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25 October 1980

Mr. John Lawrence
Project Manager
Acres American Inc.
900 Liberty Bank Building
Buffalo NY 94202

Subject: Susitna Project
First Specialist Consultants Panel Meeting
October 20 through 24, 1980

Dear Mr. Lawrence:

Introduction

The undersigned members of the Panel visited the site on October 22, were briefed in the office of Acres American Incorporated on October 21 and 23, and had previously reviewed a package of information dated October 1980. This report presents our consensus of the information obtained and suggestions regarding future investigations on the project.

We consider the Susitna Project, as now conceived, to be viable and worthy of continued investigation.

General Geology and Seismology

The WCC presentation dealt with the well known features such as the Denali fault, the Castle Mountain fault, the Border fault and the Talkeetna fault; as well as the hypothesized "Susitna fault" and other linears defined in the WCC study to date. The Denali fault, Castle Mountain fault, and the Border fault are all well known, recent, active features that show evidence of displacing or offsetting Pleistocene features. The magnitude and minimum distances to the site of credible events on these structures are not controversial and design motions predicted from events on these structures are relatively straightforward. The possible influence of the Talkeetna fault and the Susitna linear on the design motions needs more study. The Talkeetna fault is a relatively old thrust fault which brings Triassic volcanics and Permian strata from the southeast over Cretaceous argillites on the northwest side of the fault. Although this feature does not appear to cut Pleistocene deposits, WCC has tentatively assigned to the feature a magnitude 7.5 to 7.9 event at a distance of 4 mi from Watana Dam. There is a good possibility that this is an old feature that may not be a "capable" structure. Thus it is of very high priority to perform detailed field work along this structure to investigate the age of overlying materials not displaced by this fault or to define the observed offsets of formations of known age that cross the fault. Observations in the Watana creek area may prove to be of great value since Tertiary deposits appear to cover both the Cretaceous argillites and the Triassic volcanics in this area.

Field studies also need to be conducted along the Susitna linear to establish if it is a real feature which has experienced offset and, if so, what is the evidence of the time of last movement and of the magnitude of the offset.

Other linears or possible faults close to Watana Dam should be investigated to such an extent that a statement can be made as to whether the feature is truncated by Pleistocene or older geologic formations.

If possible, a statement should be made regarding any possible structural explanation for the two clusters defined from the micro-earthquake observations.

Engineering Geology and Rock Engineering

The "fins" and "finger busters" in the Tertiary diorites as well as other rock ribs exposed in the canyon indicate that there are wide shear zones in the diorite intrusion. More exploration in the form of borings and possibly adits are necessary in the right abutment area to confirm that the rock quality is good enough to permit a reasonably accurate estimate of the cost of an underground powerhouse. Preliminary observations indicate that the construction of an underground powerhouse at Watana may be difficult or infeasible due to the wide shear zones. Reorientation of the powerhouse to minimize wall and roof instability may lead to unfavorable orientations for the penstocks.

Additional exploration of the relationship of the Tertiary clastic volcanics and andesites to the underlying diorite downstream of the dam on the right abutment is also necessary to evaluate the possible effects on the tailrace tunnels and on the possible long power tunnel. The andesites may fill an old buried valley in the diorite.

An estimate of the tunneling difficulty for the long power tunnel alternative can only be made after the various formations and the nature of the contacts between formations are mapped from Watana Dam to the downstream end of the tunnel. First priority should be assigned to this mapping for Scheme 3.

The argillite formation of Devil Canyon appears suitable for an underground powerhouse. More exploration is needed to delineate the rock quality and orientation of fractures and shears to permit an optimization of the orientation and to aid detailed roof and sidewall design.

The nature of the sheared and weathered zone of the bend in the river just upstream of the Devil Canyon site needs to be studied to determine the nature and possible origin of the feature.

Watana Site

General. Although an embankment dam with a height of about 800 ft would be comparable to the highest in North America and among the highest in the world, we consider the topography and available materials favorable to the construction of Watana Dam. The foundation and abutment conditions, although not yet fully explored, present no known unusual difficulties. We believe that further investigations of seismicity are most unlikely to indicate unfavorable features for which adequate provisions cannot be made in design. We believe that emphasis in the next exploratory phase should be placed on defining the boundaries of the pluton and the nature and effects of its contacts with the adjacent rocks in the general vicinity of the damsite.

Spillway. We concur that the spillway should not discharge into or through the buried valley to the right of the dam, and believe that a layout entirely in rock, closer to the dam, should be adopted. As the geologic situation becomes better defined, an upstream shift in the axis of the dam may prove advisable.

Reservoir Slides. Our overflight of the reservoir area for several miles upstream of the dam indicated to us that the topography and the nature of the materials near the reservoir rim are such that major landslides into the reservoir, such as to endanger the dam or control works, is remote even under seismic conditions. Therefore, we consider that special investigations of this possibility are not needed to establish the feasibility of the project.

Cross Section and Materials. We concur that a conventional embankment dam section with near-central core is appropriate. For estimates, the upstream and downstream slopes of 2.25:1 and 2:1 are reasonable. We would prefer that the downstream slope of the core be at least slightly positive to assure that settlement of the shells would induce compression in the core.

We consider that the riverbed alluvium should be removed beneath the core, filters, and transitions, and within a zone defined by lines extending from the outer edges of the crest downward at slopes of 1.5:1. For the feasibility studies we consider it advisable to assume that the material will be removed beneath the remainder of the embankment except where needed to support the cofferdams. Whether some of this material can remain can best be decided during the required excavation of the central portion.

We consider rounded gravels, cobbles, and boulders to be superior to rockfill for the shells of such a high dam and suggest that the upstream shell, in particular, should consist primarily of rounded material beneath a near-surface zone of rockfill that may serve as riprap. Such material, which does not suffer corner-breakage on saturation, reduces the likelihood of longitudinal cracking near the crest and tends to dilate under small strains. The latter property substantially increases the resistance during seismic shaking. Downstream of the core, use of rounded materials near the transitions is also advantageous, but compacted rockfill in a substantial portion further downstream will be satisfactory to accommodate suitable material from structural or other required excavation.

In our judgment, static and dynamic analyses can be deferred until the general quality and availability of borrow materials has been established. To this end the emphasis in the next exploratory phases should be placed on determining the character of the riverbed materials, particularly their grain-size, and on the extent and thickness of lodgment till deposits that might be suitable for core. Attention should be given to locating deposits of sufficient thickness to permit exploitation in near-vertical faces so that the moisture content will be increased as little as possible before and during excavation and transportation. The possibility of routinely processing all or most of the alluvium for optimum use in the dam should be considered.

Continuing investigations of the permafrost conditions in the south abutment are considered of high priority.

Devil Canyon Site

We have visited Devil Canyon Site and have examined the engineering and geologic data pertinent to it. We consider the site to be well suited for the construction of an arch dam.

Adits are not considered to be essential for further definition of foundation characteristics prior to a feasibility determination. Additional boring and laboratory investigations will be necessary to define the locations, directions and characteristics of joints and shears.

The possibility of surface rupture at the Devil Canyon Site must be resolved.

A more sophisticated arch dam design based on well formulated criteria should be prepared. Such a design should be supplemented by well documented and generally accepted analytical methods. This is considered to be necessary to establish the economic feasibility of the project.

Yours very sincerely,

Merlin D. Copen

Merlin D. Copen

Alfred J. Hendron Jr.

A. J. Hendron, Jr.

Ralph B Peck

Ralph B. Peck

RBP/ajj

January 24, 1981

SUSITNA HYDROELECTRIC PROJECT

EXTERNAL REVIEW PANEL

REPORT NO. 1

INTRODUCTION

The Panel met with representatives of the Alaska Power Authority Board and its staff and representatives of Acres American in Anchorage on January 22-24, 1981 for discussions on studies for the Susitna Hydroelectric Project. On January 22nd, Power Authority staff members gave the Panel a general background of the project and studies which are underway, and Acres representatives described the current status of these studies. A site inspection of the project was made on January 23rd. Discussions of the Panel's findings were held in the morning of January 24th, and this report which summarizes the Panel's opinions and recommendations was prepared that afternoon.

GEOTECHNICAL INVESTIGATIONS

We recognize that the field exploratory program for the 1981 season may be modified somewhat depending upon relative priorities assigned to the Devil Canyon vs Watana damsites as well as FERC requirements. With this in mind, we would like to offer the following suggestions for your consideration.

Devil Canyon Site

The general geotechnical conditions at this site are reasonably well known as a result of the availabiltiy of rock outcrops and the borings done to date. The field geologic mapping scheduled for the coming season will provide further basic information and should be carried out as planned. At this time local geologic structures will be mapped and can be projected to those borings already completed. The geometry of these geologic features can then be used to orient the proposed underground structure to a degree adequate for this stage of the project.

We believe that the proposed borings could be reduced or eliminated entirely based upon the above comments and especially because Devil Canyon may be deferred well into the future. It appears that the field program at Watana requires a greater degree of study and the borings planned for Devil Canyon might better be drilled at the upstream site.

Watana Site

The field exploration program at the damsite consists primarily of geologic mapping, borings, and locating sources of borrow material. We agree with the general approach of Acres; however, we would like to see more emphasis placed upon defining the properties of the materials in the old river channel on the right abutment and upon the rock conditions at the proposed underground chamber location.

The buried channel leaves the existing river valley just upstream of the damsite and crosses the right abutment exiting downstream in Tsusena Creek. The base of the channel is believed to be about 400 feet below reservoir level and is likely filled with pervious alluvial deposits and perhaps some glacial till.

Once the proposed seismic profiling has been completed we suggest that at least two borings (rather than the one currently planned) be drilled into this feature. Sampling of the alluvial materials should be done to a degree sufficient to obtain an estimate of permeability and a flow net analysis made. This will serve to check the initial Corps of Engineers estimate that seepage through the channel is of no importance to the project. At a future stage in the project development a deep well pumping test may be advisable.

The proposed underground chambers are located in the left abutment and lie between recognized zones of poor quality rock. At present little is known of the rock conditions in the actual chamber site. We therefore recommend that two deep angle holes be drilled early in the summer program to cross the chamber site. If rock conditions are generally good, then the design can proceed to feasibility level. If not, and if serious concern exists about the technical feasibiltiy of the chambers, then exploratory adits will be required. In our experience adits provide much more precise information on actual rock conditions than a larger number of borings.

In summary, it appears that more borings will be required at Watana than currently planned. If those included for Devil Canyon are relocated to Watana, our preliminary estimate might be a net increase of about $250,000 in drilling costs.

SEISMIC STUDIES

Since Alaska is one of the most seismically active areas in the United States, the investigation for the Susitna Project has appropriately devoted much attention to the seismicity of the region in which it would be constructed, the location of active faults which could affect the design of the dams and the determination of the intensity of ground shaking to which the project facilities might be subjected.

The study is on-going but to date no faults with known recent displacement (i.e. displacement in the last 100,000 years) have been found to pass through the proposed sites for the dams. However, four features in the vicinity of the Watana site and nine features in the vicinity of the Devil Canyon site have been judged to require additional investigations to better define their potential effect on dam design considerations.

In the vicinity of the Watana dam site these features are:

(1) The Talkeetna thrust fault,
(2) The Susitna feature,
(3) The Fins feature, and
(4) a feature designated KD3-7 which follows the channel of the Susitna River in this area.

Of these features, the Talkeetna thrust and the KD-7 feature are likely to have greatest significance for the design of a dam at the Watana site - the Talkeetna thrust because it could well determine the level of design earthquake shaking if it were found to be active and the KD3-7 feature because its passes directly through the proposed dam and could lead to a significant off-set potential if its activity were established.

In genaral, however, both the Watana dam and the Devil Canyon dam appear, on the basis of present evidence, to be located within a tectonic unit designated the Talkeetna Terrain which seems to be a coherent unit, free of known active fault displacements within the crust and subject only to major strain releases (major earthquakes) along the fault systems bounding the Terrain. Within the Terrain minor strain releases, causing small earthquakes, appear to be occurring randomly within the crust. If these conditions are confirmed by subsequent investigations, they could be considered a highly favorable feature of the project location.

Under these conditions, the strongest earthquake shaking which could affect either of the proposed dams would be caused by a major earthquake generated on the Benioff zone which underlies the Terrain at depths varying from 25 miles in the southeastern part of the region to over 60 miles at the northwestern part of the region. The maximum accelerations at the proposed dam sites for such an event are of the order of 0.4g.

Present assessments of the seismic geology and the potential intensity of ground shaking could be changed considerably, however, if some of the more prominent features, currently considered to be inactive, but concerning which considerable uncertainty on this question exists, were found to have undergone recent displacements. For the Watana dam, the most important of these features appear to be the Talkeetna thrust and KD3-7 and it is therefore suggested that primary attention be directed to determining the potential activity of these features as early as possible in the 1981 study program.

It is also important to establish that no active faults pass through or in very close proximity to the Devil Canyon site since the presence of such faults could have a major effect, not only on the design criteria, but also on the type of dam which could be constructed at this site.

At the present time, reservoir-induced seismicity does not appear to be a significant problem in view of the coherence of the Talkeetna Terrain. This would change however, if active faults were found to exist in the vicinity of the dam sites and the clarification of the potential activity of the 13 features about which uncertainty exists is important for this reason.

Once the seismic geology of the Talkeetna Terrain is established, the seismic design criteria for the dams can be established and suitable design sections selected and validated. In the meantime, for preliminary planning purposes, it would seem appropriate to use a design cross-section for the Watana Dam similar to that used for the Oroville Dam in California which has already been subjected to a detailed investigation of seismic stability and found to be adequately strong to withstand the strongest levels of earthquake shaking which can currently be anticipated for the dams of the Susitna project.

HYDRAULICS AND HYDROLOGY

The field program for surveys and collection of hydrologic data, generally, appears to be adequate. After analysis of available existing and collected data, it may be found necessary to collect some additional field data, particularly with respect to downstream river channel conditions. Special attention should be given to reservoir capacities, reservoir timber, reservoir slides, nitrogen supersaturation and downstream river channel conditions.

Reservoir Capacity

The reservoir capacity curves which have been used in the studies to date are based on survey maps with 50 and 100 foot contour intervals. Recent surveys have been completed from which more accurate capacity curves will be developed. If those curves show actual reservoir capacities to be substantially less, (say 10 per cent or more), than capacities which were used, then the effect of the smaller capacities on project costs and benefits should be determined. In the case of Watana Dam, the dam would need to be raised somewhat to retain the same power benefits. If the dam is not raised, greater reservoir drawdown would be required to maintain a high level of power production. Sufficient check studies should also be made to determine whether the smaller reservoir capacities would affect the best system development.

Reservoir Timber

Consideration should be given to the possible blockage of spillways and reservoir outlets by large masses of floating timber which in all probability would occur if a large amount of the reservoir is not cleared. Masses of floating timber will have detrimental environmental effects as discussed later in this report. A determination will need to be made on what extent the reservoir should be cleared.

Reservoir Slides

Although a potential for slides in the reservoirs which would cause excessive height waves at the dams is not evident, this should be verified by field investigations.

Nitrogen Supersaturation

There should be no major problems with the hydraulic design of the spillways and outlet works, except possibly for detrimental effects due to nitrogen supersaturation. The deep stilling basins and high-velocity flow with entrained air may cause excessive nitrogen to be introduced into the flow which would be harmful to downstream fish. A flip bucket which produces a deep plunge pool may also produce a nitrogen supersaturation problem. A flip bucket which would deflect flows horizontally into the downstream channel would minimize this problem but may cause excessive channel erosion downstream of the dam. It is suggested that studies by the Corps of Engineers to minimize the nitrogen supersaturation problem on the Columbia River be reviewed for guidance on whether there will be such a problem on the Susitna River and, if so, how best to resolve it.

Downstream River Channel

The determination of future project effects on the downstream Susitna River channel configuration is an extremely difficult task. Estimates can be made of the possible changes in channel regime due to flow changes by sediment transport and flow analyses, but localized conditions often significantly affect channel changes. This may be particularly true in cold climates. It would be well if analytical or other contemplated studies were supported by studies of actual channel conditions before and after project construction elsewhere in Alaska or Canada.

SYSTEM DEVELOPMENT

The Panel is impressed with the many combinations of project units being considered for determining the best system development. We believe that all viable combinations are being considered. The depth of studies for the alternatives, subject to modifications and additions suggested in this report, should be sufficient for selecting the optimum development.

ENVIRONMENTAL QUESTIONS

Environmental questions concern fisheries, wildlife and recreation.

Additional comments on environmental matters will follow receipt of reports of on-going studies.

Fisheries

The two impoundments will change many miles of running grayling stream into impounded still water that will probably support many grayling and other species such as lake trout. The sport fishing in Devil Canyon reservoir might be substantially enhanced. Water levels in the Watana reservoir will fluctuate too much to support a desirable recreational fishery. Fortunately, few salmon reach the upper Susitna River for spawning. Possible effects of the impoundments will be down river, where breeding salmon spawn in many tributaries. The altered flow regime, following impoundment, may change the topograpy of the channel as well as the chemistry of the water. Dissolved nitrogen would be particularly harmful. Settling out of particulate matter might alter the summer behavior of salmon fry. Winter flows might be milky whereas now they are clear. Data derived from other similar impoundments should be examined to anticipate and minimize problems. We urge that relevent records from all over the world (Canada, Scandanavia, Russia, Argentina, etc.) be assemble and scrutinized.

Wildlife

The impoundment areas will obviously be lost to occupation by moose, caribou, bears and many small animals. Moose normally are forced off the higher slopes by deep snow and resort to the river banks, but this retreat will not be possible if the river banks are flooded. There will be some definite loss in moose numbers around the impoundments. Downstream, the stabilization of flows may dampen the process of cut-and-fill which is the primary process of renewal of willow browse for winter moose food. Additional reduction of moose numbers is possible there.

Caribou will be little affected by the impoundments if the water areas are kept clear of debris. However, unless the timber is stripped from the impoundments there might be an unsightly tangle of logs floating to the surface which would endanger the lives of swimming caribou and despoil the impoundments for boating, fishing, and general recreation.

