the susitna hydro studies

This is the second of several newsletters published by the Alaska Power Authority for citizens of the railbelt. The purpose is to present objective information on the progress of the Susitna hydroelectric feasibility studies so that readers may make their own conclusions based on accurate information.

Eric P. Yould, Executive Director
Nancy Blunck, Director of Public Participation

Alaska Power Authority
333 W. 4th - Suite 31
Anchorage, Alaska 99501
phone (907) 276-0001

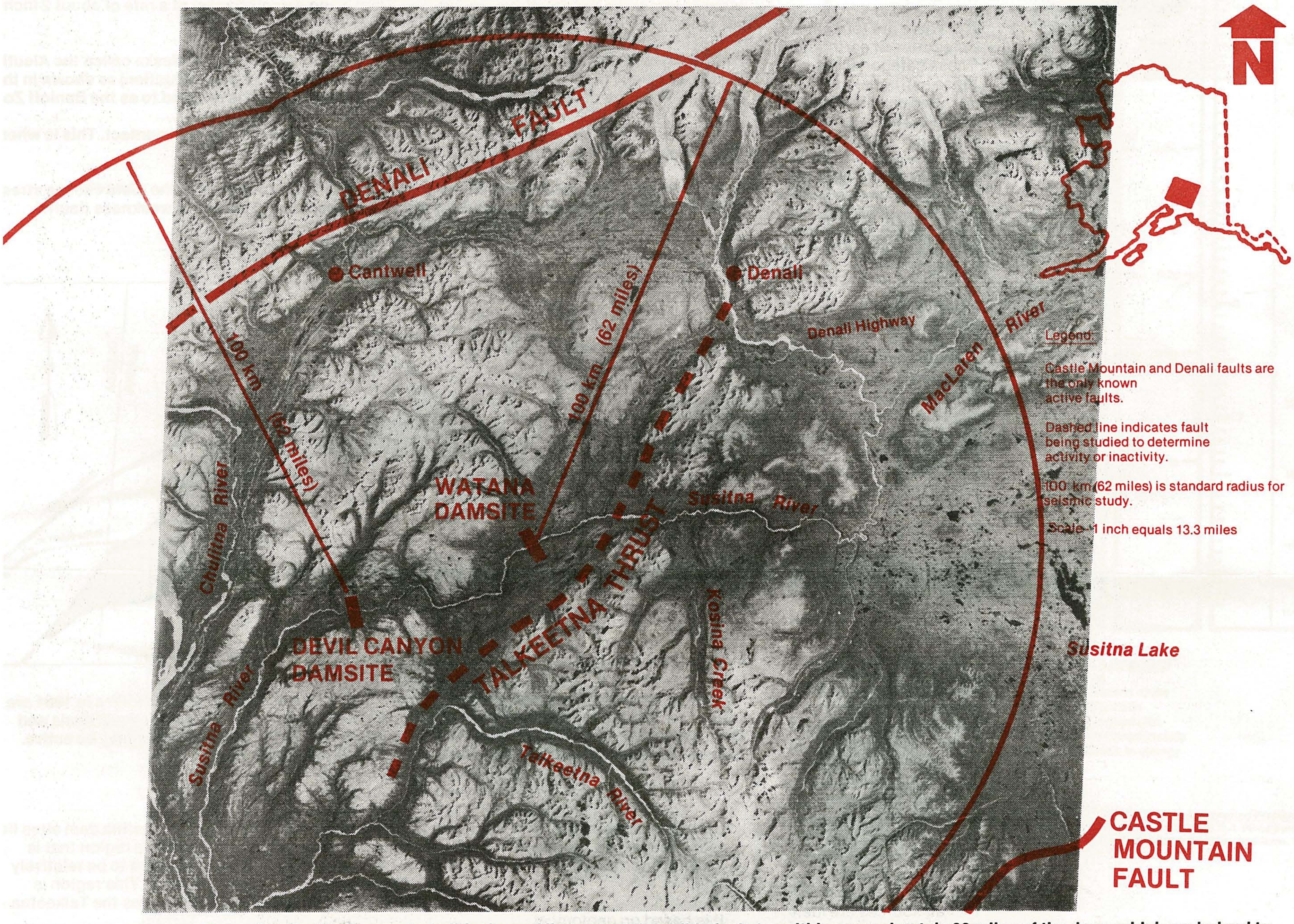
The state of Alaska is an equal opportunity employer.

IN THIS ISSUE:

ALASKA POWER AUTHORITY
PUBLIC PARTICIPATION OFFICE
333 West 4th - Suite 31
Anchorage, Alaska 99501
(907) 276-0001

the susitna hydro studies

September 1981



For the Susitna project all faults and lineaments (possible faults) within 100 km (62 miles) of either dam have been compiled from published and unpublished reference materials, satellite imagery, radar imagery, high-altitude aerial photography, and low altitude aerial photography.

Based on this work, the only faults in the North American Plate within approximately 62 miles of the dams which are judged to be active are the Denali fault and the Castle Mountain fault.

Beneath the upper 15 to 20 miles of the earth's crust is the Benioff Zone. This is also an active fault zone. The depth to the Benioff Zone beneath the Susitna dam sites is about 34 miles.

Preliminary findings available on Susitna basin seismicity

This issue gives information about the seismicity of the upper Susitna River basin and discusses the question of building safe dams in seismic areas.

The following are the preliminary seismic conclusions.

1. No faults with known recent movement (movement in the last 100,000 years) pass through or near the proposed Susitna dam sites.

2. The known faults with recent movement are: the Denali fault (north of the sites), the Castle Mountain fault (south of the sites) and the Benioff Zone (about 34 miles beneath the sites).

3. The closest distances of these faults from each site and the preliminary maximum credible earthquake magnitudes for the faults are the following:

Fault	Preliminary Maximum Credible Earthquake Magnitude	Closest Distance of Fault to Site (miles) Watana	Devil Canyon
Denali	8.5	43	40
Castle Mountain	7.4	65	71
Benioff Zone	8.5	31	37

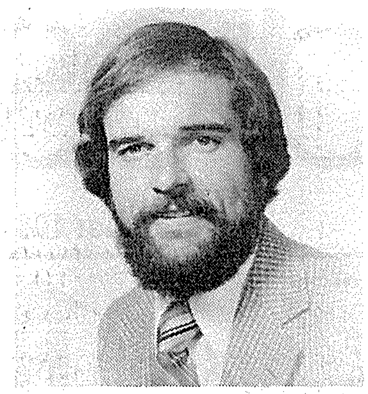
4. Within the site region, 13 faults and lineaments (potential faults) are receiving additional study in summer 1981 to better define their potential effect on dam design. Four of these faults and lineaments are near the Watana site and nine are in the area of the Devil Canyon site.

5. At present, the 13 features are not known to be faults with recent movement. If present studies show any recent movement, then the potential for surface rupture through either dam site and the ground motions associated with earthquakes on the fault will need to be evaluated.

6. Preliminary estimates of ground motions at the sites were made for the Denali and Castle Mountain faults and the Benioff Zone. Of these sources, an earthquake of magnitude 8.5 occurring within the Benioff Zone would create the maximum ground shaking at the dam sites.

Source:
Interim Report on the Seismic Studies for (the) Susitna Hydroelectric Project, December 1980, prepared by Woodward-Clyde Consultants for Acres American, Inc. and the Alaska Power Authority.

We've been asked ?



Lovegreen

The following are responses to frequently asked questions. The information was developed by Jon R. Lovegreen, Senior Project Geologist, Woodward-Clyde Consultants.

1. **Do earthquakes occur only along faults?**

   No. There are four general categories of earthquakes. These categories are collapse earthquakes, volcanic earthquakes, explosion earthquakes, and tectonic earthquakes.

   Tetonic earthquakes are the most common type of earthquakes and are the earthquakes pertinent to the design of the Susitna project.

   Tectonic earthquakes result when stresses within the earth build up to the point that the strength of the rock is exceeded. Relatively instantaneous release of strain energy takes place along a zone of weakness. The energy release causes the ground shaking of the earthquake and the zone of weakness is the fault.

2. **How do you ensure that you are identifying virtually all sources of earthquakes that could affect the dam?**

   The identification of sources for earthquakes in Alaska is based on experience with faults and earthquakes in Alaska and worldwide. From this experience, it is possible to make judgements about the potential sources of earthquakes in a region such as the Talkeetna Mountains. These judgements do not ensure that all sources are identified, rather, the judgements identify all sources of earthquakes which experience has shown could be possible.

   For large projects such as the Susitna hydroelectric project, a conservative approach is used. This approach includes the study of faults which are only remotely possible sources of earthquakes.

