PRELIMINARY ASSESSMENT OF COOK INLET TIDAL POWER PHASE I REPORT

VOLUME I

STATE OF ALASKA
OFFICE OF THE GOVERNOR

PRELIMINARY ASSESSMENT OF COOK INLET TIDAL POWER

PHASE I REPORT

VOLUME I

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ACRES

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES*

Number	Title
1	Task 1 Report (Submitted to the State of Alaska April 1981)
2	Visual Reconnaissance of Selected Sites (Submitted to the State of Alaska April 1981)
3	Parameter Selection
4	Turbine Design
5	Electrical Equipment
6	Tidal Power Plant Energy Studies
7	Closure of the Tidal Basin
8	Tidal Power Facility Design and Construction Methods
9	Cost Estimates and Schedules
10	Preliminary Environmental Assessment
11	Socioeconomic Assessment
12	Regulatory Evaluation
13	System Study and Economic Evaluation
14	Marketing and Financing
15	Preliminary Risk Assessment

*Included in Volume II.

FOREWORD

This report was prepared by Acres American Incorporated in partial fulfillment of a contract with the Office of the Governor, State of Alaska, to conduct a study entitled "Preliminary Assessment of Cook Inlet Tidal Power."

The work described herein constitutes the first phase of a planned three phase study to determine the potentials and constraints of utilizing the tides of Cook Inlet to produce useable energy. The three phases include:

(1) Phase I: Preliminary assessment of Cook Inlet tidal power potentials and characteristics.

(2) Phase II: In-depth study of the potential industries or groups of industries that appear to have a comparative advantage in association with a Cook Inlet tidal power source.

(3) Phase III: Detailed engineering and environmental investigation of site-specific configurations, as well as the preparation of a conceptual development plan.

Conclusions and recommendations contained herein are based solely upon Phase I study efforts. Results of later phases could lead to modifications in the initial findings.

For the convenience of the reader, a fold-out map is provided as the last page in this report. Knik and Turnagain Arms at the upper end of Cook Inlet are shown thereon.

SECTION 1 - INTRODUCTION

1.1 - Background

Of all the states, Alaska is most richly endowed with the potential for vast energy resource development. It is literally a state of superlatives. Oil, coal and natural gas developments in Alaska already contribute to the satisfaction of national energy goals and the chances that undiscovered fossil fuel resources exist there are strong. Undeveloped hydroelectric resources are the greatest in the nation. Geothermal, solar, and wind energy potential are known to exist. Befitting its vast size, Alaska can also boast of tidal ranges which rank among the highest in the world. There is no question that Alaska can supply its own energy needs for centuries, even as it makes significant contributions to national needs.

It is not enough, though, to know that development can occur. The more difficult issue by far is that of whether or not it should occur. No development is without consequences.

To ensure that responsible and informed choices are made, Alaska has embarked upon a program which will evaluate the relative advantages and disadvantages of possible approaches to its energy future. A major feasibility study of the Susitna Hydroelectric Project* began in January 1980. More than six billion kilowatt hours of electric energy can be produced annually from that project alone if it is constructed. Concurrent with the Susitna study is a study of Railbelt** Electric Power Alternatives which will address all viable means for providing electric energy to the most populous region of the State. One important alternative with relatively large energy potential is the prospect of harnessing the tides in Cook Inlet. Because of the unique nature of this renewable resource, the State commissioned a preliminary assessment of its potentials and characteristics. This report provides such an assessment.

1.2 - The Nature of Tidal Power

The ebb and flow of the tides occur roughly twice daily in a predictable way (see Figure 1-1). Energy is available from this natural process both

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* This project would consist of two dams on the upper Susitna River which runs in a westerly direction through a canyon between Anchorage and Fairbanks. The upper dam at Watana would be rockfilled and a thin arch concrete dam would be installed at Devil Canyon, the lower site.

** The Railbelt is the area served by the Alaska Railroad. It includes Anchorage and Fairbanks and is by far the most heavily populated region in Alaska.

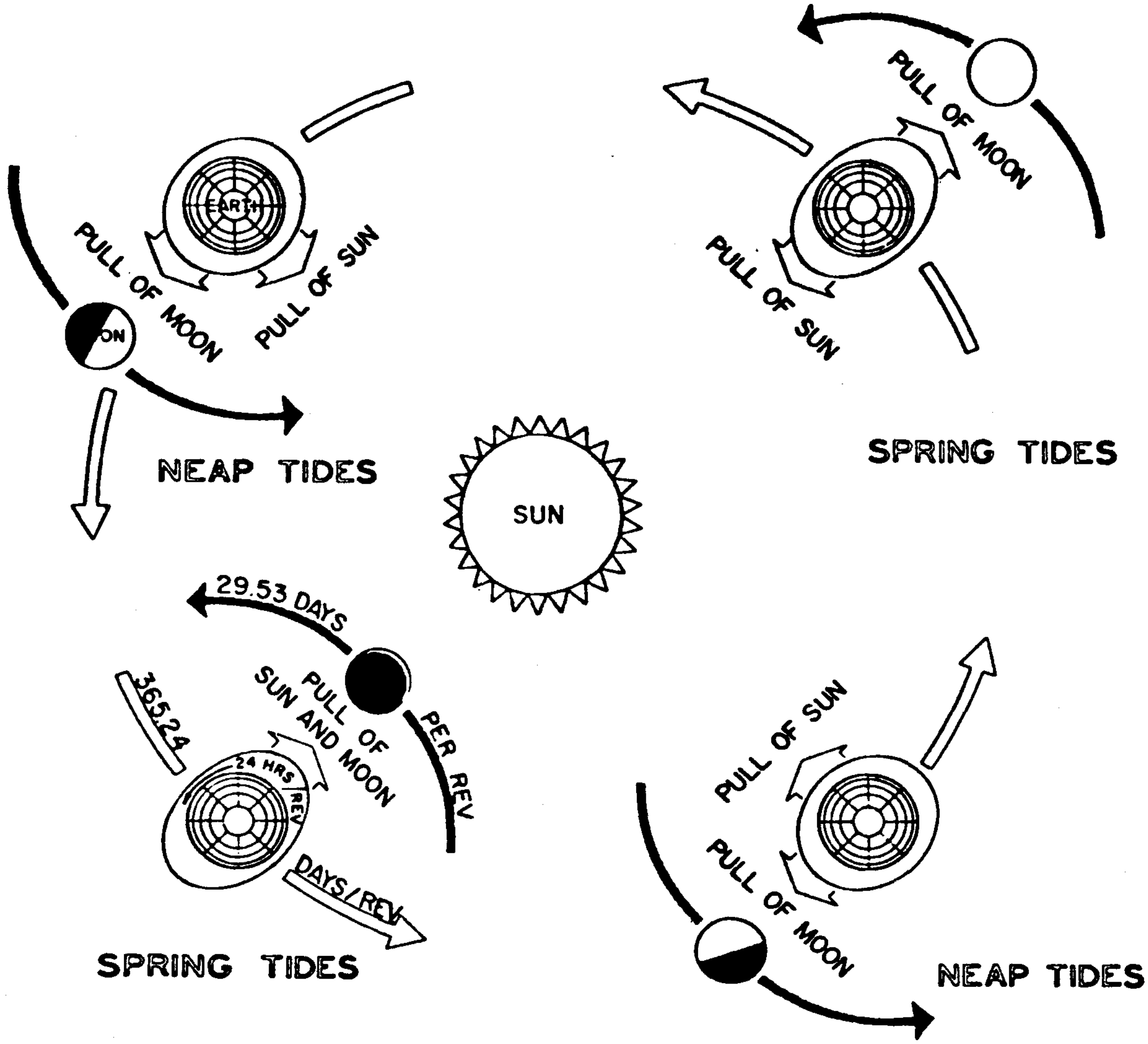

FIGURE I-I
THE ORIGIN OF
OCEAN TIDES

because tidal currents represent kinetic energy and because potential energy is associated with maintaining differences between sea level and the level of water in a basin which might be formed by the construction of one or more artificial barriers (or "barrages").

Tapping the kinetic energy of tidal currents may have useful application for communities whose energy needs are small and whose energy generating options are limited. Unfortunately, the kinetic energy density of tidal currents is relatively small and costs of extracting it are correspondingly large.

In those few places in the world where large tidal ranges exist, the technology to take advantage of the potential energy of the tides is already well proven. This latter approach involves technologies which are akin to those applied in the development of conventional hydroelectric power. This report focuses upon the use of tidal potential energy to generate electricity.

One tidal power station of commercial scale has already been successfully operated for 15 years: The 240 MW facility at La Rance in France. A small experimental plant has also been installed by Russia off the Arctic coastline at Kislaya Guba. In addition, construction work is now underway at Annapolis Royal on the Bay of Fundy where a demonstration project to test a single large straight flow turbine is to be installed by 1983 utilizing an existing causeway. A number of very small tidal power facilities has also been constructed on the coasts of China. Studies at other coastal locations around the world have been completed or are in progress.

The usual approach to tidal power development involves the creation of a barrage which permits maintaining one or more basins at elevations lower than high tide or higher than low tide. As soon as sufficient difference in elevation between sea level and basin level has been obtained, water at the higher level is allowed to flow through hydraulic turbines to the lower level, thereby generating power. The sketch at Figure 1-2 illustrates the process.

The energy produced by a tidal power plant occurs at predictable times and is in phase with the lunar cycle. In the simplest single-basin tidal power development, energy is produced in pulses several hours in duration, between which are periods when no energy is produced. Further, because significantly different tidal ranges exist at neap and spring tides, the amount of energy produced varies as the moon and sun cyclically and predictably change positions relative to the earth. This characteristic of tidal energy must be accommodated either by the system into which the energy is fed or by some method for storing or retiming tidal energy.

1.3 - Purpose

It is the purpose of this preliminary assessment to determine the potentials and characteristics of Cook Inlet tidal power. To accomplish

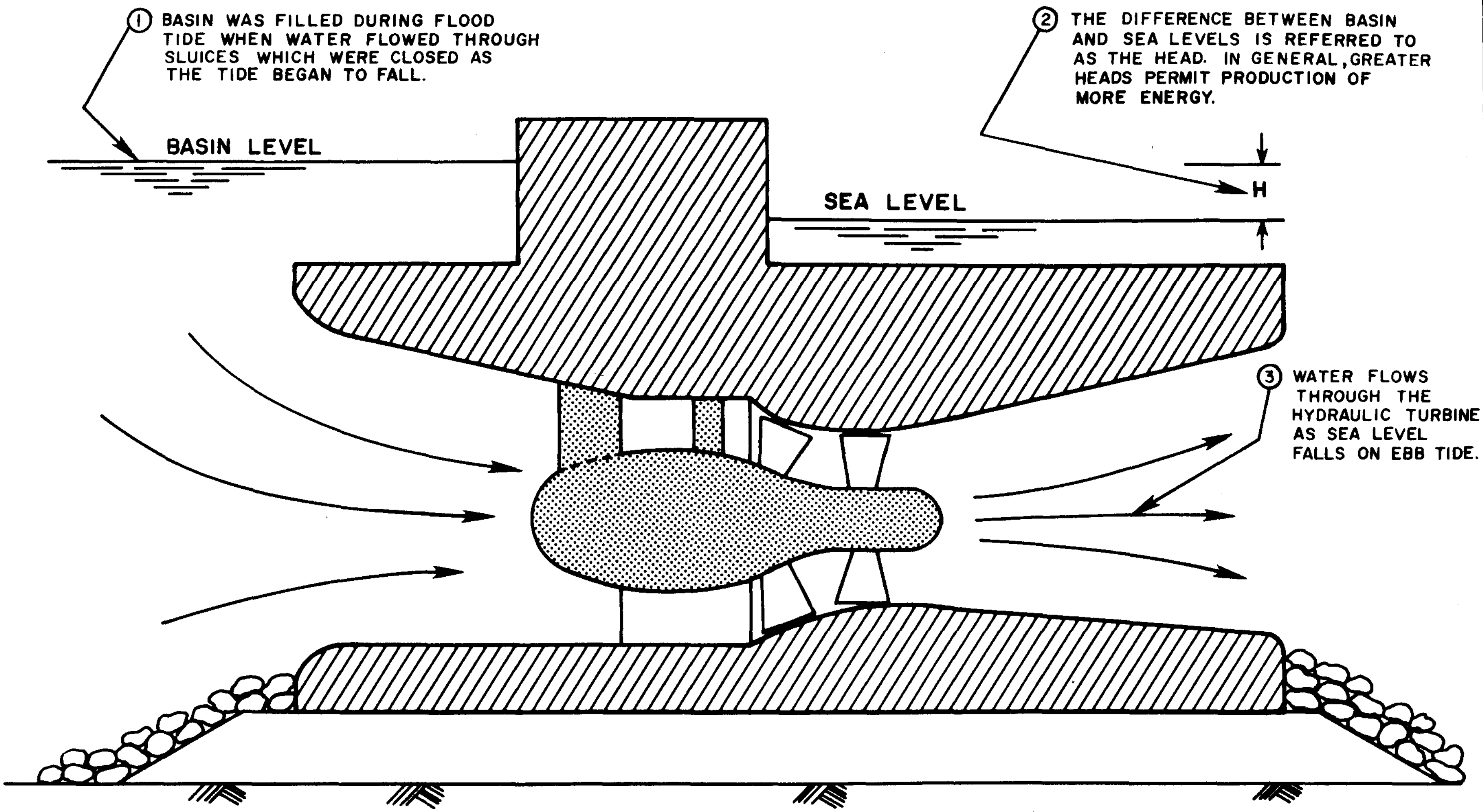

FIGURE I-2
BASIC CONCEPT
(DETAILS ELIMINATED FOR CLARITY)

this overall objective, a program involving four tasks, each of which is further divided into subtasks, has been followed. Succeeding sections summarize the report, discuss the methodology which was followed and describe the results obtained.

1.4 - Acknowledgements

Significant contributions were made by others to this Phase I study. Particular participants include:

(1) Canadian Atlantic Power Group, Limited (CAPG)

Throughout the study period, CAPG representatives worked closely with the Acres team. Having recently conducted major studies of tidal power potential in the Bay of Fundy in Canada, CAPG brought a wealth of knowledge to the project. The assistance of CAPG has been important not only in terms of building upon Bay of Fundy data, but also in analyzing the unique aspects of Cook Inlet itself. CAPG representatives from the Canadian firms of SNC, FENCO and Acres Consulting Services participated.

(2) The Anchorage Office of Hanscomb Associates (Hanscomb)

While the fact that tidal power facilities now operate elsewhere clearly demonstrates technical feasibility of the concept, determination of the economic viability of tidal power development in Alaska requires cognizance of Alaska-specific costs. Hanscomb has assisted Acres by providing important inputs for cost estimates and schedules reported in later sections of this preliminary assessment.

(3) Mr. Robert H. Clark, P. Eng.

Mr. Clark had served as Chairman, Management Committee, Bay of Fundy Tidal Power Review Board, during recent detailed studies in the Bay of Fundy. His wise counsel as a consultant has been important, particularly in terms of providing critical reviews and perceptive suggestions as the work progressed.

1.5 - Previous Studies

A number of earlier studies have addressed the potential of harnessing Cook Inlet tides:

(i) In 1967, a paper published by Wilson and Swales (Reference A.4 in Appendix 1) assessed conceptual developments and the costs and benefits of tidal power. It was noted that energy demand forecasts did not then warrant full-scale developments at either Turnagain or Knik Arms.

(ii) R. Johnson's paper (Reference A.3 in Appendix 1) recommended a two-basin Cook Inlet tidal power project with barrages across the openings of Turnagain and Knik Arms. A structure connecting Fire Island and Point Campbell would accommodate necessary turbines and generators.

(iii) A paper published in 1976 by Behlke and Carlson (Reference A.1 in Appendix 1) reviewed the hydraulic theory associated with tidal power development and suggested an innovative scheme involving the construction of small plants spaced along Cook Inlet to take advantage of the time lag between high tide at one plant and the next. Sequential generation was regarded as a means to permit relatively continuous energy production without requiring separate energy storage facilities. Behlke and Carlson also published a paper in 1972 dealing with computer modeling of Cook Inlet tidal phenomena (Reference A.4 in Appendix 1).

(iv) Stone and Webster Engineering Company completed a study in 1977 (Reference D.5 in Appendix 1) of tidal power development in the United States. A major portion of this work was devoted to Cook Inlet. The study concluded that on a life-cycle basis tidal power would be economically competitive if alternative fuel costs continued to escalate.

1.6 - Terms of Reference

The Division of Policy Development and Planning, Office of the Governor, State of Alaska, awarded a contract to Acres American Incorporated in January 1981, to conduct this Phase I Preliminary Assessment of Cook Inlet Tidal Power. The scope of work included in the contract is summarized in Section 3, Methodology, in this report.

In addition to this final report, other significant contractual requirements included:

(i) A report upon the completion of the initial site selection effort (reproduced as Appendix I to this report).

(ii) A report on the visual reconnaissance of certain sites (reproduced as Appendix II to this report).

(iii) An in-process review which was conducted in Juneau, Alaska, on May 22, 1981.

The State of Alaska appointed Arthur Young and Company as Program Manager for this Preliminary Assessment as well as for the Railbelt Alternatives Study referenced in paragraph 1.1 above. Mr. C. Sitkin fulfilled the Program Manager role for Arthur Young and Company. Mr. Sitkin's advice, assistance, interest and patience during the course of the work are gratefully acknowledged.

1.7 - Report Structure

Should tidal power be developed in Cook Inlet, its effects will be widely felt. It could contribute to relative stability in future electrical energy costs, might offer an opportunity for shorter land access to the Kenai Peninsula or to lands bordering Knik Arm across from Anchorage, and it would most certainly cause environmental impacts which deserve careful and thoughtful consideration. It follows that even a preliminary assessment of the exploitation of this renewable resource should be available to and understood by all those who might eventually benefit from it--or by those who might consider its consequences unacceptable. Thus, Volume I of this report has been structured to be responsive to the needs of the layman as well as to provide the technical details necessary to substantiate its findings. To the extent possible, Volume I presents the study process and findings with a minimum of complex mathematical descriptions and technical terminology. A series of appendices supports this report which is included in Volume II. It is in this latter set of documents that more rigorous analytical support may be found for the results obtained. A fold-out map at the end of this report is provided for the convenience of the reader.

SECTION 2 - SUMMARY OF FINDINGS

2.1 - Technical Evaluation

Of sixteen tidal power sites (ranging in energy production capability from 117 GWh to 63,700 GWh) which would be capable of producing energy in Cook Inlet, those at Rainbow on Turnagain Arm (2664 GWh), Point MacKenzie on Knik Arm (3937 GWh), and above Eagle Bay on Knik Arm (4037 GWh), would provide the best prospects for development. Energy production at any of these sites is large compared to the estimated electrical energy consumption in the Railbelt Region for 1980 of 2790 GWh. The construction of a tidal power plant at any of these three sites is technically possible. The use of "floated-in" caisson modules for the powerhouse and sluiceway sections, for which foundation conditions at these sites have been assumed to be suitable, would lead to lower capital costs than conventional *in situ* construction behind temporary cofferdams.