Bears, other furbearers and carnivores, and many birds and small mammals would lose the impoundment areas as habitat, but the effect would be minimal in terms of regional populations of the more abundant species. No rare or endangered species have been identified in the project area.

Waterfowl might be adversely affected in the Susitna delta area by reduction of flood flows in summer, which normally fill many potholes and oxbows.

All the above problems should be addressed.

Recreational

Access roads to the dam sites will permit public entry to country that currently is de facto wilderness. This will give many people access to the reservoirs for fishing and to the surrounding countryside for hunting and general recreation. It will sacrifice the wilderness value, and doubtless will lead to reduction in numbers of big game animals by increasing hunting pressure. Planning for regulated recreational development is suggested.

Some Further Studies Recommended

(1) Design spillways to minimize nitrogen intake.

(2) Assemble data on downstream effects on salmon and on moose habitat at other impoundments in similar terrain.

(3) Study water regimes in Susitna delta to see if reduced summer flows in the impounded watershed will materially affect waterfowl habitat.

(4) Plan to strip impoundment areas of trees and compute added cost to project.

(5) Plan recreational development of impoundment areas to optimize public values and minimize adverse over-development.

ECONOMIC FEASIBILITY AND FINANCING

The following are some of our very preliminary thoughts and concerns in the areas of:

Demand and markets for electricity

Economic evaluation of the Susitna Project

Financial viability

Demands and Markets

Both the ISER and subsequently modified Acres' results show a degree of uncertainty in the range of projected demands for electricity by consumers in the Railbelt Region. These range from a low of 6,200 GWH by the year 2010 to a high of 13,500 GWH with a 1980 consumption of about 2,400 GWH. Clearly, this demand forecast has a large impact on the need for the Susitna project, where one dam site alone would generate about 3,100 GWH per year.

Some of the fundamental questions are:

Under the low demand forecast is there an economic need for the Susitna project at all?

If there is a need, can the project be substantially delayed without an economic or environmental loss?

To refine the range of forecasts, the approach to forecasting could be improved in several ways.

Specifically include the potential impact of upward trends in the cost of electricity in the demand estimates for electricity. Anchorage currently has some of the least costly electricity in the nation, and as prices increase, this will clearly have a moderating impact on demand. In the Fairbanks area, the ISER report indicates that since 1975 there has been a per customer decline in electricity use. Is this decline influenced by higher electricity rates in Fairbanks?

Perform a more detailed investigation on the uses of electricity in the commercial sector and the projected demand for electricity by these office buildings, retail establishments, government institutions and the like. A definition of use patterns and a comparative analysis of trends in Alaska versus other states and provinces in Canada would be helpful. This analysis is suggested as a major share of the projected growth in electricity demand and corresponding need for the Susitna Project in related to growth in electricity use in the commercial sector. This growth is calculated to be a result of both employment gains and increased used per employee. In the lower 48, with the advent of higher electricity prices there has been an acceleration in conservation through technology. IBM, Honeywell, Johnson Control, etc., are advertising and installing control computers in buildings which reduce power requirements by upwards of 20%. Is a forecast that assumes a definite increase on a per employee use basis appropriate?

Test the sensitivity of the forecast to a reasonable set of assumptions in the growth in selected energy intensive industries such as:

- mining (Beluga coal, for example)
- petrochemicals

Because of the high level of variability in any forecast, this panel recommends the "uncertainty" be specifically included in all economic evaluations.

Economic Evaluations

The purpose of the economic analysis should initially be to test the sensitivity of the conclusions to a reasonable range of assumptions concerning the key variables. Since the economic tradeoffs are between a capital project (Susitna) and lower capital but higher operating costs of coal and gas units, the range of cost of capital needs to be fully explored. In particular, since the probable economic alternatives to the Susitna project are coal or gas generation, the reasoning and analysis behind the estimates of the capital costs, fuel escalation rates and hours of operation for each alternative need to be defined for review and tests of reasonableness. Furthermore, since we are dealing with an uncertain market, the size of any one power plant addition will impact the economic choice and mix of power plants.

The proposed project will be paid for by the ultimate customer in actual dollars; assumptions on inflation need to be included in economic analyses. However, from a comparison viewpoint, these inflated dollars can be discounted to a constant 1981 basis. The plea here is for consistency between the economic and financial calculations. The availability of tax-exempt bonds for one alternative vis-a-vis the other will also influence the competitive economics.

There are also some primary concerns as they relate to costs and escalation rates of the coal and gas alternatives, together with assumptions on federal policy as to the use of gas in power generation. Again, a range of cases needs to be examined in this area.

We understand that Acres is employing a computer model to assist in this economic evaluation, and we are available to assist Acres in defining a set of cases to be run by the model to explore the range of possibilities. As any model has a set calculation procedure that may be in error, it is advisable to test the model against other approaches. In this respect EPRI (Electric Power Research Institute) has developed other models that are currently being used by U.S. utilities.

Financial Viability

The financing of the Susitna project will be of a scale and magnitude that will challenge and possibly surpass the ability of any one underwriter. Revenue bonds, guarantees by the state and other financing mechanisms need to be fully explored. Every attempt should be made to obtain funding through a tax-exempt vehicle, which will effectively lower the ultimate electric rates to customers in the Railbelt Region. In addition, the ability to obtain tax-exempt financing could significantly increase the economic competitiveness of the Susitna project.

We understand Acres is working in this area, and we cannot comment further on their work until we have an opportunity to review their findings. However, we would like to emphasize the importance of the financing to the success of the project.

FUTURE MEETINGS

Further meetings of the External Review Panel are planned as follows:

March 20 and 21, 1981	San Francisco, California
June 3 to 6, 1981	Anchorage, Alaska
October 6 to 8, 1981	Anchorage, Alaska

The panel expresses its appreciation to the members and staff of the Alaska Power Authority and the staff of Acres American Incorporated for the many courtesies extended to the Panel during the course of the 3 day meeting.

Merlin D. Copen	Jacob H. Douma
A. Starker Leopold	Andrew H. Merritt
Dennis M. Rohan	H. Bolton Seed

March 20, 1981

Mr. Charles Conway
Chairman of the Board
Alaska Power Authority
333 West 4th Avenue, Suite 31
Anchorage, Alaska 99501

Dear Mr. Conway:

The External Review Panel met with representatives of the Alaska Power Authority Board of Directors and its staff and representatives of Acres American in San Francisco on March 20, 1981 to discuss the feasibility studies for the Susitna Hydro-lectric Project. Prior to the meeting, Panel members studied Acres reports on Review of Available hydrology Material, Review of Previous Design Development Studies and Reports and Project Overview. A first draft of the report from the Alaska Power Authority to the Governor and Legislature was reviewed before the meeting and a second draft was received during the meeting. APA staff members briefed the Panel on the draft report and the Acres representative presented an update of feasibility study events since the January, 1981 meeting.

This letter expresses the Panel's opinion whether, based on information available on four critical issues, the feasibility studies should continue to completion in April, 1982, or be terminated now. The Panel concurs that the four critical issues concern the power demand forecast, seismic risk, environmental impacts and economic feasibility. Our present opinions concerning these issues are summarized below.

The load forecasts have an inherent assumption of continued growth in the commercial market for electricity, and implied expansion in the service sector of the Rail Belt economy. If the economy develops in this manner, and real electric rates do not increase substantially and there is no major change in conservation, then the range of forecasts suggested by ISER seems reasonable.

The Susitna Project is probably competitive on a direct economic basis with power generated from coal. Insufficient information is available at this time to evaluate the attactiveness of the Susitna Project vis-a-vis other alternatives such as gas or tidal power.

Based on the field investigations completed to date, both the Watana and Devil Canyon sites appear to be well suited for the hydroelectric developments proposed. The initial studies have defined the general site and rock conditions at the sites and the general seismic geology of the area in which the proposed dams are to be constructed. The seismic design requirements appear to be well within the state-of-the-art for construction of facilities of this type. Important geologic features have also been recognized which merit further attention and investigation programs have been proposed which are well conceived and should provide a sound basis for feasibility design and cost estimates as well as insuring an ample level of seismic safety.

Some excellent studies are under way concerning ecologic conditions in the Susitna basin and possible environmental effects of hydro development. Above the dams there will be inundation of habitats occupied seasonally by moose, caribou, bears, and various lesser species, and there will be modification of the stream flow below the dams which could affect the habitats of salmon, moose and waterfowl. On-going studies should be continued, with amplification of hydrological studies in the Susitna River to better understand possible downstream effects on flora, fauna and the riverbed itself. Based on present knowledge however, there are no obvious environmental threats so serious as to suggest abandonment of continued planning for the hydro project.

Thus in non-economic terms, Alaska is fortunate to have the hydroelectric power potential in areas where the technical, social and environmental impacts appear to be of a manageable nature. The potential for developing renewable, non-polluting hydroelectric power has definite advantages which, though the economic implications require detailed study, are not always amenable to direct economic evaluation.

In summary, it appears that definite answers cannot yet be given to all of the issues involved in evaluating the geotechnical, environmental, economic and market aspects of developing the Susitna Project. However, we believe that the work accomplished to date shows sufficient promise for the future welfare and interests of Alaska and that it is clearly desirable to continue the present studies, supplemented by appropriate additional investigations, to their 1982 completion date.

Sincerely yours,

Merlin D. Copen
Merlin D. Copen

Jacob H. Douma
Jacob H. Douma

A. Starker Leopold
A. Starker Leopold

Absent but responded
Andrew H. Merritt

Dennis Rohan
Dennis M. Rohan

H. Bolton Seed
H. Bolton Seed

June 5, 1981

SUSITNA HYDROELECTRIC PROJECT

EXTERNAL REVIEW PANEL

REPORT NO. 2

INTRODUCTION

The Panel met with representatives of the Alaska Power Authority, Acres American, Terrestrial Environmental Specialists, Inc., and the Fish and Game Department in Anchorage on June 3-5, 1981 for discussions of on-going studies for the Susitna Hydroelectric Project. On June 3rd, representatives of Acres American, TES and ADF&G described the current status of these studies, after which separate group discussions were held on geotechnical, hydraulics and hydrology, and environmental subjects to review specific problem areas in more detail. A site inspection was made by Dr. Merritt on June 4th and 5th to review the field geotechnical exploration program. Dr. Rohan met with representatives of Battelle on June 2nd, Chugach Electric Association on June 4th and Union Oil on June 5th to discuss alternatives to the Susitna project. This report, which summarizes the Panel's opinions and recommendations, was prepared on June 4th and 5th and discussed with representatives of the Power Authority staff and Acres. Dr. Seed was not able to attend the meeting.

GEOTECHNICAL INVESTIGATIONS

Following Dr. Merritt's 1½ day visit to the Watana and Devil Canyon sites, discussions were held at High Lake concerning the on-going field program and preparation of information appropriate for the feasibility design. The following comments summarize these discussions and are offered to aid in the timely completion of the field program.

General - The preparation of finalized geologic maps and profiles is not keeping pace with the rapid accumulation of field information. This situation is compounded by the recent acquisition of a large quantity of field geologic data collected by previous Corp of Engineers work which was never reduced and presented in final form by the Corps. Moreover, the original Corps boring logs need to be reviewed (re-logged) to assure that all field information is presented in a consistent manner.

A schedule for completion of the various phases of work for the summer program has been prepared to assure that the necessary information is analyzed in time for the next phase of feasibility design. The External Review Panel will be prepared to review this work during our October meeting.

Watana Site

Field geologic mapping is underway, the results of which will be used to best locate the remaining exploratory borings. Present structure layouts indicate that the "Fins" shear zone should not intersect any tunnels or open cuts. Special attention is being given to the projection of the "Fingerbuster" shear zone concerning its possible intersection of the downstream portion of the tailrace tunnels. Present information suggests that this zone lies downstream of the proposed underground powerhouse; however, exploratory borings are planned to confirm this interpretation.

Additional seismic surveys will be done to better define the geometry of the buried channel on the right abutment and additional borings and pumping tests are planned for the next phase of exploration.

Devil Canyon Site

The geologic mapping is well advanced at this site and no new shear zones have been identified on the abutments. Boring BH-7 has confirmed the presence of a shear zone (previously recognized) beneath the topographic lineation on the left abutment. This feature wll be receiving careful attention during the upcoming Task 4 study.

Numerous open stress relief joints have been recognized in the upper portion of both abutments and are apparently more prevalent on the left side. The field geologists will be mapping these features in detail to assist in preliminary layouts of the required excavation for the arch dam.

Four borings remain to be drilled at Devil Canyon; 2 will pass beneath the river to explore for geologic structures and 2 more drilled into the abutments near the river to determine general rock quality. If the river hole in progress encounters favorable conditions, then the second hole may not be required for the feasibility design. Considering the excellent rock exposures, the two remaining borings may best be drilled at the upper elevations (on the left side) rather than close to the valley bottom as presently planned. These holes should be directed to cross the stress relief joints to determine their presence at depth. The drill advance can be carefully watched to determine the presence of open joints. A borehole camera would provide the most direct method of assessing the presence and magnitude of these features and is being considered by Acres' personnel.

SEISMIC STUDIES

Seismic studies have evaluated all known and detectable faults and lineaments in the project area. The 1981 field program calls for a study of thirteen features identified as signifcant in the 1980 investigations.

In order to firm up design for the major structures in the project, it is essential that conclusions regarding the significance and impact of each of these features be reached as soon as practicable. Delay in completing this work and evaluating the parameters required for design will have an important effect on meeting the project schedule.

HYDRAULICS AND HYDROLOGY

The field program for surveys and collection of hydrologic data is considered to be adequate for the current feasibility study. Modifications to the original scope of work involve studies of navigation effects. However, after analyses of available existing data and data to be collected, it may be found necessary to collect some additional short-term information to firm up tentative conclusions in one or more areas. Specific comments on some areas of data collection are presented below.

Flood Flows

Stream flow data are being obtained at a sufficient number of existing, reactivated and newly installed gaging stations throughout the drainage area to enable a reliable determination of flood flows. Studies to date indicate that the Corps PMF is about 20,000 cfs too low. A report on flood discharges will be issued for review in a few weeks. Some 80 water level cross-sections have been taken in the Susitna River. HEC programs are being developed for free surface and ice covered water levels for various size floods. Reports will be issued on free surface water levels in July and ice covered conditions somewhat later. These studies should establish reliable bases for determining river tailwater levels at the dams and water surface profiles in downstream reaches of the Susitna River.

Sediment Data Collection

The river sediment measuring program has not been started. This program should be defined and started as soon as possible under the guidance of the USGS or a private river sediment expert. It is essential that bed load measurements be made during this runoff season to enable a reasonable assessment of the effects that depletion of sediment loads by construction of the dams would have on downstream river conditions. The Panel is concerned that the necessary sediment data may not be available in time for inclusion into the June 30, 1982 feasibility report.

Reservoir Capacity

Recent reservoir surveys have been completed from which more accurate capacity curves have been developed. At Watana, the revised curve indicates one to two percent less reservoir capacity between elevations 1700 and 2100, but the capacity is essentially the same as shown by the original curve at maximum pool elevation 2200. This small difference does not require revisions in the design development studies. However, the revised capacity curve should be used in final design.

At Devil Canyon, the revised reservoir capacity curve based on the latest survey indicates significantly greater capacity than the initial capacity curve, being approximately 30 percent greater at elevation 1500. Since power operation would be near maximum pool nearly 100 percent of the time, the revised greater capacity would have little influence on design development studies. However, the greater capacity curve should be used in final design and reservoir filling and drawdown studies.

Energy Output

The firm energy output for the Watana/Devil Canyon system has been determined by routing actual stream flows which occurred for the 1969-79 period through the system. Since this was by far the period of lowest stream flow over 70 years of record, the Panel concurs that this is a satisfactory basis for establishing firm energy output.

DESIGN DEVELOPMENT

Acres described various alternative schemes for optimizing design of the main dams, coffer dams, saddle dams, spillways, power facilities and diversion tunnels for the two dams. The Panel was very impressed with the many specific alternatives which will be studied to arrive at the most functionally satisfactory and economical plan. We desire to emphasize, however, that full consideration should be given to the effects on ease of construction and construction schedules, as well as costs, for the various alternatives. Specific comments follow on some of the design features that will be considered in the optimization studies.

Multiple Level Outlets

There is some question whether multiple level outlets will be required in the power intakes, particularly at Watana Dam. Some experience in several Alaska lakes indicates that a marked thermal stratification may not occur in the two reservoirs and that the reservoir waters may never be free of turbidity, in which case multiple level outlets would not effectively enhance downstream water temperatures or quality. The Panel is of the opinion that sufficient studies should be made of other lakes to make a better assessment of what is most likely to occur in Watana and Devil Canyon reservoir. If the studies are inconclusive, then the Panel suggests that multiple level outlets be provided at both dams, since their costs would not be excessive and prototype experience may prove them to effectively enhance water temperatures and quality downstream of the dams. An exception to this statement, however, is that in the event Devil Canyon will be constructed earlier than anticipated due to greater power demand, then multiple level outlets may not be required at Watana Dam.

Low Level Outlet

Acres has given preliminary consideration to providing low level outlets at both dams for lowering the reservoirs in the event of an emergency. Based on general guidance information used by the Corps of Engineers, a low level outlet capacity of approximately 100,000 cfs would be required. This would require construction of an additional large gated tunnel at great cost. A low level outlet was provided at Mica Creek Dam in British Columbia by providing a tunnel plug and gates in the diversion tunnel which would allow substantial lowering of the reservoir in a period of 8 months. The Panel believes that this type of low level outlet should be installed in the diversion tunnels at Watana and Devil Canyon. This low level outlet would provide for regulation of initial reservoir filling, minimum flow release when the powerhouse is not in operation and emergency lowering of the reservoir over a substantial period of time for repairs in the event that seepage problems should develop.