   The past experience of the firm which is studying the faults and earthquakes (Woodward-Clyde Consultants) includes examination of active faults and earthquakes in Alaska, California, Nevada, Utah, Central and South America, Europe, Africa, the Middle East, Australia, New Zealand, and Japan.

3. **You use the term "maximum credible earthquake." What is that?**

   A Maximum Credible Earthquake is considered to be the most severe earthquake associated with a fault and is assumed to occur at the point on the fault closest to a proposed project, such as a dam site.

   It is based on geological and historical data, and is usually of a magnitude greater than historical earthquakes.

4. **How reliable is it?**
   The Maximum Credible Earthquake is considered to be a reliable parameter to use for dam design. There are over 11,000 dams worldwide. Some of these have been built in moderate to high seismic areas such as Oroville dam in California and several dams in the San Francisco Bay Area along the San Andreas fault.

   Several dams have been damaged during earthquakes, such as Koyna in India and Hsinfengkiang in the People's Republic of China. This damage was due in large part to the absence of design considerations for reservoir-induced seismicity.

5. **What are your estimates for the largest earthquakes that could occur in the area of the proposed dams?**

   One is a magnitude 8.5 earthquake on the Denali fault, 40 miles from the dams; the other is a magnitude 8.5 earthquake in the Benioff Zone, about 34 miles below the surface of the earth at the dams.

6. **How much ground shaking would that cause?**

   The ground shaking that would occur at the dams from a magnitude 8.5 earthquake on the Denali fault is considered to have an average peak acceleration of 20%g.

   The ground shaking that would occur at the dams from a magnitude 8.5 earthquake in the Benioff Zone is considered to have an average peak acceleration of 40%g.

7. **How does that compare to the 1964 earthquake?**

   As a comparison, the average peak acceleration estimated at Susitna would be 1/3 to 1/2 as much as the average peak acceleration estimated at Valdez during the 1964 earthquake.

8. **Just how seismically active is the area where the proposed dam sites are?**

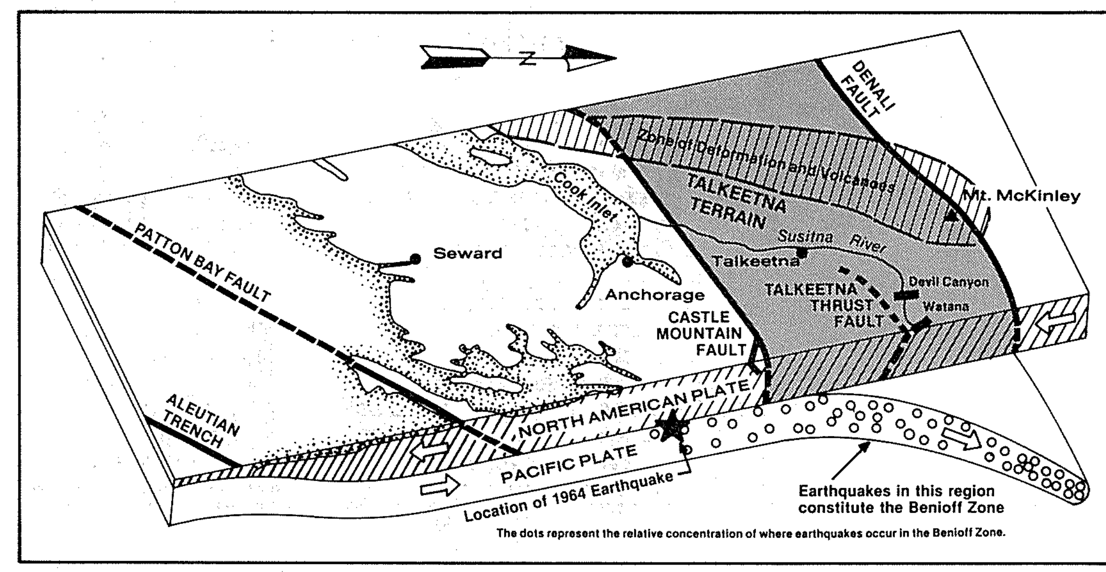
   The Susitna dam sites lie within a region that is believed to be relatively stable. This region is known as the Talkeetna Terrain.

   The boundaries of the Terrain are the Denali fault, the Castle Mountain fault, and the Benioff Zone (which is about 34 miles below the surface of the earth). These are all active fault areas.

   Energy release appears to be occurring primarily along the boundaries of the Talkeetna Terrain rather than within it.

   Within the Terrain, no evidence of active faults has been observed. Some earthquake activity is occurring and has occurred within the Terrain, but the earthquakes are typically small to moderate in size.

   To date no active faults have been identified in the Talkeetna Terrain itself. Studies in 1981 are further evaluating 13 faults and lineaments (potential faults) in the vicinity of the Watana and Devil Canyon damsites to determine whether or not the faults and lineaments may be active.

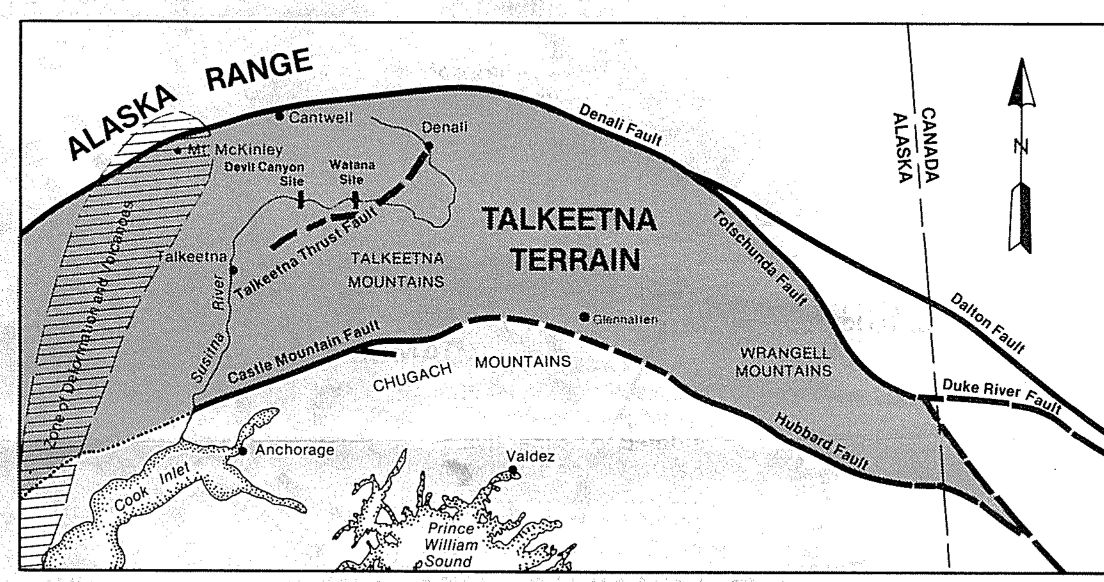


Alaska is part of a large continental landmass (the North American Plate) which lies adjacent to an oceanic mass (the Pacific Plate). The Pacific Plate is moving northwest at a rate of about 2 inches per year.

This 2 inches of movement gets absorbed along a feature in the Gulf of Alaska called the Aleutian Trench. Here one plate is thrust below the other (in a process called subduction) as shown in the diagram. The zone of seismicity associated with the subduction is referred to as the Benioff Zone.

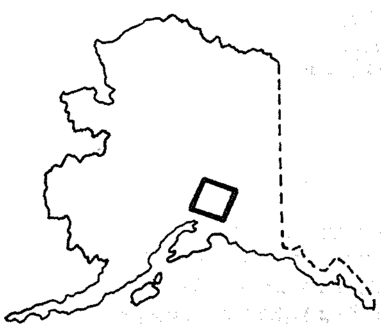
Earthquakes can occur along the Benioff Zone where the two plates are in contact. This is where the 1964 earthquake occurred as shown in the diagram.

Earthquakes are also caused within the plates themselves. Movement of the plate causes stresses to build up and the energy is released by rapid movement along planes of weakness (faults).



To date no active faults have been identified in the Talkeetna Terrain itself. Studies in 1981 are further evaluating 13 faults and lineaments (potential faults) in the vicinity of the Watana and Devil Canyon damsites to determine whether or not the faults and lineaments may be active. One of those receiving additional study is the Talkeetna Thrust Fault.

Background information on proposed Susitna project



The Susitna hydroelectric project as currently proposed involves two dams and reservoirs on the Susitna River in the Talkeetna Mountains of southcentral Alaska.

The project area is about 50 miles northeast of Talkeetna, Alaska and 118 miles northeast of Anchorage, Alaska.

