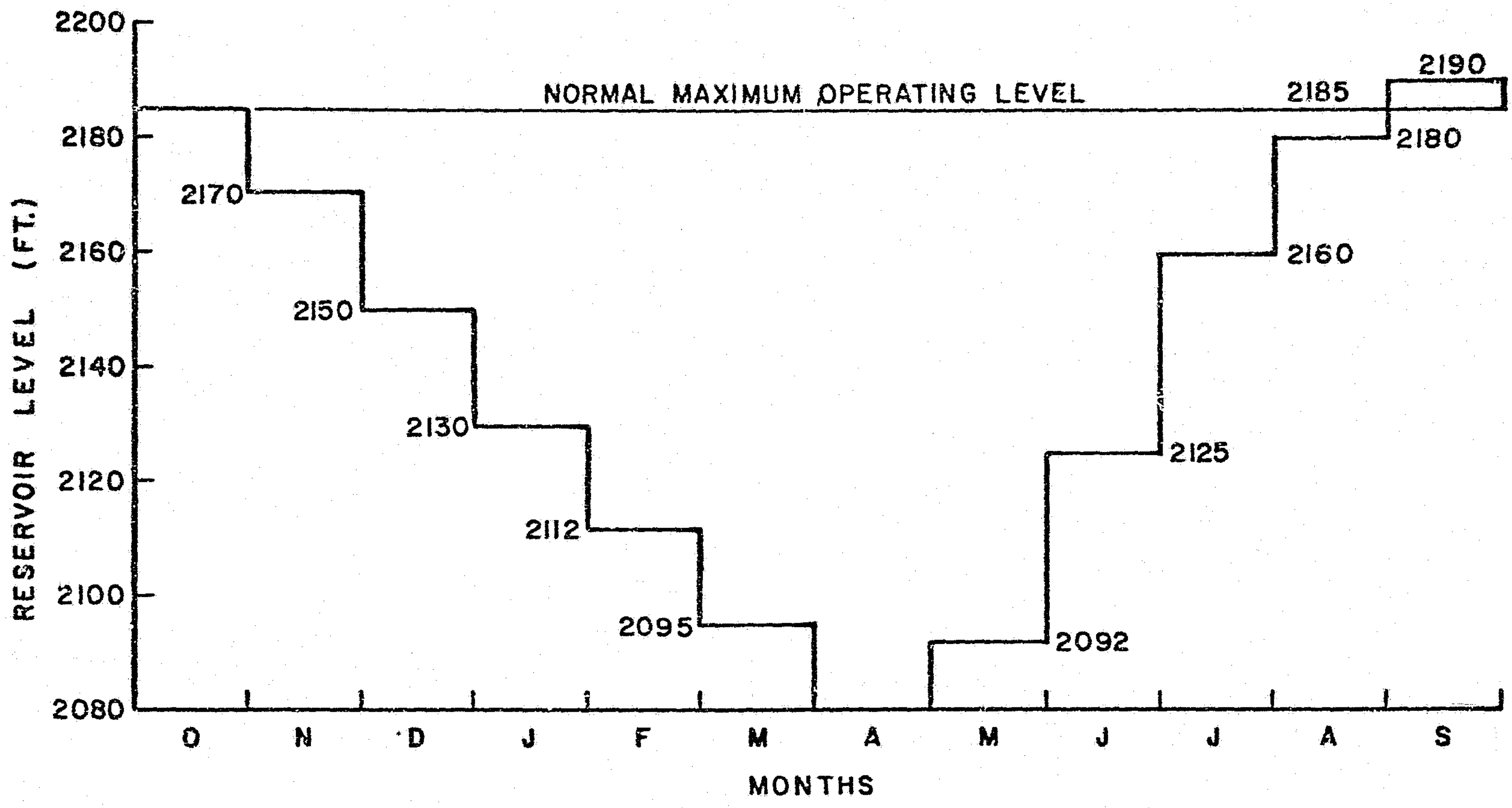
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