Service Spillway

One alternative scheme for Watana provides for a service spillway with a stilling basin designed for a 1 in 10,000 year flood and a fuse plug spillway to handle additional flows up to the PMF. While there may be some reduction in cost by reducing the size of the service spillway and increasing the size of the fuse plug spillway, the Panel is of the opinion that the service spillway should not be made smaller than required for a 1 in 10,000 year flood. However, some reduction in cost can be made by designing the stilling basin to function as a hydraulic jump basin for a smaller discharge, say 50 percent of the 1 in 10,000 year flow, and sweep out of the basin for larger discharges, if this would not endanger the stilling basin structure.

Spillway Outlets in Arch Dam

Although technically feasible, the Panel suggests that consideration be given to eliminating the spillway outlets through the arch dam at Devil Canyon and the concrete lined plunge pool near the toe of the dam by increasing the size of the service spillway. If there is not a substantial increase in cost, the Panel would prefer to eliminate the outlets through the arch dam.

Watana Dam

An embankment structure has been selected for feasibility studies at the Watana site. It appears that very little effort has been expended to study other types of dams for this site. A preliminary design has been prepared for an arch dam, but, to our knowledge, essentially no attempt has been made to compare the cost of these two structures, to evaluate construction time or difficulties, or to otherwise evaluate potential alternatives.

As a basis for proceeding with feasibility studies, we consider it important that economic comparisons be prepared for viable alternative dam types for the Watana site.

Devil Canyon Dam

An arch dam appears to be the most appropriate structure for the Devil Canyon site. This conclusion has been reached by essentially all investigators, and, we assume, is based on comparisons with other dam types for the site.

Acres has developed a satisfactory arch dam design for the Devil Canyon site. Stress levels appear to be acceptable for all normal loading conditions studies. A dynamic response spectrum analysis, assuming 0.5 gravity ground acceleration and a 5 percent damping rate, was conducted. The resulting stresses indicate that construction joints in the upper part of the dam would open intermittently. Some horizontal surface cracking may also occur on both faces.

We believe this loading to be extremely conservative. A damping rate of 10 percent is more appropriate for this situation, and a ground acceleration no greater than 0.4 gravity appears to be more realistic.

ENVIRONMENTAL CONSIDERATIONS

Substantial progress is being made in the study of various environmental considerations, such as the current status of fish and wildlife populations, cultural resources (archaeologic remains), vegetation types, and alternative location of access roads. Some crucial environmental issues, however, have not been adequately addressed. These will require extra attention in the 1981 field season. In this category are downstream effects of the dams on the river channel itself with potential secondary effects on fisheries and wildlife, effects of the dams on water turbidity, and possible effects of leaving standing timber in the impoundment areas.

Fisheries

Studies of fish population in the Susitna River Basin were late in starting in 1980, but considerable data were accrued through the fall and winter (1980-81). An accelerated program is underway in June 1981, which by 1982 should yield a preliminary picture of the existing situation.

The Susitna River above Devil Canyon apparently supports a substantial population of grayling, but few if any salmon are able to ascend the stream. Presumably, the grayling and probably lake trout will thrive in the impoundments. The question of whether they will constitute an important recreational fishery depends on the ultimate clarity or turbidity of the impounded waters. Even if the water is turbid, there will be some sport fishing at the mouths of clear streams entering the impoundments.

The lower Susitna River and its many tributaries and back waters carry substantial populations of salmon that support an important commercial fishery in Cook Inlet, as well as a sport fishery in the river channels and at the river mouth. There are additional populations of grayling and rainbow trout in many of the tributaries. On-going studies are intended to shed light on the relative importance of the various tributaries, backwaters and main channels in supporting fish life. Of particular significance in this regard is gaining an understanding of the possible effects of the impoundments on downstream hydrology. This can best be prognosticated by measuring the bed load of sediment now carried by the Susitna and its various tributaries. When the silt load from the upper Susitna is cut off by the dams, what will be the changes in the conformation of the lower river and the chemistry and turbidity of the water? Data on bed load must be obtained before this important issue can be predicted.

Wildlife

The Alaska Department of Fish and Game is making commendable progress in studying populations of moose, caribou, black and grizzly bears, wolves and dall sheep. The moose will be directly affected by loss of winter range in the Watana impoundment. In time, there may be a compensatory development of new willow stands bordering the impoundment. Black bears will be all but eliminated from the Watana impounded area by flooding of denning areas and loss of protective timber. Caribou may be somewhat affected by disruption of seasonal migration to calving grounds. Dall sheep, grizzly bears, and wolves will probably be only peripherally affected by disturbance of their wilderness habitat.

The University of Alaska and the Alaska Cooperative Wildlife Research Unit are studying populations of furbearers, non-game mammals, and birds. As far as we know these studies are progressing satisfactorily.

Downstream Hydrology

Change in the amount of bed load carried by the Susitna River may affect fisheries and wildlife in a number of ways. There is some indication that the backwaters and billabongs of the lower Susitna may be important rearing areas for juvenile salmon. Summer flooding of these backwaters, sloughs, and ponds creates extensive waterfowl habitat. Peak floods cut into timber stands and deposit open bars which are colonized by willows that constitute winter forge for moose. Understanding the dynamics of the lower river is essential in predicting long-term effects of the Susitna project on wildlife.

The need for additional hydrologic studies - especially bed load studies - was discussed in the March meeting of the External Review Panel in San Francisco. But as of June 1981, no firm plan of action has been implemented. The Panel urges immediate action to assure that some useful data on bed load will be available for consideration in October, 1981. Without it, there will be no way that downstream effects can be evaluated.

Water Chemistry and Turbidity

The water quality program is being prepared for Acres American by R & M Consultants. No results have been made available to the Panel, nor even a list of specific questions being investigated. From the standpoint of fisheries it is important to know what may be the future turbidity of the reservoirs and the Susitna River below.

In summer, a substantial flow of turbid water will enter Watana Reservoir from the glacier above. Heavy materials will be deposited in the reservoir head, and smaller particles will be carried on toward the dam. To what extent will the water clear as it approaches Watana dam? Will the water in Devil Canyon reservoir be clear or cloudy? And what of water passing Devil Canyon dam into the mainstream of the river below through summer and winter alike? Clouded water blocks the passage of light and reduces or precludes the growth of phytoplankton which form the base of the aquatic food chain. The productivity of these waters for fish will be an inverse function of turbidity. Are adequate studies underway to prognosticate post-project water conditions?

Timber in Impoundment Area

At the January, 1981 meeting of the Panel, the suggestion was made that consideration be given to stripping the timber from areas to be impounded, for the purpose of reducing the load of floating trash in the reservoirs. Has this idea been considered? Has the cost been estimated?

Nitrogen Supersaturation

To protect fish life in the Devil Canyon reservoir and in the river below, the design of both dams - including penstocks and overflow structures - must minimize or preclude the incorporation of nitrogen into solution if current studies by Mr. Milo Bell suggest this possibility.

Access Roads

Selection of the route or routes for constructing access roads should avoid, insofar as possible, disturbance of caribou or Dall sheep. These two species are expecially susceptible to environmental disturbance. The area south of the two reservoirs is of particular importance to sheep. The calving ground of caribou adjoins the upper reaches of Watana impoundment on the north.

ECONOMIC FEASIBILITY AND FINANCING

Battelle Pacific Northwest is responsible, under separate contract, to review and analyze alternatives to the Susitna project. Dr. Rohan met on June 2, 1981 at Battelle's office with Mr. Swift, the project manager and several of his staff to review Battelle's progress and to gain a better understanding of their approach. Battelle has addressed its initial effort at understanding the gas supply situation, and in improving the demand forecasting methodology. Copies of working draft reports on these subjects are being forwarded for review by the External Review Panel. Because the results of the Battelle study will be employed in Acre's final report due in April 1982, it is recommended that the Alaska Power Authority monitor the timeliness and work quality of Battelle.

From the initial Battelle meeting it was learned that Battelle's approach to comparing alternatives is not totally consistant with the work of Acres. In this respect, it clearly is advisable that Battelle and Acres meet in the near future to arrive at a common basis to make economic comparisons of the various alternatives.

Because of the high level of uncertainty in estimating a) the future markets for electricity, b) the capital costs and construction time to build power plants, c) the availability and prices for fossil fuels and, d) future regulatory environments, it is recommended that all economic analysis incorporate this uncertainty. Techniques for making economic comparisons under uncertainty are well known and include sensitivity analysis, probabilistic assessments and decision analysis. Acres' current approach needs some improvement as it is narrowly focused. The External Review Panel would like to review in October, progress in developing a consistant approach to evaluating alternatives under uncertainty.

The issue of financing mechanisms for the Susitna project and the corresponding electric rates to the customers needs further analysis. Because of the financial risks, it is likely that the Susitna project cannot be financed without support in the form of equity participation, guarantees and the like by the State of Alaska. A determination of available and likely financing mechanisms needs to be further developed by Acres and available for review in October.

If the Susitna project is financed through direct state funding, and the corresponding rates for electricity are set less than the cost of gas or oil heating, there will be economic incentives to convert to electric heat. This would greatly accelerate the demand for electricity and have a major impact on Susitna and other power projects. The full impacts of this case need to be investigated.

From an economic viewpoint, it appears that gas is the competitive alternative to the Susitna project. Chugach Electric Association, which represents about half the power requirements for the Railbelt region, is favorably disposed to this gas alternative. The gas reserve situation and future prices for gas needs further investigation. Particular emphasis should be given to understanding potential long term contracting agreements for gas from the oil and gas companies.

The Panel would like to examine the criteria that FERC will employ in the market and economic area to be certain that Acre's report fully addresses these issues.

AGENDA FOR NEXT MEETING

The next meeting of the Panel is tentatively scheduled for the week of October 5, 1981 at the Acres Buffalo location. The Panel desires to make the following recommendations regarding this meeting:

1. A site visit should be made by Panel members who desire to do so before the October 5th before the full meeting.

2. Geotechnical problems should be resolved and discussed in more detail.

3. Results of design development studies for various alternatives schemes should be discussed in more detail.

4. Environmental study results should be presented and discussed more fully.

5. Battelle should present the results of their studies for Panel consideration.

6. Consideration should be given to having a FERC representative attend the meeting if this will be useful in speeding up their review process and earlier license approval.

CLOSING REMARKS

The Panel expresses its appreciation to the staff of the Alaska Power Authority and the staff of Acres American Incorporated for the many courtesies extended during the meeting.

Merlin D. Copen	Jacob H. Douma
A. Starker Leopold	Andrew H. Merritt
Dennis M. Rohan	H. Bolton Seed

Merlin D. Copen	Jacob H. Douma
A. Starker Lecpold	Andrew H. Merritt
Dennis M. Rohan	Absent H. Bolton Seed

October 8, 1981

SUSITNA HYDROELECTRIC PROJECT
EXTERNAL REVIEW PANEL
REPORT NO. 3

INTRODUCTION

The third meeting of the External Review Panel for the Susitna hydroelectric Project was convened on October 6-8, 1981 at the Acres American office in Buffalo. In addition to Panel Members, representatives of the Alaska Power Authority and Acres American were present. Various members of the Acres American staff presented discussions regarding progress in geotechnical areas, seismicity, hydraulics, hydrology, and design. The discussions were well prepared and presented in such manner as to give a maximum amount of information in a reasonable time.

Prior to the meeting Panel Members received a document entitled "Susitna Hydroelectric Project, External Review Board, Meeting #3, Information Package, October 6-8, 1981". During the meeting other printed information was presented to the Panel as required.

The Panel appreciates the efforts of the Acres American Staff in planning and preparing for this very informative and successful meeting.

SEISMICITY AND SEISMIC GEOLOGY

Excellent progress has been made during the summer months in resolving most of the uncertainties regarding the possible presence of active faults in the vicinity of the dam sites, in developing an adequate model of the seismic geology of the region, and in assessing the maximum levels of earthquake shaking which could result from events occurring along the major seismic sources. These studies have led to the following preliminary conclusions:

WATANA DAM SITE

Four major lineaments were originally identified as being possible faults in the vicinity of the dam:

(1) The Talkeetna Thrust Fault
(2) The Fins Feature
(3) The Susitna Feature
(4) The Watana River Feature

Field geologic studies during the past several months have developed evidence indicating that:

(1) The Talkeetna Thrust Fault is not an active fault.
(2) The Watana River Feature is not a fault.
(3) The Susitna Feature is not a fault.
and (4) The Fins Feature may well be a fault but it is relatively short in length and, since there are apparently no other active faults in the area, it is very unlikely that it could be active. In any case its length would preclude the possibility of it being the source of a significant earthquake.

In consequence, there are apparently no active faults crossing the site and the major sources of earthquake shaking at the site may be attributed to earthquakes occurring on the Benioff Zone underlying the site at depth, the Denali fault, the Castle Mountain Fault, and smaller local earthquakes occurring with no apparent surface expression in the crust of the Talkeetna terrain. Considerations of fault distances and possible earthquake magnitudes leads to the conclusion that the approximate maximum levels of shaking from the different sources will be as follows:

Source	Closest Distance	Magnitude (Ms)	Peak Acc. (Mean)
Benioff Zone	≃ 63 km	≃ 8½	≃ 0.35g
Benioff Zone	≃ 48 km	≃ 7½	≃ 0.32g
Denali Fault	≃ 70 km	≃ 8+	≃ 0.22g
Local Event	*	*	*

* Information to be provided in Final WCC Report

Seismic geology considerations have led Woodward-Clyde Consultants to suggest that the maximum local earthquake which needs to be considered is a Magnitude 5½ to 6 event occurring at a distance of about 10 km from the site. Such an event would produce a peak acceleration (mean value) of about 0.35g and would therefore not be a controlling event. However, the Panel believes that in view of the past seismic history and other considerations it would probably be prudent to consider the possibility of a somewhat larger event at a slightly shorter distance. In this case the local earthquake would be responsible for the maximum accelerations likely to develop at the dam site. This does not mean however, that it will necessarily control the design.

For the Benioff Zone event, which seems to be controlling at this stage, the motions recommended by Woodward-Clyde Consultants for preliminary design evaluations appear to be entirely appropriate.

DEVIL CANYON SITE

At the end of 1980, nine lineaments were identified in the vicinity of the Devil Canyon site which could possibly be active faults. Field geologic studies during the past 6 months have led to the conclusion that only 3 of these

features are faults, that the three features recognized as faults are inactive, and that in any case they are so short in length that they could not generate earthquakes which would be controlling events with regard to earthquake motions at the dam site. Thus since there are no active faults in the vicinity of the dam site, the design earthquake motions will be determined by similar considerations to those applicable for the Watana site. The Panel agrees with these conclusions.

Consideration of the most significant seismic sources of ground shaking leads to the following:

Source	Closest Distance	Magnitude (Ms)	Peak Acc. (Mean
Benioff Zone	≃ 90 km	≃ 8½	≃ 0.3g
Benioff Zone	≃ 58 km	≃ 7½	≃ 0.3g
Denali Fault	≃ 64 km	≃ 8+	≃ 0.24g
Local Event	*	*	*

As for the Watana site, there is a need to establish very soon the significant characteristics of the local earthquake (in the crust of the Talkeetna Terrain) in order to finalize the seismic criteria to be used for project design.

* To be provided in Final WCC Report

In light of the information presented at this meeting and on the basis of past experience, the Panel believes that through the use of appropriate design and construction procedures, dams with ample margins of seismic safety can be constructed at both sites. The Panel believes, however, that the question of seismic effects due to local crustal earthquakes should be resolved in the next few weeks so that more definitive design studies can be completed.

ROCK ENGINEERING CONSIDERATIONS

As a result of discussions during this meeting as well as observations made in the field by Panel member Merritt during the period of 23-25 September, we have the following comments regarding present designs.

WATANA

Every effort should be made to reduce the height of the cut slope at the inlet to the diversion tunnel. The structures can probably be moved closer to the river and perhaps shifted slightly in a downstream direction.

The surface excavation at the outlets of the tailrace tunnels and spillway structures is likewise very extensive. Further detailed examination is warranted to minimize possible slope stability problems.

* To be provided in Final WCC Report

Recent borings in the proposed underground powerhouse site encountered a zone of soft hydrothermally altered diorite. This is not acceptable material to have in a major underground excavation. Some shifting of these openings is required. Considering all borings made in the right abutment, the general quality of the diorite is quite high and we foresee that acceptable rock can be found for the proposed structures.

DEVIL CANYON

The graywacke and argillite at this site appear to be of acceptable quality for the proposed underground structures. No major shear zones have been recognized in these areas. The underground openings have been oriented with respect to the major known joint systems and bedding planes. The present layout is acceptable and it is recognized that some slight shift could result based upon the results of future exploration.

The axis of the proposed surface spillway on the right abutment will nearly parallel the strike of the bedding of the rock. The required cuts will daylight the bedding which dips at about 50 degrees into the excavation. Potential major rock stability problems could result which might not be solved by simple rock bolting measures. This design likewise requires your review.

BURIED CHANNEL

The results of all geophysical surveys completed to date have defined a major channel beneath the plateau on the right abutment at the Watana site. The channel is approximately 15,000 ft wide when measured with respect to that portion of the bedrock channel below the proposed reservoir pool level. The deepest portion of the channel lies about 450 ft below pool level; however, perhaps as much as 60-70% of the channel lies 100 ft or less below maximum pool level.

The borings completed during the Corps of Engineers study indicated that the channel is filled with glacial till, outwash, and perhaps lacustrine deposits. The boring logs show that boulders (some as large as 12 ft) can be expected in these heterogeneous deposits, either as individual units or as thick layers. Contour maps made of the bedrock surface suggest a wide entrance channel or channels upstream of the damsite and a relatively narrow exit into Tsusena Creek downstream of the damsite.

The buried channel on the north slope of the reservoir at Watana Dam is much greater in extent than was anticipated a year ago and represents one of the greatest uncertainties associated with the Watana Dam project. Major problems posed by the presence and extent of this channel are

(1) The magnitude of possible seepage losses through the channel.
(2) The possibility of piping within the channel resulting from seepage from the reservoir towards Tsusena Creek.
(3) The possibility of seismic instability in the soils comprising the buried channel under strong earthquake shaking.