The upstream dam, Watana, is proposed to be developed first. It is currently being considered as an earth/rockfill dam, approximately 880 feet high. This would make it the fifth highest dam in the world and the highest in North America. It would impound a 54-mile-long reservoir.

The downstream dam at Devil Canyon is currently being considered as a concrete arch dam approximately 635 feet high. It would impound a 28-mile long reservoir.

These dimensions are approximate and subject to change during detailed design.

The feasibility study is being managed and conducted by Acres American, Inc. for the Alaska Power Authority. The studies conducted to date represent the first year of a planned two-year study (1980 and 1981). A draft feasibility report detailing research efforts in 10 different areas including economics, engineering, and environmental aspects of the proposed power project is due in March next year.

How proposed Susitna projects compare with existing dams

Name	Year completed	River or Basin	Nearest city	State or Province	Country	Dam type	Height above lowest foundation m	Crest length m	Reservoir capacity m³ x 10⁶	Rated capacity now (MW)	Rated capacity planned (MW)	Year of initial operation
[1]Bonneville	1943	Columbia	Portland	Oregon-Washington	USA	concrete gravity	32	277		588	1,076	1938
[2]Glen Canyon	1964	Colorado	Page	Arizona	USA	concrete arch	216	475	33,305	1,021	1,431	1964
[3]Grand Coulee	1942	Columbia	Coulee City	Washington	USA	concrete gravity	168	1,272	11,795	7,460	10,830	1942
[4]Hoover	1936	Colorado	Boulder City	Nevada-Arizona	USA	concrete arch/gravity	221	379	36,703	1,345	1,345	1936
[5]Mica	1973	Columbia	Revelstoke	British Columbia	Canada	earth/ rockfill	245	792	24,670	1,736	2,610	1976
[6]Oroville	1968	Feather	Oroville	California	USA	earth	235	2,316	4,299	679	679	1967
[7]Devil Canyon	(Proposed) (2000)	Susitna	Talkeetna	Alaska	USA	concrete arch	200	378	1,235	0	400	(Proposed) (2000)
[8]Watana	(Proposed) (1993)	Susitna	Talkeetna	Alaska	USA	earth/ rockfill	271	1,662	12,347	0	800	(Proposed) (1993)

Sources: [1]Corps of Engineers, Portland, Oregon [2]Western Area Power Office, Golden, Colorado. [3]) "Major Dams of the World," T.W. Mermel, International Water Power [4]) and Dam Construction, Special Issue May 1981, Published by IPC [5]) Electrical-Electronic Press Ltd., Quadrant House, The Quadrant, Sutton, Surrey SM25AS, England [6]Civil Design, State of California, Oroville, California [7]Acres American, Inc., Anchorage, Alaska [8]Acres American, Inc., Anchorage, Alaska

1 Meter = 3.25 Feet

Construction timed to match power demand

The proposed Susitna development is presently envisioned as having three distinct stages:

1) the Watana dam with installed capacity of 400 MW;

2) an addition to the Watana capacity of another 400 MW; and

3) the Devil Canyon dam with an installed capacity of about 400 MW.

Both the Watana capacity addition and the Devil Canyon project could be brought on line earlier or at the same time, if needed, while all three stages could be postponed if demand turned out to be less than anticipated.

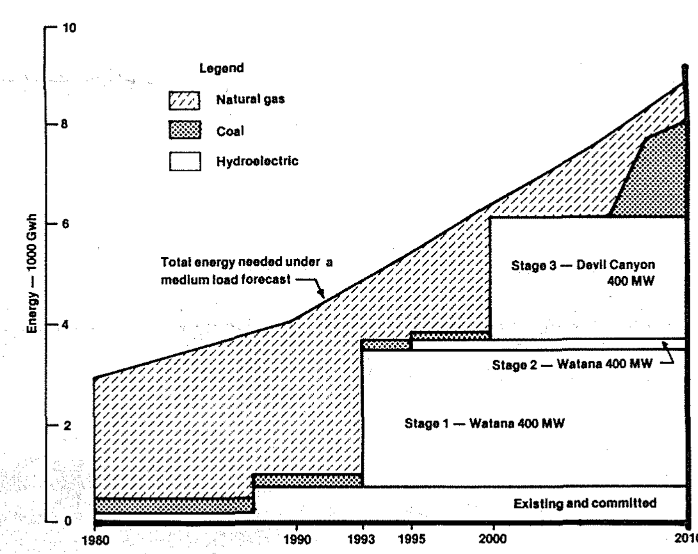
This staging provides some flexibility in the sequence and timing of construction. At the same time, there are certain constraints on that flexibility.

In staging the Susitna development, the primary objective is to keep the cost of power as low as possible. This is done by minimizing expenditures while selling as much of the available power as possible. But the power cannot be sold if there aren't consumers ready to buy it. The energy consumption forecasts provide estimates of how much power can be sold in the years ahead.

The Power Authority's approach, then, is to postpone spending money for the next stage as long as possible to ensure that there is the demand for purchasing the project's power. Money spent on a project whose power cannot be sold is money wasted.

Waiting too long to construct the next stage, however, is unacceptable because there would be an increasing likelihood of not being able to meet the peak demands. If this occurred, customers would have to go without electricity during high use periods. Thus, a balance has to be struck between postponing additional investments and ensuring adequate generation to meet peak loads.

Meanwhile, the balancing has to be done in the midst of a great deal of uncertainty about what the actual demand for power is going to be in the future. As time goes on and future power demands become more certain, the planned staging would be adjusted to suit actual conditions.



Possible staging of Susitna project

This diagram shows how the Susitna development would be staged under the medium forecast of future energy requirements. With this energy demand and ensuring that adequate generating reserves are maintained, power costs would be minimized if:

1) The Watana dam with 400 MW would be completed in 1993, which is the earliest possible date because of time periods involved in project evaluation, permitting, and construction;

2) the additional 400 MW of capacity at Watana is ready for operation in 1995; and

3) the Devil Canyon dam with its 400 MW is completed in the year 2000.

If you want to get future newsletters

This public information document on the Susitna hydropower project was developed by the Alaska Power Authority Public Participation Office, Nancy Blunck, Director. Comments on the substance of this newsletter and ideas for future publications should be forwarded to the Public Participation Office by way of the following coupon.

Name Last ______ First ______ Initial ______

Mailing Address ______

City ______ **State** ______ **Zip** ______

and mail to: Alaska Power Authority
Public Participation Office
333 W. 4th - Suite 31 - Anchorage, AK 99501

THANK YOU FOR YOUR INTEREST

9. **How can there be no active faults in the area of the dam sites when historic records show many earthquakes occurring there?**

In the area of the proposed Susitna dam sites earthquakes occur within the North American Plate (which includes the upper 15 to 20 miles of the earth's crust) and in the Pacific Plate (which is being subducted, or drawn downward, beneath the North American Plate).

Preliminary evaluation of the seismicity in these two plates, within the Talkeetna Terrain, suggests that many of the earthquakes, including virtually all of the moderate to large earthquakes are occurring in the Pacific Plate at depths of at least 34 miles beneath the dam sites.

Activity occurring in the North American Plate is associated with energy release on small fault planes which are too deep and too small to cause displacement at the earth's surface.

10. **Why do your studies not consider faults that are inactive?**

All faults and possible faults within about 100 km (62 miles) of the Susitna dam sites have been evaluated to determine whether or not they are active faults. Those faults which have not had displacement in recent geologic time are considered to be inactive. Faults which are inactive are not important for seismic design of a dam because earthquakes are not expected to occur along inactive faults.

11. **What is considered an active fault?**

Various governmental and regulatory agencies have defined active faults in order to assess the importance of faults to the design of critical facilities such as dams. Initially these definitions were based on how recently there has been movement along a fault.

For example, the U.S. Bureau of Reclamation defines a fault which has moved in the last 100,000 years as active. The U.S. Army Corps of Engineers uses 35,000 years.

Recently there has developed an increasing consensus that the activity of a fault should be considered by how often it moves, how much movement is likely to occur and what type of movement will occur. From this information the likelihood of fault movement can be made and incorporated into dam design.

12. **When you refer to active faults, how long a period of time are you referring to?**

As a guideline for the Susitna project, Acres American, Inc. has defined an active fault as one which has had movement, or displacement, in the last 100,000 years.