A variety of development schemes for each site is available. The more complex schemes offer the possibility of ascribing firm capacity and continuous output to a tidal power plant. However, adding complexity leads to increased costs. For purposes of a preliminary assessment, the simplest operation mode was selected as the basis for determining whether tidal energy has any viability from an economic standpoint. Therefore, all three selected sites were evaluated as single basin, single effect, ebb tide generation facilities.

In addition, development can be varied in terms of scale. A vastly different level of capacity can be developed at each site with a minor cost penalty as the size varies from the optimal development. This makes size selection at the site very dependent on the market for project power. A third developmental variable is the retiming of tidal project energy. This need is also dependent on project power markets. It follows that the planned study of potential users in Phase II could lead to later modifications of the initial Phase I findings contained herein.

Suitable turbine-generating equipment and electrical equipment are commercially available. Horizontal axial flow turbines, either bulb or Straflo, are appropriate choices for consideration. Both are competitive and the final selection should be made on the basis of an economic analysis at the time that final design commences.

The unique characteristics of Cook Inlet tides can be simulated by computer analysis. By taking into account the physical characteristics of a given site and the operating characteristics of particular turbine-generating equipment, it is possible to produce reasonably accurate estimates of energy produced in selected time intervals over long periods of operation. Simulation programs developed for use in this study can be used to optimize energy values at any given site.

A tidal power plant can accommodate a vehicular crossing at a relatively small cost increase and it is possible to arrange for uninterrupted traffic flow without interference with tidal power plant operation.

CONCLUSION 1: It is technically possible to construct and operate a tidal power plant at not less than three locations in Cook Inlet. Such a plant could also provide a means for vehicular access to the far shore of Knik Arm or of Turnagain Arm.

2.2 - Project Costs and Schedules

Estimates of the cost of tidal power development depend in part upon the adequacy of data regarding actual site conditions. A major field investigation program is required before firm cost estimates can be made. Within the limits of 25 percent in either direction, the most likely capital costs of tidal power development in January 1982 dollars for the three selected sites to provide mimimum "at-site" production costs of energy are:

Size	Net Plant Capacity MW	Average Annual Output GWh	Cost in $ Million* (Jan '82) Exclusive of Energy Storage Costs			Dollars per kW Excluding Vehicle Crossing**
			Tidal Plant	Vehicle Crossing Increment	Total	
Eagle Bay	1440	4037	3825	29	3854	$2656
Pt. MacKenzie	1260	3937	4131	42	4173	$3279
Rainbow	928	2664	2819	22	2841	$3038

The possibility of a lower scale of development was tested at the Eagle Bay site because of its comparatively lower cost for full scale development. The results of this test are summarized in paragraph 2.6.

Schedules for completion of a project at each of the selected sites must allow for detailed engineering and environmental investigations, satisfaction of regulatory requirements, and the time necessary for detailed final design and construction. For the selected sites, schedules are as follows:

* Includes direct costs of all components, navigation facilities where appropriate, indirect costs of 12.5 percent, and contingency of 25 percent.

** Installed capacity costs only. No retiming costs are included.

Site	Complete Feasibility Study By:	FERC License Awarded By:	Project Completion By:
Eagle Bay	1987	1989	2000
Point MacKenzie	1987	1989	2001
Rainbow	1987	1989	1997

CONCLUSION 2: **Tidal power development will require significant capital investments and long lead times before it can be implemented in Cook Inlet. Some other means of electrical generation will have to be developed to satisfy energy demand growth in the Railbelt until about the turn of the century.**

2.3 - Environmental Assessment

Tidal power development will lead to permanent changes behind tidal barrages because some diminution in land areas which are now alternately submerged and drained will occur. Shoreline habitat will be altered. Natural processes of erosion, sedimentation, ice formation and movement, salinity distributions, currents and the like will change in complex ways. Although areas selected for tidal power development are generally less productive than those in the lower Cook Inlet, accommodations will have to be made to ensure safe passage of migratory fish, to protect marine mammals, and to mitigate habitat losses. Detailed environmental investigations should be undertaken in parallel with technical feasibility studies.

CONCLUSION 3: **The complex physical processes in Cook Inlet should be thoroughly investigated, carefully modeled, and scientifically evaluated before tidal plant construction commences. A physical hydraulic model of the Inlet may be necessary for this purpose. Major baseline environmental data collection studies and rigorous analysis of their implications will be required before a decision can be made as to the environmental acceptability of identified projects.**

2.4 - Socioeconomic Assessment

Long periods for construction of tidal power plants and opportunities for fabrication of caissons at or near the project site suggest that an increase in labor force with relative stability for a period of years is possible.

Addition of a vehicular crossing to a tidal power plant would facilitate access to the Beluga area or to the Kenai Peninsula, depending upon which site is selected for development. Some relief would be possible from the pressures now felt in the Greater Anchorage area for lands suitable for development. Improved access across either Arm would inevitably lead to increased recreational usage in areas where some limitations are now posed by distance and traffic problems (the Kenai Peninsula) or relative remoteness (Beluga area).

Based upon experience at La Rance tidal plant in France, a Cook Inlet tidal power plant could become a major tourist attraction.

There is a potential for industrial growth as a result of the availability of tidal energy at relatively stable, long-term rates. Investigation of the applicability of tidal power development to industry is scheduled as a Phase II study.

CONCLUSION 4: An average on-site employment level of 1900 to 2500 persons for periods of 7.5 to 11.5 years in the 1990's can be expected if tidal power is developed at one of the selected sites in Cook Inlet. An additional off-site labor force requirement of 300 to 400 persons would be required during construction.

2.5 - Regulatory Evaluation

While a variety of federal, state and local regulatory requirements must be satisfied, the most significant is the Federal Energy Regulatory Commission (FERC) licensing requirement. Experience to date on major hydroelectric projects has demonstrated that detailed engineering and environmental investigations are necessary to support a license application. Depending upon how much relevant data may otherwise have been collected for a particular project, periods of from three to five years may be necessary before the application is submitted. Another period of some years (depending upon the quality of the application and the extent to which the proposed project is controversial) is involved in processing before a license is awarded.

CONCLUSION 5: In spite of the long lead times imposed by regulatory requirements, there do not appear to be any regulatory constraints which would preclude tidal power development in Cook Inlet.

2.6 - Economic Evaluation

Tidal energy from a single-basin, single-effect plant is in phase with the moon. Maximum energy output frequently coincides with minimum system demand. Energy which cannot be absorbed by the electrical system is "excess" unless it can be stored or otherwise used. Energy storage facilities are within the state of the art, but a cost penalty must be associated with providing storage to support a tidal power plant. Certain industries can, however, accept "excess" energy on a cyclic basis without intermediate storage.

There are several alternative methods of retiming available for use with a tidal plant, including such methods as compressed air storage, hydroelectric pumped storage, and hydrogen production. Although each method has apparent advantages and disadvantages, detailed study is needed prior to selection of the best method. Costs developed for retiming in this study were selected as "generic" retiming costs, not for one specific method. Phase III studies will address site-specific retiming after industrial needs are defined in Phase II.

A preliminary economic analysis was undertaken to determine how the costs of tidal energy might compare with those associated with a new coal fired plant. Economic parameters were used (0 percent inflation, 3 percent interest rate) and a differential escalation of coal prices at 1.5 percent per annum perpetually was allowed. The mid-range forecast was used because it was considered most likely. The initial system evaluation of the three tidal projects indicated that a smaller development at the sites may be more favorable economically. Although the unit production costs of energy would be higher than for the optimal site development, a savings to the system would occur with the ability to directly use (without retiming) a higher percentage of the energy from the scaled-down project. For this reason, a one half-size Eagle Bay development of 720 MW was tested economically in the system context. This smaller alternative was not developed to the same level of detail (optimization, closure velocities, layout drawings) as the three primary alternative sites, since it was considered to check a preliminary conclusion of the system and economic study at a later stage.

		Energy Cost in Mills/kWh			
	(1)	(2)	(3)	(4)	(5)
SITE	Installed Capacity MW	Production Costs of Raw (Unretimed) Energy	Energy Cost if "Excess" Energy Cannot Be Used	Energy Cost if "Excess" Energy is Retimed	Energy Cost if all "Excess" Energy is Retimed and Causeway Value is Subtracted From Total Capital Cost
Eagle Bay	1440	48	121	79	74
Eagle Bay	720	58	87	76	68
Point MacKenzie	1260	54	133	83	77
Rainbow	928	53	105	77	74
New Coal Plant (Levelized-1995 First Year)	200 MW Increments				
•At 1.5% esc.		44	44	44	44
•At 3% esc.		53	53	53	53

It is important to note that tidal energy costs will remain relatively stable after initial startup whereas the price of coal will probably continue to increase after 1995. It may be anticipated, then, that on a life cycle basis, tidal energy costs will become increasingly more attractive over the nominal 50-year life of the tidal plant.

After Phase II studies are accomplished, the extent to which unretimed (not requiring storage) energy can be marketed to industry will be determined. If some industry is attracted by the availability of unretimed tidal energy at a relatively stable cost, the at-site energy values for a tidal plant without vehicular crossing facilities will probably lie between those listed in columns (2) and (4) in the above tabulation. It is important to note that tidal plant capacity cannot be regarded as dependable capacity in the conventional sense because it is intermittent. On the other hand, it is entirely predictable and its energy output may be more valuable than conventional secondary energy whose availability cannot be guaranteed.

CONCLUSION 6: The production costs of unretimed tidal energy are likely to be reasonably competitive with those associated with a coal fired plant, provided a market can be found for predictable but intermittent energy (see Column (2) in the tabulation above). If the tidal plant provides a vehicular crossing which is separately accounted for as a transportation benefit, a tidal plant/energy storage facility with some firm capacity may also be economically competitive on a life cycle basis with a conventional coal-fired generating plant, depending upon the extent to which coal costs escalate in future over general price inflation (see Column (5) in the tabulation above).

2.7 - Constraints and Uncertainties

The potential market for Cook Inlet tidal power differs substantially from that into which tidal energy from the existing La Rance tidal plant now feeds. Cook Inlet marketing prospects also differ from those for tidal power developments which have been studied at Passamaquoddy (a potential joint U.S. - Canadian project) and in the Bay of Fundy in Canada.

Electrical systems associated with La Rance, Passamaquoddy and the Bay of Fundy are large in comparison to the output of existing or potential tidal power plants. Energy demand in the Railbelt in 2000 in the mid-range case will be only about 50 percent greater than the amount of unretimed energy which would be produced by the larger developments generating on the order of 4000 GWh at either Eagle Bay or Point MacKenzie. For a lower level of development at Eagle Bay (2300 GWh) or optimal development at Rainbow (2664 GWh), total Railbelt energy demand in 2000 in the mid-range forecast would be little more than double the tidal power plant energy production capability.

CONCLUSION 7: In the absence of unusual industrial expansion, smaller scale and possibly staged developments at Rainbow (2664 GWh) and at Eagle Bay (2300 GWH) would be consistent with demand growth in the Railbelt during the first 10 years of operation. Because of the capital intensive nature of a tidal power development, difficult financing problems will have to be dealt with, particularly during the early years of operation--an issue shared by such large projects as hydroelectric developments, nuclear plants, and major pipelines.

Only limited site-specific data are available for the selected sites. Professional judgements made on the basis of extrapolating this limited data must be verified before a final determination of feasibility can be made. Depending upon the results of a field investigation program, estimated capital costs could increase or decrease by as much as 25 percent in real terms. In addition, at least 13 risk categories with potential major impact on the feasibility of project development have been identified. Detailed studies based upon a rigorous field investigation program would permit elimination of or significant reductions in uncertainties which must now be associated with data limitations.

Risks which could have major impacts on project viability and which generally demand further study and investigation at the feasibility study stage include:

(1) Foundation condition uncertainties,
(2) Seismic considerations,
(3) Ice formation and movement behind tidal barriers,
(4) Ability to construct "in the wet" if subsurface conditions are found to be unfavorable,
(5) Availability of construction materials,
(6) Length of periods during which weather conditions will preclude construction,
(7) The potential for and effects of tsunamis,
(8) Precise high water levels as determined by on-site gages,
(9) Tidal current variations,
(10) Environmental resource inventories and evaluations,
(11) Compatability with the existing generation system, and
(12) Economic and financial uncertainties.

CONCLUSION 8: The study results are sensitive to assumptions regarding conditions for which precise on-site measurements have not been made. A detailed feasibility study including a major field investigation program is necessary to remove or reduce uncertainties stemming from limitations in the current data base.

2.8 - Preferred Site

The site across Knik Arm north of Eagle Bay and Goose Bay would be the preferred candidate project for consideration in Phase II and III studies for the following reasons:

(i) The production costs of unretimed energy for optimal development of this site compare favorably with those associated with alternative coal-fired generation and are lowest of the three sites considered.

(ii) This site lends itself well to staged development, permitting an initial installation which would be consistent with projected energy demand growth in the Railbelt or allowing for higher development levels which could support the energy needs associated with industrial growth.

(iii) Seismic problems are less likely to be encountered at this site than at Rainbow which is nearest to an area of earth movement stemming from the 1964 earthquake or at Point MacKenzie where possible liquefaction of unfavorable materials under earthquake conditions may cause concern in design of safe facilities.

(iv) No interference with operations at the Port of Anchorage or with ocean shipping will occur.

(v) Important wildfowl habitat at Eagle Bay and Goose Bay which would be altered by construction at the Point MacKenzie site is less likely to be seriously impacted by construction above Eagle Bay. Even so, some change in the Palmer Hayflats habitat resulting from construction at the Eagle Bay site would be avoided at the Rainbow site.

(vi) There is less likelihood at this site than at either Point MacKenzie or Rainbow that interference with the natural movements of Beluga whales and other marine mammals would occur.

(viii) This site is better situated to support through hydrogen production the methanization of Beluga coals than the Rainbow site.

(ix) Closure velocity problems which may limit construction progress at Point MacKenzie are not likely to be experienced at this site.

(x) If any site causes a change in normal tidal level variations (the barrier effect), the smallest effect would be attributable to this site.

(xi) In the event that Phase II studies lead to the conclusion that industrial development is not likely to be encouraged by tidal power development, the at-site sales price of energy produced by less than full development at this site and retimed as necessary comes closest to being economically competitive with the costs of energy produced by an alternative coal-fired generating plant.

CONCLUSION 9: The results of this preliminary assessment warrant proceeding with Phase II and Phase III studies specifically oriented toward industrial potential and conceptual plans for development of the site above Eagle Bay on Knik Arm.

2.9 - Succeeding Phases

The recommended site at Eagle Bay can be developed in a manner which is consistent with the projected energy demand in the Railbelt. Because multiple turbine-generating units are involved, it would be possible to begin operation in the year 2000 at less than full capacity, adding capacity as demand increases over the next 7 or 8 years. The 10-year demand growth between 2000 (the time at which Eagle Bay could be completed) and 2010 is projected at 2500 GWh annually in the mid-range case. Installation of 30 turbines and the use of energy storage would permit the tidal plant/storage system to contribute 2050 GWh of firm energy annually after accounting for retiming losses. If a vehicle crossing is included in the scheme, the tidal energy cost in this case would be economically favored over the nominal energy cost for the coal alternative by 2020 if coal prices escalate perpetually at 3 percent over the normal inflation rate and by 2040 at a more modest escalation rate of 1.5 percent.

CONCLUSION 10: **Tidal power development at Eagle Bay need not depend upon the encouragement of industrial growth in the Railbelt Region. A viable scheme for meeting most likely demand growth (the constrained case) is available, if energy can be retimed economically.**

As originally conceived, "Phase II is intended to look in depth at the potential industries or groups of industries that appear to have a comparative advantage in association with a Cook Inlet tidal power source." (Excerpt from letter, Office of the Governor, dated September 23, 1980, seeking consulting services for the Preliminary Assessment of Cook Inlet Tidal Power).

A higher level of development at Eagle Bay is possible (the unconstrained case). Installation of 60 turbines would permit an annual production level of 4037 GWh. Up to 1600 GWh of unretimed energy annually could be directly absorbed by the Railbelt system in this case, so that from 2437 GWh to 4037 GWh annually of unretimed tidal energy could be made available to industry at 48 mills per kWh. If no retiming is required, this energy cost would be competitive with alternative energy costs from a coal fired plant at the turn of the century; and, if coal prices continue to escalate, tidal energy will become increasingly more attractive. In the event that retiming is necessary, up to 3200 GWh annually could be made available at 74 mills/kWh--a cost which would be favored over the coal alternative before 2025 if coal prices continue to escalate perpetually at 3 percent per annum above the inflation rate and by 2050 at 1.5 percent per annum.

It follows that if a decision is made by the State of Alaska to encourage industrial development, it would be possible to support such a decision with a 60 powerhouse installation at Eagle Bay. Thus, the proposed Phase II study would include the following:

(1) Identify industries which would be attracted by the amounts and costs of energy available from full development of Eagle Bay site;

(2) Identify and address technical problems associated with transmission and distribution of energy, either electrical energy or energy converted to some other form (such as heat) or fuel (such as hydrogen); and

(3) Determine how much and what type of energy storage system is required to meet industrial needs.

"Phase III would involve a detailed engineering and environmental investigation of site-specific configurations, as well as the preparation of a conceptual development plan" (Office of the Governor, September 23, 1980).

Whereas this report considers retiming in generic terms and evaluates project economics on the basis of an expected cost penalty for energy storage capacity, it will be possible after completion of Phase II to develop site-specific details regarding the apparent optimal retiming needs for the preferred tidal power developments. This work would be accomplished in Phase III, which would have three major components:

(1) Development of site-specific characteristics and potentials of a preferred retiming facility (either to support the Railbelt System alone in the case of tidal power development with a low level of installation or to support identified industries in the case of high levels of installations);

(2) Preparation of a conceptual development plan to include layouts for the tidal plant, storage system, transmission system, road network, caisson prefabrication area, and ancillary facilities; and

(3) An environmental assessment of the proposed conceptual development plan for the entire tidal plant/storage system/vehicular crossing facility.

2.10 - Recommendations

It is recommended that:

(i) Information developed in this preliminary assessment be made available for use in the ongoing study of Railbelt Energy Alternatives,

(ii) A public meeting be conducted to inform the public of the results of this preliminary assessment as well as to solicit comments and recommendations for consideration in further tidal power investigations, and

(iii) Phases II and III be undertaken as soon as practicable and that they be carried out concurrently so that the tidal power alternative can be properly assessed before the ongoing Railbelt Alternative Energy Study is completed.

SECTION 3 - METHODOLOGY

3.1 - Introduction

The overall approach to the scope of work set forth in the original terms of reference (paragraph 1.6) involved the completion of four major tasks:

Task 1 - Preliminary Field Reconnaissance

Task 2 - Comparative Evaluation

Task 3 - Reports

Task 4 - Project Control and Administration

Each task was divided into a set of subtasks and, in one case, further subdivided into individual work packages. Figure 3-1 is a logic diagram illustrating the sequence in which certain subtasks were undertaken.