It appears that problems (1) and (2) above could be eliminated by construction of a cut-off wall and grout curtain through the soils filling the channel. However, the provision of such a cut-off would not solve any problems of seismic instability on the upstream side of the wall.

Since very little information is available concerning the nature of the soils forming the channel fill it is not possible to assess the magnitude of the seismic instability problem, if indeed it exists at all, or the need for an extensive cut-off wall, currently projected to be about 15,000 feet long and varying from a few feet to 450 feet in depth. However, it is clear that both the possibility of seismic instability and the cost of a cut-off would be dramatically reduced if the reservoir level were about 100 feet lower than currently planned. Such a lowering could reduce the length of the cut-off to about 4,000 feet, facilitate its construction, and by lowering the water table in the soils, increase their seismic stability. In view of these advantages, together with the fact that economic advantages associated with the top 50 to 80 feet of Watana Dam do not appear to be very great, the Panel believes that careful consideration should be given to the potential benefits of reducing the height of Watana Dam by 50 to 100 feet. Such a reduced height might also facilitate layout problems for the dam.

The Panel cannot be sure that a reduction in dam height would be advantageous but believes that a careful study of the question is warranted in the next several months.

WATANA DAM EMBANKMENT

The Panel believes that the preliminary design section selected for Watana Dam is satisfactory and will produce a stable and economical structure. It is suggested however, that consideration be given to the following items:

(1) If the shells are constructed of densely compacted gravel or rockfill and the core of a much more compressible sandy-silty-clay, there is a danger of deleterious stress redistribution due to differential settlements. Consideration should be given to minimizing this possiblity by:

(a) inclining the core slightly upstream, providing this can be done without jeopardizing stability.

and/or (b) locating a relatively incompressible core material which is adequately impervious. Such a material appears to be available as a GC material in one of the borrow areas.

(2) Deformations of the upstream shell of the dam due to strong earthquake shaking can be minimized either by densifying the shell material to such extent that high pore pressures cannot develop or by using highly pervious rock-fill which will dissipate any pore pressures resulting from earthquake shaking almost as rapidly as they develop. Consideration should be given to using gravel-fill and rock-fill in the upstream shell in such a way as to optimize their use from a seismic design point of view.

(3) There is apparently ice in the rock joints in the abutments at Watana Dam site and this will have to be thawed before grouting. It would be desirable to determine whether construction costs have allowed for this.

(4) It appears that there may well be permafrost in the foundation soils for the saddle-dam. When this melts it could leave the soils in a very loose condition which may be adequate for static stability but inadequate for seismic stability. It would be desirable to explore this possibility further and examine the need for excavation of frozen foundation soils prior to saddle-dam or dike construction.

DEVIL CANYON DAM

Sufficient study has been completed to adequately support the present arch dam design for feasibility purposes. However, the linear feature through the pond areas where the wing dam will be located should be further explored in the near future. Similar considerations to those discussed for the Watana Site should be given to the foundation soils under the Devil Canyon wing dam.

WATANA DAM DIVERSION TUNNELS

Two diversion tunnels are proposed for diverting up to a 1 in 5-year flood during construction of Watana Dam. One tunnel would be located at a low level so that it would flow full at all times. The second tunnel, located at a higher level, would have free flow. After diversion the lower tunnel would be plugged. Two plugs would be constructed in the upper tunnel with gated outlets through them to permit release of low flows until Devil Canyon is completed and serve to lower the reservoir in case of an emergency. The Panel concurs in the general concept of the diversion tunnels and modification of the high level tunnel for use as a low-flow and emergency release outlet, subject to refinements discussed by Acres.

WATANA DAM SPILLWAYS

Spillway flows at Watana Dam would be handled by three separate flow release structures. Discharges corresponding up to a 1 in 100-year flood would be released through a low-level tunnel controlled by three or more Howell-Bunger or similar valves located at the downstream end of the tunnel. Discharges corresponding to floods in excess of 1 in 100-years and up to 1 in 10,000-years would flow through an open chute spillway with a flip bucket. Discharges in excess of the 1 in 10,000-year flood up to the PMF would pass through a bypass channel controlled by a fuse plug.

The Panel concurs in the proposed concept of handling spillway flows. Release of floods up to 1 in 100-years by low level valves would maintain the nitrogen supersaturation level to an acceptable limit. The Panel suggests that fixed cone valves as installed by the Corps of Engineers at New Melones Dam be used, since their greater rigidity makes them more suitable for high-head operation. The smaller chute spillway flows would reduce erosion in the downstream river channel. Hydraulic model tests will be required to determine the extent of material that should be pre-excavated in the plunge pool area. In view of the infrequency and short duration of spillway operation and the relatively high quality of rock in the steep river banks, the Panel is of the opinion that excessive erosion would not occur due to service spillway operation. With respect to the emergency spillway bypass channel, the Panel is concerned over the 45-ft height of the fuse plug. This high plug would need to be designed as a small earth dam to retain the power pool at maximum levels and also be capable of failure as a fuse plug when it is overtopped. It is suggested that the entrance to the bypass channel be widened, thereby requiring a smaller height of fuse plug. This would also reduce the amount of reservoir lowering in the event of fuse plug failure.

DEVIL CANYON DIVERSION TUNNEL

One diversion tunnel is proposed for Devil Canyon Dam to divert flows up to a 1 in 50-year flood during dam construction. The tunnel would be plugged after it is no longer needed for diversion. The Panel suggests that this tunnel could be used for spillway flow releases in an alternative spillway design discussed hereinafter.

DEVIL CANYON SPILLWAYS

As for Watana Dam, spillway flows at Devil Canyon would be handled by three separate flow release structures. Flows up to the 1 in 100-year flood would be released by four or five outlets through the base of the concrete arch dam controlled by Howell-Bunger or other type high pressure valves. Discharges in excess of 1 in 100-years and up to 1 in 10,000-years would flow through an open chute spillway with a high level flip bucket. Discharges in excess of the 1 in 10,000-year flood up to the PMF would pass through a bypass channel controlled by a fuse plug.

The Panel concurs in the concept of handling the spillway flows subject to the question raised below. Release of small flows through valves at the base of the dam will prevent excessive nitrogen supersaturation in the downstream river channel, as well as reduce discharges and flow frequency and duration in the chute/flip bucket spillway, thereby reducing plunge pool erosion. Based on a ground and air inspection of the river channel at the Devil Canyon Site by Panel member Douma and Acres representatives on September 17, 1981, the Panel is of the opinion that the very high quality rock in the canyon walls should not experience excessive erosion due to spillway operation. In this case, pre-excavation of streambed material and weathered rock is probably not required. The Panel is concerned, however, over the deep sidehill rock cut required for construction of the spillway chute. It suggests that consideration be given to providing spillway tunnels, as required, instead of the chute spillway. In this alternate plan, the diversion tunnel and probably only one additional tunnel would be required. With respect to the emergency bypass channel spillway, the Panel is concerned over the 57-foot high fuse plug for the reasons stated for the Watana fuse plug. Consideration should be given to increasing the length and reducing the height of this fuse plug as described for Watana.

DEVIL CANYON POWERHOUSE TAILRACE

The Panel concurs in extending the tailrace for the Devil Canyon powerhouse about 1¼ mile to take advantage of the additional approximately 30 feet of head.

CLOSING REMARKS

The Panel requests that the topics raised in this report be thoroughly discussed in the next External Review Board Meeing tentatively scheduled for the week of January 11, 1982 in Anchorage.

The Panel greatly appreciates the many courtesies extended to it by the staff of the Alaska Power Authority and the staff of Acres American, Inc.

Merlin D. Copen

Andrew H. Merritt

Jacob H. Douma

H. Bolton Seed

18 November 1981

Mr. John Lawrence
Project Manager
Acres American Inc.
900 Liberty Bank Building
Buffalo NY 94202

Subject: Susitna Project
Specialist Consultants Panel Meeting No. 4
November 18, 1981

Dear Mr. Lawrence:

INTRODUCTION

On this date, Profs. Hendron and Peck met in Buffalo to discuss certain geotechnical features of the project. Briefing and discussions followed the attached agenda.

This letter was drafted in the Acres American office at the end of the meeting and was finalized by the undersigned shortly thereafter.

WATANA CORE MATERIALS

The well graded materials from borrow area D are suitable for use in the core of Watana Dam; current thought regarding filter requirements for well graded materials should be taken into account in the design of the filters (John Lowe III, 4th

Nabor Carrillo Lecture, 1979). The well graded materials from borrow area H are also suitable and have some plasticity which possibly makes them slightly more desirable when considering design against piping. However, the clayey materials may be more compressible than the materials from area D; also, they may exist at water contents too high to be placed at the desired densities and there will be little possibility of drying them during the construction season. In summary, both materials are acceptable on the basis of present information. More information is necessary on insitu water contents and desired densities in the dam before the final selection can be made properly.

WATANA DAM SHELL MATERIALS

We feel that the dam would perform better statically if river gravel and cobbles were used for the upstream shell, because rock fill dams over about 500 ft high usually develop longitudinal cracks upon first filling due to additional breakage at sharp contacts on saturation. Zones of processed gravel could be provided to eliminate the fines and assure higher permeabilities if excess pore pressures are thought to be a problem during earthquakes. It is possible that too low an assumed stiffness for the compacted river gravels may be a cause for the high pore pressures computed in dynamic analyses. Stiffness values for these materials could be approximated by back calculation from the observed settlement of Portage Mountain Dam in which both processed and pit-run compacted gravels were used.

WATANA CORE GEOMETRY

Although static analyses may indicate that a more favorable stress distribution is achieved if the core is sloped upstream (on the assumption that the core is more compressible than the shells), we feel that a central core is preferable under earthquake conditions because the shells will probably shake down more than the core. Thus the downdrag on the core will tend to produce higher vertical stresses in the core and so reduce the probability of cracking.

WATANA RELICT VALLEY

Control of seepage through this buried valley is required for safety; the cost of the lost water is of little import because the seepage loss merely offsets the requirement for a minimum downstream flow. Three alternatives have been considered:

1) An upstream blanket over the entire inflow area. This would be costly and, in fact, impractical because of the limitation on its extent imposed by the entrance to the diversion works.

2) A cutoff across the pervious channel. This would be extremely costly and probably ineffective. For practical reasons it would hardly be possible to construct a slurry wall deeper than 200 ft. Attempts to create a grouted alluvial cutoff between the bottom of the wall and bedrock would have small chance for success in view of the likelihood of encountering permafrost and in view of the great variation of permeability likely to exist. If such a cutoff were to be provided, it would be necessary to monitor points of possible emergence of seepage downstream in the Talkeetna* valley and, in all probability, to protect part of the area by filter blankets. In our judgment no further consideration should be given to the cutoff alternative.

3) Prevention of piping or backward erosion by providing suitable filters in the zone of seepage emergence in the Talkeetna* valley. This can be done, as the need is demonstrated, in the following steps:

*note Tsusena valley - [signature] 12.7.81

a) Establish the location and regime of springs that presently exist in the area of possible emergence, and install and observe piezometers at suitable locations prior to reservoir filling.

b) If discharges appear or increase during reservoir filling (or thereafter as permafrost zones melt), or if piezometric levels so indicate, cover the emergence areas with filter drains. If seepage emerges high above the Talkeetna* valley bottom, consideration can be given to directing the seepage into lower strata by means of filter wells and providing filter protection for the lower strata.

We consider this alternative to be the most positive control measure. It will, in addition, be the least costly. Similar treatment would be necessary to a lesser extent even if one of the other alternatives were adopted. The procedure requires a period of surveillance, adequately funded, for several years until conditions stabilize, including the melting of permafrost until thermal equilibrium develops. It also requires maintaining the ability at site to execute the measures that may be found necessary. It should be noted, however, that the requirements of surveillance and capability of

* Note: Susitna valley – [illegible] 1/7/81

remedial work would exist in any event, in view of the remoteness and rigorous climatic conditions at the site.

SADDLE DIKE AT WATANA RELICT VALLEY

In view of our preference to eliminate the cutoff in the valley, the design of the saddle dike would not be premised on the incorporation of the cutoff in its foundation. The relatively low head across the dike would permit conventional seepage control. However, consideration must be given to the possible existence and thawing of permafrost zones in the foundation after the reservoir has risen and to the influence of liquefiable zones. Exploration is presently inadequate to determine if such zones exist. If the maximum reservoir level would be no higher than the natural saddle, these considerations would become insignificant. We believe the proposed studies of reservoir elevation will be useful to determine if there is an optimum level at which most of the project benefits may be retained while the problems of the dike can be substantially reduced.

WATANA UPSTREAM COFFERDAM

We are concerned about the space limitation that may require steepening the downstream slope of this cofferdam if the bedrock in the river should be lower than anticipated where the main-dam excavation would occur adjacent to the cofferdam. We also have concern that constructing the proposed cutoff to rock beneath the cofferdam may involve delays due to its depth and to obstructions in the alluvium. We suggest that the cofferdam design be studied further.

PERFORMANCE OF CONCRETE DAMS

We believe it would be pertinent to review the experience in arctic climates of concrete dams, including the long-time history of several dams in Norway. (For example, Heggstad and Myran, Investigations on 132 Norwegian Concrete Dams, 9th Congress Large Dams, Q34, R28, Istanbul 1967; Berdal and Kiel, Skogfoss Hydroelectric Power Station, Norway/USSR; Civil Engineering Works, Proc. Inst. CE, Vol. 30, pp. 271-290, Feb. 1965, discussion Vol. 33, pp. 481-491, March 1966.) This information would be pertinent to several features of the project, including possible consideration of a concrete-faced rockfill dike at the side channel to the left of the Devil Canyon site.

Yours sincerely,

alfred J. Hendron Jr.

A. J. Hendron, Jr.

Ralph B Peck

Ralph B. Peck

RBP/ajj

January 13, 1982

SUSITNA HYDROELECTRIC PROJECT
EXTERNAL REVIEW PANEL
REPORT NO. 4

INTRODUCTION

The fourth meeting of the External Review Panel for the Susitna Hydroelectric Project was convened on January 12-13, 1982 at the Alaska Power Authority office in Anchorage. In addition to Panel Members, representatives of the Alaska Power Authority and Acres American were present. Various members of the staff presented discussions regarding progress in geotechnical areas, seismicity, hydraulics, design, and economics.

Prior to the meeting Panel Members received documents entitled "Susitna Hydroelectric Project, External Review Board, Meeting #4, Information Package, January 12-13, 1982"; "Susitna Hydroelectric Project, Acres Specialist Consultants Panel, Report, November 18, 1981"; and "Final Report on Seismic Studies for Susitna Hydroelectric Project, February 1982, prepared by Woodward-Clyde Consultants".

A separate meeting was held in Bellevue, Washington on January 14 and 15, 1982 to review Battelle's preliminary findings of alternatives to the Susitna project, and to be briefed on the status of Acres' work regarding demand forecasts, economic evaluation, risks analysis, and financing considerations. Representatives from Alaska Power Authority, Acres, Battelle, and Dr. Rohan from the External Review Board attended the meeting. A report on that meeting is attached.

Similarily, a separate series of meetings were held in Anchorage, Alaska to review the project environmental aspects. Representatives from Alaska Power Authority, Susitna Hydroelectric Project Steering Committee, Acres American Incorporated, various resource management agencies and Dr. Leopold attended these meetings. A report of those meetings is attached.

The Panel appreciates the efforts of the Acres American staff in planning this meeting and preparing the discussions presented therein.

SEISMICITY AND SEISMIC GEOLOGY

The seismic geology and seismicity studies have progressed satisfactorily since the last meeting of the Panel. At that time, the major sources of earthquake ground motion had been determined and the only remaining uncertainty was the establishment of the significant characteristics of the local earthquake (occurring in the crust of the Talkeetna Terrain) which could affect the design of the dam.

Woodward-Clyde Consultants have addressed this issue in their draft of the "Final Report on Seismic Studies for Susitna Hydroelectric Project" and in their presentation at this meeting. They term this source "the detection level earthquake" and conclude that such earthquakes would have a magnitude of 6 and could possibly occur very close to either dam site.

Based on this conclusion and other known sources of earthquake ground motions, recommendations have been presented concerning the level of ground motions which project structures should be designed to withstand. These are presented in terms of mean response spectra and the Panel considers the recommendations for mean ground motions to be entirely appropriate. We would note, however, that "critical" structures such as major dams are normally designed to withstand earthquake motions at about the 80 percentile level and the characteristics of such motions should be developed and considered in evaluations of the seismic stability of the project structures.

The Panel has considered the characteristics of possible motions resulting from earthquakes on the various sources (Benioff Zone, Denali Fault, Castle Mountain Fault, and Talkeetna Terrain) and concludes that it is feasible to design both the gravel-fill dam at Watana and the concrete arch dam at Devil Canyon, as well as the appurtenant structures, to safely withstand the effects of such earthquake shaking.

WATANA DAM EMBANKMENT

The Panel believes that the design section for Watana Dam, presented at this meeting, is satisfactory and will produce a stable and economical structure. With regard to the questions raised in our previous report, we note that:

(1) It is proposed to construct the core with the well-graded glacial moraine material from Borrow Area "D". This material is satisfactory for construction of an impervious core and further studies of its properties can be made in the design stage.

(2) It has been decided to use an essentially vertical core with a width sufficiently large to prevent arching of the core caused by differential settlements between the core and the shell materials.

(3) It is proposed that the upstream shell be constructed of compacted clean river alluvium gravels, this material being processed to ensure that not more than 10% of the material is less than 3/8" in size, in order to provide a high coefficient of permeability and thereby facilitate rapid dissipation of any pore water pressures generated by a seismic event. This treatment, together with placement in 2 ft. lifts, should ensure adequate stability for static and seismic loading conditions.

(4) The crest level of the dam and associated reservoir levels have been lowered by 30 feet so that the saddle dike has no water retaining function except in the case of the probable maximum project flood. This change greatly reduces the significance of foundation stability associated with the thawing of permafrost zones in the foundation of the saddle dike after reservoir filling.