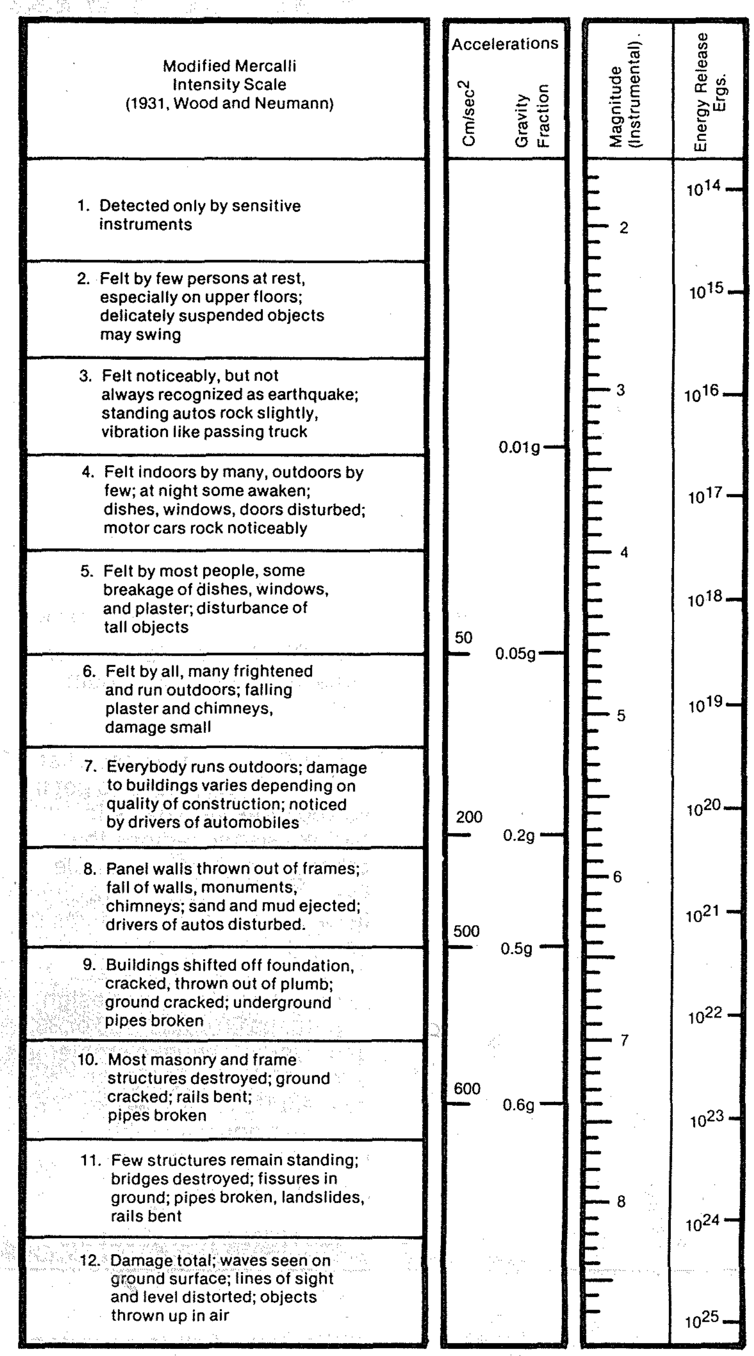
Source: Interim Report on Seismic Studies for Susitna Hydroelectric Project, December 1980, prepared by Woodward-Clyde Consultants for Acres American, Inc. and the Alaska Power Authority.

In Anchorage, copies are available at the Alaska Resources Library in the Federal Building; at the University of Alaska Consortium Library; at the Arctic Environmental Information and Data Center; and at the Z.J. Loussac Library.

In Fairbanks, copies are available at the Elmer E. Rasmuson Library, University of Alaska; and at the Noel Wien Library.

In Talkeetna, a copy is available at the Talkeetna Public Library.

Three ways to measure the force of an earthquake



Modified Mercalli scale
This scale verbally describes the effects of earthquakes.

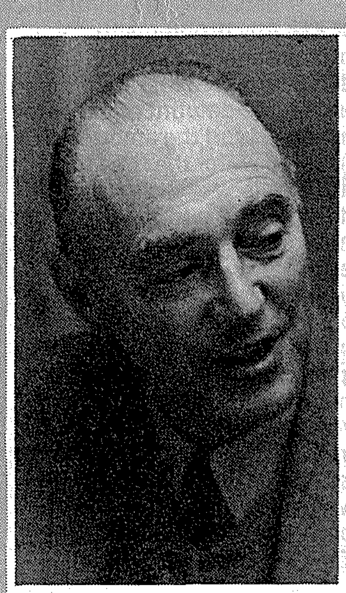
Acceleration
Engineers often use acceleration to measure the severity of earthquake motions. The relationship of acceleration to magnitude must include a consideration for the distance from the earthquake source.

Magnitude and amount of energy release
These two columns show that each increase in magnitude (for example, from 5 to 6) is approximately a 30-fold increase in energy release.

Source:

Modified from Earth-Rock Dams, Engineering Problems of Design and Construction, J.L. Sherard, R.J. Woodward, S.F. Gizienski, W.A. Clevenger, John Wiley and Sons, Inc., New York.

What about reservoir-induced seismicity (RIS)?



Dr. Harry Seed

1. **What is reservoir-induced seismicity (RIS)?**

Reservoir-induced seismicity (RIS) refers to earthquakes which are triggered by the filling of a reservoir. Typically these earthquakes occur beneath the reservoir area. Recent studies suggested that RIS earthquakes are triggered in certain geologic and seismologic terrains by the weight of the water in the reservoir and by the reduced friction along fractures (caused by water being forced into the fractures.)

2. **Does that mean reservoirs can cause earthquakes?**

"A reservoir cannot induce more seismic activity than an area could have produced if the reservoir had not been there. In other words, a seismic event that would have occurred sooner or later is induced to occur sooner."

"If, at the time of the filling of the reservoir, the accumulated strain energy is small, the corresponding seismic event could be small. Conversely, if the accumulated strain energy is high, the resulting event could be large, but not larger than what would naturally occur sooner or later."

3. **What is the potential for RIS at Watana and Devil Canyon dam sites?**

The potential for RIS is largely a function of the size and depth of the reservoir. Since the Watana reservoir would be both very large and very deep, Woodward-Clyde Consultants has estimated both the probability of RIS occurrence and the potential magnitude of the resulting earthquake.

Preliminary results suggest a moderate reservoir-induced earthquake could occur at the Watana site. The estimated magnitude of such an earthquake is 5.5 or less, because no active faults have been found in the immediate area of the Watana reservoir. The probability of occurrence was estimated by comparing the Watana reservoir with other very large and very deep reservoirs that have experienced RIS worldwide.

Preliminary results indicate a similar likelihood of RIS at Devil Canyon.

Additional evaluation of the likelihood of reservoir-induced seismicity is currently being done.

4. **Is the potential for RIS taken into account in dam design?**

Yes. The design criteria for the dam actually exceeds design criteria for a reservoir-induced earthquake.

Dam design criteria will incorporate both the effects of earthquakes on more distant active faults (the Denali Fault and Benioff Zone) as well as earthquakes which occur near the sites including those which are reservoir-induced.

Source:
Dr. Harry Seed,
Specialist in Earthquake-Resistant Design,
University of California, Berkeley.

Designing Dams in Earthquake Country —An Interview With Dr. Harry Seed

Dr. H. Bolton (Harry) Seed, is a specialist in earthquake-resistant design and professor of civil engineering at the University of California, Berkeley. He also serves on the Susitna External Review Panel which is made up of six eminent engineers and scientists who provide independent review of the Susitna hydroelectric feasibility study.

Dr. Seed has been a consultant on soil mechanics and seismic design problems since 1953. Over the years, he has worked extensively with a variety of clients, including the U.S. Army Corps of Engineers, the Executive Office of the President of the United States, the World Bank, the Federal Power Commission, Bechtel Corporation, Woodward-Clyde, the Metropolitan Water District of Los Angeles, the Canadian Ministry of the Environment, and many foreign government agencies. He has worked on about 80 dams worldwide, most of which were in seismic areas. After a dam failure in California in the early 70's, Dr. Seed authored design procedures for California so that dam failures would not happen again. These procedures are now used throughout the world to produce safe, seismic designs for dams.

Following are excerpts from an interview conducted by Nancy Blunck, Director of Public Participation, the Alaska Power Authority. The complete text is available upon request.

QUESTION: What is your personal experience with dam design?

SEED: Since I am a specialist in earthquakes, I tend to get involved more with dams in highly seismic regions than other areas. So, for example, I've worked on a lot more dams in California than with dams in Texas or Florida, which are nonseismic regions. My experience includes the design of perhaps 80 dams—50 or 80 dams for earthquake problems of one kind or another. I suspect that I have worked on more earthquake problems related to dams than anybody else in the world.

QUESTION: What about the question of building safe dams in a seismic area?