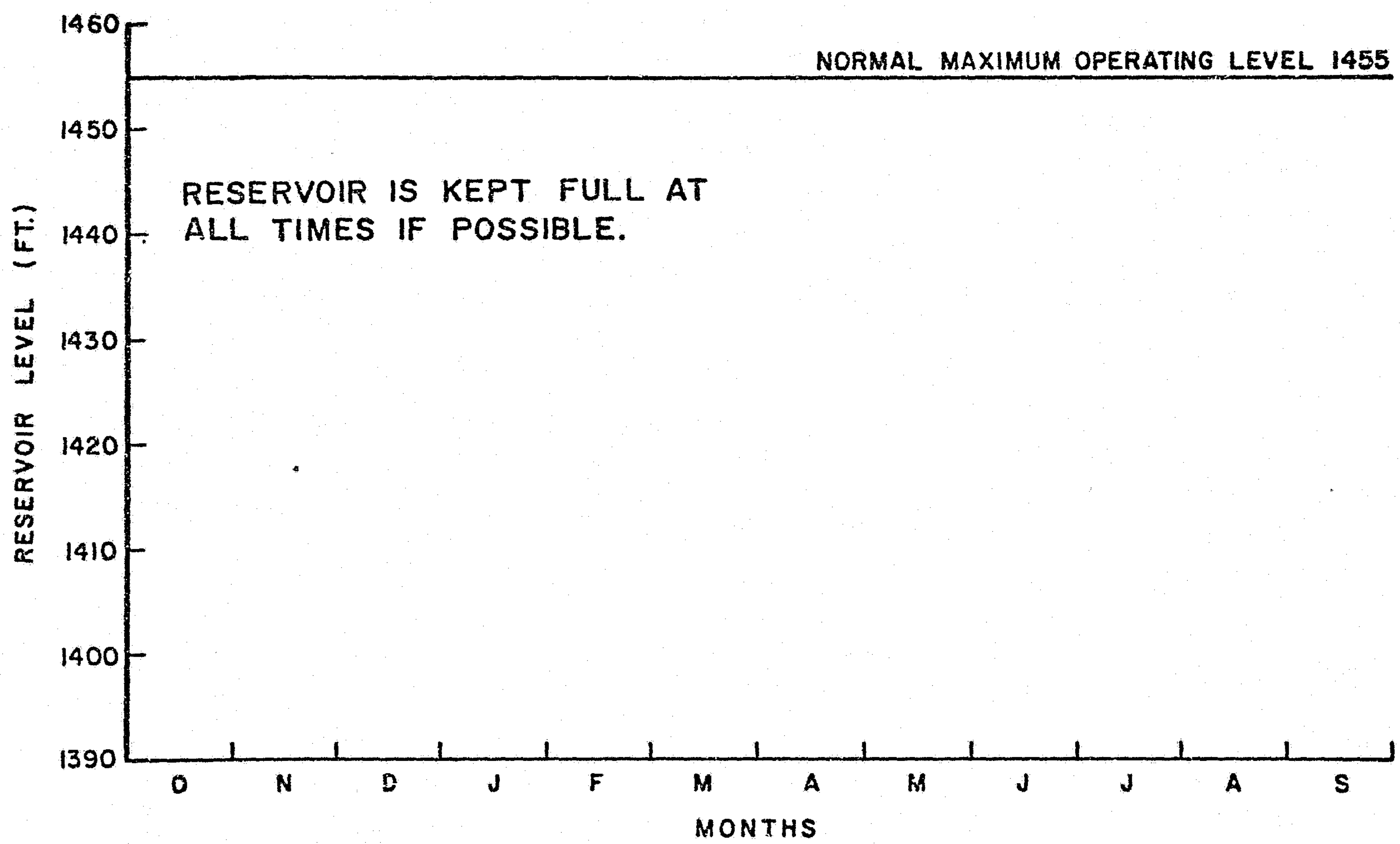
DEVIL CANYON
HYDROLOGICAL DATA
SHEET 1

ACRES AMERICAN INCORPORATED

MARCH 1982



WATANA RESERVOIR

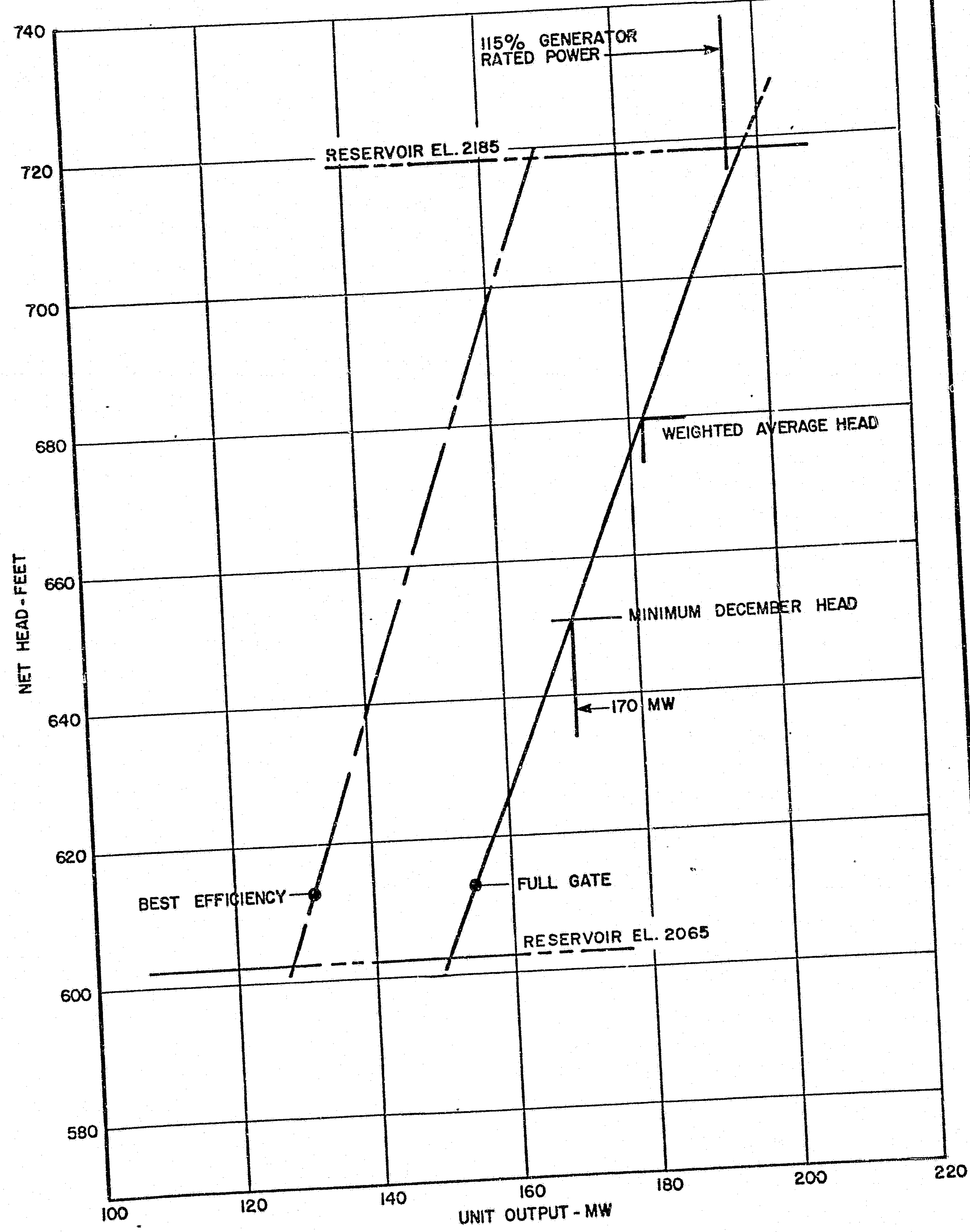


DEVIL CANYON RESERVOIR

MONTHLY TARGET MINIMUM RESERVOIR LEVELS