BURIED CHANNEL

In our Report No. 3, we noted potential problems posed by the buried channel to be as follows:

(1) Magnitude of seepage losses through the mixed glacial and alluvial deposits.

(2) Piping of these materials towards Tsusena Creek.

(3) Seismic instability of the soils under strong earthquake shaking.

Acres has addressed these concerns and has concluded that: a) seepage losses are not significant, b) piping can be controlled if necessary by filter blankets placed on the slopes adjacent to Tsusena Creek, and c) seismic instability or liquefaction is not a problem, especially since the saddle dam has been reduced in height and the reservoir level lowered 30 feet.

At this stage in the project, only limited information is available on the engineering and geological properties of the materials within the channel. Thus any present assessment of seepage, piping, and liquefaction potential is based upon the broadest assumptions.

The External Review Panel continues to believe that the behavior of the buried channel under full reservoir as well as seismic events is important to the performance of the project. However, the lack of specific knowledge of material properties at this time does not compromise project feasibility. In our opinion, technical solutions are available to handle the concerns mentioned above at a reasonable cost. These solutions might include a filter blanket, partial or complete cut-off, pumping to reduce porewater pressures, or possible densification of loose soils. The potential for liquefaction increases with the height of the reservoir or increase in water level in the channel soils. Thus any further economically justifiable reduction in dam height has positive geotechnical benefits.

The External Review Panel gives its unqualified support to on-going exploration within the channel area. We agree with Acres that borings are required to define the extent and properties of the various anticipated deposits. We also believe that once defined, large scale pumping tests will be required to determine general values of permeability. Acres has noted that buried channels have been found on other projects which have not permitted large water losses or caused piping when the reservoir was filled. They have agreed to document these cases and present this information prior to our receipt of the feasibility report.

DEVIL CANYON DAM

The Panel requested in its Report No. 3 that the linear feature through the pond areas adjacent to the Devil Canyon damsite, where the wing dam will be located, be further explored in the near future. Acres agrees that the investigation is necessary but, because of time limitations, they are unable to conduct this work prior to submission of their Feasibility Report. They do not believe that delaying this investigation will affect the feasibility of the project. We concur.

WATANA DAM SPILLWAYS

In its Report No. 3 the Panel concurred in the concept of handling spillway flows at Watana Dam by three separate flow release structures, as follows: discharges corresponding to floods up to the 1 in 100-year flood through a tunnel controlled by downstream valves; discharges corresponding to floods in excess of 1 in 100 years and up to 1 in 10,000-years through a gated chute spillway with a flip bucket; and discharges in excess of the 1 in 10,000-year flood up to the probable maximum flood through an emergency fuse plug spillway.

The Panel suggested that fixed cone valves be used instead of Howel Bunger valves for the tunnel spillway because fixed cone valves give better service for high-head operation. The Panel also suggested that consideration be given to adopting a wider entrance and lower fuse plug for the emergency spillway. These two suggestions have been adopted. The Panel concurs in the general layout of a manifold at the downstream end of the 28-foot diameter low flow spillway tunnel with six 8-foot diameter conduits each terminating with a 96-inch fixed cone valve. We also concur in the proposed wider entrance to the emergency spillway with the lower 31-foot high fuse plug.

The service spillway is designed so that in combination with the tunnel spillway the 1 in 10,000-year flood will have a maximum reservoir elevation of 2193. The corresponding service spillway discharge is 114,000 cfs. Since the fuse plug crest would be at elevation 2200, discharge through the service spillway would continue to increase until the reservoir level reached about elevation 2202, at which level the discharge would be 147,000 cfs, which is the discharge being used for design of the service spillway. Thus, the low-flow tunnel spillway and service spillway would handle a flood somewhat larger than a 1 in 10,000 year flood. The Panel suggests that consideration be given to reducing the size of the service spillway so that in combination with the tunnel spillway the 1 in 10,000-year flood would have a maximum reservoir elevation of 2202. This should result in a substantial saving in service spillway cost.

WATANA SERVICE SPILLWAY CHUTE

Consideration should be given to providing concrete paving for a short distance on the invert of the approach channel upstream of the ogee crest. Four aeration slots in the chute invert should be located at approximately stations 5+00, 10+00, 14+00 and 17+00. A small ramp should be located just upstream of each slot. The slots should be open on top and a bevelled curved surface should be provided from the downstream edge of the slots to the main invert slope. The slot design should be similar to that developed for Tarbela dam at Colorado State University in a 1:12 scale model and found to function satisfactorily in the prototype.

DEVIL CANYON SPILLWAYS

In its last report, the Panel suggested that fixed cone valves be used instead of Howell Bunger valves for the low level spillway outlets. The Panel also suggested that the entrance to the emergency spillway channel be widened and the fuse plug height be reduced. These suggestions have been adopted.

The Panel suggested that consideration be given to using one diversion tunnel and an additional tunnel instead of the gated chute service spillway for release of spillway discharges between the 1 in 100-year and 1 in 10,000-year floods. Acres has studied this alternative and found it to be significantly more costly. The Panel is satisfied that a tunnel spillway is not an economic alternative.

SEDIMENTATION AND RIVER MORPHOLOGY STUDIES

Panel member Douma met with R & M Consultants, Inc. and Acres representatives in Anchorage on December 9 and 10, 1981 to review reservoir sedimentation, sediment yield and river morphology studies for the Susitna Hydroelectric Project. A report dated December 10, 1981 was prepared and submitted to the Alaska Power Authority.

The report generally concurs with the study's main conclusions, as follows:

(1) Reservoir sedimentation would be of little concern to the project as less than 5 percent of the reservoir storage would be depleted in 100 years and much of the depleted storage would be below the dead storage level.

(2) It will be important to identify locations in the Susitna River main channel between Devil Canyon and the Chulitna River confluence where post-project channel conditions may be detrimental to the fishery and whether or not remedial work can be accomplished at reasonable cost to minimize damage to fish spawning areas.

(3) Sediment analyses indicate that there will be some change in sediment loads in the river reach from Devil Canyon to the Talkeetna confluence but sediment loads in the lower Susitna River downstream of the confluence will be essentially the same for pre- and post-project conditions due to the long, wide, gravel flood plain and large sediment loads transported by other tributary streams into the lower Susitna River.

(4) Stages of 1.5 to 3.5 feet lower, depending on the reach in the lower Susitna River, will occur after flow regulation which should not cause major flooding and navigation impacts.

(5) Under post-project conditions, the frequency of occurrence of dramatic changes in river morphology will decrease, resulting in a more stabilized flood plain, a decrease in number of subchannels and an increase in vegetative cover.

It should be recognized that changes in morphology of the lower Susitna River due to project construction are extremely difficult to quantify with a high degree of reliability. The analyses which have been made, however, lead to a better understanding of the natural processes and the changes that may occur due to project construction. Future studies should include monitoring the river conditions by data collection and observation of changes for a considerable period of time after project construction.

The External Review Panel is impressed with the excellence of the studies made by R & M Consultants, Inc., and believe that the study conclusions, in spite of the general sparsity of basic data, are quite reasonable.

CLOSING REMARKS

The Panel is of the opinion that the outstanding topics discussed in this report must be resolved in the very near future. It is therefore suggested that Panel Members meet with the Acres Specialists Consultants Panel on February 17-18, 1982 in Buffalo to reach agreement with Acres American on the unresolved issues.

The Panel appreciates the courtesies extended to it by the Alaska Power Authority and Acres American, Inc.

Merlin D. Copen	Dr. Andrew H. Merritt
Jacob H. Douma	Dr. H. Bolton Seed

February 4, 1982

SUSITNA HYDROELECTRIC PROJECT
EXTERNAL REVIEW PANEL

SUPPLEMENT TO REPORT NO. 4

During the three day period January 18-19-20, I visited the APA offices in Anchorage where I had the opportunity to confer with representatives of Acres, TES, Mitigation Core Groups (both Fisheries and Wildlife), and the Susitna Hydro Steering Committee, consisting of representatives of state and federal agencies. Additionally, I had individual meetings with David Spencer and William Wilson of U of A, Al Carson of Alaska Department of Natural Resources, and David Cline of National Audubon Society. Prior to this trip I reviewed a number of reports on Environmental (Task 7) and hydrology (Task 3) studies. The notes which follow are a synopsis of my thoughts on some environmental issues in the proposed Susitna project. Most of these concern fisheries and the river itself below the impoundments.

Fisheries

The section of the Susitna River that will be most altered in flow characteristics and in morphology is the reach from Devil Canyon dam down to Talkeetna. The normal summer flow of 25,000 cfs will be withheld behind the dams and released at a reduced rate which will alter the shape and depth of the channel and will possibly preclude flooding of side channels that are important for salmon spawning and rearing. I am not clear as to the projected post-project flow. In various meetings I heard reference to flows as low as 5,000 cfs and as high as 12,000 cfs. The adverse impact on salmon will be minimized if reasonably high summer flows are permitted during the two months of salmon spawning. Special care will be required to maintain salmon spawning habitat during the period when the reservoirs are filling. I would like to see a firm plan of how flow is to be regulated from the time construction begins on Watana Dam until Devil Canyon Dam is completed and filled.

Water temperatures in the river below Devil Canyon may be important in stimulating or inhibiting salmon spawning and fingerling development. I would like to see better data on present seasonal water temperatures and a plan for regulating temperature in released water after the project is completed. It would appear to me that a multiplelevel inlet from Devil Canyon reservoir would be essential if water temperature is to be manipulated. I understand that such an inlet is not currently planned.

The vertical descent of water discharged from both Watana and Devil Canyon dams is so great as to pose a threat of supersaturation of nitrogen. I am told that outflow structures can be designed to circumvent this problem. I want assurance that such is being done.

Assuming that some spawning habitat will be lost between Devil Canyon and Talkeetna, a mitigation plan should consider the possibility of creating artificial spawning channels along this stretch. Needed first is a careful survey of possible sites where such channels might be built. I have seen no such data nor any plans for obtaining it.

Concern over changes in turbidity of post-project flows below Devil Canyon is somewhat allayed by R&M report 3.10 (Jan. 1982). Apparently, summer turbidity will be reduced by settling in the reservoirs, but winter flows should be nearly clear, as at present. This change does not seem to threaten salmon reproduction. On the other hand, elimination of bed load and heavy sediment now carried by the river will affect the shape of the river below the dams as far down as Talkeetna. Instream flow assessments must be continued for several years to fully understand variations in flow. Some information on bed loading was obtained in 1981 but more data are needed. Below Talkeetna the effects on the river apparently will be minimal, but assurance on this point will grow with additional study.

Data on salmon numbers in different parts of the Susitna Basin are still fragmentary, but a rough estimate is now available of numbers of fish that start up the river (Susitna Station) and those that pass Talkeetna to spawn in the upper reaches below Devil Canyon. I have summarized and averaged data given by Dana Schmidt (report Dec. 22, 1981) as follows:

	Approximate escapement above:		% escapement above:
Species	Susitna Station	Talkeetna	Talkeetna
Coho	33,470	3,522	10.5%
Chinook	76,258	763 (5 yr. aver)	
Sockeye	340,232	3,464	1.0%
Pink (odd yr.)	113,349	2,529	2.2%
Chum	286,363 (est.)	20,835	7.2%

Assuming that adverse effects on salmon will be felt largely or entirely by the escapement above Talkeetna, the last column depicts the portions of the total Susitna runs that might be impacted adversely. These figures, when improved over time, can serve to guide plans for mitigation.

As the above table shows, most salmon in the Susitna basin spawn in tributaries or in the lower river and its channels and sloughs below Talkeetna. Salmon habitat in the sloughs is probably regulated by water level in the main river, but possibly also by aquifers that flow through the river-bottom gravels. Where do these aquifers originate? Studies of water dynamics in the sloughs are seriously needed.

Wildlife

By comparison with the complexities of fisheries studies, the data on wildlife are relatively straightforward and complete. Within the areas of impoundment, there will be substantial losses of moose, black bears, various fur-bearers and many small vertebrates. Caribou may be troubled in reaching their traditional calving ground, and wolves will be disadvantaged by any decrease in moose or caribou. Caribou and some other kinds of wildlife would be adversely affected by a road from Watana Dam to the Denali Highway, for this upper reach of the Susitna basin is a richly productive habitat. (This road is not being recommended by Acres.) In my opinion, ongoing studies of wildlife species and problems are generally adequate for purposes of project planning.

Mitigation

The "Draft Analysis of Wildlife Mitigation Options" is a well prepared document that defines possible wildlife losses and lists quite adequately the available choices for mitigation. For many species compensation is the only form of mitigation that is possible. In some, however, like moose and beaver, habitat management procedures outside the areas of inundation are recommended. This document can serve as a guide to development of a specific program of mitigation.

By contrast, the "Draft Analysis of Fisheries Mitigation Options" seemed to me cursory and incomplete. There are a substantial number of mitigative measures that might be considered, but these are neither discussed nor evaluated in any meaningful way. Development of a usable report on fisheries mitigation options is very much needed.

Respectfully submitted,

A. Starker Leopold

February 18, 1982

SUSITNA HYDROELECTRIC PROJECT
ACRES AMERICAN EXTERNAL REVIEW PANEL
REPORT NO. 4

INTRODUCTION

The Acres American External Review Panel for the Susitna Hydroelectric Project met with the Alaska Power Authority Review Panel on February 18, 1982. The Acres External Review Panel had convened independently on February 17. Both meetings were conducted at the Acres American offices in Buffalo.

In addition to Panel Members, Robert Mohn of the Alaska Power Authority and representatives of Acres American were present.

The objective of these meetings was to discuss the few remaining topics regarding the project which require resolution. Various members of Acres American staff presented discussions regarding geotechnical questions, seismicity, hydraulics and design.

The Panel appreciates the courtesies extended to it by Acres American and the planning and preparation of discussions presented in the meetings.

Buried Channel

Regarding the feasibility of Watana Dam, it is our opinion that the possible seepage losses through the buried channel are not large enough to impact the feasibility of the project. Moreover, possible piping of alluvial materials can be controlled, if necessary, by weighted filter blankets placed on the slopes between the reservoir and Tsusena Creek. The cost of providing the downstream filter should be considered in the feasibility report.

The present reservoir elevation of 2185 is low enough such that the water is not required to be permanently supported by the freeboard dike. In fact, the free-board dike will not be required to resist differential water levels for the PMF (el. 2202) because the lowest point above the relict channel is elev. 2202.

Recently, the possibility of liquefaction of the uppermost layers of the buried channel fillings has been raised. If these materials liquified, and if large volumes of these materials could move under the gentle slopes shown in attached section W-16 of Figure 6.34, Task 5 Report; then it would be hypothetically possible to breach the reservoir. Recent stratigraphy has been developed for the buried channel which is shown in attached Figure 1. As shown in Fig. 1, the lower unit K is the buried alluvium, unit J is a preloaded till, unit J1 is an interglacial alluvium, unit I is a preloaded till, unit H is an alluvium, unit G is a waterlain till or lucustrine deposit, and units A,B,C,D,E and F are more recent outwash deposits. It is highly unlikely that liquefaction could be a problem from the top of unit I downward as shown in the cross section given in Figure 2.

The alluvium in stratum H will be saturated by the reservoir, however, and more information is needed to conclude whether liquefaction is or is not a problem in stratum H. Stratum H is buried beneath the water laid till unit G, which indicates it was saturated under the water levels which produced unit G and was probably subjected to earthquakes during that time period. Further development of the pleistocene geology may clarify this point. The strata above unit G are outwash materials and more information is required on density, gradations, and blow counts in order to make definite comments on liquefaction susceptability. Because of the above, it is advisable to consider the possible remedial action shown in Fig. 3 where in the worst case, a compacted dike would be placed in a trench excavated down to the top of the overconsolidated till, (Unit I). The costs of this remedial action should be included in the feasibility report, but the decision to employ or omit this possible remedial action must be delayed until after more investigations are conducted in the area of the buried channel.

At its meeting held on February 18, 1982 the APA review panel made recommendations concerning the design earthquake motions for Devil Canyon concrete arch dam. We concur with these recommendations.

Alfred J. Hendron

Ralph B. Peck

Merlin D. Copen

APA 2427 lacks the four illustrations accompanying the report "Susitna Hydroelectric Project Acres American External Review Panel report no. 4" (February 18, 1982). Those illustrated pages are included in APA 2954 and 2955 (documents very similar to APA 2427).

February 18, 1982

SUSITNA HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY
REPORT NO. 5

INTRODUCTION

The Alaska Power Authority External Review Panel for the Susitna Hydroelectric Project met with the Acres Review Panel on February 18, 1982. The Acres External Review Panel had convened independently on February 17. Both meetings were conducted at the Acres American offices in Buffalo.

In addition to Panel Members, Robert Mohn of the Alaska Power Authority and representative of Acres American were present.

The objective of these meetings was to discuss the few remaining topics regarding the project which required resolution. Various members of Acres American staff presented discussions regarding geotechnical questions, seismicity, hydraulics and design.

The Panel appreciates the courtesies extended to it by Acres American and the planning and preparation of discussion presented in the meetings.

Design Earthquake for Devil Canyon Dam

The studies conducted by Acres' consultants on seismology (Woodward-Clyde Consultants and Dr. Sykes) have indicated the need to design both Watana and Devil Canyon Dams for an earthquake occurring in the Talkeetna Terrain very close to the damsites and having a magnitude of the order of M = 6¼.

For this purpose, it is recommended that both dams be designed to withstand motions having a peak acceleration of 0.65g, a spectral shape similar to that presented in the Woodward-Clyde reports, and a duration of strong shaking of about 8 seconds. These are appropriately conservative motions for critical structures such as the dams of the Susitna Project.