SEED: First of all, it is comforting that at the present level of knowledge of the Susitna project the intensity of shaking which can be anticipated at either dam site is considerably less than those in areas for which we have already designed dams. Secondly, the people in Alaska should know that dams have been proposed to be built in some extremely critical areas.

QUESTION: What must dam design in highly seismic areas take into account?

SEED: The first thing in a highly seismic area is to study the dam site and find out if there is a fault in the foundation of the dam or very close to the dam. We prefer not to build dams directly over faults, although once in a while we have done that when there is no way to avoid it.

Even if you avoid the faults in a highly seismic region, that doesn't eliminate the problem of the dam being subjected to extremely strong ground shaking in the event of a major earthquake...

So the second aspect of the problem is to design the dam to remain stable even though it is shaken by very strong motions from an earthquake. There are various ways in which that is effected. One is by controlling the materials of which the dam is built. When I say controlling them, I mean selecting materials which are capable of withstanding earthquakes better than others. Also, placing them in the dam using construction techniques which enhance their natural ability, and providing a finished product which can safely withstand the effects of the earthquake shaking.

The primary construction procedure involved in placing earth materials in dams is in compacting the material to a high enough density to make it strong enough to withstand the earthquake shaking. That has been done in many areas, but first you must carefully predict the effects of earthquake shaking on the dam and how dense the material needs to be to withstand a given level of earthquake motions.

QUESTION: What projects are you familiar with that resemble the Susitna project?

SEED: Oroville Dam in California is a cobble and gravel fill dam 700 feet high. Auburn dam in California is a concrete dam about 600 feet high...The Uribante-Caparo project in Venezuela is a complex of four dams and three powerhouses, with 400 to 500 foot high dams. The Alicura project in Argentina is a complex of three dams about 400 feet high...The Pueblo-Viejo dam in Guatamala is a rockfill dam 500 feet high...And many others.

"I suspect that I have worked on more earthquake problems related to dams than anybody else in the world."

QUESTION: How do these projects resemble Susitna, and are there greater or lesser problems?

SEED: The Oroville dam is in California. The region in which it was built was supposedly nonseismic, but in 1965 they had an earthquake very near the dam. So the design earthquake for Oroville is now a magnitude 6.5 (on the Richter scale) earthquake occurring directly under the dam site, which is a very strong earthquake.

Oroville is about the same height as the proposed Watana dam and, as a matter of fact, was the one we suggested in our first report as probably being the best model for that particular dam. I have been on the consulting board for that dam since it became an earthquake problem, which means having responsibility for determining the adequacy of the seismic design.

The Auburn dam in California is a highly controversial dam. Again, the design earthquake is a magnitude 6.5 event directly at the dam site. The complicating feature of that dam is that there is much debate about the possibility of a fault going through the foundation of the dam and, therefore, directly through the dam.

The Consultant Board on which I served determined that the dam ought to be designed for a fault offset in the foundation of about 6 inches. That recommendation led to redesign of the dam from the thin arch dam to a concrete gravity dam...

The Uribante-Caparo project in Venezuela involves four dams and three powerhouses and some parts of this project are built about 15 miles from the Bocono fault, which is one of the largest faults in the world.

The seismic design of the project in Venezuela is an important controlling aspect of the project. The materials available for building the dams there are not the best in the world. There is a lot of friable sandstone (friable means breaks easily, from solid to sand), and so it turns out that designing the dam to be seismically stable is a critical aspect of the design...One of the design earthquakes is a magnitude 7.5 event occurring about seven miles from the dam. This is almost identical with one of the possible design earthquakes for the Watana dam unless Acres is successful in proving that the Talkeetna thrust is not active...

The Talkeetna thrust is a fault near the Watana dam site whose activity is questionable, but it is believed to be inactive. If it remains in the inactive category, then the severity of shaking for Watana will be less than that for Uribante-Caparo project in general.

The Pueblo Viejo project in Guatemala is designed for a magnitude 7.75 earthquake passing directly through the project site—not the site of the dam, but the overall project site. The fault passes through a power tunnel very close to the dam site. The shaking there is of the order of 0.7g acceleration, lasting for maybe 45 seconds—one of the most severe seismic environments of any dam in the world. Nevertheless, a safe design has been worked out for that project.

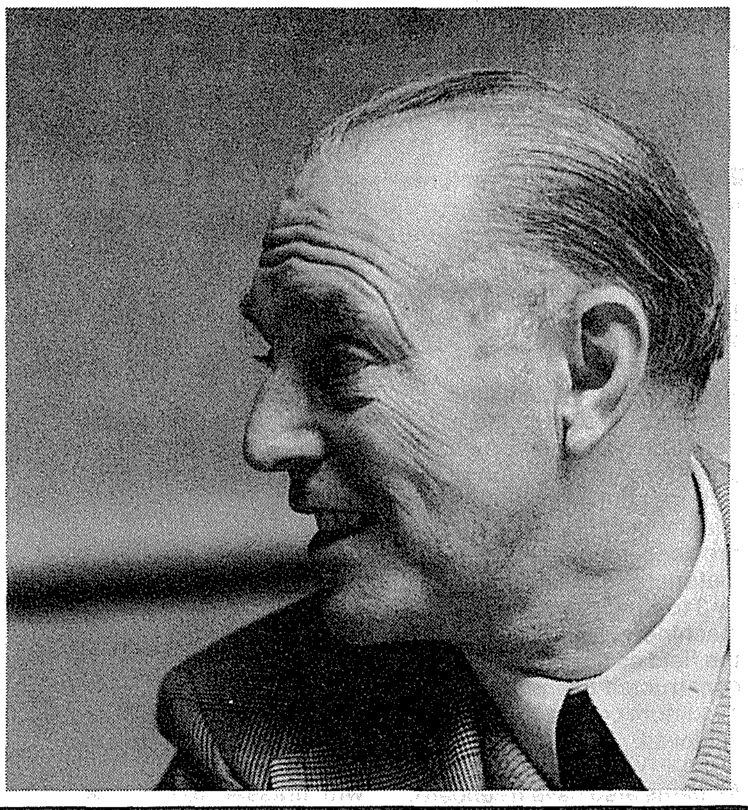
Incidentally, on all these dams, designs have been produced which have been adequate to accommodate the motions produced by the earthquakes. It is a matter of how you build the dam, how you arrange the dam, what materials you use in the dam, and how you place the materials in the dam. These factors will determine whether the dam will adequately withstand the effects of the earthquake.

"...on all these dams, designs have been produced which have been adequate to accommodate the motions produced by the earthquakes. It is a matter of how you build the dam, how you arrange the dam, what materials you use in the dam, and how you place the materials in the dam."

QUESTION: What knotty problems have you encountered on other hydroelectric projects?

SEED: Any problems that you encounter are essentially related to three major ones—the amount of water to be stored and the amount of flooding water that has to be stored at any given time; the stability of the foundation materials; and the possible effects of faults in the foundation. The first is not my area of expertise. It is a hydrological problem and there are other specialists who can handle that part of the problem. I would say the most difficult problems, in the earthquake sense, are primarily those of evaluating the stability of the foundation materials on which dams are to be built.

For example, there was much debate about the safety during earthquakes of Revelstoke Dam in Canada and what they should do about the foundation. I was invited to be a consultant on that project because of the different points



of view about the safety of the dam...

They were dealing with a very difficult foundation soil. As a matter of fact, I told them that the foundation soils in some parts of the dam foundation bore a great resemblance to those at Turnagain Heights in Alaska (the soils that failed in the 1964 earthquake). Some of the foundation material for Revelstoke Dam reminded me alot of Bootlegger Cove clay. I told them that it was an unstable material, especially at the level of shaking they were designing for. I advised them to excavate the material out, and that's what they elected to do. I would say that was a knotty problem.

Other knotty problems involve faults in the foundation. After the San Fernando dam nearly failed in the San Fernando earthquake in California, the people living downstream did not want another dam to be built at that site, but it turns out to be a critical point of entrance for water into California for the city of Los Angeles. Therefore, the Department of Water and Power in Los Angeles considered it essential to have a reservoir in that area, and it was necessary to rebuild the dam at that location. There was a possibility of a fault movement in the foundation, so we had to devise a special design which could accommodate a very high level of shaking and the possibility of a fault movement in the foundation both occurring at the same time. That was successfully done.

"...it is a comforting fact that at the present level of knowledge of the Susitna project, the intensity of shaking which can be anticipated at either dam site is considerably less than those areas for which we have already designed dams."