3.2 - Task 1 - Preliminary Field Reconnaissance

The primary purpose of Task 1 was to identify three schemes for tidal power plant configurations at specific sites so that succeeding, more detailed evaluations could be focused upon actual local conditions. More weight was given to identifying good representative sites with distinct differences from one to another than to attempting to find the best possible site in the Cook Inlet area. Indeed, the latter optimization process can only be reasonably undertaken after a rigorous data collection program is conducted to determine precise values for certain parameters which were extrapolated or based on professional judgement in the preliminary assessment stage.*

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* The distinction between representative sites at the preliminary assessment stage and optimum sites determined during a major feasibility study is illustrated in the history of the Susitna Hydroelectric Project. Early studies by the U.S. Bureau of Reclamation, Kaiser Engineering Company, and the U.S. Army Corps of Engineers each settled upon different dam heights and locations. In spite of these marked differences, all of the initial assessments were sufficient to suggest that hydroelectric development of the Susitna was probably technically, economically and environmentally justifiable.

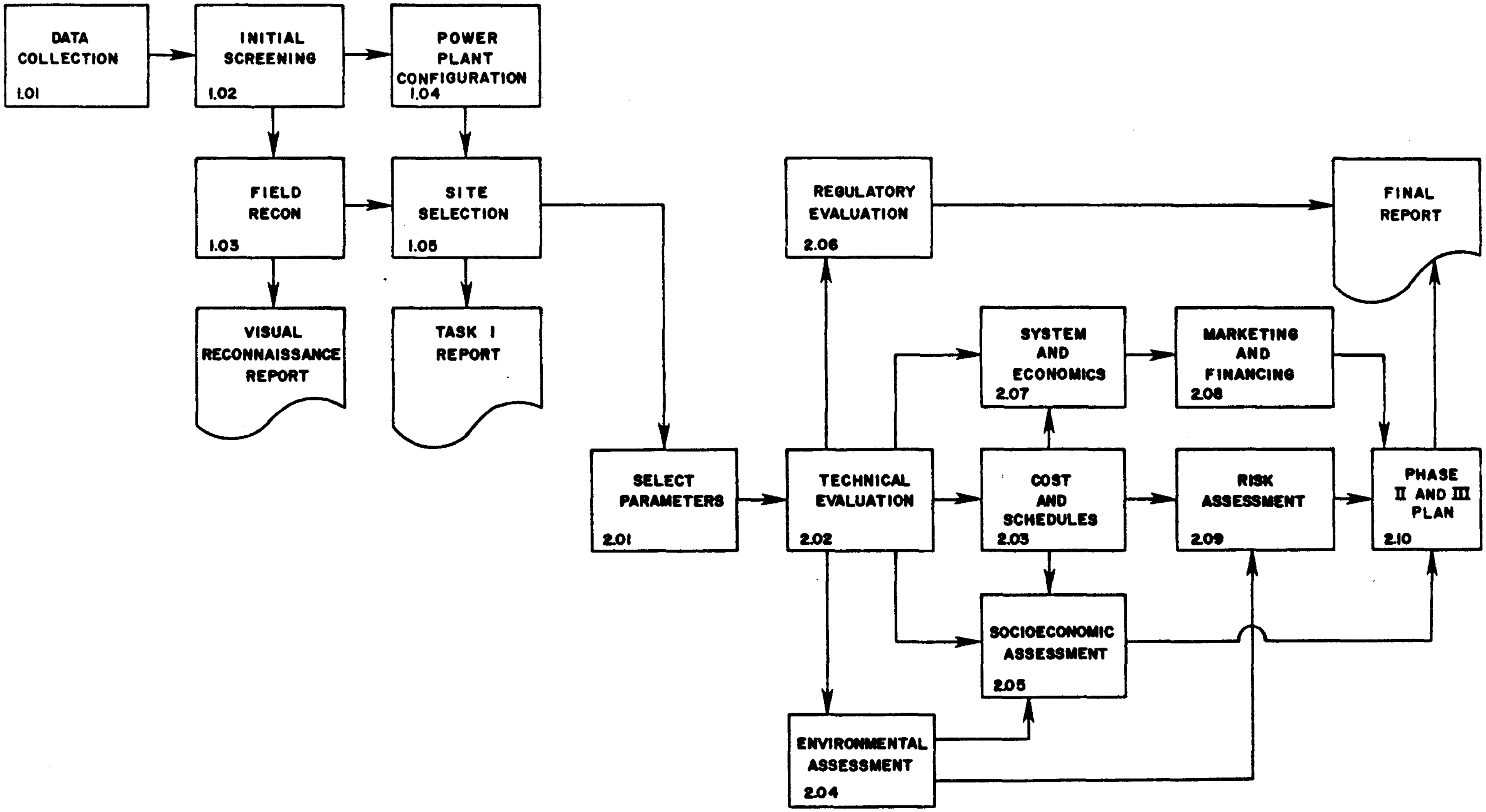

FIGURE 3-1
LOGIC DIAGRAM,
STUDY METHODOLOGY

(i) Subtask 1.01 - Data Collection

A major data collection effort marked the start of the assessment process. The quantity and quality of information available to the study team was surprisingly good, particularly in terms of the many published references on existing and potential tidal power developments. Less satisfactory, though not unexpected, was the relative dearth of site specific data. Major uncertainties in geotechnical information, oceanography, and the like were evident, although several studies of Turnagain and Knik Arm crossings did provide a basis upon which professional judgement and extrapolation could be used to define probable values for parameters later needed in the technical evaluation process.

(ii) Subtask 1.02 - Initial Screening

Possible tidal power sites were located on a map of Cook Inlet and initial parametric comparisons were made to determine relative rankings in terms of theoretical energy production capabilities and costs. Selection criteria were established and an initial list of sixteen sites was reduced to seven. Particular cognizance was taken of sites which had been considered in earlier reports on tidal power potential in Cook Inlet.

(iii) Subtask 1.03 - Field Reconnaissance

Each of the seven best sites remaining (after the initial screening process) was visited and a visual examination of conditions was made. Photographs were taken and a brief report was prepared on each site (See Appendix 2).

(iv) Subtask 1.04 - Power Plant Configuration and Operation

A review of alternative concepts (including, for example, multiple tidal basins, double effect operation) was made and an initial estimate of the extent to which a barrage might itself affect tidal ranges was formulated. Preliminary conceptual configurations were considered at each of the seven sites and selection criteria were further evaluated for each.

(v) Subtask 1.05 - Site Selection

Based upon the selection criteria which had been established in Subtask 1.02, three sites were selected in this subtask for more detailed evaluation in Task 2.

3.3 - Task 2 - Comparative Evaluation

The primary purpose of Task 2 was to evaluate each of the three earlier selected sites in sufficient detail to determine characteristics, likely costs and schedules, and constraints which might be associated with each.

Whereas much has been written about tidal power in general and whereas exhaustive earlier studies of major tidal projects in the Bay of Fundy were particularly useful, it is nonetheless true that certain unique aspects in Cook Inlet had to be specifically accounted for.

(i) Subtask 2.01 - Select Parameters

As the basis for preparing conceptual tidal plant layouts and evaluating them, it was necessary to establish certain parameters. Thus, for example, values had to be selected for design waves, crest elevations, foundation conditions, tidal currents and the like. To the extent that precise data had not been physically measured, extrapolations were made from data which did exist and professional judgement was applied. Note was taken of uncertainties at this point, for a later risk assessment and cost estimate had to allow for the possibility that actual parameters to be determined from instrumentation and drilling programs will vary from assumed values.

(ii) Subtask 2.02 - Technical Evaluation

A major share of the project man-hours was devoted to completion of this subtask. Because of its size, it was further subdivided into work packages:

(a) Determination of Turbine-Generator Capacity and Energy Output

Although it had originally been planned to extrapolate results of the 1976 - 1977 Bay of Fundy studies to the tidal levels and characteristics of Cook Inlet, simple extrapolation was found to be less than satisfactory. Pacific tides evince different characteristics than Atlantic tides. Thus, a special computer program was modified to specifically model Cook Inlet tides, basin levels, and energy outputs. Preliminary cost estimates were prepared to permit initial optimization of the number of sluiceways and turbines at each of the sites. (This site optimization process is an iterative one. See Work Package (i) below.)

(b) Turbine-Generator Equipment Design

Contacts were made with potential suppliers of equipment so that it was possible to develop realistic values for operating characteristics and costs in succeeding analyses.

(c) Sluiceway Design

(d) Closure of the Tidal Basin

A second computer program was developed to determine closure velocities which increase during construction as the open water gap narrows.

(e) Dike Design

(f) Construction Methods

(g) Electrical Equipment

As for turbine-generator equipment investigations, manufacturers provided useful data on electrical equipment characteristics and costs.

(h) Preparation of Layout Configurations

(i) Optimization Procedure

It was noted in work package (a) that an initial optimization of numbers of turbines and sluiceways was made based on very preliminary cost estimates. As better cost estimates evolved during the conduct of Subtask 2.03, further optimization runs were made in order to produce the apparent best facility (from an economic standpoint). Optimization was based only on the least cost of raw energy without retiming.

(iii) Subtask 2.03 - Cost Estimates and Schedules

Based upon layouts for the three selected sites and upon studies of civil, mechanical and electrical features, cost estimates were formulated. Account was taken of unique construction costs and constraints in Alaska. Actual operating experience at La Rance and the extensive Bay of Fundy studies and cost estimates were reviewed. Percentages applied to account for engineering, management, owner's costs and contingencies are generally consistent with those used in the ongoing Susitna study.

(iv) Subtask 2.04 - Preliminary Environmental Assessment

The literature was reviewed to identify probable environmental impacts associated with construction at each site. This information also was used to develop an initial overview of the nature of extensive environmental data collection efforts which will be necessary if a major feasibility study is later conducted.

(v) Subtask 2.05 - Socioeconomic Assessment

An identification, on a regional basis, of the significant socioeconomic issues related to tidal power development was made in this subtask. Account was also taken of the possibility that a tidal power development could provide causeway access across Turnagain or Knik Arms.

(vi) Subtask 2.06 - Regulatory Evaluation

Federal, state and local institutional considerations--including licensing, legal and regulatory requirements--were reviewed. Work accomplished on this subtask also provided useful information insofar as determining the expected duration of essential activities which must be successfully accomplished before construction can commence.

(vii) Subtask 2.07 - System Study and Economic Evaluation

A review of the nature of the Railbelt System and the probable energy and load demands at the time that tidal power might come on line was conducted. Estimates were made of the amount of tidal energy which might be absorbed by the then extant system. "Excess" energy quantities were estimated as the basis for determining the extent to which energy storage may be necessary.

An examination of energy storage possibilities was made as the basis for evaluating the approximate costs of converting "excess" energy to a form more readily acceptable to utilities or to industry. A preliminary economic assessment of the selected facilities followed.

(viii) Subtask 2.08 - Marketing and Financing

A summary of marketing and financing constraints was prepared in this subtask.

(ix) Subtask 2.09 - Preliminary Risk Assessment

Major uncertainties associated with tidal power development in Cook Inlet were identified and consequences were assessed. Of particular note here is that some of the "risks" carried at the preliminary assessment stage can be reduced or eliminated during later feasibility studies where more precise data are collected.

(x) Subtask 2.10 - Preparation of Phase II, III Plans

A preliminary statement of work was drawn up for activities which should be accomplished to conduct a study of industry which might use tidal energy (Phase II) and to carry forward engineering and environmental studies into a more detailed conceptual development plan (Phase III).

SECTION 4 - SITE SELECTION

4.1 - Introduction and Purpose

Cook Inlet is a major tidal estuary. With width as great as 80 miles and length in excess of 180 miles, literally hundreds of potential tidal power sites and a variety of types of development could be located within it. It follows that a rational process for identifying and screening candidate sites and types of development was essential before selection and technical evaluation of particularly good representative sites was possible. The identification and screening exercise is described in detail in Appendix I. This section summarizes the selection process.

4.2 - Existing Conditions

4.2.1 - Physical Setting

Cook Inlet lies in a large structural depression between the Alaska Range to the west and the Kenai and Chugach Ranges to the east. Tertiary sedimentary formations were the foundation for later glacial activity which at one time occupied its entire length, developing the broad trough-like characteristic of the basin. The many glacial fed tributary waters have carried enormous quantities of sediment into the Inlet, forming mud flats exposed at low tides especially in the Knik and Turnagain Arms and the Susitna River Delta.

Human activities in Cook Inlet are relatively extensive in comparison to other parts of the State. The predominant activities that share the Inlet waters include a broad based fishing industry, increasing exploration of energy and mineral resources, as well as cargo and passenger traffic to and from the ports of Anchorage, Kenai, Homer, and Seldovia.

The tides in Cook Inlet are significantly higher than those prevailing in the nearby open ocean. For example, the mean tidal ranges recorded in the National Ocean Survey tide tables vary from 6.6 feet at Kodiak Harbor to 11.4 feet at the Barren Islands up to 26.1 feet at Anchorage. Because the gross potential energy available at a given tidal power site varies directly as the square of the tidal range, the upper portion of Cook Inlet is particularly attractive for consideration of tidal power development.

4.2.2 - The Railbelt Electrical System

The electrical system which could benefit from tidal energy lies within the Railbelt and includes the urban areas of Fairbanks, Anchorage, Homer, Seward and a number of other smaller communities. Projections of electrical energy demand in the Railbelt were recently made by the Institute for Social and Economic Research (ISER), University of Alaska. Figure 4-1 illustrates the mid-range (most likely) and high forecasts through 2010 as derived from the ISER forecasts.

Planning for potential Cook Inlet tidal power plants considers two cases: (1) A constrained case, consistent with the most likely forecast, and (2) An unconstrained case, resulting from encouragement of industrial growth if the State of Alaska chose to adopt such a policy and if tidal energy were found to be sufficiently economic to attract energy-consumptive industry. Since it is unlikely that tidal power could be brought on line much before 1995 to 2000, the 10-year increase in average annual energy demand of 2500 GWh* between 2000 and 2010 in the most likely forecast was selected as an indicator of the required energy production capability for plants to be considered in the constrained case. By the same reasoning, the high forecast (which itself assumes increased industrial development) would range between 4000 GWh to 15,000 GWh in 2010 for the unconstrained case. The most attractive tidal power development would be one that developed either continuous power or sufficient dependable peak energy production to contribute capacity to the power system as well as energy.

4.3 - Concept Selection

In the simplest concept for tidal power development, water flows from a high pool through a hydraulic turbine to a low pool as illustrated earlier in Figure 1-1. Three basic components are necessary: (1) Powerhouses equipped with turbines and generators, (2) Sluiceways to permit rapid filling of a basin, and (3) A barrage (or dike) to contain water within the basin. A plot of typical variations in basin and sea levels and corresponding energy production is provided as Figure 4-2. This basic scheme is referred to as "single basin, single effect, ebb tide operation." As noted, the production from such a scheme is in pulses of energy in phase with the moon rather than the sun. This means the energy is out of phase with normal human activity. It also means that continuous power is not available without retiming the energy.

Double effect (operation on both ebb and flow tides) is possible if reversible turbines are used. Multiple basins linked hydraulically or electrically--or even operated independently on ebb and flow tidal cycles--are possible. The primary advantage of the more complex schemes is that energy generation can be made to occur for longer periods or continuously and

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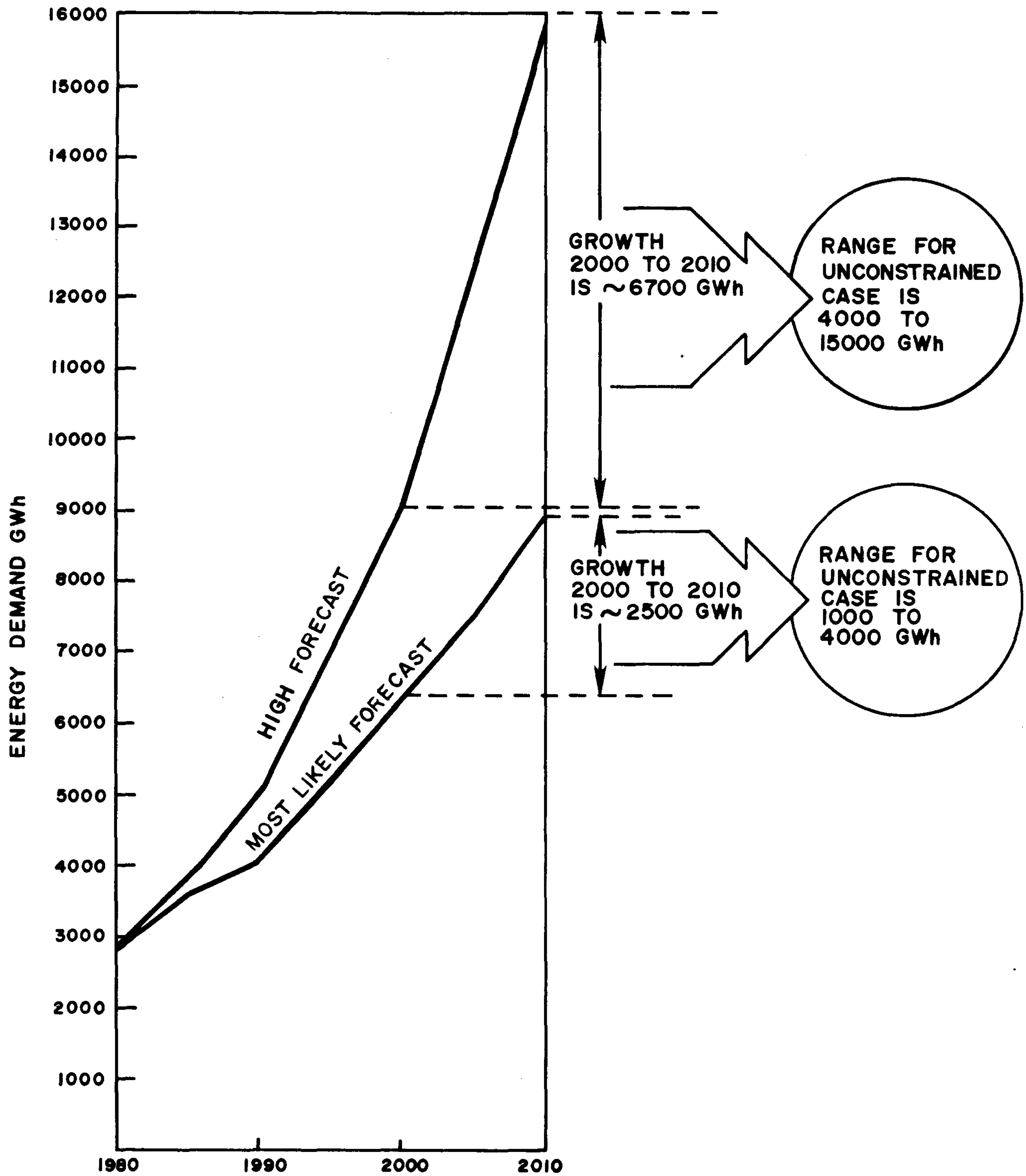
* A range between 1000 and 4000 GWh bracketing this amount was selected for identifying constrained case candidates.