For the purposes of engineering analysis, the motions used for excitation of an analytical model of a dam may well be different from those of the Seismic Safety Evaluation Earthquake discussed above. For the type of analysis being used by Acres to evaluate the seismic safety of Devil Canyon Dam, the Panel believes that it is appropriate for this structure to base the analysis on design motions having the following characteristics:

Peak acceleration:	0.55g
Damping Ration :	10%
Spectral Shape :	As recommended in Woodward-Clyde report for 10% damping

The use of these motions for analysis and design purposes is in keeping with those used for similar earthquakes for critical structures in other highly seismic regions and will provide the required degree of assurance of the ability of Devil Canyon Dam to withstand very strong motions (peak acceleration = 0.65g) in the remote possibility that a local earthquake of magnitude - 6½ should occur.

It should be noted that the above recommendation applies only to the proposed Devil Canyon concrete arch dam and that design motions for other structures in the Project may be different from that recommended above, depending on the characteristics of the structures and the analysis procedure being used for evaluating their earthquake resistance.

Hydraulic Design of Spillways and Outlets

Acres reponded to questions raised by the External Review Panel in its review of Watana and Devil Canyon drawings which are to be included in the final draft of the Feasibility Report. The Panel concurs in the answers to these questions and the design revisions that have been made with the exception that it still is of the opinion that the Tarbela air slot design for the spillway chutes would be more effective than the proposed aeration gallery with outlet ducts. However, this question will need to be resolved by large-scale hydraulic model tests in the final design of the spillways.

The Panel concurs that the revised emergency excavated spillway channel with a long relatively small invert slope to a pilot channel with a steep slope is superior to the previously proposed excavated channel with several invert drops. It is suggested that in final design the slope of the excavated channel be reduced as much as is practical in order to decrease velocities and erosion in this channel.

Liquefaction Potential of Soils in Relict Channel

At its last meeting in January, the Panel requested that Acres investigate the possible effects of earthquake-induced liquefaction in the surface soils of the relict channel. This question has been addressed in the report of Acres External Review Panel, dated February 18, 1982. We agree with the recommendations expressed in this report relative to the liquefaction potential of the soil in the relict channel.

H. Bolton Seed

H. Bolton Seed

Jacob H. Douma

Merlin D. Copen

March 1, 1982

SUSITNA HYDROELECTRIC PROJECT
EXTERNAL REVIEW PANEL

SUPPLEMENT TO REPORT NO. 4

Introduction

On January 14th and 15th, staff from Acres and Battelle met with representatives of Alaska Power Authority and Dr. Rohan of the External Review Panel to Access:

- o The preliminary results of the Battelle study.
- o The status of Acres' Work in this area.

Prior to the meeting, draft reports were received for review from both Acres and Battelle and were reviewed by Dr. Rohan.

Battelle Report

The report from Battelle focused on the future demand for power in the Railbelt region, alternative plans for power generation to meet this demand, fuel availability and costs, and the comparative economics of these plans.

In developing a range of load forecasts, Battelle extended the modelling approach of ISER and developed three basic cases each based on a different level of economic growth in Alaska. (Each level of economic growth is related to state revenues and correspondingly to the outlook for world oil prices.)

Each case provided a projection of the demand for peak power and energy on a year-by-year basis to the year 2010. Average annual growth in demand was projected to range from 2.2% to 4.5% per year. This range seems reasonable.

Price forecasts were developed for oil, gas, and coal. The oil prices showed a real increase in price from 1% to 3% per year. Because of currently depressed oil markets, actual oil prices over the next several years could be lower than projected. Future gas prices were estimated for gas from the Cook Inlet and the North Slope. These gas forecasts were based on a combination of regulatory considerations and market forces. Coal prices were forecasted to increase in real terms at about 1% to 3% per year. The range of price forecasts for oil, gas, and coal is consistent with a consensus forecast of experts in 1980; however, the higher ranges seem less likely in today's environment.

To meet the projected demand for power, Battelle investigated a wide variety of energy sources. These sources included a combination of thermal power from coal and gas; hydropower from Bradley Lake, Chakachamna and Susitna; and wind energy, tides, etc. Separate capital and operating cost estimates were made for each of these alternatives.

Battelle's economic analysis compared the levelized annual cost of power generation for six technically feasible plans. Two of these plans included the Susitna project as a source of power. Each of the six plans was designed to meet the power requirements for the medium-load growth forecast.

Battelle's primary conclusion regarding the economics was that the cost of power for all six plans was essentially the same (58 mill/kWh versus 59 mills/kWh in 1980 dollars). Comparisons of levelized annual costs were made over a 30-year period, 1980-2010. On a year-by-year basis, the two plans that included the Susitna as a source of power showed a slight decline in annual electric costs starting in approximately the year 2000. All plans would result in a near doubling in the real cost of electricity by the year 2005.

Battelle's analysis of alternative generation schemes and conservati potential was relatively complete. However, the time horizon of 30 years does not fully capture the true economic benefits of hydro-facilities, which have useful lives of 50 years or more. In February, Battelle issued a draft comment report on its findings and incorporated this longer time horizon.

Acres Report

Representatives from Acres presented their preliminary economic analysis, risk assessment, and financial analysis of the Susitna project.

Acres' economic analysis compared the present worth of the costs of a Susitna project with a thermal plan using coal for base load generation.

Acres' analysis employed a more rigorous optimization approach to systems planning than did Battelle's analysis. Nevertheless, Acres' findings are essentially consistent with Battelle's. Over a 30-year time horizon, both the Susitna and thermal unit projects would have essentially the same cost.

On a 60-year time horizon, which is more appropriate, the Acres' analysis indicated that for the medium-load forecast the Susitna project would yield a net benefit over the thermal plan of about $1.1 billion (in 1982 dollars). Both Acres and Battelle's analysis excludes any marketing or financial risks. These risks are substantial and could alter the comparative economic advantages of the Susitna data.

Furthermore, the computed net benefits are highly sensitive to:

- Load forecasts
- Fuel prices escalation
- Real interest rates and discount rate
- Capital cost of the Susitna project

For example, if the real discount rate is increased from 3% to 4% per year, then the net economic benefits of the Susitna project are eroded to zero. As a second example, if the lower load forecast is used, the benefits of the Susitna dam decreases to $0.2 billion.

Because of this high degree of sensitivity and uncertainty in these key variables, it was agreed that Acres, in its final report, would (a) show the sensitivity analysis, and (b) incorporate a probabilistic assessment of the likelihood of the various economic outcomes.

Acres' analysis of risks was limited, and focused on the capital cost and construction risks in building the Susitna dam. Although the quality of the work on these construction risks appeared to be excellent, the concept of risk needs to be broadened to incorporate the major load, marketing, and financial aspects of the Susitna project.

The financial analysis and market assessment study was in its preliminary stage. Even from its initial work, it is clear that the financial and marketing risks are critical to the project feasibility. Unless there is a form of state equity funding or guarantees on a least 50% of capital costs, the project feasibility becomes highly unlikely. This implies state participation in the amount of at least $2.5 billion (1982 dollars).

This infeasibility is caused by the problems of marketing the initial high cost of power generated by the Susitna dam, and general problems of contracting to organizations with different economic interests. It is also related to the uncertainties in the market rate of interest for bonds and the inherent risks of financing large capital projects in an inflationary environment.

Subsequent to this meeting, there was another meeting with Acres, the investment advisors of Alaska Power Authority, representatives of Alaska Power Authority, and Dr. Rohan. This meeting was held in Seattle on February 19th to review the substantial progress on the financial and marketing aspects of the Susitna project.

Respectfully Submitted

Dennis Rohan

Dr. Dennis Rohan

ALASKA POWER AUTHORITY

334 WEST 5th AVENUE - ANCHORAGE, ALASKA 99501

Phone: (907) 277-7641
(907) 276-0001

April 14, 1982

Mr. Charles Conway, Chairman
Alaska Power Authority
334 West Fifth Avenue, 2nd Floor
Anchorage, Alaska 99501

Dear Mr. Conway:

In response to your letter of February 3 to members of the Alaska Power Authority External Review Panel for the Susitna Project and your request for a critical evaluation of the Acres American Inc. Feasiblity Report and findings and the responses of individual Panel members to specific questions, we offer the following attached comments on the various aspects of the study.

It has been a pleasure working with members of the Alaska Power Authority staff and Acres American, Inc. on this important study and we would like to express our appreciation to you and all concerned for the help and support we have received in preparing our reports and recommendations over the past two years.

Sincerely,

EXTERNAL REVIEW PANEL
MEMBERS

Merlin D. Copen
Merlin D. Copen

A. Starker Leopold
A. Starker Leopold

Dennis Rohan
Dennis M. Rohan

Jacob H. Douma
Jacob H. Douma

Andrew H. Merritt
Andrew H. Merritt

H. Bolton Seed
H. Bolton Seed

Attachment: as stated

ENVIRONMENTAL CONSIDERATIONS

Development of the Susitna Hydroelectric Project will impact the environment of the Susitna basin in a number of ways. The two reservoirs will inundate substantial areas which now support forests and some kinds of wildlife; the construction camps, roads, and transmission lines will disturb various upland ecosystems; and the flow of the Susitna River below the dams will be modified as salmon spawning and rearing habitat. A number of on-going studies have shed considerable light on existing animal populations and vegetational types. Although some information is still far from complete, it is possible now to anticipate some of the impacts that the project will impose on these communities. In the aggregate, the total impact will be relatively small. Moreover, by judicious management, it will be possible to mitigate some of the habitat losses by improving habitats elsewhere. The discussions which follow summarize the environmental problems as they are now understood.

Reservoir Areas

The two impoundments, with an aggregate area of about 71 square miles, will obviously be converted from terrestrial to lacustrine habitat with a loss of all the plants and wildlife that use these areas now. Among the larger animals whose numbers will be reduced are moose, black bear, and several species of mustelid fur-bearers. A wide variety of small birds and mammals will be evicted. Yet most of these species are common in this part of Alaska; there are no known endangered species of either plants or animals. In the case of the moose, it is proposed to manipulate vegetation along the lower Susitna, by burning or mechanical means, to create more winter range and hence to increase moose populations there to compensate for losses of moose in the impoundment areas. A somewhat reduced moose population in the upper Susitna basin might mean some reduction in the dependent wolf population. The Watana impoundment intersects a migration route used by the Nelchina caribou herd. Although caribou swim well, and easily cross natural water barriers, there is a possibility that ice shelving along the shore of the Watana reservoir might interfere with caribou movements. If such a problem is detected, the ice shelf could presumably be blasted. Of greater importance, perhaps, is the necessity to clear and remove all the timber from the impoundment areas to preclude the formation of floating log jams that could create a truly dangerous barrier to migrating caribou.

The upper Susitna River supports several native fish, of which the grayling is the primary game species. Although the river habitats that are inundated will be lost to grayling production, it is possible that the reservoirs themselves may support modest populations of grayling and perhaps lake trout.

Downstream Effects

Below the Devil Canyon dam the flow of the river will be substantially altered from its natural cycle. High summer flows will be captured in the reservoirs to supply winter discharge. The reduced summer flows in the river might adversely affect salmon spawning and rearing habitat as far downstream on the confluence with the Chulitna River, near Talkeetna. Side sloughs that are used as spawning areas by chum and sockeye and as rearing areas by juvenile coho and chinook will be cut off from flushing flows which normally occur at high levels of discharge. Considering the total runs of salmon that spawn in the Susitna drainage and its tributaries, the proportions that utilize the reach between Talkeetna and Devil Canyon are as follows (figures from Schmidt and Trihey):

Species	Total Susitna runs (approx.)	Percentage spawning above Talkeetna
Coho	33,000	8%
Chinook	76,000	2%
Sockeye	340,000	1%
Pink (odd years)	113,000	3%
Chum	286,000	15%

Chum and coho salmon are the two species that might be adversely affected by construction of the dams. There are good prospects for mitigation of those potential losses. Thirty-two sloughs have been identified along this stretch of the river. Mechanical opening of intake channels might permit flushing flows at discharge levels planned for normal power production. Occasional higher flows might be released, if needed. Additionally, artificial spawning channels might be constructed. If proper multiple outlet structures are installed in the dams, water temperature can be regulated as well as flows. Much of the silt in the upper river will settle in the reservoirs, resulting in clearer water flowing from Devil Canyon dam, which may be highly advantageous for rearing of young salmon. All of these mitigation measures could preserve the salmon runs at nearly pre-project levels, or potentially at even higher levels. Below Talkeetna, no significant changes in the salmon habitat are anticipated.

Elimination of peak floods may result in stabilization of bars, islands, and river banks in the river bottoms below Devil Canyon Dam, with the result that riparian forest may develop in areas now in willow brush. Such advance in plant succession will be unfavorable to moose, since willow is a prime winter food. This trend can be reversed by a program of logging of the bottomland forest or by judicious controlled burning.

Summary

Considering the environmental impacts as a whole, and the possibilities for partial mitigation, it does not appear that environmental considerations should preclude the development of the Susitna Project.

GEOTECHNICAL CONSIDERATIONS

General

The External Review Panel, as a group and individually, has visited the proposed dam sites, inspected the rock formations, reviewed the results of the exploration program, and read the interpretations and conclusions presented by Acres in their Feasibility Report. We recognize that the site exploration has been done in various stages over the past years and note that the Feasibility Report has included the pertinent portions of these earlier studies.

We conclude that the amount of site geologic investigations completed for the Feasibility Report is adequate to effectively preclude unknown geotechnical conditions which would have a major adverse impact on project design and costs.

Geology and Project Layout

The geologic conditions revealed in outcrops and borings are generally very favorable for the structures required for the project. Where local shear zones or other areas of poorer quality rock have been identified, the proposed project features have been positioned to avoid them to the degree possible. For example, the diversion tunnel inlet structure at Watana has been moved downstream to avoid the "Fins" feature, the major underground chambers at Watana have been moved to the right abutment to avoid the "Fingerbuster" shear zone, and the orientation of the open cuts and underground chambers have been located where possible to obtain the most favorable orientation with respect to the joints and shear zones and thereby avoid major rock stability problems.

The very good rock conditions revealed in the borings are favorable for the major underground openings proposed and we foresee that the excavation and support of the chambers will proceed using well established construction methods. We expect that subsequent exploration will provide the information required to establish the most favorable final position for the chambers as well as providing more detailed information on the most appropriate excavation and support methods for the large diameter tunnels and high slopes.

Special Geologic Conditions

The results of the exploration program at both sites have revealed no geologic structures that can not be handled by conventional methods. Moreover, the field work has been sufficiently widespread to embrace the general geologic conditions so that no major adverse feature is likely to have been overlooked.

One of the most important geologic aspects that will receive careful attention during future field work is the buried or relict channels on both abutments at Watana. To date the studies have identified a deep channel on the right side that passes between Deadman's and Tsusena Creeks that has been filled with varied glacial deposits. The geometry of the channel and general nature of the deposits have been defined by geophysical surveys and borings. More recent studies on the left side in the Fog Lakes areas indicate that a similar channel exists here also.

The importance of this channel and its deposits for the Watana site are threefold: 1) magnitude of seepage, 2) piping of materials towards Tsusena Creek, and 3) seismic instability of the soils under strong earthquake shaking. These items have been fully addressed in our meetings with Alaska Power Authority and Acres and among other items, modifications have been made in the level of the reservoir to decrease the height of water against the saddle dike on the right side. It is clear that further field studies are required (and are planned) to assess the importance of the above mentioned three factors. However, as has been clearly pointed-out in previous reports, we believe that there are technically and economically viable solutions to these potential problems. Acres and their External Review Panel hold the same opinion. For the various possible solutions, estimates have been developed and are reflected in the project costs. We believe that the estimate is reasonable and should cover possible contingencies that may develop as more information becomes available.

SEISMIC DESIGN CONSIDERATIONS

The Susitna Project is clearly located in an area of potentially strong seismic activity and must be designed to safely withstand the effects of earthquakes. For this reason, a greater than normal effort has been devoted during the feasiblity studies to determining the possible sources and magnitudes of seismic events which could affect the project and the intensity of shaking which these events could produce at the proposed sites for Watana Dam and Devil Canyon Dam.

The extremely comprehensive studies of the seismicity of the project area are probably more extensive than those conducted for any other hydropower project in the world. They have been conducted by a highly competent group of earth scientists and engineers and they have identified the major potential sources of seismic activity, the potential magnitudes of earthquakes which oculd occur on these sources and the levels of ground shaking which could occur at the project sites as a result of the largest earthquakes likely to occur on these sources.

Design ground motions for the required studies have been selected with a degree of conservatism appropriate for critical structures, taking into account the possibility of a great earthquake (Magnitude 8.5) occurring on the Benioff Zone underlying the dam-sites as well as the possibility of local earthquakes (Magnitude about 6 1/4) occurring within a few kilometers of either of the sites.

Watana Dam

The preliminary design of the Watana Dam is a high embankment dam with gravel shells and an impervious central core. The design is similar to that successfully used for other very high dams (Oroville Dam in California and Mica Creek Dam in British Columbia, for example) and generally considered to be the most desirable for embankment dam construction. Sources of the required types of soils have been located and investigations have shown that ample quantities are available.

The proposed section of the dam is appropriately conservative with a proven capability to withstand normal loadings and excellent characteristics to enable it to withstand any anticipated earthquake loading. The proposed design is in fact very similar to that of Oroville Dam in California which has probably been subjected to more detailed analysis of seismic stability than any embankment dam in the world. These studies have shown that the Oroville Dam would be stable even if a Magnitude 8 1/4 earthquake should occur within a few kilometers of the dam-site. The controlling design earthquake for Watana Dam is comparable in magnitude but is source is located about 65 kms from the Watana site so that the shaking intensity is less than that used in the Oroville Dam investigation. Furtnermore, the proposed materials for construction of the upstream shell of Watana have equally desirable characteristics as the Oroville Dam shell materials. Consequently, there is no reason to doubt, and preliminary analysis by Acres American, Inc., confirm that, with appropriate attention to engineering details, the proposed Watana Dam section will be able to withstand the effects of the conservatively evaluated earthquake shaking with no detrimental effects.

Devil Canyon Dam

The proposed design of Devil Canyon Dam is a concrete arch and an evaluation of the design is presented in the following section. With regard to earthquake-resistant design, dynamic analyses have been made to determine the stresses developed by conservatively-selected design earthquakes: a magnitude 8 1/2 event occurring at a distance of 90 kms and a local earthquake of magnitude 6 1/4 occurring very near the dam-site. The computed stresses are with the acceptable limits for concrete arch dams.