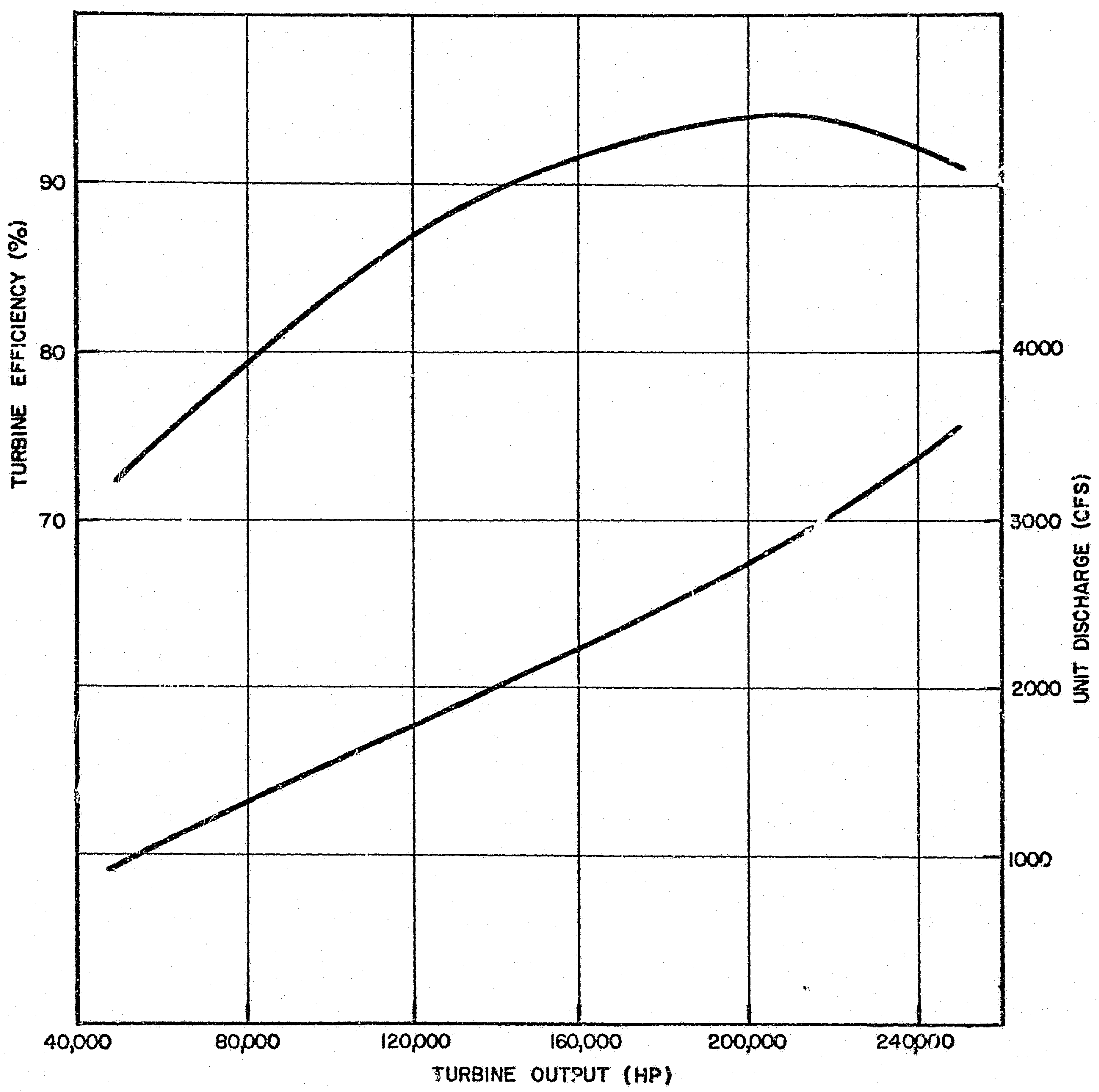
ACRES

FIGURE B.69



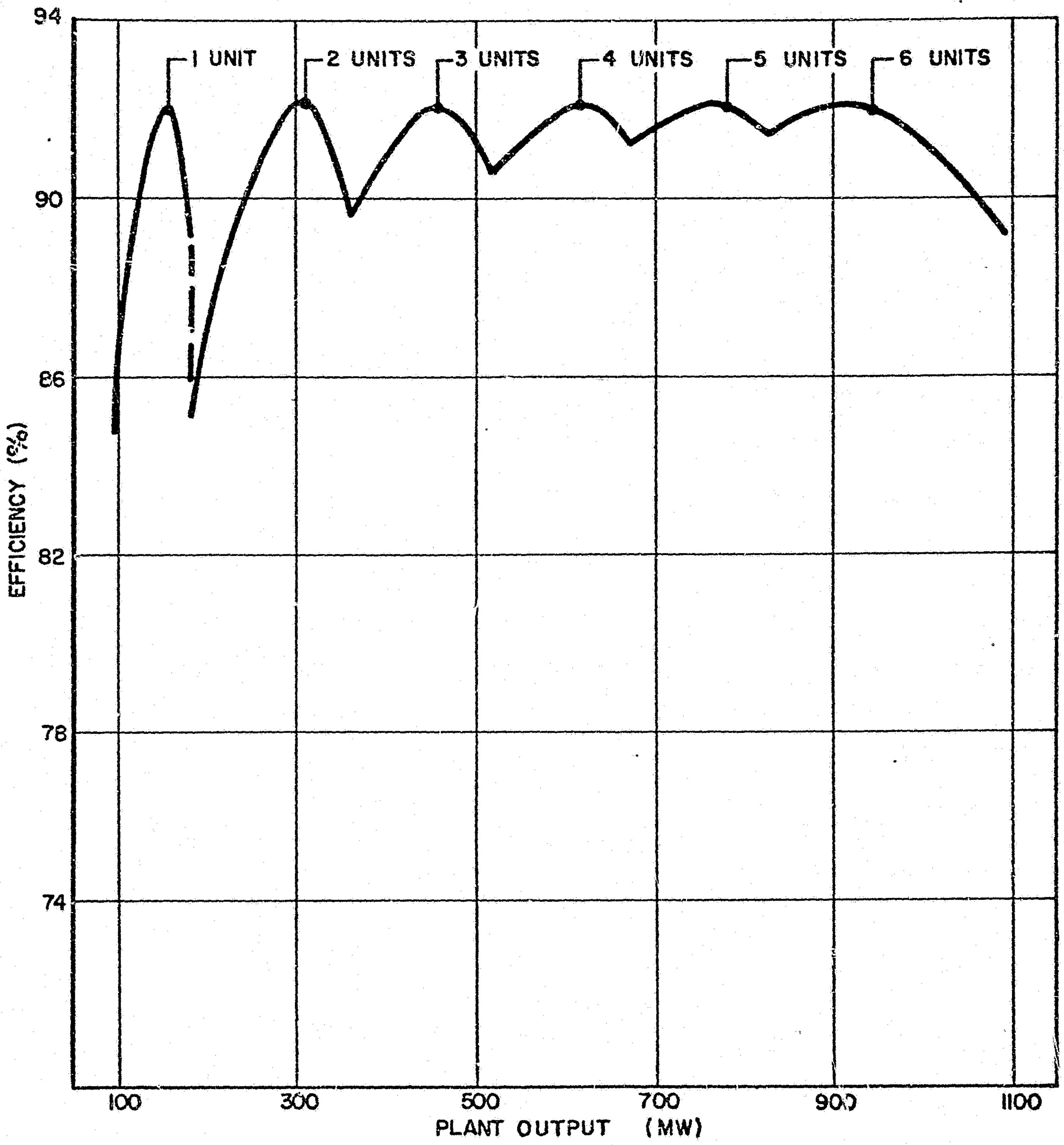
WATANA - UNIT OUTPUT

FIGURE B.70



WATANA - TURBINE PERFORMANCE
(AT RATED HEAD)

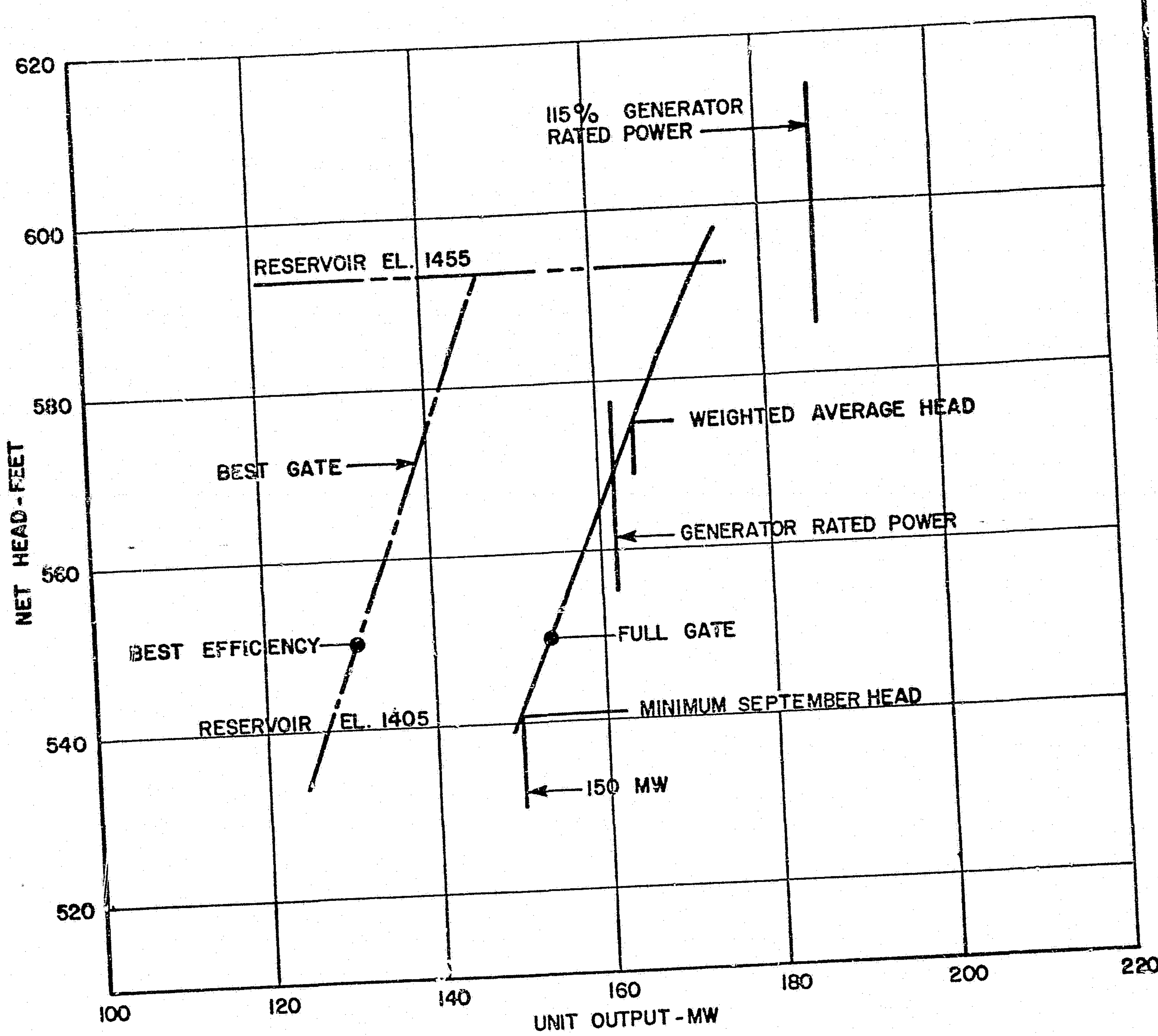
FIGURE B.71



WATANA-UNIT EFFICIENCY
(AT RATED HEAD)