NOTE: BASED UPON ISER FORECASTS

FIGURE 4-1
SELECTED DEMAND FORECASTS

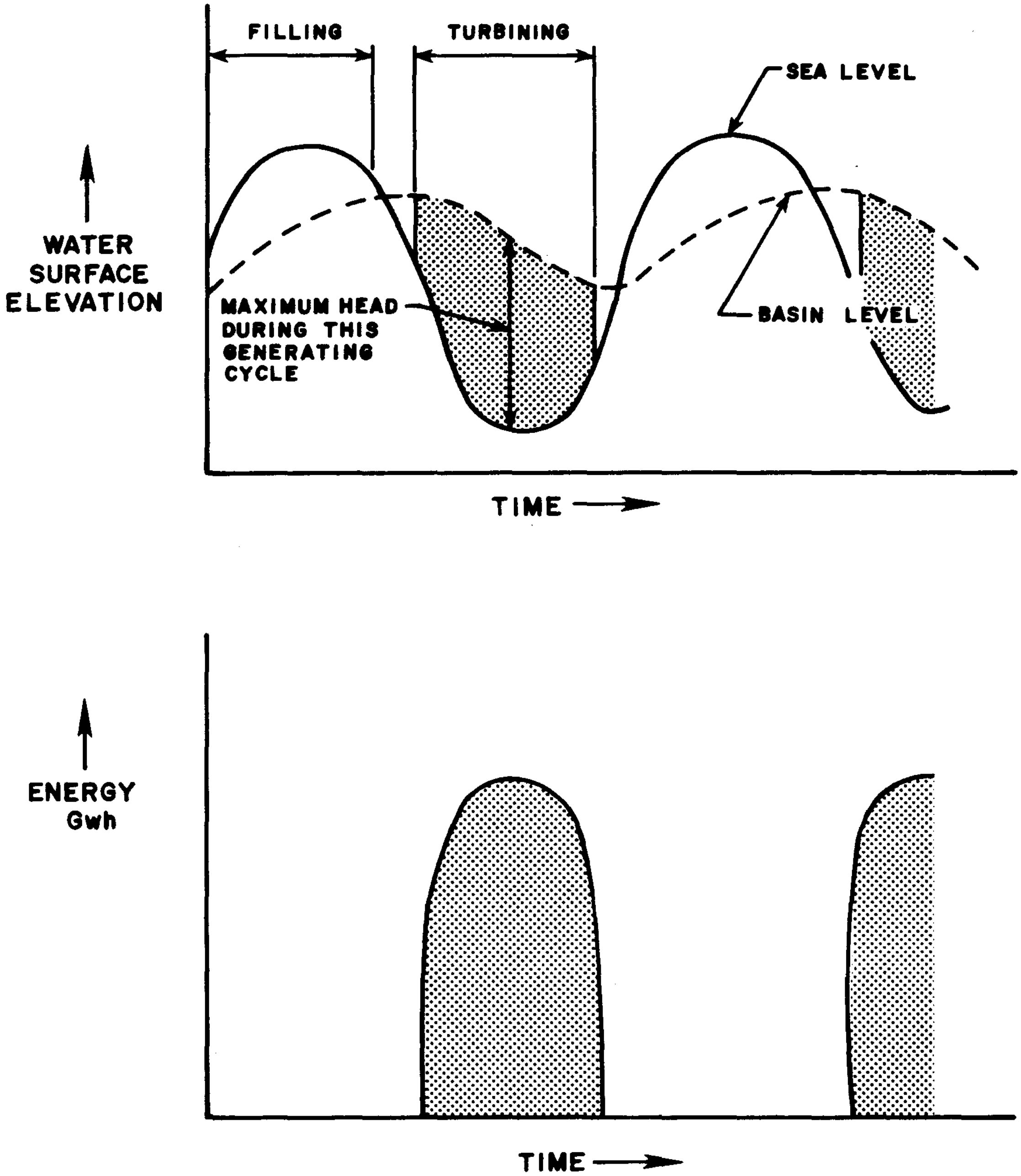


FIGURE 4-2

WATER LEVELS AND ENERGY PRODUCTION DURING A TYPICAL CYCLE.

some dependable peaking capacity can be achieved. On the other hand, significant cost penalties have to be paid without greatly changing total energy generated.

For purposes of the preliminary assessment, it was reasoned that a single basin, single effect concept providing raw tidal energy at a minimum cost would provide the best basis for determining if such energy can be produced economically.

4.4 - Site Selection

4.4.1 - Selection Criteria

Based upon reviews of earlier studies and the physical nature of Cook Inlet, sixteen potential tidal power sites were initially selected as indicated on Figure 4-3. A set of selection criteria was devised as the basis for comparing one site with another. The criteria, together with brief descriptions of how they were applied, are as follows:

(i) Relative Cost

It is, of course, not possible to produce reasonable cost estimates at any particular site until site-specific configurations are first developed. Even so, relative costs (which suggest the probable order in which potential sites can be cost-ranked) can be evaluated. An appropriate parameter for this purpose is the ratio of annual energy produced to a value which is proportional to the volume of a potential tidal barrier. Approximate annual energy was estimated based on gross energy potential calculated with Bernshtein's Formula* using factors from previous studies to predict optimum net annual energy production and installed capacities.

Since actual costs tend to depend heavily upon the total volume of materials placed, the ratio of energy to approximate volume is in effect providing a measure of the kilowatt hours per dollar on a relative basis. High values, of course, indicate economically favored sites. Table 4.1 provides parametric values for each site under the heading "AE/LH^2."

It will be seen from this tabulation that the three sites ultimately selected (Numbers 12, 14, 15) had high values for the cost parameter.

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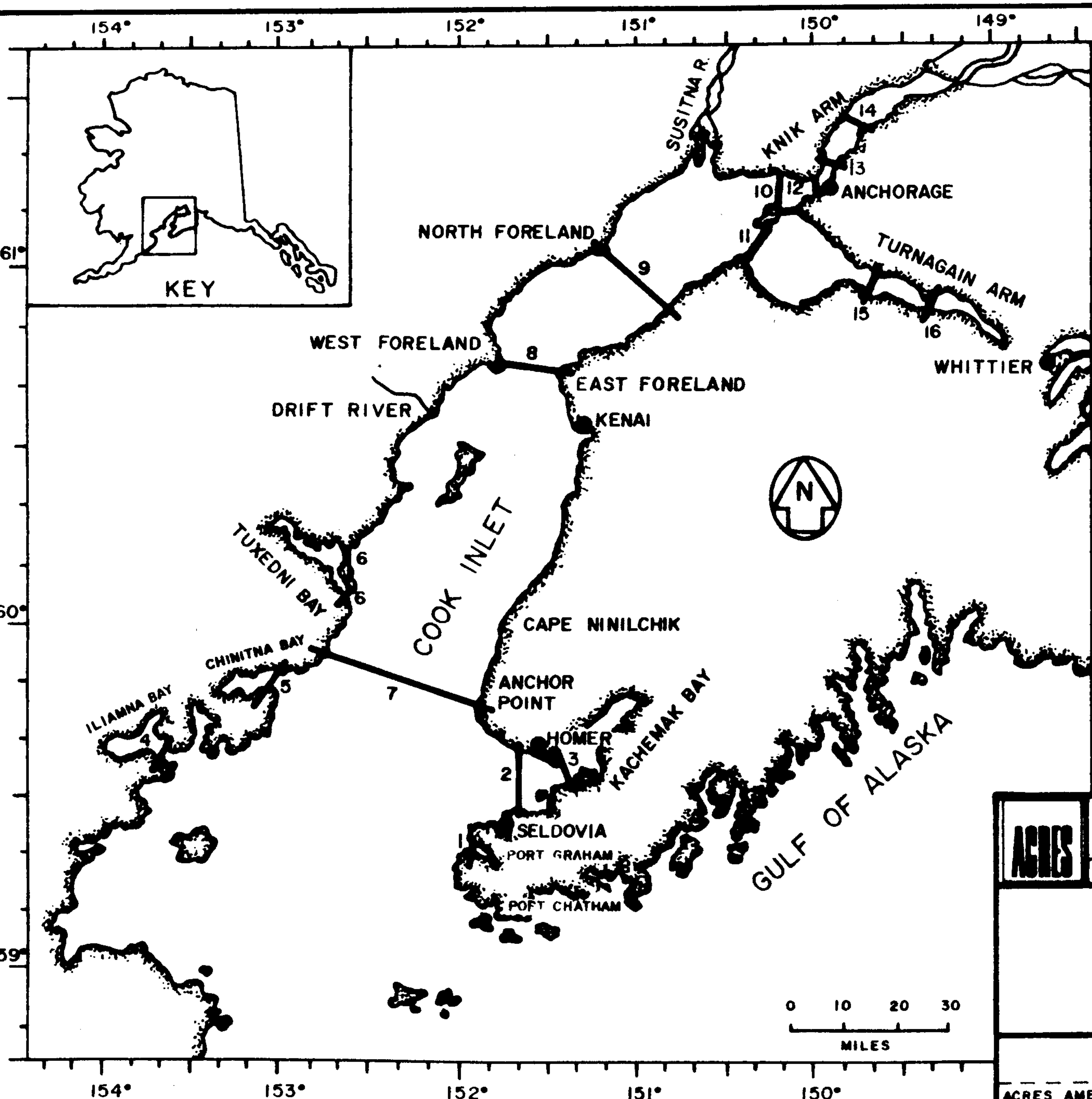
* Gross Potential Energy - $0.475\ AR^2 \times 10^6$ kWh/year where
A = Area of the basin at mean tide range in square miles
R = Mean tidal range in feet
(Reference Source D.2--See Appendix I)



SITE LIST

1. PORT GRAHAM
2. KACHEMAK BAY (1)
3. KACHEMAK BAY (2)
4. ILIAMNA BAY
5. CHINITNA BAY
6. TUXEDNI BAY
7. ANCHOR PT.
8. FORELAND EAST/WEST
9. FORELAND NORTH
10. FIRE ISLAND/KNIK
11. FIRE ISLAND/TURNAGAIN
12. POINT MACKENZIE
13. CAIRN POINT
14. EAGLE BAY
15. RAINBOW
16. SUNRISE

ACRES

OFFICE OF THE GOVERNOR
STATE OF ALASKA

COOK INLET TIDAL POWER

CANDIDATE SITES

ACRES AMERICAN INCORPORATED

FIGURE 4-3

(ii) Closure Criteria

Even under natural conditions, tidal velocities are highest in locations where the width of the Inlet is narrow. When a tidal power facility is constructed by floating in prefabricated units or by construction behind cofferdams, the remaining open water at any particular site is gradually reduced and maximum tidal velocities at the partially completed facility increase correspondingly. Because there is a limiting velocity beyond which marine equipment cannot be operated safely, closure criteria may force a decision to develop less than the theoretical optimum capacity at a particular site. Indeed, as will be seen in later sections of this report, one of the sites selected for more detailed technical evaluation in Task 2 was found to be constrained in this way.

The relative degree to which closure limitations may apply is found by evaluating the ratio between the length required to accommodate powerhouses and the total length of the gap. Extremely high values are undesirable since major closure problems are then likely. Very low values are also not favored since they indicate that major investments in dike construction will have to be made to achieve relatively small energy production.

Table 4.1 provides values for the closure parameter (LP/L) for each site. Of the three sites ultimately selected, the one with the highest closure parameter (Site 12) actually was constrained by closure problems in the technical evaluation.

It is important to understand that the closure velocity problem applies primarily to the floated-in construction technique. An alternative construction approach wherein units are built in place behind protective cofferdams is possible. Based on earlier studies in the Bay of Fundy and the particular nature of bottom conditions assumed in Cook Inlet, floated-in units were considered to be the least-cost approach.

(iii) Causeway Potential

Anchorage is by far the most heavily populated city in Alaska. Land available for commercial and residential development is presently limited. A tidal power facility astride Knik Arm could also serve as a causeway and would make valuable lands more accessible west of Anchorage. Also, it could slightly reduce the driving distance between Anchorage and points north.

Causeway access to the Kenai peninsula would significantly reduce the driving distance to populated areas and recreational attractions southwest of Anchorage.

Thus it was reasoned that, where potential tidal power sites could also serve as a causeway, such sites could be more economically attractive. That is to say that some of the high capital investment required to develop a site can be partially offset by the value of a causeway.

(iv) Access

If access to any particular site was found to be relatively easy, such a site was favored. Not only is the development of access routes to a remote site costly, but also such development inevitably leads to environmental impacts which could be significant in some cases.

(v) Environmental Issues

Whereas a more detailed environmental assessment was prepared later for selected sites, an attempt was made in the initial screening process to identify major sensitivities which might limit developments. In this regard, for example:

- Sites through which major anadromous fish runs must pass were regarded as environmentally more sensitive.
- Sites at the lower end of Cook Inlet tended to be in areas of higher biological productivity than those in the silt-laden waters in the upper Inlet. Thus, Knik Arm and Turnagain Arm were considered less environmentally sensitive on this point.
- Where tidal power development had the potential of producing major changes in known wildfowl resting areas or habitat, such sites were considered more sensitive.
- Highly productive areas such as Kachemak Bay were regarded as particularly sensitive.

(vi) Probable Foundations

Only limited data are available on foundation conditions under Cook Inlet. Even so, a combination of this information and professional judgement led to preliminary conclusions as to probable preferred locations for facility construction.

(vii) Navigation Issues

Sites lying astride major ocean shipping channels or heavily used routes for commercial and private vessels will require navigation locks and could lead to some shipping delays. On the other hand, average basin levels above tidal barrages would remain higher than under natural conditions and could facilitate movement of deep draft vessels. Navigation issues were not regarded as limiting tidal power development, but the need for lockage represented an increase in relative costs.

(viii) Transmission Tie

Sites which required lengthy transmission lines and/or long undersea cables were regarded as less favorable than those situated near existing transmission corridors.

(ix) Energy Ranges for Constrained and Unconstrained Cases

Section 4.2 noted energy ranges which had been selected as appropriate for constrained and unconstrained cases. Sites whose apparent energy potential was within the selected ranges were favored. Multiple small sites were also considered to be possible solutions to the unconstrained case, although very low values for the cost parameter (see Table 4.1) ultimately ruled them out. Table 4.1 provides initial estimates of net energy for each site.

(x) Seismicity

Seismic risk is associated with all potential sites. Even so, those lying near known major faults were considered least desirable.

Figure 4-4 provides a summary of selection criteria evaluations. More detail is presented in Appendix 1.

4.4.2 - Selected Sites

In addition to the criteria described above, consideration was also given to the fact that the value of a preliminary assessment would be enhanced if each of the three sites to be selected evinced a reasonable degree of difference from another. In this regard, for example, both the Rainbow and Sunrise sites in Turnagain Arm fared well in terms of the criteria. Only one was selected, however, because the location and characteristics of each are similar.

The three sites selected for further analysis (see Figure 4-3 for location) are:

(i) For the constrained case,

- Rainbow (Site 15) on Turnagain Arm
- Above Eagle Bay/Goose Bay (Site 14) on the Knik Arm

(ii) For the unconstrained case,

- Point MacKenzie - Point Woronzof (Site 12) on the Knik Arm.

TABLE 4-1

SELECTED PARAMETERS

	Site	Tidal Range (ft)	Initial Estimate of Net Energy (kWh x 10^6)	Cost Parameter $\frac{AE}{LH^2}$* (kWh/ft^3)	L_p/L_B** Closure Parameter
1.	Port Graham	14.4	117	0.98	.04
2.	Kachemak Bay (1)	15.5	3,730	0.39	.16
3.	Kachemak Bay (2)	15.5	2,230	0.53	.16
4.	Iliamna Bay	12.3	120	4.3	0.17
5.	Chinitna Bay	13.0	408	5.4	0.17
6.	Tuxedni Bay/Snug Harbor	13.2	484	0.64	0.08
7.	Anchor Point	14.5	63,700	3.3	>1
8.	Foreland East/West	17.5	39,500	11.2	>1
9.	North Forelands	19.0	32,800	11.5	.74
10.	Knik/Fire Island	24.4	7,400	15.7	.31
11.	Turnagain/Fire Island	25.0	16,600	13.0	.57
12.	Point MacKenzie	25.7	6,000	27.4	.53
13.	Cairn Point	26.3	5,500	14.5	.82
14.	Above Eagle Bay/ Goose Bay	27.6	3,500	46.1	.21
15.	Rainbow	27.5	3,000	29.1	.13
16.	Sunrise	30.3	1,900	28.7	.11

* See Paragraph 4.4.1 (i) for explanation

** See Paragraph 4.4.1 (ii) for explanation

	1 PORT GRAHAM	2 KACHEMAK I	3 KACHEMAK II	4 ILIAMNA	5 CHINITNA	6 TUXEDNI	7 ANCHOR PT.	8 FORELAND E/W	9 FORELAND NORTH	10 FIRE ISLAND KNIK	11 FIRE IS. TURNAGAIN	12 PT. MACKENZIE	13 CAIRN PT.	14 EAGLE BAY	15 RAINBOW	16 SUNRISE
RELATIVE COST	■	■	■	■	■	■	■	◪	◪	◪	◪	□	◪	□	□	□
CLOSURE CRITERIA	■	□	□	■	■	■	■	■	◪	□	◪	◪	■	□	□	□
CAUSEWAY POTENTIAL	■	■	■	■	■	■	■	■	■	□	◪	□	□	◪	◪	◪
ACCESS	◪	□	□	■	■	■	□	□	□	◪	□	□	□	□	□	□
ENVIRONMENTAL ISSUES	◪	■	■	◪	◪	■	■	■	■	◪	◪	◪	◪	□	□	□
PROBABLE FOUNDATIONS	□	□	■	◪	◪	◪	■	◪	■	■	■	◪	□	◪	◪	◪
NAVIGATION ISSUES	◪	◪	◪	◪	□	◪	■	■	■	■	□	■	□	□	□	□
TRANSMISSION TIE	◪	□	□	■	■	■	◪	◪	□	□	□	□	□	□	□	□
ENERGY (CONSTRAINED) 1500 - 4000 G	■	□	□	■*	■*	■*	■	■	■	■	■	■	■	□	□	□
ENERGY (UNCONSTRAINED) 4000 - 8000 G	■	◪	◪	■	■	■	■	■	□	■	■	□	□	◪	◪	■
SEISMICITY	■	◪	◪	■	■	■	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪

LEGEND:

■ MAJOR CONSTRAINTS

◪ MINOR CONSTRAINTS

□ FAVORABLE CONDITIONS

* MULTIPLE SMALL SITES COULD MEET UNCONSTRAINED CASE LIMITS.

FIGURE 4-4
SUMMARY OF
SELECTION CRITERIA
EVALUATIONS

SECTION 5 - TECHNICAL EVALUATION

5.1 - Parameter Selection

As the basis for detailed energy evaluation and conceptual design of a tidal power facility, site specific physical parameters must be identified and quantified wherever possible. It is important to know, for example, what sort of waves must be withstood under the most extreme conditions. But wave heights and frequencies depend in turn upon expected wind speeds and directions, fetch (the length of open water over which winds will blow) and the bathymetry near the site.