Furthermore, the ability of such dams to safely withstand extremely strong earthquake shaking has been demonstrated by the excellent performance of the Pacoima Dam in California in the San Fernando earthquake of 1971. This 350 ft. high dam safely withstood the effects of a Magnitude 6 1/2 earthquake occurring directly below the dam and producing some of the strongest earthquake motions ever recorded. This full scale test of a prototype structure provides convincing evidence that such dams can be designed to safely withstand the effects of strong earthquake shaking.

Other structures

In final design careful attention will have to be given to the earthquake-resistant design of other features of the project including spillways, powerhouses, intake structures, etc. The safe design of these structures is well within the state-of-the-art of engineering design for the anticipated levels of earthquake shaking and should present no major problems with regard to unacceptable levels of damage or public safety.

Uncertainties in Design

Probably the greatest uncertainty with regard to seismic design is in the required treatment of the buried channel on the right bank of the Watana reservoir. This uncertainty stems mainly from the fact that it has not been possible at this stage of project development to ascertain by borings the types of soils filling the buried channel and their engineering characteristics.

However, this is not a major problem since even if very unfavorable characteristics are assumed for these soils (and this will not necessarily be the case), remedial design measures have been explored and developed to eliminate any problems which could arise. Provisions for the costs of these measures are included in the cost-estimate even though the mitigation measures themselves, which may not be required, are not presented in the feasibility design reports.

Conclusion

In summary, it may be stated that the feasibility studies for the Susitna Project included an extremely comprehensive investigation of the seismicity of the project area and the development of design concepts for the major critical structures which, with appropriate attention to details in the final design and construction, should certainly eliminate any concerns regarding the provision of an adequate level of public safety and the prevention of any significant damage to the project as a result of earthquake effects.

DEVIL CANYON DAM

The Devil Canyon Damsite is ideally suited for an arch dam. The canyon is narrow and V-shaped. The abutment rock is sound and competent.

Devil Canyon arch dam has been designed and analyzed by use of the Arch Dam Stress Analysis System (ADSAS) computer program, which is the computerized version of the Trial Load Method of Analysis. This method was developed by the U. S. Bureau of Reclamation and has been thoroughly examined by rigorous mathematical analyses. In addition, results from this method have been successfully compared with structural models and prototypes in service.

The design selected for Devil Canyon is a thin double curvature arch. It is curved in both horizontal and vertical planes to produce the most efficient distribution of stresses possible under the site and loading conditions to which it may be exposed at this site.

The static loading conditions examined are the most severe combinations of gravity, reservoir and temperature loads anticipated at the site. The resulting stresses indicate a factor of safety greater than four, based on the anticipated compressive strength of concrete in the structure. The maximum tensile stresses occur on the downstream face of the arch, where, if cracking were to occur, no damage would result. The magnitudes of tensile stresses indicated will not occur since a redistribution of load in the dam will result as such stresses develop.

The dynamic loads applied to the dam are considered to be very conservative. Even so the resulting stresses will not cause serious damage to the structure. The analytical method used for stress studies is based on elastic theory. If the stresses indicated should occur, contraction joints in the upper part of the dam may open momentarily but would not result in major release of water or permanent damage to the structure.

The preliminary design for Devil Canyon Dam does, in every respect, respond to the seismic environment of the site.

With proper construction control, the dam will provide adequate safety under all loading conditions. It is extremely important that the very best construction techniques be employed in this dam. Proper concrete mix designs, consistent consolidation of the concrete and careful treatment of the rock contact and construction joints are of the utmost importance. The resulting concrete must be a homogeneous and isotropic product.

There are always risks of inadequate or inconsistent construction practices which would present problems in the behavior of a dam. Fortunately an arch dam has the capability of distributing load from weak areas to stronger, more capable concrete. This is not meant to excuse any but the best concrete control possible, because any weaknesses are not acceptable in this important structure.

Additional foundation investigations and insitu measurements will be required before a final design for Devil Canyon Dam is completed. Deformation moduli, joint orientation and continuity, and shearing resistance along joints will be required. Because of the preliminary nature of the present studies, such investigations are not considered necessary at this time. Instead, conservative assumptions have been made to assure a safe and satisfactory structure.

The proposed foundation treatment, consisting of consolidation and curtain grouting and adequate drainage, is satisfactory.

The engineering consultant has used adequate conservatism throughout the design for Devil Canyon Dam. Very little change from the preliminary design is anticipated for a safe and efficient final design for Devil Canyon Dam.

HYDROLOGY AND HYDRAULIC DESIGN CONSIDERATIONS

Flood Potential

The engineering consultant's assessment of the flood potential in the project area has properly identified the potential magnitudes and frequencies of flood flows.

The assessment utilized all available precipitation, snow survey and stream gaging data for stations within and adjacent to the Susitna River Basin. The probable maximum flood is based on the most critical combination of precipitation, snow melt, infiltration losses and flow concentrations that is reasonably possible. The hydrologic analyses are in accordance with accepted engineering practice which has been developed in the United States and is being used in many parts of the world.

Spillway Capacity and Dependability

The proposed design adequately responds to the hydrologic environment in terms of spillway capacity and dependability.

Both Watana and Devil Canyon dams will have low-level valve-controlled outlets to pass the once in 50-year flood, a gate controlled chute spillway in combination with the valve outlets would pass the once in 10,000-year flood and a fuse plug emergency spillway in combination with the valve outlets and chute spillway would pass the probable maximum flood without overtopping the dams. Similar valve outlets and emergency spillways have been constructed and operated elsewhere with successful service. There is no reason to believe that they would not be successful at the Susitna project.

Public Flood Safety

The proposed project adequately protects public safety in terms of the flood danger and there are no increased flood risks inherent in building the project.

The reservoirs will be drawn down in winters providing significant amounts of reservoir capacity for storage of summer floods. Virtually all normal river flows would pass through the powerhouses with very little spillway operation. Peak discharges for major floods would be reduced substantially. Consequently, project operation would enhance the public safety by reducing the magnitude and danger of floods in the lower Susitna River.

Spillway capacities and heights of dams are designed with conservative safety factors. The dams and water conveyance structures are designed and would be constructed with high safety factors in accordance with best engineering practice. For these reasons, there would be no increased flood risk inherent in building the project.

Project Damage or Shutdown

There is no reason to expect that the project would experience damage and/or require shutdown as a result of floods.

Major floods may cause some cavitation erosion in spillway chutes, river bank and bed erosion downstream of flip buckets and valve outlets, and erosion in the unlined emergency spillway channel.

Because of the infrequent occurrence and relatively short duration of major floods, none of these types of damage would become so extensive during any single flood to require project shutdown.

One or more of the valve controlled low-level outlets may sustain damage during a major flood requiring temporary shutdown for repairs. This shutdown would not significantly affect flood regulation since each outlet discharges a small percentage of the total flood flow.

As the powerhouses will be underground, floods would not cause them to be damaged or shutdown.

Design and Operation Assumptions

The engineering consultant has not made any major assumptions regarding design, operational mode, etc. of water conveyance structures that lack a satisfactory level of conservatism.

The low-level outlets, main spillways, and fuse plug emergency spillways have all been designed in accordance with current engineering practice which is based on conservative assumptions. Fixed cone valves are superior to any other type of valve for high-head operation. Air slots will be provided in spillway chutes to prevent cavitation erosion by high velocity flow. Pre-excavated plunge pools and/or bank protection will be provided downstream of flip buckets and fixed cone valves to prevent excessive streambed and bank erosion. The fuse plugs are designed conservatively to withstand reservoir pressures until they are overtopped and then wash out rapidly to activate emergency spillway operation. The assumption that excessive erosion would not occur in the unlined emergency spillway channel is conservative in view of the mild channel slope and favorable rock quality.

The proposed operation of the water conveyance structures is believed to be the most reasonable and practical operational mode which provides a satisfactory level of conservatism with respect to downstream effects and project safety.

Reservoir Sedimentation

The effects of reservoir sedimentation have been properly assessed in design of the project.

Based on conservative values of the sediment inflow and reservoir trap efficiency, less than 5 percent of Watana reservoir would be filled in 100 years, and deposits in Devil Canyon would be less than 25 percent of that deposited in Watana reservoir. A large percentage of the sediment would be deposited in the dead storage portion of the reservoirs. Reservoir sedimentation is not a controlling factor in project design as larger reservoirs or higher dams are not required and power production due to reservoir sedimentation would not be affected for well over 500 years.

Potential Downstream Effects

The proposed design and operation of the water conveyance structures adequately addresses potential downstream effects on river morphology, fisheries and wildlife.

Multi-level intakes will be provided for the power intakes and/or low-level outlets, as necessary, to permit release of reservoir water in the temperature range suitable for the downstream fishery. The valved outlets will discharge into relatively shallow basins, thereby preventing nitrogen supersaturation conditions harmful to fish. Spillway flip buckets and plunge pools will be designed to minimize nitrogen supersaturation. Their infrequent operation of once in 50 years would also greatly reduce any potential for serious effects on fish by nitrogen supersaturation. Planned increased reservoir releases during critical spawning periods together with remedial river channel work in spawning areas would minimize detrimental effects caused by lower river water levels due to project operation. While turbidity levels of reservoir releases would be sharply reduced in the summer, winter turbidity levels may be above natural levels due to suspension of fine sediments in the reservoirs; but this is not believed to be significant. Project operation will cause the following addtional effects in the Susitna River downstream of Devil Canyon Dam:

1) Eliminate and/or reduce thickness of ice cover for 20 to 30 miles downstream of Devil Canyon Dam in the winter due to release of reservoir flows above freezing temperatures which would prevent river crossings over ice by some wildlife and humans.

2) Sediment loads would be reduced in the Susitna River upstream of the confluence with Talkeetna causing some degradation of river channels.

3) Sediment loads would be essentially unchanged below the confluence because of the extremely large volume of sediment in the flood plain and contributed by tributary streams below the Talkeetna confluence.

4) Summer water stages in the lower Susitna River will be reduced by 1.5 to 3.5 feet which would reduce flooding in some areas and should not cause major impacts on navigation and other river operations.

5) The lower river will become more stabilized, resulting in a decrease in the number of small subchannels and an increase in vegetative cover.

6) The absence of annual floods may result in some loss of new lands for moose browse.

In summary, the potential downstream effects do not appear to be of such significance as to seriously jeopardize project construction.

Mitigation Measures in Water Conveyance Structures

Based on successful experience at other projects, mitigation measures that will be incorporated in the design of the water conveyance structures should be reliable and effective.

Multi-level intakes would have ports at several reservoir levels and a gate control system which would permit reservoir water to be released at the best possible temperatures suitable to the downstream fishery. The fixed cone valve sizes and operating heads for the Susitna project are well within their acceptable limits. Additional reliability of operation is provided by the use of 5 and 6 valved outlets at Devil Canyon and Watana, respectively. This enables continued operation at a high level of reservoir release in the event that one or two outlets would need to be closed. Operation of the valved outlets, as proposed, will reduce operation of the main spillway to once in 50 years, thereby reliably and effectively minimizing nitrogen supersaturation effects on the downstream river fishery.

Conclusions

In summary, it may be stated that the feasibility studies for the Susitna Project includes a thorough development of hydrologic aspects of the Susitna River and the development of design concepts for the major water conveyance structures which, with appropriate attention to details in the final hydraulic design, would assure an adequate level of public safety against flooding and the prevention of excessive detrimental downstream effects on river morphology, fisheries and wildlife.

MARKETS, ECONOMICS AND FINANCE FOR THE PROJECT

This section responds to the basic issues of the macroeconomic forces impacting the economic viability of the project, the future demand for power, economic measures and risks for the project, financial opportunities and problems, marketability of power and suggestions for an overall strategy.

Macroeconomics

Two factors, future world oil prices and market rate of interest strongly impact (if not dominate) the economic and financial viability of the project. Both of these factors are in a large measure outside the control of the Alaska Power Authority.

Oil prices strongly affect the State's revenues, which in turn influence the State's economy, the rate of economic development in Alaska and correspondingly the future demand for power. These prices, through competitive market forces, establish the long run competitive price of natural gas and influence the price of coal and thus strongly influence the costs of thermal alternatives to the Susitna Project. These same prices affect State revenues and available funding from the State for the project, and the marketability of power.

More than 90% of the direct costs of operating a hydro facility are interest charges. The market rates of interest, thus strongly determines the cost of the Susitna Project and its relative economics.

The Susitna project is economically attractive in an environment of rising oil prices and low interest rates. Interest rates for State Government bonds are the highest they have been in fifty years. With a growing surplus of crude on world oil markets, the spot prices of crude have declined and future price trends are uncertain.

Demand For Power

We have reviewed the range of demand forecasts developed by ISER and Battelle and employed by Acres in their report and it is our opinion that these forecasts appear reasonable. Actual growth rates will probably lie between the expected and low cases. This is true because essentially all of the power will serve the residential and commercial market, which tracks population and employment trends.

Economics of the Susitna Project

The present value of the cost of the Susitna Project versus another source of power is related to the time horizon of the evaluation and the discount rate. The time horizon is important because the economics may be different depending on the period of evaluation.

Work done by Acres and Battelle, and supported by our independent evaluation show that over a 30 year period through the year 2010, the Susitna project would probably yield no net benefits. With current interest rates and oil prices, over a thirty year period, power from the Susitna could very likely be more costly than a thermal alternative.

However, hydro projects usually have long useful lives of many decades, and over a 60 year period, the Susitna project appears to be economically attractive.

With this framework, there is a value trade-off for Alaskans to choose between

* Receiving the current benefits from funds that would be invested in the Susitna Project

or

* Investing and receiving the potential long term benefits of hydro power in the next century.

Sensitivity and Risk Analysis

The net economic benefits for the Susitna project versus alternatives are highly sensitive to load forecasts, real discount rates, fuel escalation costs, capital costs of the project, and financing strategies.

For the Acres' base case analysis, which has escalating energy prices of 9-10% per year based on inflation of 7% per year and an implied interest rate of 10%, the net gain over a 60 year period is about $1.3 billion (1982). The investment in the Susitna Project corresponding to this gain is $5.1 billion (1982). If the load forecast follows a low growth scenario, the net gain is reduced to nearly zero, or if the discount rate is reduced to 12% (5% real) the project would yield a loss of $500 million or more.

If the fuel costs escalated at an inflation rate of 7% per annum, the impact would also be a loss of $1.1 billion dollars. Conversely, if the escalation rate for fuel is 10%, the impact would be a net sum of about $1.5 billion. If the capital costs of the project were 20% more than estimated, the cost of the Susitna Project and a thermal alternative would be essentially the same.

There is a wide range of possibilities for forecasts of these variables and corresponding values for the net benefits or losses. Through a probabilistic assessment of each of these variables, Acres estimated that there is about 25 - 30% chance for a net loss and a 70 - 75% chance for a net gain. These assessments were made in an environment of increasing oil prices and medium increases in load, and did not directly account for the financing and marketing risks in these economic analysis. If we include these factors in todays environment, the risks increase although the weight of the economics still slightly favors the Susitna Project.

The major economic risks for the project are:

(1) Inability to obtain favorable bond rates and corresponding high financing charges for the project.

(2) Lower than expected energy price increases could make the project economically nonviable.

(3) Capital cost estimates may be too low, placing severe financial strain on the project.

(4) Possible opportunity losses, that is, foregoing the benefits of other investments in Alaska, for example, industrial development in enterprises which might generate net revenues or a stable long term employment base. The Susitna project would generate jobs during construction. However, in the long term during operation, the number of jobs added to Alaska's economy is minimal.

(5) Difficulty in entering into long term contracts for the power.

(6) A possible combination of the above.

Management of Economic Risks

Many of these risks can be managed, thereby substantially increasing the possibility of favorable economics for the project. The essence of this management is (1) timing and (2) additional low-cost studies.

A strategy of waiting patiently for favorable bond interest rates and an increase of oil prices would substantially reduce the risks. Taking a long term view, over say ten years, there is a strong possibility that interest rates will decline giving the Power Authority a window to obtain inexpensive financing. Correspondingly in the same time frame, it is likely that oil prices may start to rise again. In order to finance and start construction when these favorable events occur requires positioning now. This includes obtaining in advance all permits and licenses, and completing the engineering design and environmental studies.

To further reduce the risks, it is recommended that the Power Authority develop a business plan which would, among other things, identify viable power alternatives if the Susitna project is delayed or the demand forecast changes.

Financing

In the current inflationary environment, the Susitna Project would probably need state goverment participation of about 50% of the project's value -- $2,500,000,000 in 1982 dollars and more than $3,500,000,000 in actual costs. Because of the high level of risks, the debt portion of the project would probably require implicit or explicit state guarantees, or possible general obligation bonding. The State of Alaska effectively takes all the risk on the entire cost of the project including potential bonding of $2,800,000,000 in 1982 dollars and a correspondingly greater numbers of actual dollars.

A combination of escalating construction costs, high interest rates, and declining state revenues could put a revenue cash flow squeeze on the project. Positioning, patience and timing are critical to minimizing this risk.

These are some major opportunities in the financing area including the arbitraging of funds during the construction period or obtaining low cost debt financing. For example, if the project could be financed today at the lower rates that prevailed in 1977 and 1978 (7 to 8%), the present value of the costs could be reduced by about $1,500,000,000 (1982 dollars). A recurrence of low rates would markedly affect the financing of the project.

The tactics and strategy for financing needs further study and should be developed in the business plan.

Marketability

The power from the Susitna Project probably could not be sold unless it were less costly than alternatives. Anchorage, Fairbanks, and other regions within the Railbelt Area have different power sources and, correspondingly, different cost bases for power. This means that if uniform electric rates were used for Susitna power, the cost of power may be pegged to the least costly alternative. This would further exacerbate the financing and contracting problems.

A solution lies in organizational changes and a possible state referendum to gain support from the interested parties. This problem of marketing needs further study in the suggested business plan.