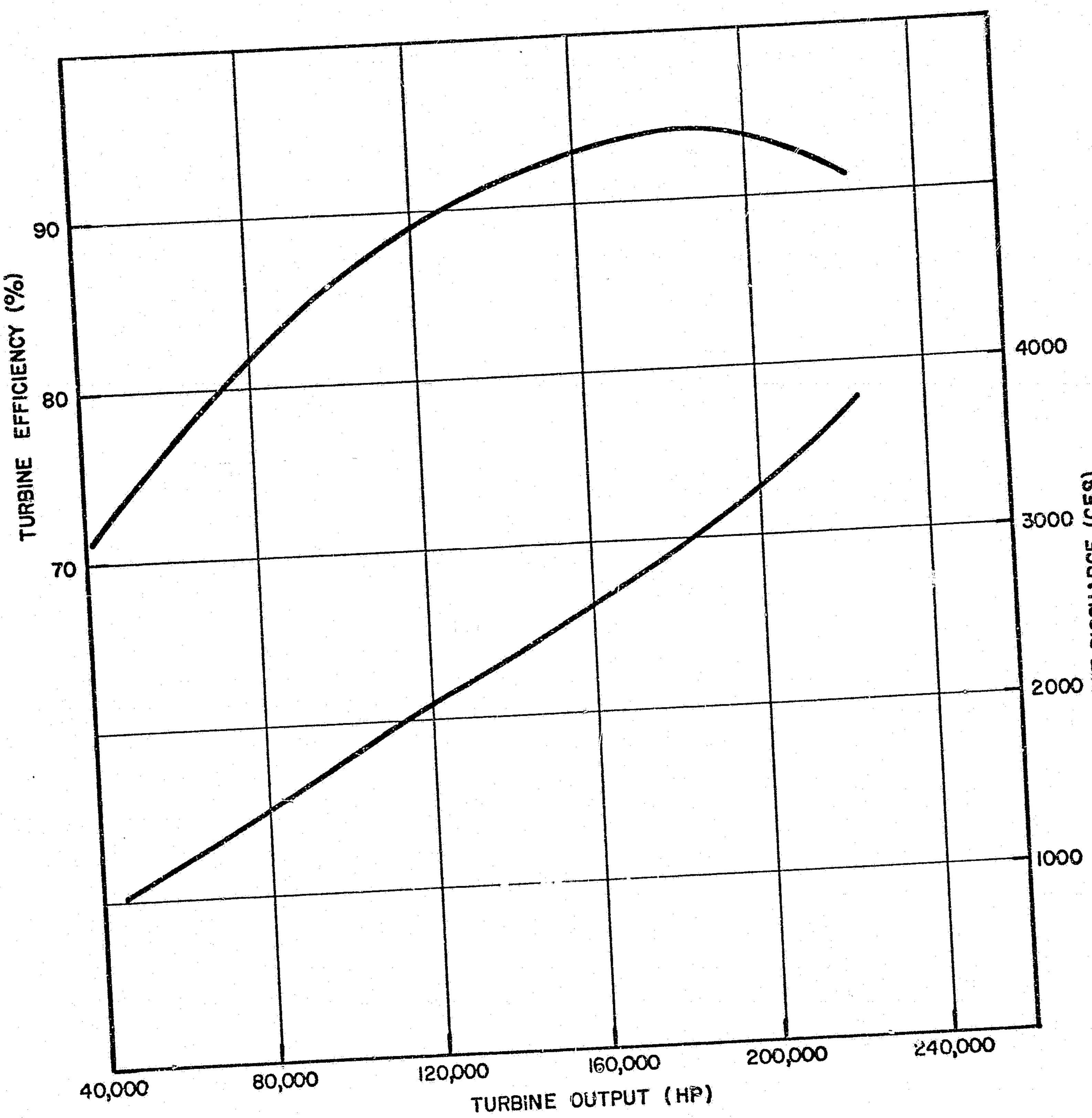
ACRES

FIGURE B.72



DEVIL CANYON-UNIT OUTPUT

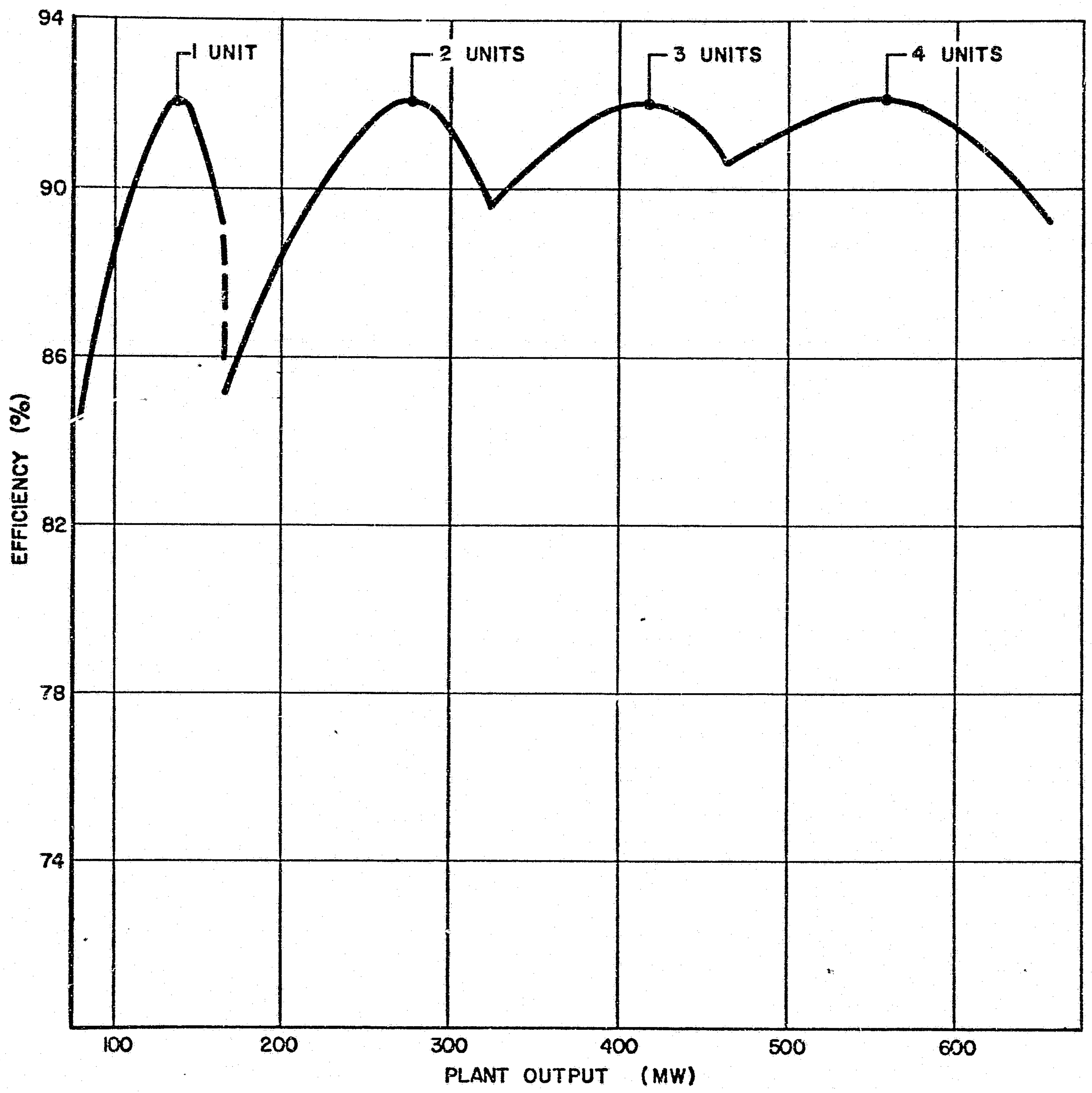
FIGURE B.73



DEVIL CANYON - TURBINE PERFORMANCE
(AT RATED HEAD)