A number of important components is associated with a tidal power plant. The parameter selection effort considered unique characteristics of each. Particular components include:

(i) Powerhouses and Turbine Generators

Development of any one of the selected sites will require the installation of thirty or more large turbine-generator units. Powerhouse modules or caissons, each containing two turbine-generators, were considered appropriate for application in Cook Inlet.

(ii) Sluiceways

After any single generating cycle, it is necessary to fill the basin rapidly so that sufficient head is available for the next generating cycle. Sluiceways permit rapid filling. The small amount of reverse flow through the turbines is relatively inconsequential. Sluiceways consisting of large water passages which can be opened or closed as necessary are contained in modules. These modules accommodate two sluiceways each and their exterior dimensions are such that they match with powerhouse modules to form a regular and functional structure.

(iii) Access Dikes

In cases where tidal current velocities are not likely to exceed safe limits for floating in modules, an access dike is constructed from one abutment out to a point where sufficient depth and bearing capacity will permit placement of the first module. As powerhouses and sluiceways are successively placed, the access dike facilitates movement of equipment and personnel across the partially completed facility. Where high currents represent a constraint, a temporary bridge may be used to gain access to the first caisson after it is placed.

(iv) Closure Dike

After placement of the last module, the remaining gap in the barrage is closed by a closure dike. Construction techniques similar to those commonly used for breakwater construction are applicable. Unlike a conventional dam, some leakage through the dike is tolerable and the dike core is designed accordingly.

(v) Electrical Equipment and Controls

A system is necessary to take energy at the operating voltage from the various generators to a point where it is then converted for transmission to external points. A computer controlled supervisory system for the whole tidal power plant will be required.

A description of selected parameters and the basis upon which they were chosen is provided as Appendix 3.

5.2 - Turbine-Generator Equipment Design

Selection of the type of hydraulic turbine for any particular site depends primarily upon the operating head at that site. For example, vertical shaft turbines have generally proven cost-effective for conventional hydroelectric power installations over a wide range of heads. In the particular case of tidal power development, operating heads are low. In this case, modern experience has shown that horizontal shaft units are most effective, particularly when relatively long structures in the direction of flow are otherwise required. For the foundation conditions in Cook Inlet, powerhouse stability required that the total length of a powerhouse unit measured in the direction of flow be large, so that horizontal axis turbines are attractive.

Three principal types of horizontal axial flow units are available and the location and type of generator is decidedly different for each. Figure 5-1 provides a sketch of each type.

Up to the present time the most popular unit for large diameter low head installations has been the bulb turbine. The generator is located within a bulb shaped watertight enclosure upstream from the turbine runner. Large bulb units are operating effectively in low head hydroelectric installations around the world.

A second type of horizontal unit involves a tube arrangement. In this case, the generator is outside the water passage and is connected to the turbine by a long shaft. Tube units have not generally proven effective for runner diameters as large as those which will be required in Cook Inlet. Thus, tube units were not given further consideration in this study.

A third arrangement is the Straflo in which the generator is mounted around the outside of the turbine runner. The generator rotor rotates outside the

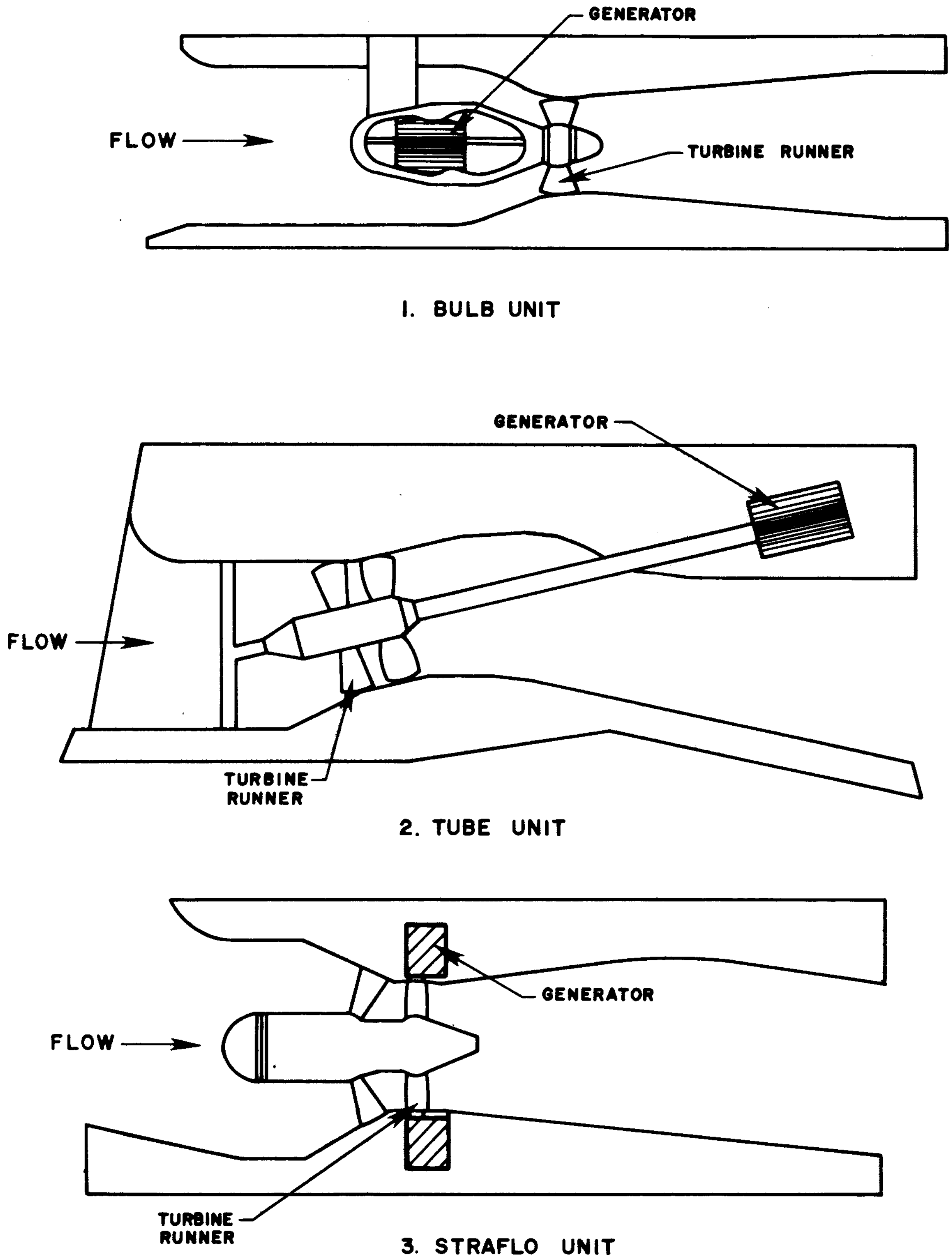


FIGURE 5-1
HORIZONTAL AXIAL
FLOW TURBINE TYPES

water passage, but it is connected to the turbine runner in much the same way that the rim of a wheel (the generator) is attached by spokes to the hub (the turbine runner). Special seals are required to keep the generator dry. In the absence of any other governing requirements, the length of the water passage for a Straflo unit can be shorter than for a comparable bulb unit. The first large Straflo unit (runner diameter 25 feet, rated at 17.8 MW at 18 feet net head) is now under construction for the tidal power demonstration project at Annapolis on the Bay of Fundy.

Both bulb units and Straflo units are viable candidates for application in Cook Inlet. For purposes of a preliminary assessment, energy calculations and conceptual layouts have been based on bulb units in this study, primarily because of the much greater experience data available for them. Large fixed blade units with runner diameters on the order of 28 feet and capacities ranging from 21 to 24 MW were considered. In the event that a later detailed feasibility study is undertaken, both bulb and Straflo units should be considered. Final selection will probably depend upon an economic analysis based on actual performance data.

Because of space limitations within the bulb, there are some constraints on generator design. For heads greater than the rated head (i.e., for periods when tidal heads are extreme) the continuous maximum rating (CMR) of the generator limits the turbine power output. This limitation was accounted for in the energy generation simulations (see paragraph 5.3 below).

A large number of powerhouse units is required at each of the three selected sites. To minimize costs as well as to permit reliable operation, turbine generator units would be connected into the electrical system in blocks of four units each.

Appendix 4, Turbine Generator Equipment Design, and Appendix 5, Electrical Equipment Design, provide further details.

5.3 - Tidal Power Plant Energy Study

5.3.1 - Base Case Analysis

It was noted in Section 4 that initial site screening efforts depended upon preliminary annual energy estimates related to volume of barrier. In that assessment, mean tidal ranges were used. More accurate calculations of energy production depend upon summation of continuously varying energy production derived from operating heads that change with both sea and basin levels, and upon specific operating characteristics of the turbine-generator equipment. As will be seen from Figure 4-2, the operating head varies continuously during any single generating cycle.

About 6 feet of head between basin and sea levels is required before turbining commences.

A special computer model was developed to simulate the operation of the tidal power plant for single basin, single effect schemes at selected sites in Cook Inlet. Without this model, accurate representations of the tidal levels would have been extremely difficult and estimates of energy production would have suffered accordingly. In this regard, it is worth noting that the shape of the tide curve and other tidal characteristics for Cook Inlet are quite different from those studied exhaustively for the Bay of Fundy and at La Rance. Details of the simulation model and sample outputs are provided in Appendix 6.

The objective of the model is to produce estimates of energy production at a selected site for use in optimization studies. By estimating the energy for several combinations of turbine numbers and sluiceway capacities and applying costs, it is possible to select the installation that produces the most economical energy at site. In simple terms, it can be imagined that if only a small number of turbines is used for one way, ebb-tide generation, only a small amount of water is released from the basin and the basin water level remains relatively high. As the number of turbines is increased, more water is released and the basin level falls off more rapidly. Figure 5-2 illustrates the point.

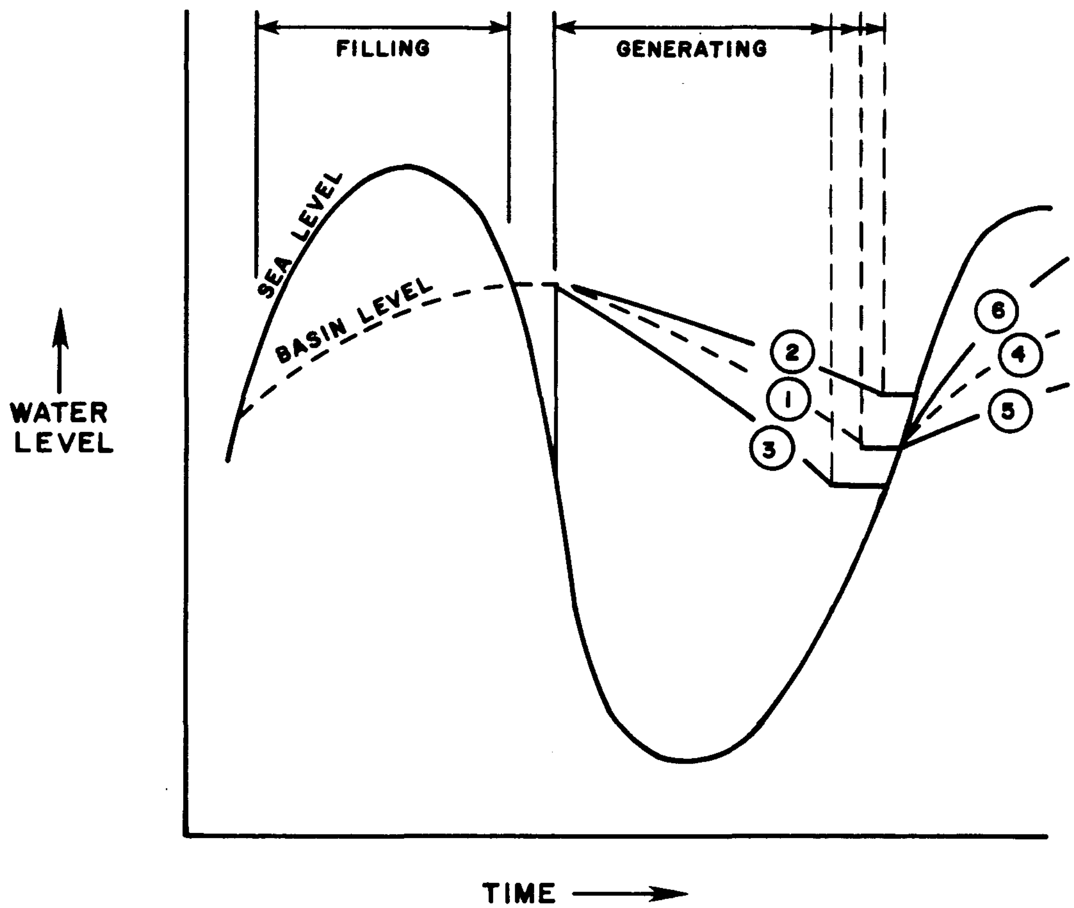
To ensure rapid filling of the basin as the tide rises, the sluices must be opened. Some water will also pass through turbine water passages in the filling process. Too few sluices will lead to a low basin level at the start of the next generating cycle, resulting in a loss in head and less energy. More sluices permit attaining higher starting levels for generation, but each sluice represents a cost. Too many sluices cause cost increases with little gain in energy production.

A characteristic optimization curve is illustrated and annotated on Figure 5-3.

Figure 5-4 is the actual optimization curve developed for the Eagle Bay site. In this case, it was determined that the minimum cost of unretimed energy corresponded to a facility containing 60 turbines and 36 sluices. With this level of development, 4037 GWh would be generated annually. The "cost of energy" in mills per kWh recorded on Figure 5-4 differs from energy costs used in the economic analysis because interest during construction was not included in the optimization program.

Optimization is an iterative process. An initial rough estimate of costs was necessary to find the preliminary optimum number of units. Once more detailed cost estimates were prepared, a new energy value was determined. This in turn led to further optimization of the number of units. The process was repeated to obtain the curve of Figure 5-4.

It is interesting to note that the at-site optimization curve tends to be relatively flat across a broad range of possible energy outputs. That is to say that variations of as much as 50 percent



NOTES:

IF THE OPTIMUM NUMBER OF TURBINES CAUSES BASIN LEVEL VARIATION ①, FEWER TURBINES PRODUCE BASIN LEVEL ② ,AND MORE TURBINES PRODUCE ③. SIMILARLY, IF THE OPTIMUM NUMBER OF SLUICES CAUSES THE BASIN LEVEL TO RISE AS IN ④, FEWER SLUICES WILL CAUSE SLOWER FILLING ⑤. INCREASING NUMBER OF SLUICES PRODUCES FASTER FILLING ⑥.

FIGURE 5-2
EFFECT OF VARYING NUMBERS OF TURBINES AND SLUICES.

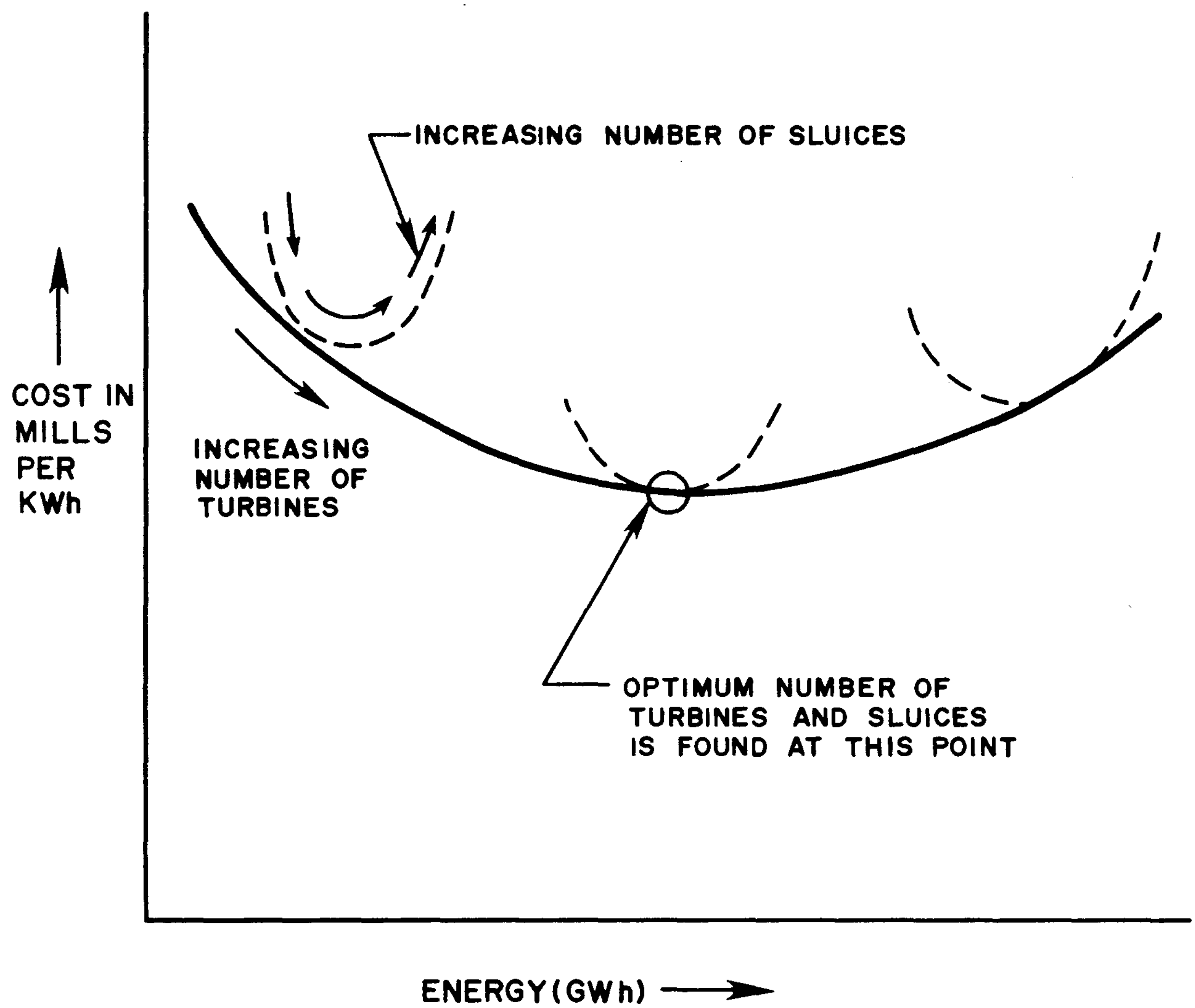
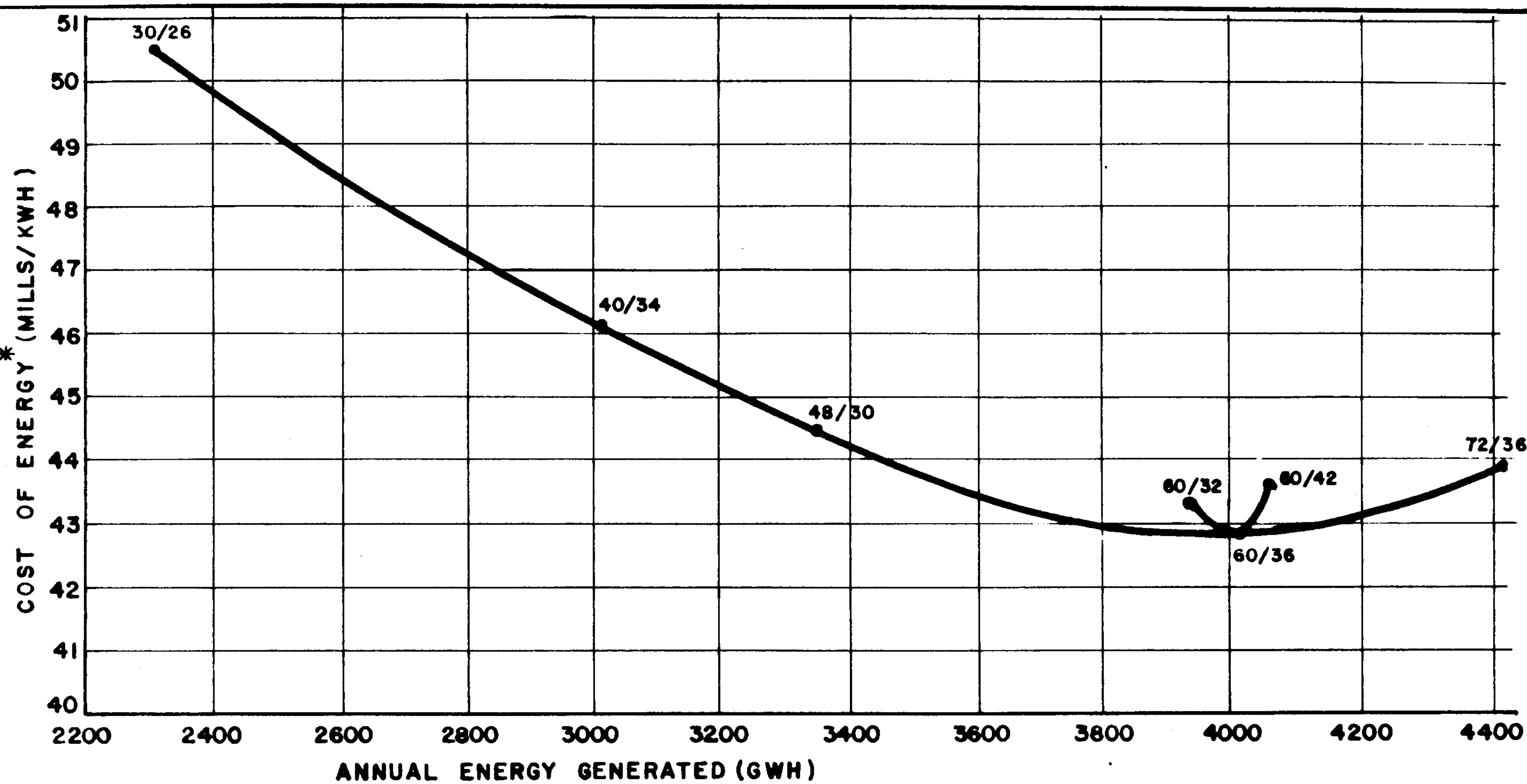