REPORT TO
BOARD OF DIRECTORS, ALASKA POWER AUTHORITY

From

EXTERNAL REVIEW PANEL, SUSITNA HYDROELECTRIC PROJECT

After reviewing the comprehensive Feasibility Report prepared by Acres American Inc., the External Review Panel offers to the Alaska Power Authority the following unanimous comments on the proposed Susitna Hydroelectric Project:

1. It is recognized that the project will have environmental impacts on wildlife, fisheries, and botanical resources. However, the extent and severity of these impacts appear to be relatively small and furthermore many of these environmental losses can be mitigated in full or in part.

2. The high dams proposed for Watana and Devil Canyon can be designed to safely withstand the maximum anticipated earthquake forces.

3. The proposed design adequately responds to the hydrologic environment in terms of spillway capacity and dependability.

4. If the project is financed at an opportune time when bond interest rates and oil revenues are favorable, the potential long term benefits of the Susitna project will be considerable.

5. Accordingly we consider that the overall impact of the project on the State of Alaska could be attractive.

6. To this end we endorse the plan to apply in September 1982 for a permit from the Federal Energy Regulatory Commission.

7. Moreover, we endorse the proposal to proceed with site investigations and design of the project, with concurrent work on some of the critical environmental studies, particularly those concerning downstream effects of the dams on the stream and its fish life.

8. The arrival of any opportune time to proceed with construction will depend on critical issues of finance and marketing of power which cannot now be accurately forecast. Our recommendation is that tender documents with all supporting geotechnical investigations and design studies be developed. We estimate that a total period of three to four years will be required for this phase of work. The project will then be ready to be implemented whenever the financial climate for contracting becomes favorable. The advantages of proceeding in this manner are:

(1) The economic benefits of being ready for financing;
(2) the momentum of the ongoing study and an informed staff; and
(3) the ability to avoid a crash design program.

The disadvantage is the small risk of loss of the design costs in the event that, for some reason, the project is never built.

9. We recommend that the Alaska Power Authority develop a detailed business plan which incorporates a financing and marketing plan into an overall business strategy. The plan would describe the critical events that need to be accomplished, the interrelationship of these events, the approach to accomplishing these goals, the management and control practice that are appropriate, the most economic financing strategy, and power alternatives if the Susitna project is delayed or the demand forecast changes.

10. This Panel is of the opinion that the economic climate will eventually indicate that it is advisable to proceed with the construction of the Susitna project and at that time it will be in the best interests of the State of Alaska to develop this important natural resource.

Merlin D. Copen
Merlin D. Copen

Andrew H. Merritt
Andrew H. Merritt

Jacob H. Douma
Jacob H. Douma

Dennis Rohan
Dennis M. Rohan

A. Starker Leopold
A. Starker Leopold

H. Bolton Seed
H. Bolton Seed

Panel Meeting Report #7

November 19, 1982

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ALASKA POWER AUTHORITY

Mr. David D. Wozniak
Project Engineer
Alaska Power Authority
334 West 5th Avenue
Anchorage, Alaska 99501

Dear Mr. Wozniak:

The undersigned met with staff members of Acres International, Harza-Ebasco and APA on November 18 and 19, 1982, to review (1) the 1982 summer geotechnical exploration program and its impact on the feasibility and design of the Susitna Hydroelectric project, and (2) the geotechnical exploration program proposed for the winter of 1982-83.

Our comments on these programs are presented below:

1. 1982 Geotechnical Program

During the summer of 1982 geotechnical studies were made of:

1. The geology and rock conditions at the Watana damsite
2. The soil conditions in Borrow Area D
3. The stratigraphy, geometry and characteristics of the soils in the Watana Relict Channel, and
4. The configuration of the Fog Lakes Relict Channel.

The scope of this program included 83,000 ft of seismic refraction lines, 16 borings, geologic mapping at the damsite and a substantial laboratory program of grain-size distribution tests and Atterberg limit tests in the samples obtained.

Preliminary information on the program was presented during the meeting. The program has provided a significantly improved basis for assessing the geologic and soil conditions in the area of the Watana site.

Of special interest in this regard were the studies completed in the Watana Relict Channel. Concerns to be addressed by this program of investigation were (1) potential reservoir leakage and piping along the channel; (2) potential for soil liquefaction during earthquake shaking; (3) potential settlements due to the saturation and permafrost thawing.

This summer's program did not provide information on the more permeable unit of the soil deposits filling the relict channel (unit K) but it provided useful data on the density of the soils in the upper 200 feet, through the acquisition of penetration test data, and therefore, on the liquefaction and settlement potential of these soils.

A preliminary interpretation of this data was presented showing that penetration resistance was generally high except in the surficial deposits and in unit G at a depth of about 70 to 90 feet. However unit G was also found to be generally cohesive (indicated by grain-size tests and Atterberg limit tests). Overall these results are generally encouraging with regard to the settlement and liquefaction problems, since dense cohesionless soils or stiff cohesive soils are not likely to be vulnerable to either significant settlement or liquefaction due to saturation or earthquake shaking. While more work remains to be done, the preliminary results would seem to indicate that some of the present concerns may ultimately prove to be unfounded.

2. Damsite

The principal objectives of the winter program are to improve knowledge of the thickness and engineering properties of the alluvium and the corresponding configuration of the underlying bedrock. We agree with these objectives. These factors will have a considerable effect on the design and layout, inasmuch as they control (1) the extent to which the alluvial material must be removed from the area to be occupied by the shells of the dam, (2) whether the upstream cofferdam could possibly be incorporated in the main dam and, therefore, (3) whether the diversion-tunnel portals might be located in more favorable rock downstream from the present tentative position. The significance of these effects leads us to suggest that consideration should be given to concentrating the hammer-drill holes along a line near the upstream toe of the dam. This will provide the maximum probability of learning the depth of the lowest bedrock surface in this area, the most critical factor in establishing the position of the cofferdam.

We concur in the intention to gather as much quantitative data as possible by in-situ testing in the drill holes and accompanying refraction surveys and believe that the correlation between the seismic and drillhole data near the upstream toe will be useful in interpreting the results of refraction surveys at the other proposed locations at the damsite. We believe, however, that the design should take account of the likelihood that conclusive information regarding the possibility of allowing part of the alluvium to remain in place may not be obtained before the core trench is excavated during construction. Consideration should, therefore, be given to preparing the contract documents in such a way that deferring the decision until that time will not adversely affect the cost and schedule.

Diamond drillholes on the abutments and along the axis in the river bottom will, of course, be necessary for detailed final design, but the rock on which the dam will be supported leaves no doubt regarding the feasibility of constructing an embankment dam at the site.

3. Relict Channel

Acres presented a stratigraphic profile of the various deposits believed to exist in the Watana Relict Channel which is a composite section based upon the results of the Corps of Engineers and recent exploration programs. Of the 14 different units shown on the profile, the lowermost alluvial deposits (K) are believed to be the most pervious and therefore the most likely to allow higher seepage through the right abutment.

The seismic refraction surveys completed during the past summer have basically confirmed the geometry of the buried channel as had been revealed in previous programs.

The abutment drilling program for the coming winter will consist of Becker drilling in the deepest part of the buried channel where unit K is believed to be thickest. Pumping tests are planned as well as some in-hole geophysical logging.

We are basically in agreement with the proposed program and recognize that some modifications may be proposed by the engineer as the work proceeds. We suggest that consideration be given to exposing the channel deposits in Deadman's and Tsusena Creeks by side-hill bulldozer cuts to obtain a better idea of the channel deposits.

The next phase of exploration following the winter program has not yet been defined. Such work would include, among other items, the exploration adits and borings for portals, underground chambers, and shafts. We foresee that delays in this work could affect the ongoing design process and we would endorse an early start in this phase of the explorations.

Please do not hesitate to call if you have any questions.

Sincerely yours,

Andrew H. Merritt

Ralph B. Peck

H. Bolton Seed

ALASKA POWER AUTHORITY

334 WEST 5th AVENUE - ANCHORAGE, ALASKA 99501

Phone: (907) 277-7641
(907) 276-0001

August 12, 1983

Alaska Power Authority
334 West 5th Avenue
Anchorage, Alaska 99501

ATTENTION: Mr. David D. Wozniak

On August 9 - 12, the Technical Subpanel of the newly expanded Susitna External Review Panel met in Anchorage with all members present except Mr. James W. Libby, whose schedule had an unavoidable conflict.

Briefings were presented by Harza-Ebasco in Anchorage on August 9. The site was visited on August 10 by the members except Professor Seed, whose arrival in Anchorage was delayed and who was briefed on the afternoon of the 10th. After further short briefings, the attached report was prepared on August 11 and presented on August 12.

We appreciate the excellent presentations and look forward to continuing participation in this challenging project.

SUSITNA HYDROELECTRIC PROJECT
EXTERNAL REVIEW PANEL
ENGINEERING SUB-PANEL MEETING
Report No. 1

August 9, 10, 11, 12, 1983
Anchorage, Alaska

9808/050

Contents

1. Economic Studies

Studies directed toward evaluating the need for power and the benefit/cost ratio for the project were described briefly. It is apparent that the economic forecasts are highly sensitive to the world price of oil, a figure not subject to rational determination. However, we note two important advantages of a hydro development over equivalent thermal installations: the inflation-proof character of a hydro plant once it has been constructed, and the conservation of valuable irreplaceable resources such as natural gas.

2. Exploration

We have been advised of the delays in continuing the exploration program required for final design. The only field work in progress is geologic mapping. Further drilling, test pits, sampling, and testing will not be initiated until the summer of 1984. It is our understanding that this delay has resulted from budget constraints imposed on the Alaska Power Authority.

We are concerned that the late acquisition of the necessary field information will interfere with the orderly progress of the final design. At this time Harza-Ebasco (H-E) has suggested that major savings could result from the adoption of a surface powerhouse scheme; however, the lack of exploratory borings in this area leaves some question as to the final layout and potential savings. The final design of the dam requires that sources of suitable borrow material be located and the necessary laboratory testing be carried out. On the basis of the current schedule, no further information concerning materials for the dam will be forthcoming for at least one year. Similar comments can be made for the tunnel portals, inlet structures, and waterways.

While the financial matters of the Alaska Power Authority are beyond our terms of reference, we urge that all efforts be made to continue with the field exploration, which at this time would desirably give full attention to the main dam and powerhouse.

3. Excavation of River Channel Deposits

The panel members reviewed at length the desirability of removing the alluvial deposits in the river bed and the colluvium on the abutment slopes under the shells of the dam, in relation to the cost savings of leaving these materials in place. Although it is probable that the in-situ materials are relatively dense, it is concluded that prudent design requires the removal of the alluvium and colluvium over most of the base of the embankment for the following reasons:

a. Uncertainties concerning the characteristics of the alluvium
b. The need to remove the alluvium under the core of the dam and to provide seepage cut-off walls under the cofferdam together with a dewatering system for this purpose
c. The great height of the dam
d. The highly seismic environment in which the dam is to be constructed, and
e. The advantages of exposing the hydrothermally altered rock under the downstream shell of the dam.

The alluvium and colluvium may be left in place in the following zones:

1. Under the upstream shell outside a line drawn from the upstream edge of the crest and sloping at about 1 on 2 to the horizontal
2. Under the downstream shell outside a line drawn from the downstream edge of the crest and sloping at about 1 on 1.5 to the horizontal
3. In deep pockets of limited lateral dimensions which may be encountered under the upstream and downstream shells when the major part of the bedrock surface is exposed
4. Under the upstream shell and under portions of the downstream shell where it may be evident that no erodible shear zones would be present in the bedrock, if excavation in the core area discloses that portions of the alluvium are more compact than the replacement fill would be.

4. Rock Excavation Beneath the Dam

Numerous borings were made through the alluvium and into bedrock along the axes of the main dam and cofferdams. The rock encountered was principally a hard, jointed diorite; however, most borings also encountered zones of hydrothermally altered diorite which varied from hard and jointed to soft, sheared, and soil-like. In two instances to date these altered zones are believed to be related to thin shear zones mapped on the abutments during the feasibility study.

H-E has concluded that the amount of rock excavation required beneath the dam can be significantly reduced from that indicated on the feasibility drawings. On the basis of our inspection of much of the rock core, we concur that the initial allowance for excavation, about 20 feet beneath the shells and up to 50 feet beneath the core, is excessive and can be reduced substantially.

As has been discussed, special attention needs to be given to the soft, possibly ungroutable, hydrothermally altered diorite once the foundation has been excavated and cleared. We foresee that dental excavation and backfill concrete as well as special treatment with filters may eventually be required for these zones.

5. Cross Section of Embankment

H-E presented for consideration a drawing showing modifications to the proposed cross section of the main embankment dam. Our comments are as follows:

The upstream slope is shown as 2.4:1 and the downstream slope as 2:1, except for the customary slight steepening near the crest to allow for camber in the central portion of the embankment. These slopes appear to be reasonable at this stage of design.

The upstream shell is composed of two zones, an outer zone of rock fill and an inner zone of processed gravel fill. The two zones are separated by a 40-foot-wide transition zone of raked rockfill. We do not consider this transition to be a necessary element of design and recommend that it be eliminated. Any oversize rock in the rockfill can be raked to the upstream slope if desired.

The central impervious core is symmetrical about the axis and has upstream and downstream slopes of 1:4; thus the maximum hydraulic gradient through the core will be less than two. This seems to be amply conservative, subject to verification based on future laboratory testing.

The core is separated from the upstream gravel fill by a fine filter and a coarse filter, both of variable but ample thickness.

The downstream shell is composed of an outer zone of rockfill and an inner zone of sand fill which constitutes the minus 3/8" material removed from the processed upstream gravel zone. The sand fill is separated from the impervious core by a fine filter, and from the rockfill by a coarse filter followed by a 40-foot zone of raked rockfill. A 30 foot thick fine filter underlies the sandfill, separating it from the foundation.

The panel questions the necessity of the 30-foot-thick fine filter on top of the exposed foundation rock downstream from the core, suggests that its thickness be reduced to 5 feet, and that it be placed over only those portions of the foundation that appear to be erodible. We also suggest that below approximately elevation 1500, the sandfill zone be replaced by compacted gravel. We also suggest that the 40-foot-wide raked rockfill be eliminated.

Detailed specifications for zoning, gradation, placement and compaction cannot be prepared until borrow explorations and testing are completed.

6. Spillway

H-E has refined the layout of the right-bank hydraulic structures by eliminating the separate emergency spillway containing a fuse plug, by enlarging the service spillway sufficiently to accommodate the PMF, and by combining the spillway and power intakes into a single structure. We consider these refinements to be a substantial improvement, and in particular are pleased by the elimination of the fuse plug spillway.

7. River Ice Problems

The layout of the diversion works, particularly the provision of two tunnels with intakes at different levels, has been influenced at least to some extent by the need to avoid blockage by ice. However, we have seen few other comments concerning ice problems and their influence on the design, construction, and operation of a large hydroelectric plant in the Susitna region.

A wealth of experience concerning the behavior of ice under similar conditions has recently been accumulated in Canada, especially on the James Bay Project, and we believe that advantage should be taken of this development by consultation with one or more of the individuals having this expertise.

8. Powerhouse Type and Location

H-E has proposed a surface powerhouse because estimates have indicated that substantial savings could be realized as compared to the underground design presented in the feasibility report. It was pointed out that the total of the construction contingency items would be less for a surface structure than for an underground structure. Initial layouts show a surface powerhouse located on the right abutment between the toe of the dam and the outlets of the diversion tunnels and spillway discharge structure. The possible need for slope stability treatment in the surface scheme has been recognized by including a substantial contingency for this possibility.

Without the benefit of much exploration in this area, we agree in principle with H-E that a surface powerhouse would be cheaper.

However, we note that the combination of adjacent powerhouse and discharge structures will require major open cuts. The impact of these cuts on costs cannot be adequately assessed on the basis of the current level of exploration. Also, it appears that the surface powerhouse open cuts have led to a relocation of the discharge structures to a position somewhat closer to the "fingerbuster" area of sheared rock.

In our opinion, these matters should be carefully analyzed using all available geotechnical information to assist in laying out the desired open cuts. However, final layout studies will require additional subsurface information.

9. Relict Channel

Preliminary results of the 1983 winter exploration program were presented by H-E. This program included 9 hammer-drill borings from which samples were recovered for determination of grain size and other index properties, and from which some information concerning penetration resistance was obtained. The results have improved knowledge of the stratigraphy and properties of the deposits, and confirm our previous impression that earlier concerns regarding liquefaction and settlement potential may be unfounded. We understand that a report documenting the findings will be available shortly. We note that the potential for instability of the saddle in the reservoir rim associated with the relict channel, as well as any uncertainties caused by the possibility that permafrost in the saddle may be melted, would be greatly reduced by a modest lowering of the reservoir level.

It is our understanding that the difficulties of drilling and sampling the lowermost sedimentary unit in the channel, the K alluvium, and the need to accomplish the river-bed exploratory program while ice conditions were suitable, precluded the permeability studies planned for stratum K. We agree that it is reasonable, however, to proceed on the premise that any seepage can be controlled by downstream drainage. This can be deferred until the need is demonstrated by instrumentation and surveillance as the reservoir rises, especially because filling the reservoir will require several years.

10. Concluding Remarks

A high level of technical information is required before the final decisions on the concept and design of a complex hydroelectric project can be developed. The budget required to obtain this information may seem considerable. However, money well spent at this time can make the difference between a successful project or one beset with problems. We suggest the establishment of a budget commitment on a continuing basis for the necessary studies and the development of proper access to the site. The Consultant needs the full support of the owner and his management group.

Future Meetings

We recognize the difficulties in planning the activities of the Subpanel for the future, but would suggest that our services would be most effective if provided on a reasonably regular basis. We feel it would generally be useful to include a trip to the site during each visit. We suggest that our next visit be tentatively scheduled during the first week of April 1984.

Respectfully submitted,

Robert A. Boyd

Andrew H. Merritt

Ralph B. Peck

H. Bolton Seed

Stanley D. Wilson