The Teton dam involved problems with highly erodible soils. The dam failed, but I believe that if the design had been modified, a safe dam could have been built at that site. The knotty problem there was assessing the effect of the jointing of the rock and the simultaneous erodibility of the soils used to build the dam on the safety of the dam. That was a tricky problem. The engineers who made the design thought they had solved it, but as events eventually proved, they had not. The dam failed. I believe we know enough about it now that we could rebuild the dam very safely...
To tell you the truth, I don't know of any dam which doesn't involve one or two knotty problems.

QUESTION: How does the seismicity of the Susitna area compare to the seismicity of other regions where you have worked?

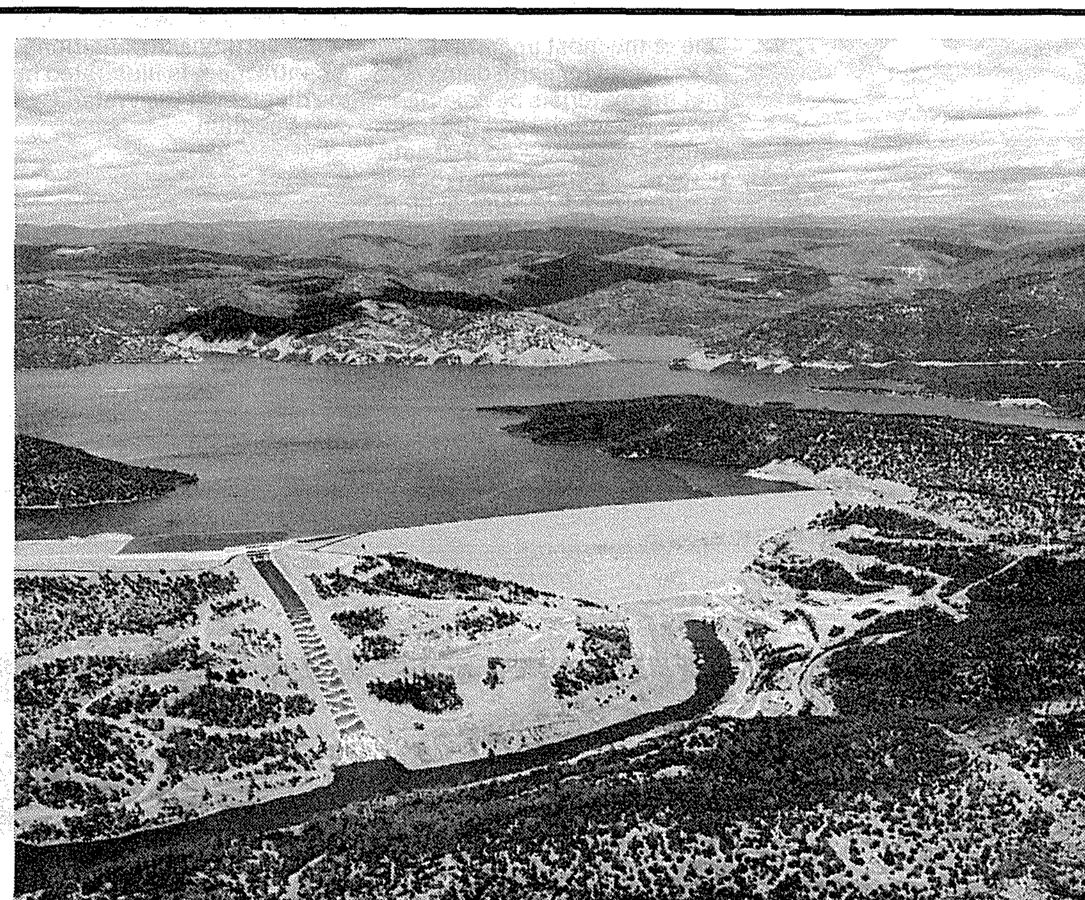
SEED: I would say that the seismicity of the Susitna area as it is presently understood (and if it is established) is somewhat less than that which I have encountered in other parts of the world. There are a number of faults whose activity has not yet been established in the Susitna area. They are believed to be inactive faults, but they are on record for being investigated very carefully during the 1981 summer. The Talkeetna thrust fault is one of these and probably the most important of them. If all the faults that are presently not clearly recognized as active are found to be inactive, then the seismicity of the Susitna area (or the intensity of ground shaking that would develop) would not be as strong as many of the dams that we have already designed.

QUESTION: And what if the opposite were true?

ANSWER: If the opposite were true, if the Talkeetna trust turns out to be an active fault, then the level of shaking at Susitna would be comparable to that of some of the strongest seismic regions where dams have been built.

Since we have been able to build and design dams which can be shown to be seismically stable in those regions, then I believe that the same techniques would be capable of demonstrating the same thing for the dams of the Susitna project.

The design in any case will require great care, but it would require even more care if those faults like the Talkeetna thrust turn out to be active faults...



The design of the Oroville dam in California has been suggested as an appropriate model for preliminary design of the Watana dam. It is an earthfill dam like Watana is proposed to be, is in a seismic area, and is of a similar height (Oroville is 770 feet, Watana is proposed to be 880 feet).

The design earthquake for Oroville was a magnitude 6.5 earthquake occurring directly under the dam site. The Oroville dam design can accommodate strong ground motions very near the dam for a relatively large earthquake.

There has been tremendous progress in the field of earthquake engineering, and the earthquake-resistant design of dams has been totally revolutionized in the last 10 years. It is almost like the developments of space technology. Things we can do now, our understanding of the problems now, are so very much greater than they were 10 years ago that we can feel enormous confidence now in comparison. In those days people felt confident because they didn't really understand the problems. Now we feel confident because we have a very good understanding of the problems.

QUESTION: Can you give some examples of why you can be so confident?

SEED: We can point to virtually dozens of dams which have withstood very strong earthquake shaking, even the strongest imaginable earthquake shaking. In California, in 1906 there were at least 15 dams within 5 miles of the San Andreas fault on which a magnitude 8.3 earthquake occurred, and they were built by the rather primitive pre-1900 construction methods. There wasn't a single one of them that suffered any major damage due to the earthquake. During the last 10 years we have learned what the properties of those dams are that enabled them to do that. We can also point to a few dams that have failed during earthquakes and what we have learned over the last 10 years is what made those dams fail as compared with the other ones that haven't failed.

"...the earthquake-resistant design of dams has been totally revolutionized in the last 10 years."

The record is very positive. There have been literally hundreds of dams which have withstood strong earthquake motions. In the total history of the United States, so far as I know, I think there are only four or five known failures of dams during earthquakes, and some of those were quite small dams...We better understand which ones are likely to be vulnerable and which ones are likely to be safe and how to transform the unsafe ones into safe ones...

In the most recent survey of the safety of dams in California, the conclusion was that there are no dams in California which are a threat to the public...In the last 10 years there have been a number of dams in California which have been recognized as earthquake hazards that have either been taken out of service or rebuilt or modified in some way to eliminate the threat to the public.

California is obviously one of the more seismically active states in the United States, along with Alaska, and if we can do it here, you can do it in Alaska, too.

Earth dams combine natural materials and careful construction

Earth/rockfill dam:

"Any dam constructed of excavated materials placed without addition of binding materials other than those inherent in the natural material. The materials are usually obtained at or near the dam site."

—The International Commission on Large Dams

Earth/rockfill dams contain about 25 percent earth to retain the water and 75 percent rock to hold the earth up and ensure stability.

In seismically active regions it is not unusual to flatten the slopes of the dam more than in non-seismic areas. The actual slope and proportions at a particular site is dependent on the materials available for construction and the size of the design earthquake.

One of the most important requirements for earth dams is that the materials be selected and compacted—and the foundation stabilized—so that settlement of the earth and rock is minimized. For dams in high seismic regions, any river bed materials under the dam which would be unstable during earthquakes is either removed or improved.

The core

The core is a membrane built within an earth dam to form an impermeable barrier. It may be of natural materials (clays, sands, etc.) or prepared materials (cement or asphaltic concrete), or of metal, plastic, or rubber.

In the case of Watana, the core is proposed to be of glacial till (a mixture of gravels, sands, silts, and clays). It would be more than 400 feet thick at the riverbed level, and tapered to about 30 feet in thickness at the crest of the dam.

Unlike concrete, earth cores cannot support their own weight even though they are as effective as concrete at impounding water. Gently sloping man-made mountains of compacted sand, gravel, and rockfill are needed to support the dam's core and keep it in position.

Location of core

In general, a centrally located core provides the best security under earthquake conditions. A central core is illustrated in the diagram of the Watana cross-section.

Design

Each earth/rockfill dam is unique — its watertightness and stablility are directly related to the materials used for its construction and the materials upon which it is founded.

Earth/rockfill dams are usually constructed in zones. The primary purpose of this is to ensure safety in terms of strength, control of seepage, and protection against cracking.