ACRES

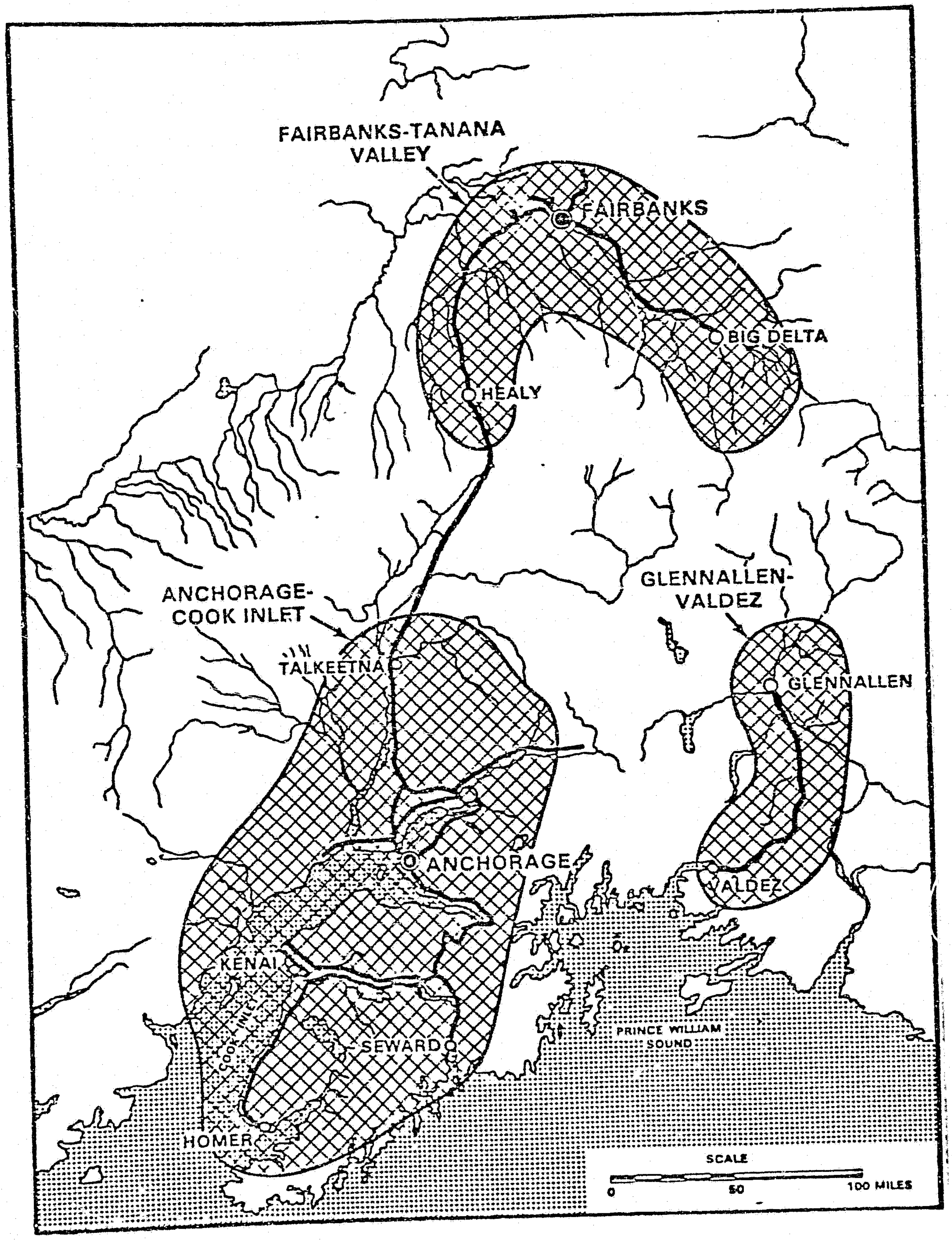
FIGURE B.74



DEVIL CANYON - UNIT EFFICIENCY
(AT RATED HEAD)