FIGURE 5-3
CHARACTERISTIC
OPTIMIZATION CURVE



LEGEND

60/36 TYPICALLY DENOTES
"60 TURBINES/36 SLUICES"

* EXCLUDING INTEREST
DURING CONSTRUCTION

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STATE OF ALASKA

COOK INLET TIDAL POWER

EAGLE BAY

PLANT OPTIMIZATION

ACRES AMERICAN INCORPORATED

FIGURE 5-4

from optimum energy output may change energy values by only 20 percent or so. In the particular case of Eagle Bay, Figure 5-4 shows that a 10 percent increase in annual energy is possible with an increase in energy cost of only one mill/kWh. Thus, it is possible that other factors may govern the final selection of plant capacity. In the case of the Point MacKenzie site, closure velocity constraints could require a reduction from an apparent optimum of 80 units to only 60 units if the construction program were unable to accept the restriction without cost penalty. Since this item was not investigated in detail, the number of units was restricted to 60 to provide a conservative estimate for the purposes of this preliminary study.

A plant which has been optimized to produce the least cost raw (unretimed) energy is not necessarily the optimal plant for the Railbelt Electrical System. Of 2300 GWh produced by a 30-turbine installation at Eagle Bay (see Figure 5-4), about 1540 GWh* can be absorbed without retiming in the Railbelt System. On the other hand, only about 1600 GWh* of the 4037 GWh for a 60-turbine installation can be absorbed without retiming. When energy costs are adjusted to account for the addition of energy storage, the new mill rate for the smaller 30-turbine installation is actually less than that for the larger 60-turbine installation.

Total system optimization should be accomplished during Phase III studies when site-specific retiming costs are known.

Table 5-1 provides information on selected numbers of units and annual energies for each site. It will be seen from the tabulation that while the preliminary estimates give a useful screening tool and give the correct coarse ranking of sites, they are not accurate enough for final concept evaluation. Variations of 10 percent to 20 percent occurred between the preliminary estimate and more precise simulation values.

5.3.2 - Studies With Variable-Blade Turbine Characteristics

The power plant energy studies in the base case assumed that fixed blade bulb turbines would be used. By varying the blade angle, greater power and energy outputs can be achieved at low tides. A limited number of simulations were performed for variable-blade turbines. Total annual energy increases on the order of 5 to 10 percent were found to be possible with reductions in raw energy costs of from 2.6 to 4.6 mills per kWh. It follows that equipment improvements offer the potential for enhancing the economic attractiveness of selected sites. After industrial needs for retiming are studied in Phase II, further analysis of variable-blade units is warranted in succeeding studies.

---

* See Appendix 10 for the basis upon which these values were computed.

TABLE 5-1

ANNUAL ENERGY AND NUMBERS OF UNITS AT SELECTED SITES
(Based Upon At-site Optimization of Raw Energy Values)

	Number of Turbines	Number of Sluices	Computed Annual Energy (GWh)	Preliminary Gross Estimate of Annual Energy (GWh)	Variation of Computed Estimate From Preliminary
Rainbow	40	24	2664	3000	- 12.6%
Eagle Bay	60	36	4037	3500	+ 12.3%
Point MacKenzie	80*	60*	5000*	6000*	- 20.0%

---

* The installation at Point MacKenzie was reduced to 60 turbines as a contingency in case higher closure velocities caused restriction in the construction program leading to higher costs. With 60 turbines and 46 sluices, annual energy at Point MacKenzie is reduced to 3937 GWh.

5.4 - Closure of the Tidal Basin

Preliminary considerations favoring floated-in caissons indicate that for the site conditions in Cook Inlet the most appropriate type of closure structure is a dike constructed with a core of heavy rocks or blocks that can resist closure velocities. It was noted in paragraph 5.3 above that closure velocities impose some restrictions on construction operations at sites where closure gap widths are relatively narrow. The magnitude of tidal currents which must be dealt with is determined by such factors as tide range, closure width, barrage height, basin storage area and the number of operating sluices contained within the partially completed structure.

A special computer model was developed to predict closure velocities. This model was useful for several purposes:

(i) It permitted determination of velocities under varying conditions as powerhouses and sluice units are floated into place; and

(ii) It provided information necessary for the size and type of materials which must be placed in the dike closure operation.

A typical example of water surface levels and velocities at Point MacKenzie appears as Figure 5-5. For the illustrated tidal range of 40 feet, placement of floated-in caissons would not be possible since flow velocities will exceed the limit of 13 feet per second which was set by construction requirements. The next placement of a floated-in caisson would be delayed in this case until four consecutive tidal ranges of 25 feet occurred.

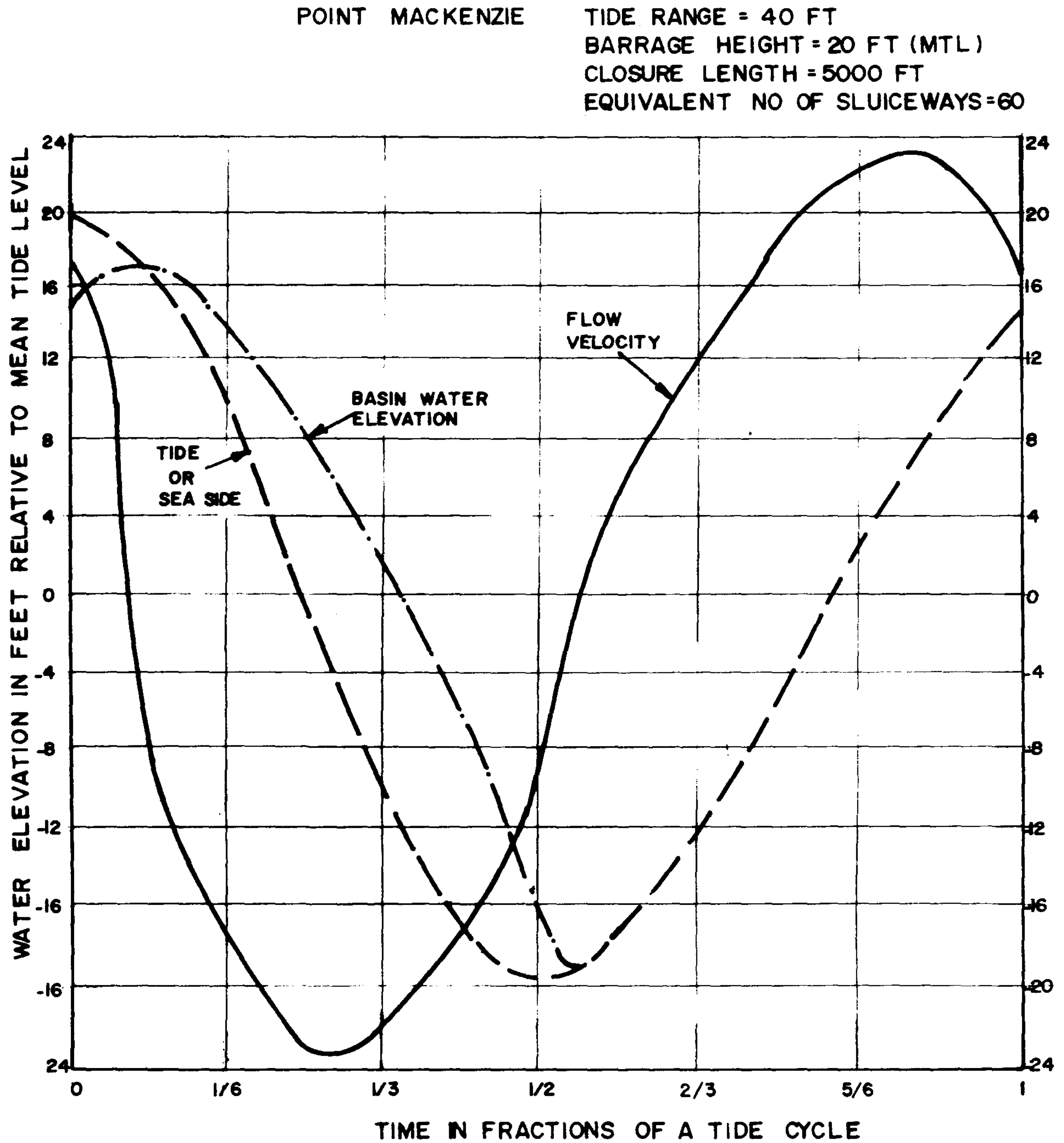
Appendix 7 offers further details on closure calculations.

5.5 - Civil Design

5.5.1 - Concept

A tidal power installation can also accommodate a vehicle crossing facility. Design approach depends upon whether or not land access is of paramount importance.

Given that the primary objective of this study is to conduct a preliminary assessment of Cook Inlet Tidal Power, the initial conceptual design effort was oriented toward producing a facility whose sole purpose is to generate electricity economically. Once that conceptual design had been completed, it was then possible to analyze those particular modifications which would be necessary in order to accommodate traffic safely. Thus, both the engineering design efforts and the cost and schedule work treat causeway potential as an increment which could be added to a facility optimized for tidal power.



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COOK INLET TIDAL POWER

TYPICAL EXAMPLE OF WATER SURFACE & VELOCITIES THROUGH A TIDE CYCLE DURING CLOSURE

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FIGURE 5-5

Civil design focused upon key elements as follows:

(i) Powerhouse structure and layouts

(ii) Sluiceway design concept

(iii) Dike design (closure and access)

(iv) Development of site profiles including caisson positions.

There are two fundamental approaches to construction of a tidal power facility: (1) Construction in place "in the dry" behind temporary cofferdams, or (2) Prefabrication of modules away from the site and construction "in the wet" by floating these modules into position and sinking them on prepared foundations. Each approach offers particular advantages and poses certain problems.

The use of temporary cofferdams is common in marine construction. Because construction work-forces and equipment must work within an area which has been pumped out and is protected from flooding by the cofferdams, safety considerations are important. The La Rance tidal power development employed dry construction techniques.

Floated-in caissons have also been successfully employed elsewhere. A major extension of the harbor breakwater at Baie Comeau, Quebec, adopted caisson construction in the 1960's. The Kislaya Guba experimental tidal power development in Russia employed wet construction techniques. The closure of tidal estuaries on the coast of the Netherlands also employs this technique.

The choice between wet and dry construction is governed primarily by economic considerations. The same final result is achieved with either approach. To a great extent, cost differences between wet and dry construction depend upon the particular nature of the bottom conditions. As has been noted elsewhere, however, only limited information was available for site-specific conditions in Cook Inlet.

Even so, the most likely bottom conditions at each of the selected sites are such that wet construction would be the more economical approach. In the event that future detailed field investigations demonstrate that actual conditions favor dry construction, that method can be adopted in the detailed feasibility study. In short, for purposes of this preliminary assessment, wet construction was chosen. If tidal energy is competitive under this selection and if later data collection leads to a more economical approach, it follows that tidal energy could become even more competitive.

By way of comparison, cost estimates prepared for both wet and dry construction at preferred sites in the Bay of Fundy led to the conclusion that dry construction would increase the costs of that portion of the work by between 33 percent and 100 percent, depending upon the site being considered.

Details of the civil design considerations are presented in Appendix 8.

5.5.2 - Powerhouses and Sluiceways

A number of factors must be considered in selecting appropriate dimensions for a powerhouse unit. A major consideration is, of course, the need to fit in all of the necessary mechanical and electrical equipment. For example, the minimum length of water passage for selected bulb turbines must be accommodated. Calculations must be made to ensure integrity of the structure against seepage, sliding, overturning and settlement.

Assumed foundation conditions led to the conclusion that the maximum length of the structure is governed by the required factor of safety against sliding and overturning and the allowable bearing capacity of the material upon which the plant is placed.

Other factors such as ice, wind, waves, salt water attack, temperature extremes, and expected seismic conditions were also considered.

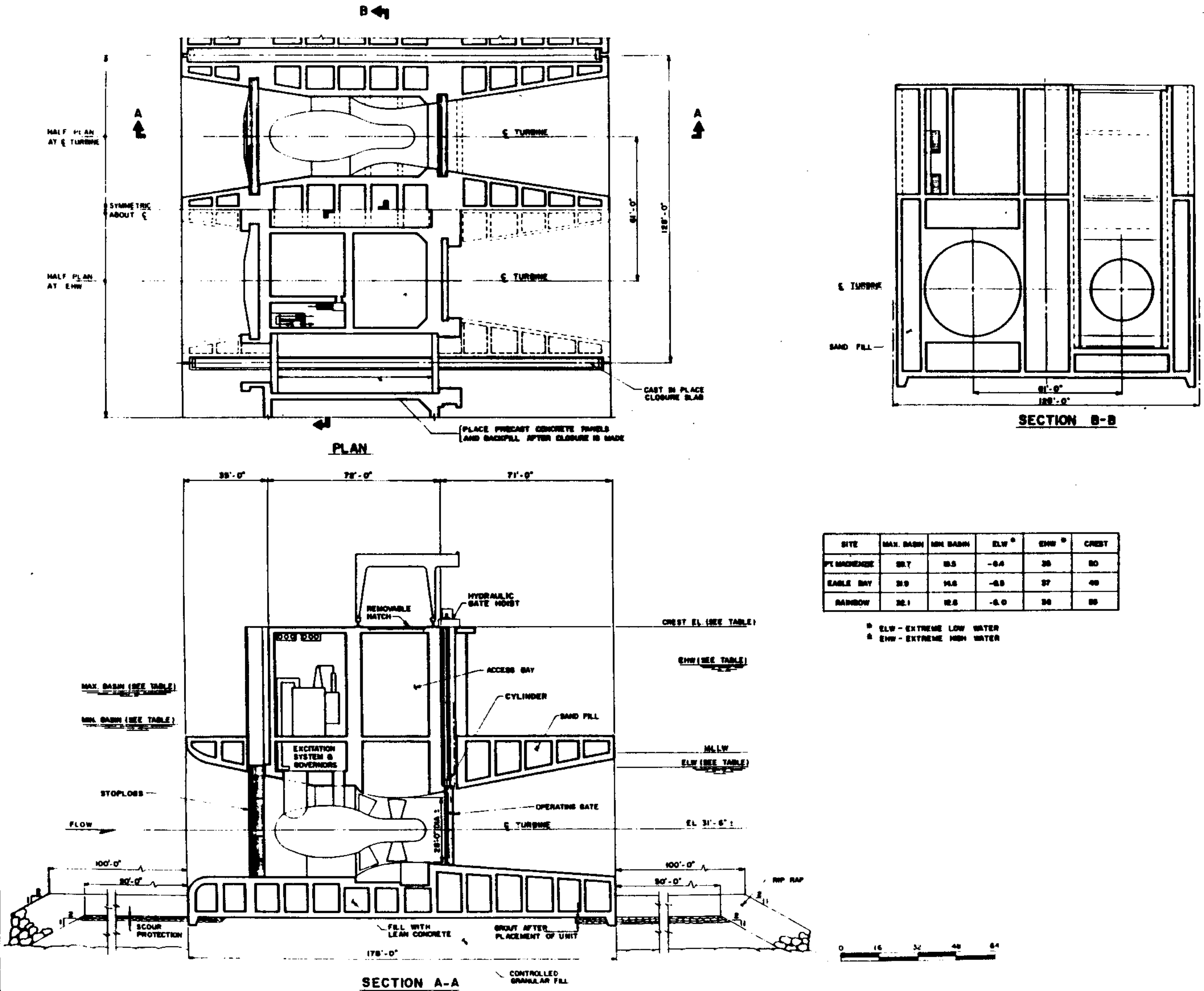
A typical layout for the powerhouse is illustrated on Figure 5-6. Site profiles, sluiceway layouts, and other technical drawings appear in Appendix 8. Throughout the conceptual design process, account was taken of constructability aspects. Only construction techniques and equipment within the state of the art were considered.