Earthquake-resistant features in earth/rockfill dams:

Some of these provisions are being considered for the Watana dam.

All earth/rockfill dams are compacted to make them dense. In earthquake areas the process of compaction is no different but more compaction is done because denser rock provides more stability. Most materials can be compacted by 3 to 8 passes with heavy machinery. Tests are made in the field as the dam is being constructed to ensure that maximum compaction is achieved.

All dams also have freeboard. This is the height above normal water level and it allows for waves, floods, and ice. In earthquake areas, additional height is added to allow for settlement.

If there is a potential for waves passing over the crest of earth/rockfill dams, the crest can be treated so that the waves pass safely. Such a wave could result from a seismic disturbance or a landslide into the reservoir. Preliminary studies indicate there is no potential for landslides in the Watana reservoir because of the topographic character of the valley.

Earth/rockfill dams are usually zoned for strength and stability. In earthquake areas, wider filter zones are provided to increase stability.

In addition, the materials in the filter zones are selected to provide self-healing of cracks. This conservative approach increases the level of confidence in the design. The dam is designed not to crack and also designed to self-heal if it did crack.

Slope Protection

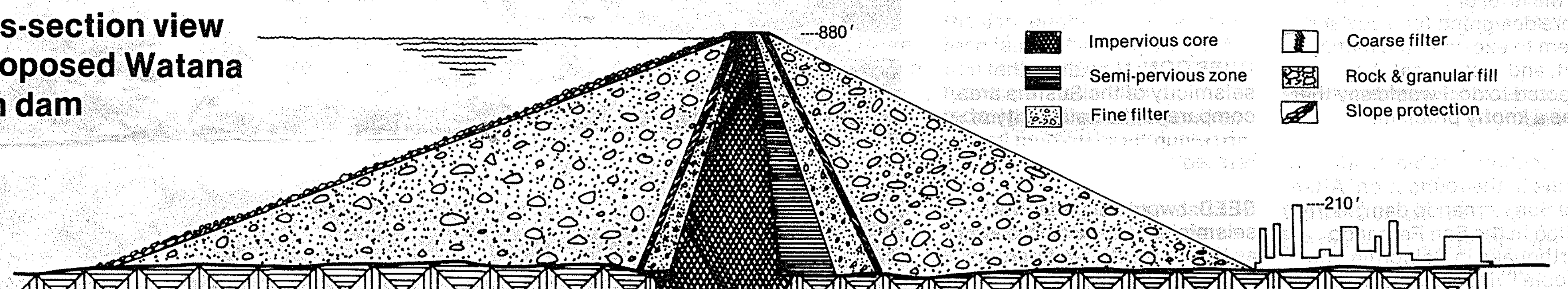
Both faces of an earth dam must be protected against structural damage.

The downstream face needs protection against natural erosion and may be covered with grassed soil or rock.

The upstream face must be protected against damage by wave action, ice, or floating debris. Various methods include rock (riprap), precast concrete forms, soil cement, or the waterproofing membrane of the dam.

Source:
The Engineering of Large Dams Part II, Henry H. Thomas, 1976, John Wiley & Sons Publishers, New York, A Wiley-Interscience Publication.

Cross-section view of proposed Watana earth dam



Source: Development Selection Report, Task 6, Design Development, Second Draft, June 1981, prepared by Acres American, Inc. for the Alaska Power Authority.

Susitna construction not assured by SB 25

The 1981 Alaska Legislature authored a far-reaching bill that relates closely to the evaluation of the Susitna project's feasibility and to the possible development of the project. SB 25 provides for direct State funding of at least a portion of the construction costs of certain power projects and it provides for a single wholesale rate for power from all projects that are part of the State program.

The following discussion answers some questions about SB 25 and the Susitna studies.

What SB 25 Does Do

1. The new law, along with a companion appropriation bill (SB 26), **DOES** indicate a desire on the part of the 1981 Legislature to lower the cost of power to Alaskans. The portion of the Susitna construction cost funded by the State would not have to be recovered through power sales. The rates for the power would, however, have to be set sufficiently high to cover the costs of project operation, maintenance, and inspection and high enough to also cover the debt service associated with any borrowed construction costs not funded by the State.

2. SB 25 **DOES** mean that the Susitna project will be easier to finance if the decision is made to build it. It is recognized that Wall Street is hesitant to buy revenue bonds for the full cost of Alaskan hydroelectric power projects. The primary problem is Wall Street's perception that Alaskan projects are extremely expensive in relation to the size of the population that will use the power.

3. SB 25 **DOES** indicate an intent by the 1981 Legislature to appropriate as much as $5 billion for the construction of power projects over the next five years. Based on very preliminary estimates, this amount would be enough to fund most of the construction costs of all the power projects presently under serious consideration throughout the State, including the Susitna project. Several projects have already been funded under this program, but Susitna is not one of them.

4. SB 25 **DOES** differentiate between power rates to utilities and those to industrial consumers. According to the legislation, the rate for industrial consumers may not be less than the rate charged residential consumers and it may be higher.

What SB 25 Does Not Do

1. The new law **DOES NOT** mean, at least as far as the Alaska Power Authority is concerned, that a decision has already been made to build the Susitna project.

   Several points should be kept in mind. They are:

   - According to SB 25, State money can only be used for a power project that will provide the lowest power cost to utility customers. It has not been determined that the Susitna project is, in fact, the lowest cost alternative for the Railbelt. The Susitna project feasibility study and the companion Battelle alternatives study will provide this relative cost information during the first three months of 1982.

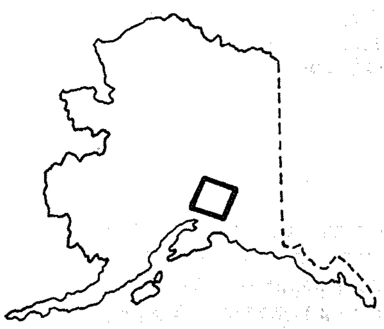
   - **A decision has not yet been made by the Alaska Power** Authority to recommend the preparation and submittal of a license application to the Federal Energy Regulatory Commission (FERC). That decision will be made in late April 1982.

   - Construction of the project cannot begin until the FERC prepares an environmental impact statement and grants a license.

2. SB 25 **DOES NOT** affect the determination of project feasibility, either in the Susitna feasibility study program or in the independent Battelle power alternatives study.

   The basic approach being used in both studies involves a comparison of Railbelt electrical system power production costs with various combinations of power alternatives. The costs associated with any alternative will reflect the actual full cost of construction, operation, and maintenance without any consideration of subsidies. This approach is designed to ensure that, if the State is going to contribute funds to power project construction, those funds will go towards the most economical and preferred alternatives.

Background information on proposed Susitna project



The Susitna hydroelectric project as currently proposed involves two dams and reservoirs on the Susitna River in the Talkeetna Mountains of southcentral Alaska.

The project area is about 50 miles northeast of Talkeetna, Alaska and 118 miles north-northeast of Anchorage, Alaska.

The upstream dam, Watana, is proposed to be developed first. It is currently being considered as an earth/rockfill dam, approximately 880 feet high. This would make it the fifth highest dam in the world and the highest in North America. It would impound a 54-mile-long reservoir.

The downstream dam at Devil Canyon is currently being considered as a concrete arch dam approximately 635 feet high. It would impound a 28-mile long reservoir.

These dimensions are approximate and subject to change during detailed design.

The feasibility study is being managed and conducted by Acres American, Inc. for the Alaska Power Authority. The studies conducted to date represent the first year of a planned two-year study (1980 and 1981). A draft feasibility report detailing research efforts in 10 different areas including economics, engineering, and environmental aspects of the proposed power project is due in March next year.