ACRES

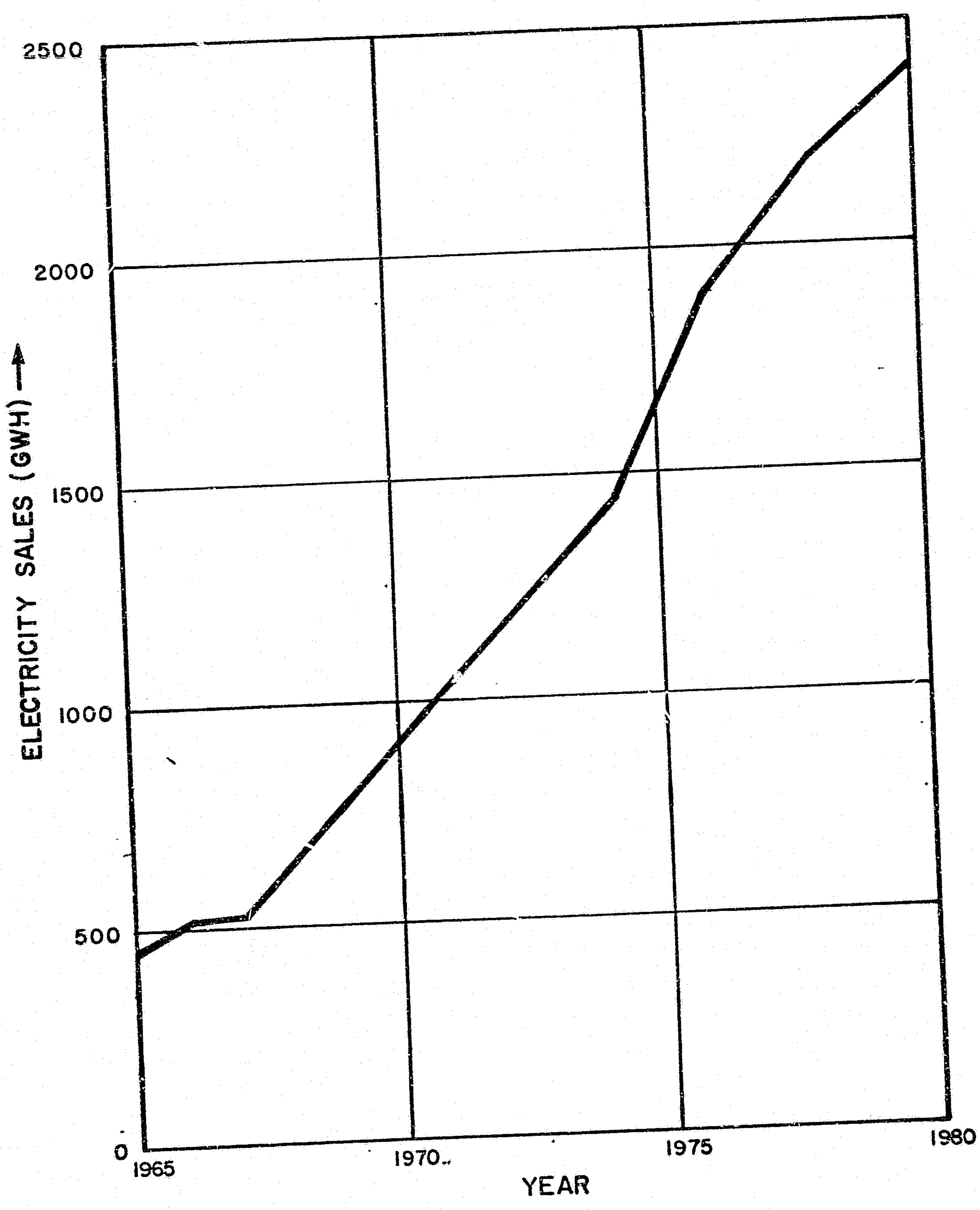
FIGURE B.75



RAILBELT AREA OF ALASKA
SHOWING ELECTRICAL LOAD CENTERS

FIGURE B.76

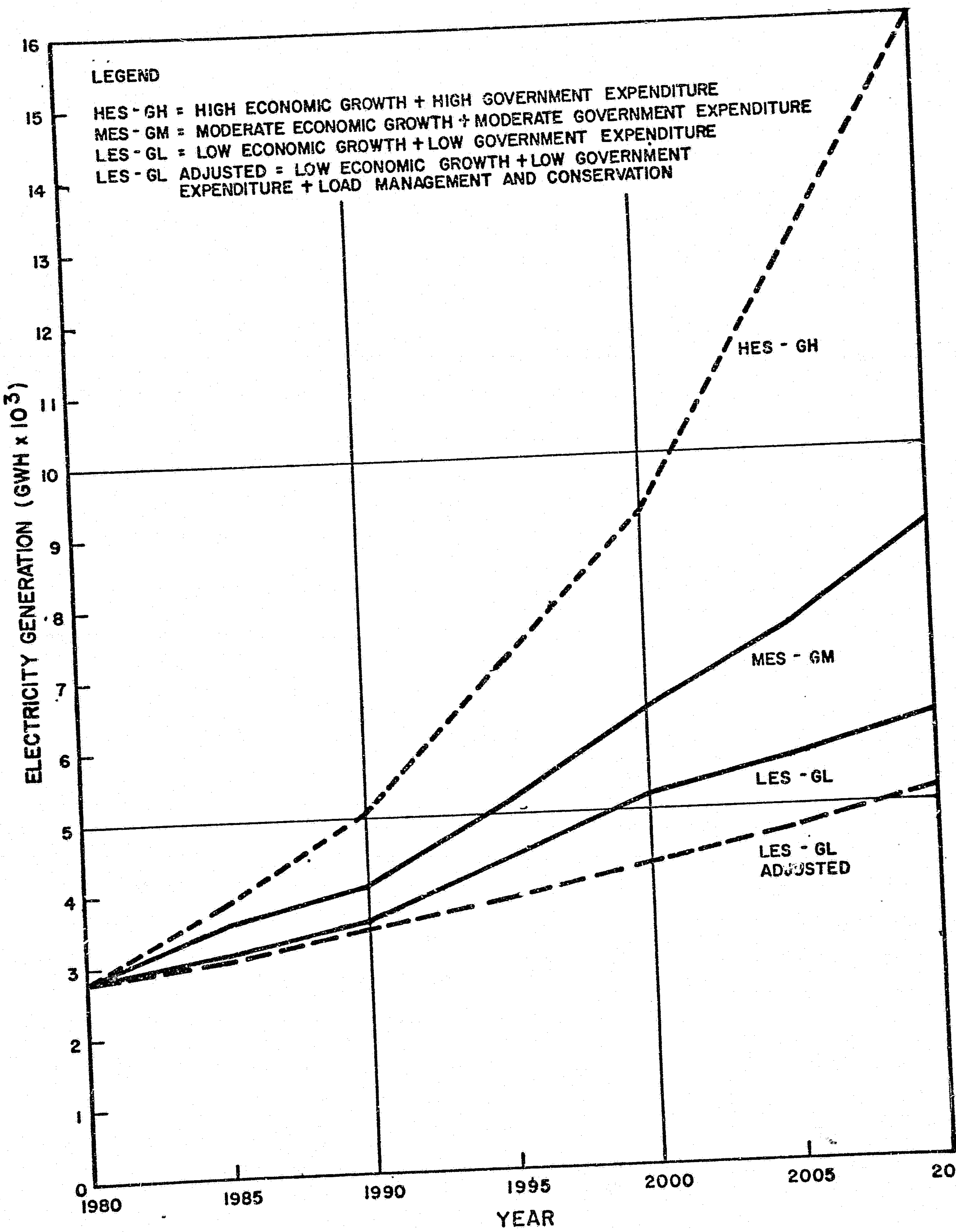
ACRES



HISTORICAL TOTAL RAILBELT UTILITY SALES TO FINAL CUSTOMERS

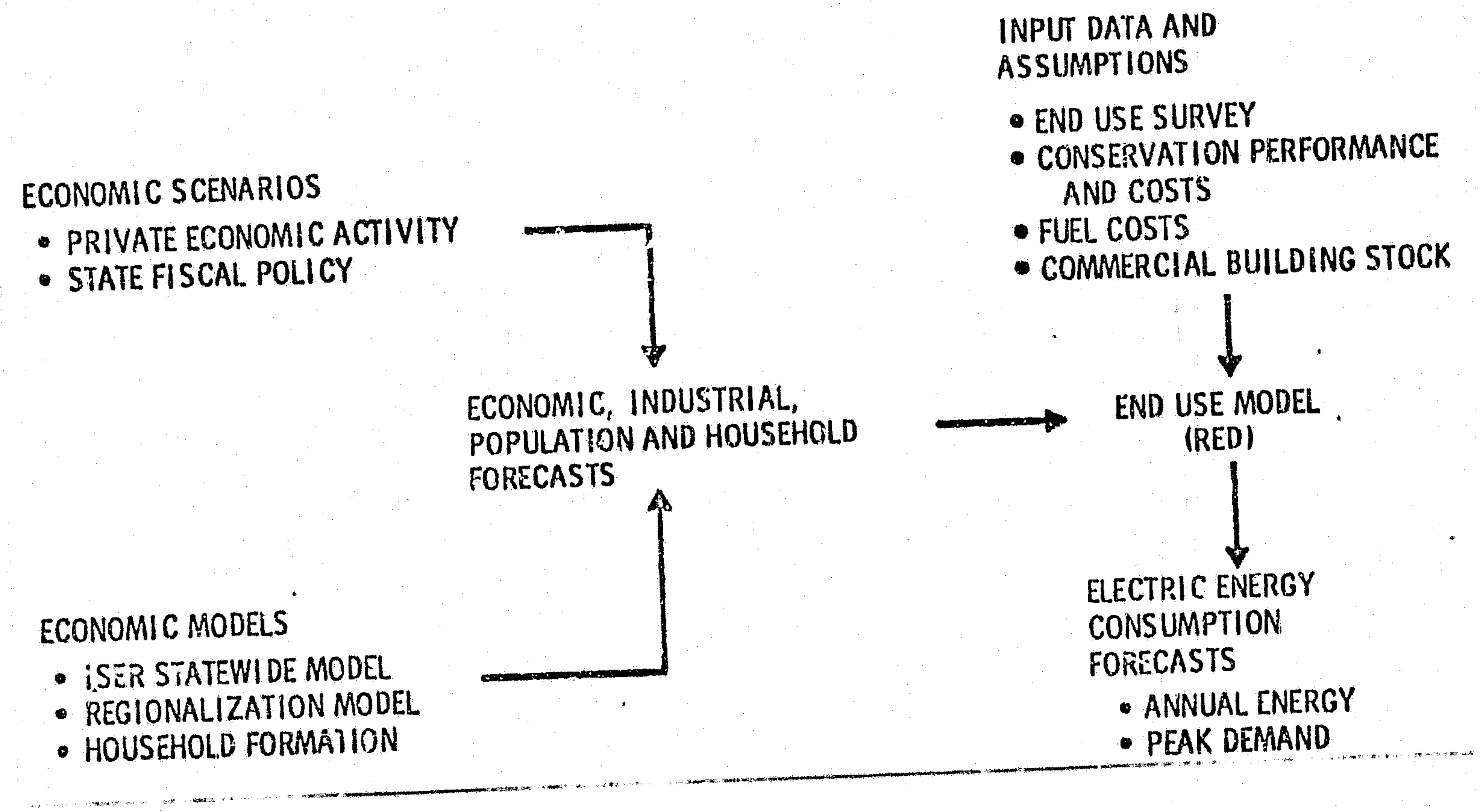
ACRES