5.5.3 - Dike Design

Dikes are necessary for both access and closure sections. Significant design requirements in the dike sections are that they can be constructed under the extreme tidal conditions in Cook Inlet and that seepage through the section be controlled within limits imposed by safety and the necessity to maintain basin levels higher than sea level for periods of eight hours or so. A typical dike cross section is illustrated in Figure 5-7.

During construction operations, the first sections placed will be the sea side of the rockfill zone (appearing on Figure 5-7 as zone (4)) and portions of the transition zone (appearing as zone (2) in Figure 5-7). Consistent with techniques commonly found in construction of conventional breakwaters, zone (4) materials will provide a measure of protection as succeeding zones are placed. The material sizes will include boulders up to 5 feet in diameter because of high tidal velocities which will be encountered during closure operations. Complete closure is achieved before additional transition zone materials are placed on the basin side of the rockfill slope.

It will be noted on Figure 5-7 that the access dike also accommodates a tunnel for the electrical conductors (SF_6 bus) which carry energy from the generators to a switchyard.



NOTES

1 ALL ELEVATIONS ARE REFERENCED TO MLLW. ELEVATION 0 AND ARE IN FEET

2 SERVICE BAY WILL BE PROVIDED AT EVERY 16th POWERHOUSE UNIT

SITE	MAX. BASIN	MIN. BASIN	ELW *	EHW *	CREST
PT MACKENZIE	28.7	18.5	-8.4	36	50
EAGLE BAY	31.9	14.6	-6.5	37	40
RAINBOW	32.1	12.6	-6.0	34	55

* ELW - EXTREME LOW WATER

* EHW - EXTREME HIGH WATER

0 16 32 48 64

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POWERHOUSE STRUCTURE

FIGURE 5-6

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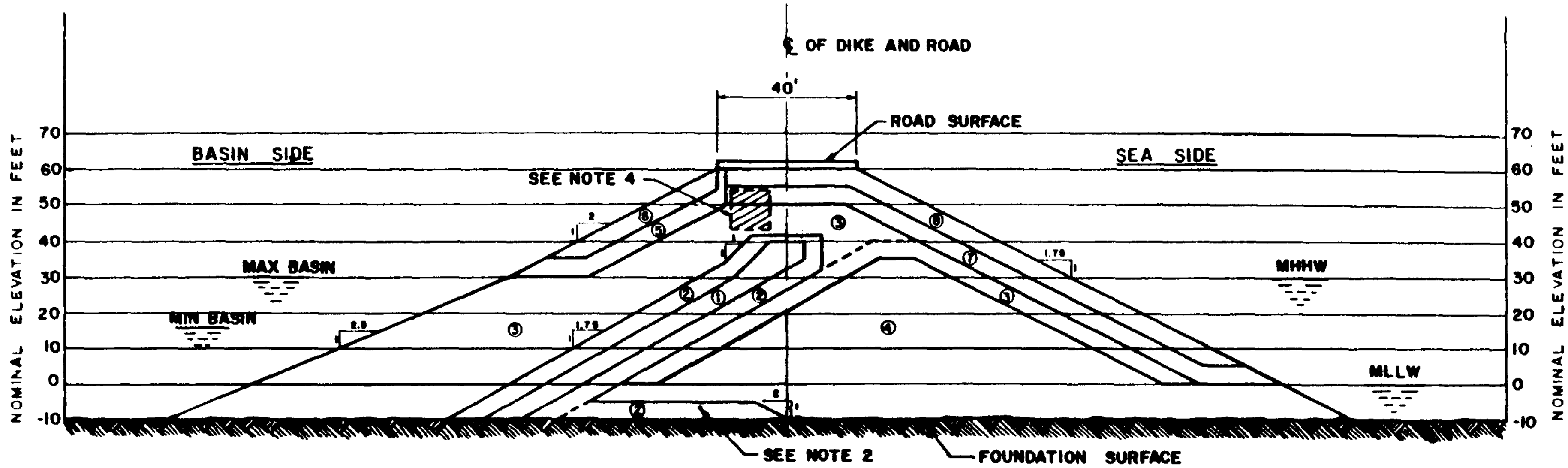

LEGEND	
①	CORE ZONE (SAND & GRAVEL)
②	TRANSITION ZONE (CRUSHED ROCK OR EQUIVALENT)
③	ROCK FILL ZONE (QUARRY RUN)
④	ROCK FILL ZONE (BOULDERS UP TO 5-ft DIAMETER)
⑤	ARMOR BEDDING ZONE: BASIN SIDE
⑥	ARMOR ZONE: BASIN SIDE
⑦	ARMOR BEDDING ZONE: SEA SIDE
⑧	ARMOR ZONE: SEA SIDE

SITE NAME	MAX BASIN	MIN BASIN	MHHW	MLLW	CREST EL. OF CLOSURE DIKE (FEET)	CREST EL. OF ACCESS DIKE (FEET)
PT. MACKENZIE	28.7	18.5	28.6	0	45	53
EAGLE BAY	31.9	14.6	30.5	0	45	50
RAINBOW	32.1	12.6	29.7	0	49	59

NOTES:

1. PROPOSED DIKE SECTION ASSUMES A COMPETENT FOUNDATION SURFACE.
2. AN INVERTED FILTER WILL BE REQUIRED UNDER THE ROCK FILL TO CONTROL PIPING WHERE THE DIKE FOUNDATION IS COMPOSED OF FINE SEDIMENTS.
3. PLACEMENT OF THE BACKFILL WILL BE BY THE VERTICAL CLOSURE METHOD.
4. PROPOSED SF_6 BUS TUNNEL FROM POWERHOUSE TO SWITCHYARD IN ACCESS DIKE ONLY.

30 0 30 60

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ACCESS/CLOSURE DIKE
TYPICAL CROSS SECTION

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FIGURE 5-7

5.5.4 - Bridge and Causeway Crossing

The tidal power facility can provide vehicular access across the barrage if a bridge section is used over the powerhouses and sluiceways and if a roadway is built atop a widened and raised dike section. As may be seen from the typical cross section of the dike in Figure 5-7, only a 40-foot roadway is provided to serve operation and maintenance needs for a tidal plant. If general public access is to be allowed, the dike would be raised and the roadway would be widened to permit 44-foot clearance for one lane of traffic in each direction. Details of the bridge and causeway crossing are provided as Figure 5-8.

It is clear that a combined tidal power facility/causeway could be constructed for significantly less than two separate facilities. It is also clear, however, that while a tidal power plant can accommodate vehicular traffic at a small cost increase, the addition of a tidal power plant to an initial vehicular crossing offers less potential for cost savings unless provisions are made at the outset for a future tidal power installation. Important scheduling impacts and extreme financing problems apply in this latter case.

5.5.5 - Construction Methods

An overview of applicable construction methods is provided as Appendix 9. The general construction sequence is as follows:

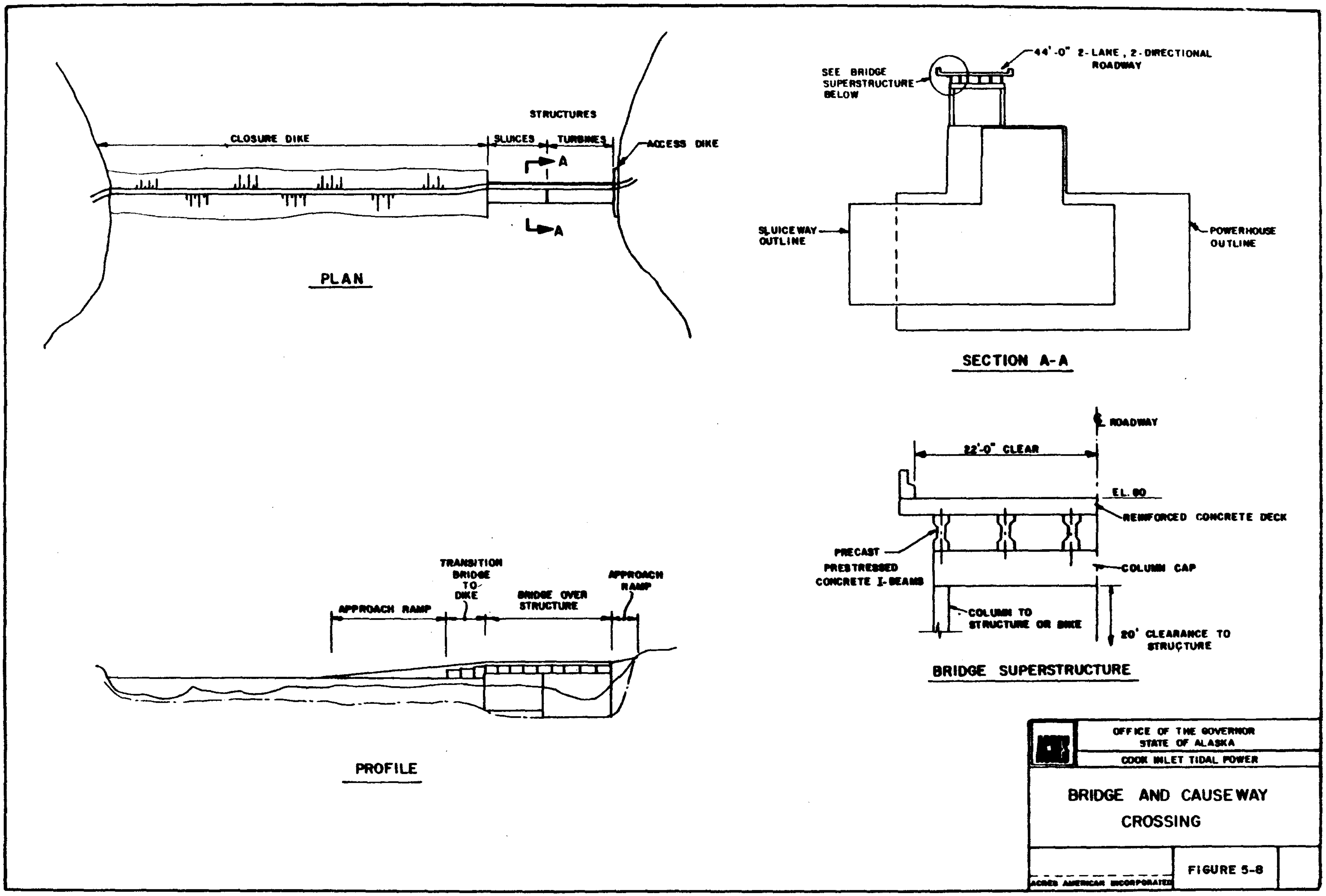
(i) Construct the access dike and dry dock facilities.

The access dike for the Rainbow and Eagle Bay sites will be constructed at the outset. Because of closure velocity limitations, a temporary bridge will provide access to powerhouse units at the Point MacKenzie site. Concrete crib structures filled with rock retain the access dike at the point where the first powerhouse caisson will be placed. Concurrent with access dike construction is the construction of dry docks and wharf facilities. It is from the dry docks that caissons will be floated to the point where they are placed in the structure or to a wharf for temporary storage when conditions do not favor immediate placement.

(ii) Dredge a channel and prepare the foundation base.

Because of shallows near the shore at each of the three sites, a channel must be dredged from the dry dock and wharf location to deeper waters where caissons will be placed. Major dredging requirements also exist to ensure removal of unsuitable materials.

(iii) Construct prefabricated powerhouse and sluiceway units and float into position.


STRUCTURES
CLOSURE DIKE
SLUICES
TURBINES
ACCESS DIKE
A
A
PLAN
SEE BRIDGE SUPERSTRUCTURE BELOW
44'-0" 2-LANE, 2-DIRECTIONAL ROADWAY
SLUICEWAY OUTLINE
POWERHOUSE OUTLINE
SECTION A-A
TRANSITION BRIDGE TO DIKE
APPROACH RAMP
BRIDGE OVER STRUCTURE
APPROACH RAMP
PROFILE
℄ ROADWAY
22'-0" CLEAR
EL. 80
REINFORCED CONCRETE DECK
PRECAST PRESTRESSED CONCRETE I-BEAMS
COLUMN CAP
COLUMN TO STRUCTURE OR DIKE
20' CLEARANCE TO STRUCTURE
BRIDGE SUPERSTRUCTURE
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STATE OF ALASKA
COOK INLET TIDAL POWER
BRIDGE AND CAUSEWAY CROSSING
ACRES AMERICAN INCORPORATED
FIGURE 5-8

Special forms and a number of modern, time saving construction methods (e.g., steam curing, quick stripping) permit fabrication of caissons under factory conditions using mass production methods. As units are completed, the dry dock is flooded and completed caissons are floated to the holding area at the wharf or directly into place.

(iv) Complete construction of powerhouse and sluiceway units and install equipment.

As may be seen from Figure 5-6, caissons are honeycombed with individual cells to facilitate floatation. These interior cells will be filled with lean concrete or sand when the unit is moved into position. Sluiceways will be kept open as construction proceeds to permit some reduction in high closure velocities which will otherwise be experienced. Staged development at any of the three selected sites can be accommodated by placing all powerhouse caissons initially, installing mechanical and electrical equipment only in an initial group of powerhouses.

(v) Construct the closure dike.

Self-propelled bottom-dump vessels will place the rockfill zone of the dike section in horizontal levels until insufficient draft for the vessel is reached. Succeeding layers will be placed from a walking platform on which a large crane operates. Final layers of the closure dike can be placed by end dumping after the crest rises above expected high tide levels. Transition zones, other materials on the basin side, and armoring of slopes will be placed after complete closure is achieved with the rockfill section.

SECTION 6 - COST ESTIMATES AND SCHEDULES

6.1 - Site-Specific Costs

Based upon analysis of comprehensive Bay of Fundy estimates, quantity takeoffs from conceptual designs, and information obtained from major manufacturers and dredging firms, base case cost estimates were developed for each site. These estimates are summarized in Table 6-1 and are presented in more detail in Appendix 9. All prices reflect cost levels as of June 1981 and January 1982 in the Anchorage area.

Reasonably conservative judgements were made where data gaps existed, particularly with respect to geotechnical conditions at each site. In light of the fact that much more field data has been collected for the Susitna Project than for Cook Inlet Tidal Power, a contingency allowance was set at 25 percent of the total estimate (as compared to 20 percent for Susitna). While the values presented in Table 6-1 are considered to be the most likely costs for each site, deviations up to 25 percent in either direction* are considered possible. A major feasibility study including a detailed field investigation program would be necessary to improve estimating precision.

6.2 - Schedules

Although partial operation of a tidal power plant may be possible even while additional turbine generator equipment is being installed, the earliest expected final completion dates for full development of optimized plants are 1997 for Rainbow (928 MW), 2000 for Eagle Bay (1440 MW), and 2001 for Point MacKenzie (1260 MW). A significant portion of the schedule in each case is devoted to satisfaction of regulatory requirements. Indeed, it is not anticipated that a license will be awarded by the Federal Energy Regulatory Commission (FERC) until late in 1989.

There is a possibility that staged development at any of the sites could permit earlier dates for initial "power on line." Even so, operation earlier than 1995 is not considered likely in any case.

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* Potential cost savings relate to possible equipment improvements (see paragraph 5.3.2); marine disposal of dredged materials in lieu of containment (see paragraph 7.3); conservative assumptions as to foundation conditions (see Section 11); usefulness of dredged materials (see paragraph 7.3); and other considerations.

TABLE 6-1

SUMMARY COST ESTIMATES
(June 1981 Cost Levels, $ Million)

	Item	Rainbow (40 Turbines)	Eagle Bay (60 Turbines)	Point MacKenzie (60 Turbines)
1.	Lands	20	20	20
2.	Site Preparation	18	32	29
3.	Access Dike	10	17	123
4.	Units			
	Powerhouses	1,016	1,470	1,480
	Sluices	261	383	517
5.	Sluice Extension, Fishways	25	25	25
6.	Closure Dike	283	312	82
7.	Transmission	120	120	101
8.	Locks	---	---	191
9.	Subtotal	1,753	2,379	2,568
10.	Contractor Facilities	228	309	334
11.	Total Direct Costs	1,981	2,688	2,902
12.	Engineering, Management Owner's Costs at 12.5%	248	336	363
13.	Contingency at 25%	495	672	726
	CAPITAL COST TOTAL, JUNE 1981	$2,724	$3,696	$3,991
	CAPITAL COST TOTAL, JANUARY 1982	$2,819	$3,825	$4,131
	CAPACITY (MW)	928	1,440	1,260
	CAPITAL COST PER INSTALLED KW, JUNE 1981	$2,935	$2,567	$3,167
	CAPITAL COST PER INSTALLED KW, JANUARY 1982	$3,037	$2,656	$3,279

SECTION 7 - PRELIMINARY ENVIRONMENTAL ASSESSMENT

7.1 - Introduction

Construction of a tidal power plant anywhere in Cook Inlet will inevitably lead to change in the physical setting and will in turn impact environmental resources there. A major environmental field data collection and analysis program is necessary in order to define these impacts with reasonable precision. Such a program should be included in a detailed feasibility study in the event that the State of Alaska later chooses to proceed with tidal power development.

A preliminary environmental assessment was conducted to

(i) Gain a macroscopic understanding of physical processes in Cook Inlet;

(ii) Identify sensitive and important components of the natural environment;

(iii) Forecast the change in the natural environment which might result from construction of a tidal plant; and

(iv) Identify requirements for further more detailed environmental study.

The preliminary environmental assessment is presented in Appendix 10 to this report.

7.2 - Unique Effects

Many of the effects of tidal power development are essentially the same as those which would be experienced by construction of any major marine project. Dredge and fill, access and traffic and disruptions during construction all fall into this category. In addition, however, a tidal power facility would produce unique and important changes stemming from the nature of its operation.

Lands bordering the Inlet are alternately inundated and exposed as the tides rise and fall. Closest to the extreme low tide level are lands which only occasionally are exposed and drained. By the same token, areas extending away from the shores of the Inlet may be only rarely submerged during periods of highest high tides. Operation of a tidal power plant would permanently alter this natural condition because (1) the basin level upstream of a tidal power barrage would normally not fall as low nor rise as high as under natural conditions and (2) the average basin level would be maintained above mean tide level.

Hydraulic characteristics would also be altered. Currents, erosion processes, sedimentation deposition, ice formation and movement are examples.

Under ebb tide generation, mud flats bordering proposed basin areas could diminish and marshland vegetation could encroach seaward. It follows that habitat for waterfowl, shore birds and miscellaneous species will change.

Evaluation of expected change and determination of resulting beneficial or deleterious impacts will depend upon rigorous field studies. Furthermore, because of the complex nature of physical processes now occurring in Cook Inlet, there is much to be said for developing a hydraulic and/or a mathematical model in much the same way as has been accomplished elsewhere for other important estuaries (e.g., the Chesapeake Bay, San Francisco Bay).

Consideration must be given in the design of tidal power plants to the need for safe passage of migratory fish runs as well as for protection of marine mammals which normally frequent areas selected for tidal power development.

Table 7-1 summarizes the potential interaction between a tidal plant and elements of the environment.

7.3 - Short-Term and Local Effects

In addition to unique long-term impacts summarized in the preceding paragraph, construction activities will introduce important short-term effects which can be reduced by careful construction management.