How proposed Susitna projects compare with existing dams

Name	Year completed	River or Basin	Nearest city	State or Province	Country	Dam type	Height above lowest foundation m	Crest length m	Reservoir capacity $m^3 \times 10^6$	Rated capacity now (MW)	Rated capacity planned (MW)	Year of initial operation
[1]Bonneville	1943	Columbia	Portland	Oregon-Washington	USA	concrete gravity	32	277		588	1,076	1938
[2]Glen Canyon	1964	Colorado	Page	Arizona	USA	concrete arch	216	475	33,305	1,021	1,431	1964
[3]Grand Coulee	1942	Columbia	Coulee City	Washington	USA	concrete gravity	168	1,272	11,795	7,460	10,830	1942
[4]Hoover	1936	Colorado	Boulder City	Nevada-Arizona	USA	concrete arch/gravity	221	379	36,703	1,345	1,345	1936
[5]Mica	1973	Columbia	Revelstoke	British Columbia	Canada	earth/ rockfill	245	792	24,670	1,736	2,610	1976
[6]Oroville	1968	Feather	Oroville	California	USA	earth	235	2,316	4,299	679	679	1967
[7]Devil Canyon	(Proposed) (2000)	Susitna	Talkeetna	Alaska	USA	concrete arch	200	378	1,235	0	400	(Proposed) (2000)
[8]Watana	(Proposed) (1993)	Susitna	Talkeetna	Alaska	USA	earth/ rockfill	271	1,662	12,347	0	800	(Proposed) (1993)

Sources: [1]Corps of Engineers, Portland, Oregon [2]Western Area Power Office, Golden, Colorado. [3]) "Major Dams of the World," T.W. Mermel, International Water Power [4]) and Dam Construction, Special Issue May 1981, Published by IPC [5]) Electrical-Electronic Press Ltd., Quadrant House, The Quadrant, Sutton, Surrey SM25AS, England [6]Civil Design, State of California, Oroville, California [7]Acres American, Inc., Anchorage, Alaska [8]Acres American, Inc., Anchorage, Alaska

1 Meter = 3.25 Feet

Construction timed to match power demand

The proposed Susitna development is presently envisioned as having three distinct stages:

1) the Watana dam with installed capacity of 400 MW;

2) an addition to the Watana capacity of another 400 MW; and

3) the Devil Canyon dam with an installed capacity of about 400 MW.

Both the Watana capacity addition and the Devil Canyon project could be brought on line earlier or at the same time, if needed, while all three stages could be postponed if demand turned out to be less than anticipated.

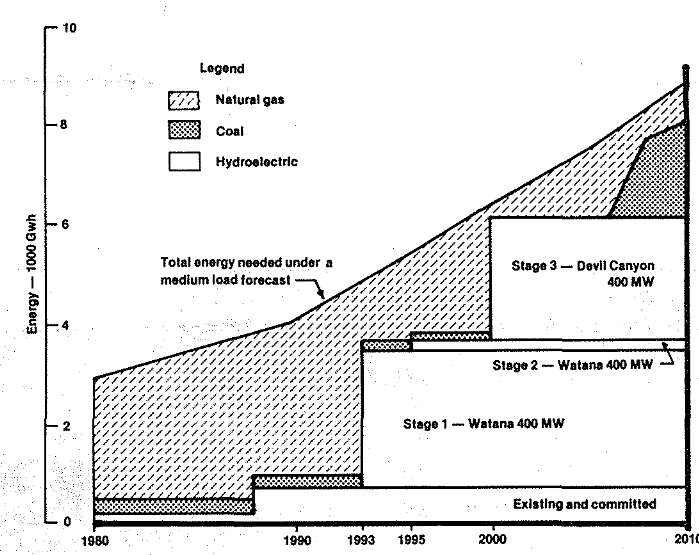
This staging provides some flexibility in the sequence and timing of construction. At the same time, there are certain constraints on that flexibility.

In staging the Susitna development, the primary objective is to keep the cost of power as low as possible. This is done by minimizing expenditures while selling as much of the available power as possible. But the power cannot be sold if there aren't consumers ready to buy it. The energy consumption forecasts provide estimates of how much power can be sold in the years ahead.

The Power Authority's approach, then, is to postpone spending money for the next stage as long as possible to ensure that there is the demand for purchasing the project's power. Money spent on a project whose power cannot be sold is money wasted.

Waiting too long to construct the next stage, however, is unacceptable because there would be an increasing likelihood of not being able to meet the peak demands. If this occurred, customers would have to go without electricity during high use periods. Thus, a balance has to be struck between postponing additional investments and ensuring adequate generation to meet peak loads.

Meanwhile, the balancing has to be done in the midst of a great deal of uncertainty about what the actual demand for power is going to be in the future. As time goes on and future power demands become more certain, the planned staging would be adjusted to suit actual conditions.



Possible staging of Susitna project

This diagram shows how the Susitna development would be staged under the medium forecast of future energy requirements. With this energy demand and ensuring that adequate generating reserves are maintained, power costs would be minimized if:

1) The Watana dam with 400 MW would be completed in 1993, which is the earliest possible date because of time periods involved in project evaluation, permitting, and construction;

2) the additional 400 MW of capacity at Watana is ready for operation in 1995; and

3) the Devil Canyon dam with its 400 MW is completed in the year 2000.

If you want to get future newsletters

This public information document on the Susitna hydropower project was developed by the Alaska Power Authority Public Participation Office, Nancy Blunck, Director. Comments on the substance of this newsletter and ideas for future publications should be forwarded to the Public Participation Office by way of the following coupon.

Last First Initial

Name

Mailing Address

City **State** **Zip**

and mail to: Alaska Power Authority
Public Participation Office
333 W. 4th - Suite 31 - Anchorage, AK 99501

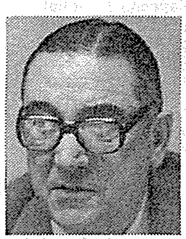
THANK YOU FOR YOUR INTEREST

Independent panel reviewing Susitna feasibility studies

External Review Panel Members:

Copen

Douma



Leopold

Merritt

Seed

Rohan

Six leading scientists and engineers have been named to an independent external review panel by the Alaska Power Authority Board of Directors. The specialists, who collectively have more than 200 years' experience in their fields, are reviewing the Susitna feasibility studies conducted by Acres American and other research contractors.

Interview with members of the review panel will be available in future publications as the specialists comment on general plans for the Susitna development and specific feasibility studies.

Exerpts from an interview with Dr. Seed appear in this newsletter.

Merlin D. Copen is an expert on concrete dams. He has had major responsibility for the design of the Glenn Canyon Dam on the Colorado River, California's Auburn Dam (proposed as one of the longest concrete arch dams in the world), and many others. He has consulted on numerous international projects as well as other Alaskan developments.

Jacob H. Douma served as chief of the Hydraulic Design Branch of the U.S. Army Corps of Engineers prior to his retirement from active government service after more than 40 years. In addition to his government work on American dams, he has extensive consulting experience with Canadian hydroelectric projects.

Dr. A. Starker Leopold is a distinguished zoologist who has been associated with the University of California since 1946. A one-time vice-president of the Sierra Club, he has served on many wildlife and conservation organizations and has conducted extensive research around the world.

Dr. Andrew H. Merritt is a geologist who has been involved in the research, design, and review of major construction projecs around the world. A specialist in tunnels and rock work, he has extensive experience with hydroelectric and nuclear power projects.

Dr. H. Bolton Seed is a former chairman of the Department of Civil Engineering at the Berkeley campus of the University of California. A specialist in earthquake engineering problems, he has consulted on dozens of the world's largest dam projects.

Dr. Dennis M. Rohan is an economist with the Stanford Research Institute who specializes in energy matters. He has been involved in economic analyses of all phases of energy production and consumption.

Dam at Devil Canyon recommended over tunnel

Following 2,500 manhours of study (in excess of one man year of effort) a twin power tunnel plan has been eliminated as an alternative to a dam at Devil Canyon.

The tunnels, 15 miles long and 30 feet in diameter, were eliminated from further consideration when it became clear that they would generate 26% less electricity and would cost $637 million more than a dam at Devil Canyon.

The difference in energy output, primarily due to friction losses along the length of the tunnel, is equivalent to about 30% of the total energy generated in 1980 by both Anchorage utilities (Municipal Light and Power and Chugach Electric Association).

In the long term, an additional generating plant would have to be added to fill this gap and this could create an additional source of environmental impact which has not been included in the comparison at this time.

Excluding consideration of this additional generation to make up the shortfall, the tunnels' main advantages were environmental. The adverse effects upon the aesthetic value and uniqueness of Devil Canyon would be lessened with a tunnel, although the flows through the canyon would be severely depleted because the water would be flowing through the tunnel instead.

The kayaking experience at Devil Canyon could be preserved, but not in the same way that it exists now. With a tunnel, kayaking would be dependent upon the controlled release of water through the canyon.

In addition, by virtue of size alone, construction of the smaller re-regulation dam (245 feet) would have less environmental impact than the Devil Canyon dam. The river miles flooded and the reservoir area created by the re-regulation dam for the tunnel would be about half those of the Devil Canyon dam, thereby reducing negative consequences such as loss of wildlife habitat and possible archeological sites in the reservoir area.

With the tunnel, there could conceivably be a rare mitigation opportunity of creating new salmon spawning habitat in an 11-mile section of the river above Devil Canyon. Presently, Devil Canyon presents a physical barrier to fish migration.

Source:
"Susitna Hydroelectric Project, Tunnel Alternatives Report, Task 6, Design Development," prepared by Acres American, Inc. for the Alaska Power Authority, July 1980.