FIGURE B.77



ISER 1980 ENERGY FORECASTS USED FOR DEVELOPMENT SELECTION STUDIES

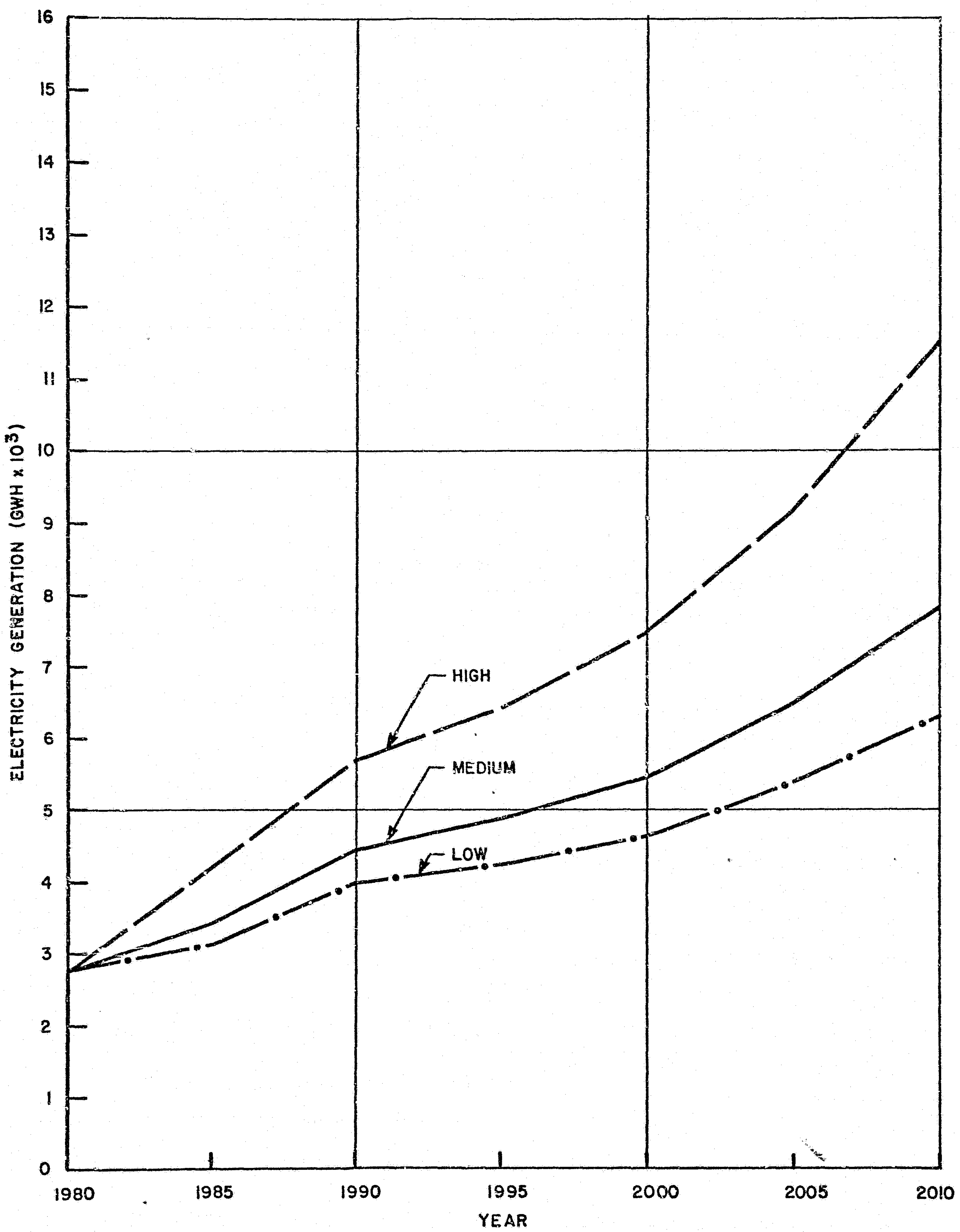
FIGURE B.78



ELECTRIC POWER FORECASTING PROCESS

FIGURE B.79

ACRES



DECEMBER 1981 BATTELLE LOAD AND
ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES

ACRES

FIGURE B.80

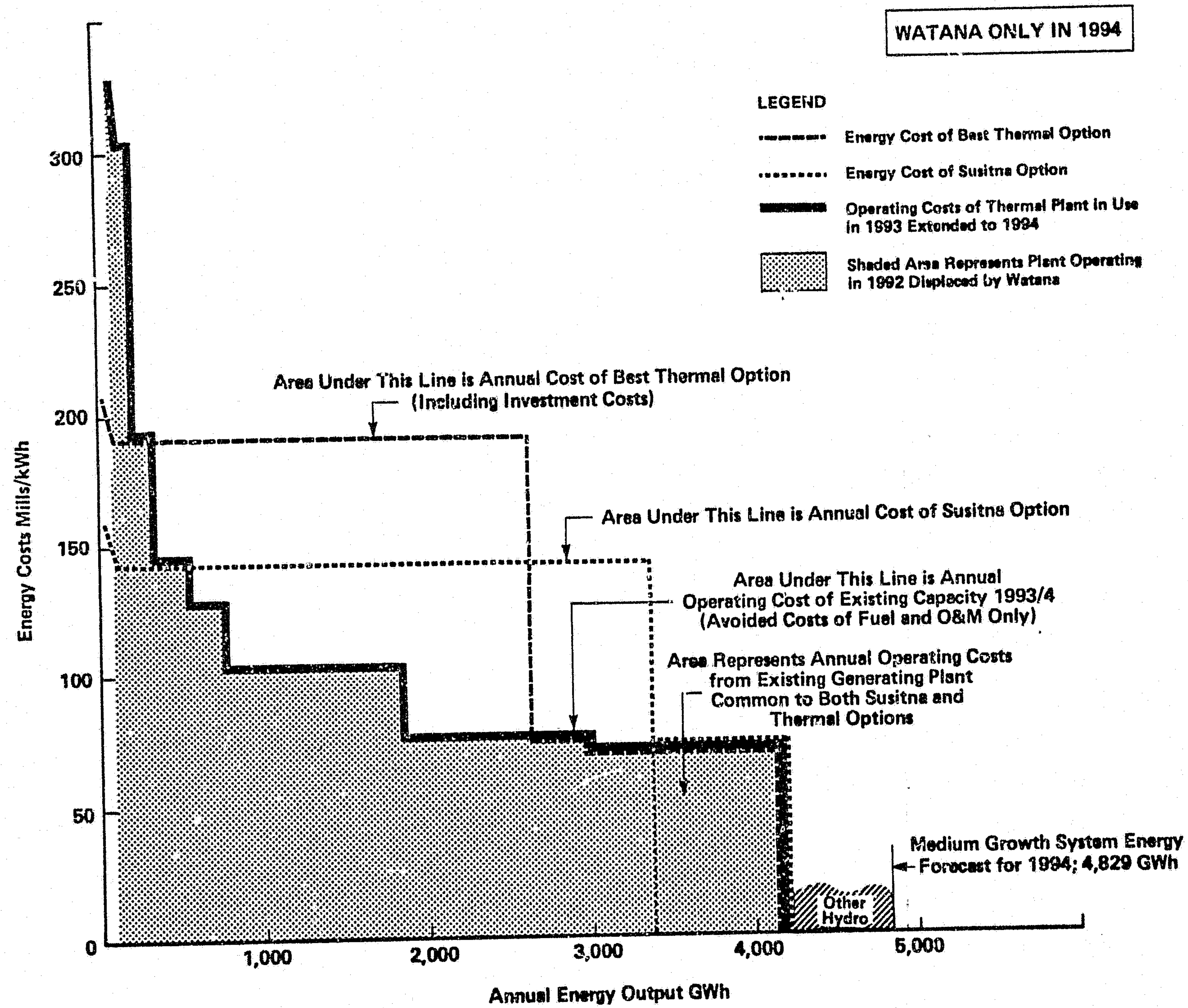


FIGURE B.81 - ENERGY PRICING COMPARISONS – 1994

ACRES

Rev. 1

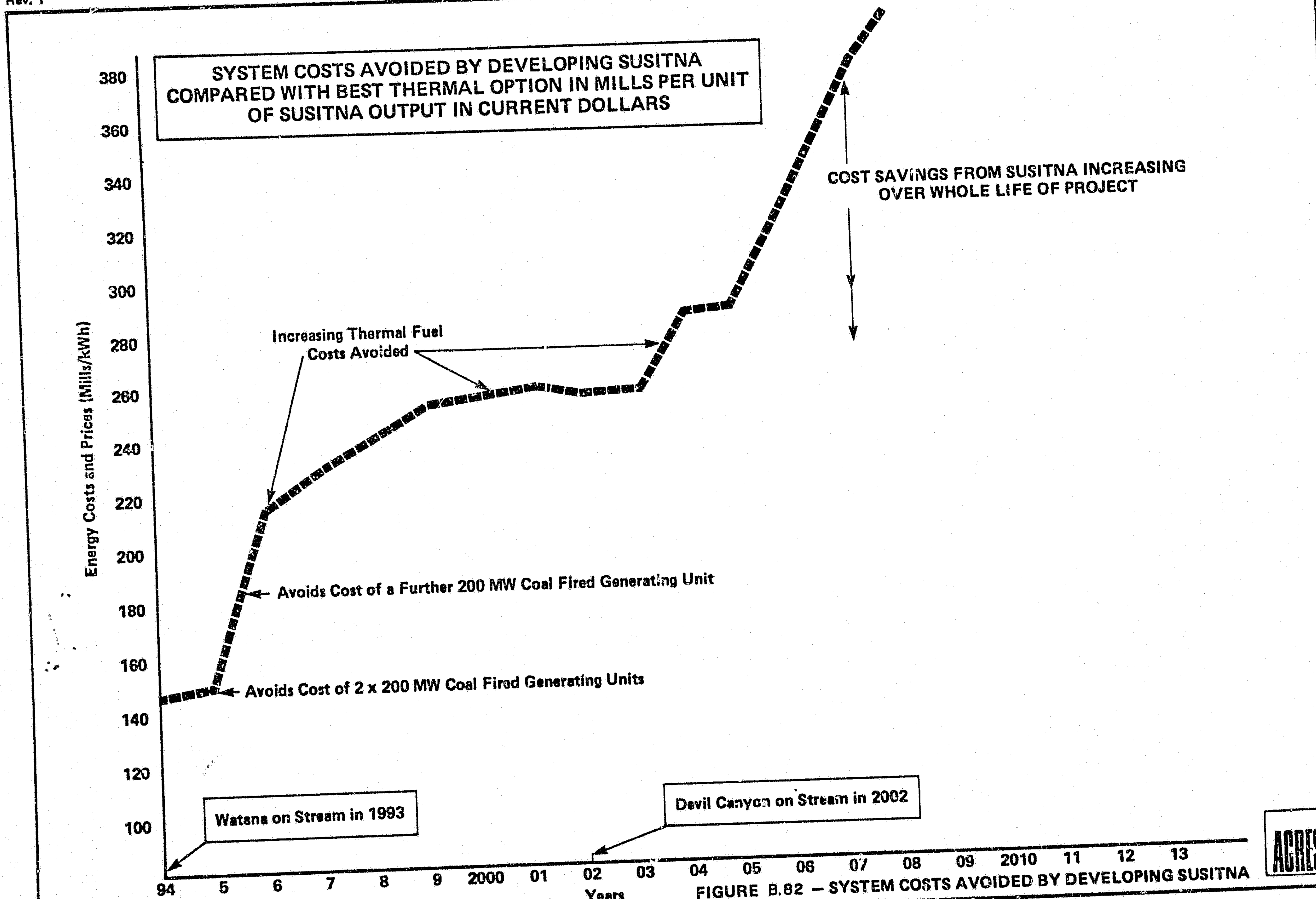


FIGURE B.82 – SYSTEM COSTS AVOIDED BY DEVELOPING SUSITNA

ACRES

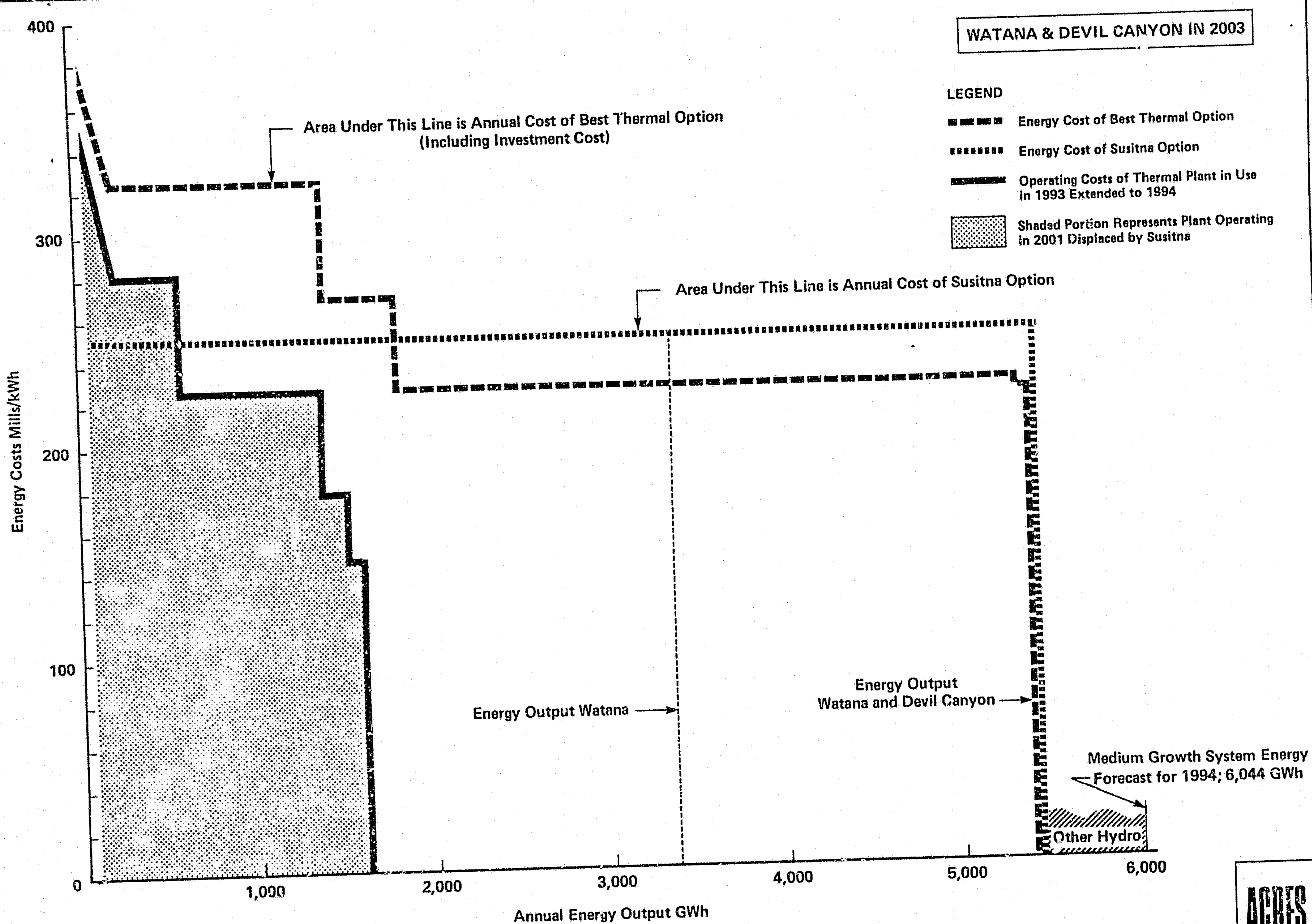


FIGURE B.83 – ENERGY PRICING COMPARISONS – 2003