Dredging, particularly at the Eagle Bay and Rainbow sites, will require the removal of about 30 million cubic yards of sediments. It is not anticipated that most of this material will have any useful value as a construction material.* A major disposal effort is required. Although organic and chemical pollutants are not likely to be present, studies will have to be made of the effects of marine dumping on bottom organisms. Three disposal methods were considered in this study: (1) marine dumping, (2) enclosed landfill areas, and (3) use of suitable materials for construction. For estimating purposes, a disposal area contained by dikes or cellular cofferdams was tentatively located near the dredging site.

Site development will require access from both land and sea for heavy equipment. Careful selection of access routes will be necessary to avoid sensitive areas.

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* The assumption as to lack of value is taken in the interest of conservatism. It is worth noting that when the U.S. Army Corps of Engineers dredged a shoal southwest of Anchorage in Cook Inlet in 1976, surprisingly large quantities of cobbles and clean, well-graded granular materials were found.

Good environmental practices during construction should include noise reduction measures, erosion control, proper disposal of wastes and landscaping of borrow and quarry areas.

7.4 - Environmental Constraints

No environmental impacts have been identified which would be so severe as to preclude development of tidal power at Eagle Bay, Point MacKenzie, or Rainbow. On the other hand, it would be premature to assert that tidal power development will be environmentally acceptable. Detailed environmental studies in parallel with technical feasibility studies are considered necessary and appropriate before a decision is made to construct a tidal power facility in Cook Inlet.

TABLE 7-1 - POTENTIAL INTERACTION BETWEEN THE TIDAL PLANT AND ELEMENTS OF THE ENVIRONMENT

TIDAL PLANT FACILITIES AND CONSTRUCTION ACTIVITIES	ELEMENTS OF THE ENVIRONMENT																						
	TOPOGRAPHY/BATHYMETRY	MINERAL RESOURCES	SOIL	DRAINAGE & SURFACE RUNOFF	GROUND WATER	TIDAL REGIME	FRESH/SALT WATER INTERFACE	PHYSICAL OCEANOGRAPHY	SEDIMENTATION/EROSION	WATER CHEMISTRY	AQUATIC ECOSYSTEMS	MIGRATING AQUATIC SPECIES	BENTHIC ECOSYSTEMS	INTERTIDAL ZONE PRODUCTIVITY	WETLAND VEGETATION	WETLAND WILDLIFE HABITAT	UPLAND VEGETATION	UPLAND WILDLIFE HABITAT	CLIMATE	AIR QUALITY	NOISE AND VIBRATION	ICE FORMATION	SURFACE WATER HYDROLOGY
CONSTRUCTION ACTIVITIES																							
SITE DEVELOPMENT - LAND BASED																							
CLEARING, GRADING, SURFACE EXCAVATION, BUILDING STRUCTURES, MATERIAL STORAGE	●		●	●	●				●	●	●				●	●	●	●		●	●		●
ROAD, RAIL SPUR CONSTRUCTION	●		●	●	●				●	●							●	●		●	●		
EXCAVATION FOR ABUTTMENTS	●		●	●	●				●	●				●	●	●	●	●		●	●		
MATERIAL PLACEMENT	●		●	●	●				●	●				●	●	●	●	●		●	●		
OPERATE LAND BASED MARINE EQUIPMENT	●		●	●	●			●			●		●	●	●	●	●	●			●	●	
WORKER FACILITIES AND USE	●		●	●	●					●						●	●	●					
SITE DEVELOPMENT - MARINE																							
PILE DRIVING	●		●					●	●		●	●	●	●	●	●		●			●	●	
INTERTIDAL CONSTRUCTION ZONE	●		●	●				●	●	●	●	●	●	●	●	●	●	●		●	●	●	
DREDGING	●		●					●	●	●	●	●	●	●	●	●					●	●	
MATTRESS/DIKE PLACEMENT	●		●					●	●	●	●	●	●	●	●	●					●		
TUG AND BARGE OPERATION	●									●	●	●								●	●	●	
CAISSON STORAGE AND TRANSPORT	●							●	●		●	●	●	●							●	●	
CAISSON INSTALLATION	●							●	●		●	●	●								●	●	
STATIONARY MARINE EQUIPMENT	●							●	●	●	●	●	●	●							●	●	
MECHANICAL/ELECTRICAL EQUIPMENT INSTALLATION																				●	●		
SITE ACCESSIBILITY																							
ROAD, RAIL TRANSPORT OF PERSONNEL, MATERIALS, OR EQUIPMENT			●														●	●		●	●		
MARINE TRANSPORT OF PERSONNEL, MATERIALS, OR EQUIPMENT								●		●	●			●	●	●					●	●	
REMOTE CONSTRUCTION FACILITIES																							
CONSTRUCTION MATERIAL SOURCE AREAS	●	●	●	●	●												●	●		●	●		
DREDGE DISPOSAL SITES - UPLAND	●		●	●	●												●	●		●	●		
DREDGE DISPOSAL SITES - MARINE	●							●	●	●	●	●	●	●									
OPERATION OF PERMANENT FACILITIES																							
ACCESS AND CLOSURE DIKE (PRESENCE)	●			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●				●	●
PHYSICAL ESTUARY BARRIER	●				●	●	●	●	●	●	●	●	●	●	●	●			●			●	●
POWERHOUSE AND SLUICEWAY (PRESENCE)						●	●	●				●	●									●	
TURBINE OPERATION						●	●	●	●	●		●									●	●	●
SLUICEWAY OPERATION	●					●	●	●	●	●		●									●	●	●
POWER FACILITIES (PRESENCE)	●			●													●	●				●	
SWITCHYARD OPERATION																					●		
DRYDOCK AND DOCK FACILITIES (PRESENCE)	●			●					●	●	●		●	●	●	●						●	
LONG-TERM OPERATION										●	●			●		●			●		●	●	
IMPOUNDMENT (PRESENCE)	●			●	●	●	●	●	●	●	●	●	●	●	●	●			●			●	●
WATER LEVEL FLUCTUATION	●		●	●	●	●	●	●	●	●			●	●	●	●			●			●	●
LOCKS (PRESENCE)													●									●	
OPERATION								●	●			●	●								●	●	
SITE ACCESS (PRESENCE)	●			●										●	●	●	●	●					●
ROAD, RAIL SPUR USE																	●	●		●	●		
MARINE USE								●		●	●			●	●	●				●	●	●	
WORKER FACILITIES (PRESENCE)	●			●								●					●	●					
USE OF WORKERS					●							●									●		

● INDICATES POTENTIAL FOR INTERACTION BETWEEN ENVIRONMENTAL ELEMENT AND PLANT COMPONENT.

SECTION 8 - SOCIOECONOMIC ASSESSMENT

8.1 - Introduction

Development of tidal power at any of the three selected sites would be characterized by three distinct stages, each of which would lead to certain socioeconomic impacts:

(i) An initial pre-construction period of about nine years during which detailed investigations would be accomplished. Total labor force involvement during this stage would consist largely of professional engineers and scientists and would peak at 200 to 300 persons. No significant adverse socioeconomic impacts on the community are likely to be felt during this period.

(ii) Intense construction, manufacturing and support activities would take place for a period of 7 to 12 years, involving large direct and indirect work forces.

(iii) Tidal plant operation following construction would involve only a small direct labor force. On the other hand, long-term socioeconomic impacts would result from the availability of energy at relatively stable prices, the potential for industrial growth, improved access to the far shore across Knik or Turnagain Arm, and changes in recreation and tourism in the area.

A socioeconomic assessment dealing primarily with stages (ii) and (iii) is provided as Appendix 11. Results are summarized in this section.

8.2 - The Construction Period

A preliminary estimate of work force requirements indicates that an average of 1875 man-years per year would be the direct on-site labor requirement at Rainbow for a period of 7.5 years. Corresponding figures for full development of Eagle Bay are 2000 man-years and 10.5 years; and for Point MacKenzie, 2500 man-years and 11.5 years. Indirect labor for the supply of raw materials would employ 300 to 400 persons per year for any of the three sites.

These requirements correspond to about 3 percent of the total labor force and about 50 percent of the construction labor force as it existed in the Anchorage-Matsu region in March 1981.

Raw materials such as aggregate and rock will be quarried and crushed locally. Steel products, cement and lumber will probably be supplied from outside sources. It is assumed that turbines, generators and other equipment will be manufactured elsewhere in North America or in Europe.

Even so, an opportunity to consider the potential for manufacturing hydroelectric equipment in Alaska is available since a tidal plant alone may require as many as 60 large turbines and a large potential for other hydroelectric development also exists in Alaska. No study of in-State manufacture was conducted, however.

8.3 - The Operation Period

A tidal power plant can also serve as a causeway either across Turnagain Arm (the Rainbow site) or across Knik Arm (Point MacKenzie or Eagle Bay sites). Perceived advantages for better land access to the Kenai Peninsula or to the Beluga area have been addressed in earlier studies of potential vehicular crossings. The Knik Arm sites in particular would provide a stimulus for rapid land development on the west shore. Mineral development, industrial development and increased recreational pressures would be likely consequences of a Knik Arm crossing.

Based on experience at the La Rance tidal power plant in France, a tidal power plant within easy driving distance of Anchorage would probably become a major tourist attraction.

The extent to which industrial growth is a necessary consequence of tidal power development depends upon the development level selected at a given site. The Rainbow site and a reduced scale development at the Eagle Bay site are constrained cases which meet expected energy demands without unusual industrialization.

SECTION 9 - REGULATORY EVALUATION

A variety of federal, state and local licenses and permits must be obtained before construction of a tidal power plant can commence (see Table 9.1). Insofar as a major license from the Federal Energy Regulatory Commission (FERC) is concerned, development of tidal power is most analogous to development of a large low-head hydroelectric plant on a major river.

Because FERC has jurisdiction, a major feasibility study will be needed as the basis for preparing an acceptable license application. Detailed environmental investigations and rigorous technical evaluations will necessarily be required. Based upon recent major project filings with FERC, it is likely that three to four years will be required to conduct the necessary feasibility study and file an application. An additional 30 months will probably be needed for processing.

A number of additional permits and certifications must be secured from federal, state, and local agencies. While information and documentation requirements are in some cases significant, none of these additional regulatory efforts is expected to occupy the critical path. Appendix 12 provides details on applicable regulatory matters.

It was earlier mentioned that the potential for combining a tidal power plant with a causeway offers opportunity for cost savings. If the most immediate needs of the State would be best served by providing a vehicular crossing in advance of tidal power development, regulatory requirements would require varying lead times depending upon the selected approach:

(i) A vehicular crossing could be built as a causeway incorporating empty caissons which could later be used for installation of turbines and sluices. While some cost savings may accrue if tidal power is ultimately developed, it is probable that a license from FERC will be needed because of the ultimate project purpose. Thus, long lead times as discussed above would apply.

(ii) A vehicular crossing could be built independently of tidal power development. No FERC license would be required, but it is likely that another Federal Agency (possibly the Corps of Engineers) would take the lead insofar as preparation of an environmental impact statement is concerned. Detailed field studies would be required, but it might be possible to satisfy regulatory requirements a year or two sooner than in case (i) above. Furthermore, construction could probably be completed more rapidly. The disadvantage, of course, is that little or no cost sharing between a later tidal power development and the crossing would be possible.

TABLE 9-1

COOK INLET TIDAL POWER
MAJOR REQUIRED PERMITS FOR PROJECT DEVELOPMENT

FEDERAL

- FERC License
- Corps of Engineers

STATE

- Department of Commerce
  - Coastal Zone Certificate of Compliance
- Department of Environmental Conservation
  - Water Quality Certification
- Department of Natural Resources
  - Water Rights
  - Water Quality Certification
  - Tideland Submerged Land Use
  - Right-of-Way or Easement
  - Dam Safety
- Department of Transportation and Public Facilities
  - Encroachment with Highway Right-of-Way
- Department of Fish and Game
  - Anadromous Fish Protection
  - Critical Habitat*
  - Fishwarp*
- Department of Public Safety
  - Building Plan Check

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* May not be needed at some sites.

SECTION 10 - SYSTEM STUDY AND ECONOMIC EVALUATION

10.1 - Use of Raw Tidal Energy

Although relatively large values of annual energy production are possible from each of the three sites considered in this study, the nature of tidal energy is such that it is cyclic in nature. Periods of high energy production are interspersed twice daily with somewhat longer periods when no energy is produced. It is frequently true that more energy can be generated at a site than the existing system can absorb at that particular time. A number of alternatives exist for dealing with this situation. These are discussed briefly below and are presented in more detail in Appendix 13.

Before addressing the question of what can or should be done with "excess" tidal energy, it is useful to review the basis upon which certain portions of energy produced can be absorbed.

In a typical electrical system, the electrical load is not constant during a given day. Demand is usually low during the hours following midnight and it gradually rises to a peak in the late afternoon or early evening. The electrical system itself consists of various types of generating units. Some of these units operate most efficiently when they generate on a relatively uniform and steady basis (baseload generation). Others can be cycled to varying degrees to meet peak loads as they come. Coal-fired steam plants are typical baseload units. Only a few such units operate in the Railbelt. Gas turbines frequently are maintained for peaking. Because of the relatively low costs of Cook Inlet natural gas, much of the electrical energy in the Anchorage area is produced by gas turbines.

A sketch of a stylized demand curve for an example electrical system appears as Figure 10-1. Tidal energy production from a single-basin, single-effect plant is also superimposed on the demand curve. More tidal energy is produced in the morning hours than can be absorbed by the example system, resulting in a significant amount of "excess" energy. The remaining tidal energy is absorbed by the system because cycling units are turned on and off as necessary.

Real electrical systems are not normally as simplistic as the example implies. The Railbelt is no exception. Some units which can be cycled were not designed originally for as many rapid starts and stops as would be required in the example. Other units which can be easily cycled from a technical standpoint are subject to environmental constraints (e.g., hydroelectric plants lend themselves well to rapid load-following but the necessity to maintain certain minimum or maximum flows downstream of the site for fisheries or recreation can restrict usage of hydro for peaking).

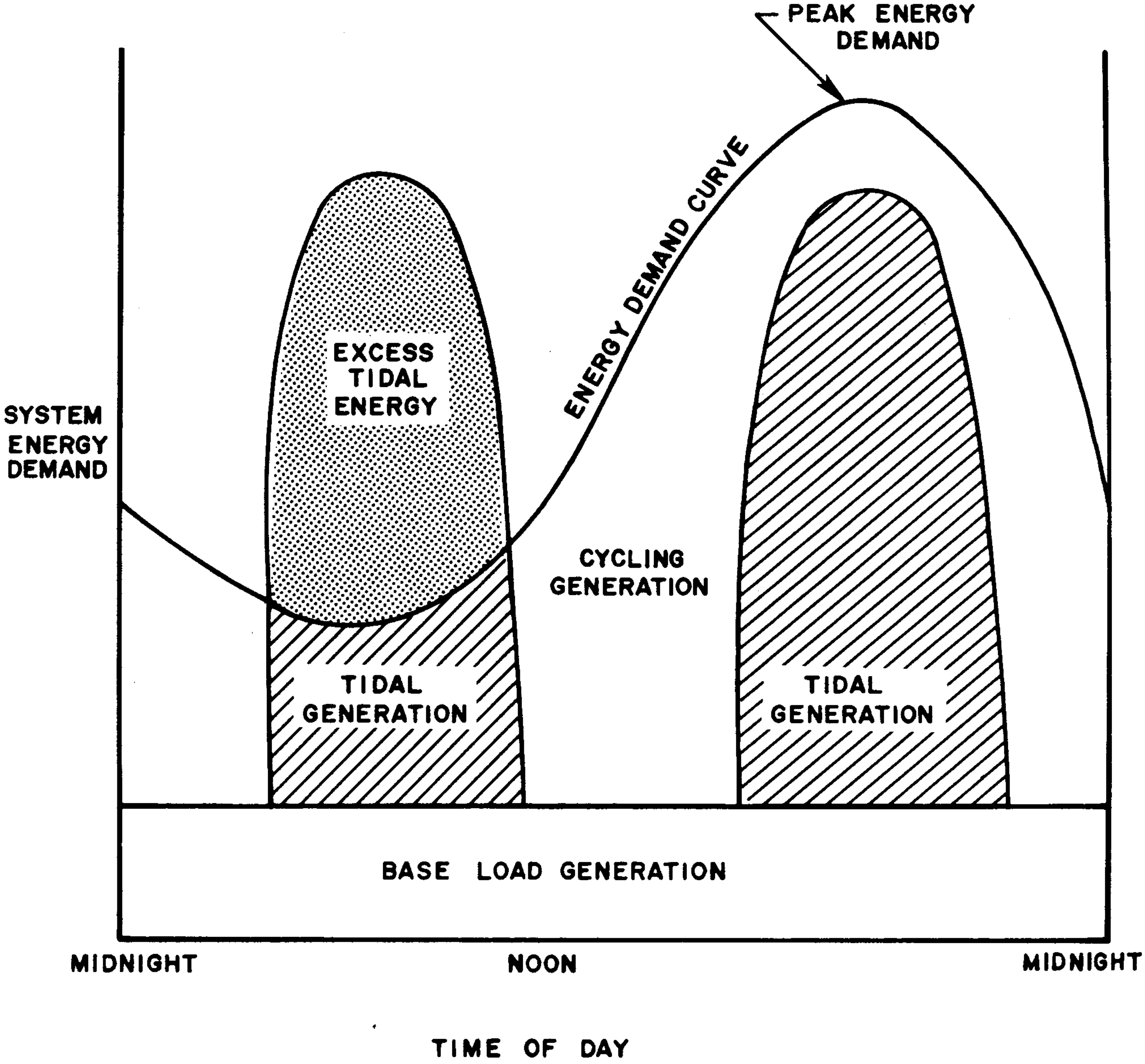

FIGURE 10-1
DEMAND CURVE
FOR AN EXAMPLE
GENERATING SYSTEM

Based upon the configuration of the Railbelt system as it is expected to exist in the late 1990's, estimates were made of the maximum amount of tidal energy which could be absorbed in its raw form and of the "excess" energy which may be available for other purposes.

10.2 - Energy Storage

If a system could be devised for storing "excess" energy for use at later times when system demand is higher, then the "excess" could be converted to usable energy. Fortunately, a variety of schemes exists for this purpose.

Appendix 13 reviews energy storage possibilities and provides estimates of cost penalties which would be incurred if a storage system were constructed. One example involves hydroelectric pumped storage. In simple terms, a high reservoir (perhaps on a mountain) and a low reservoir (possibly Cook Inlet itself) are linked by a hydraulic passage.* When excess energy is available from the system, water is pumped up to the higher reservoir. When energy is required, water flows through hydraulic turbines into the lower reservoir. In practice, the turbines are reversible and alternate between pumping and turbining modes.

The penalty which must be paid for energy storage is relatively high in terms of dollars per installed kilowatt. Thus, economies will be achieved if storage requirements are reduced. A number of possibilities exist in this regard:

(i) The tidal power plant could begin initial operation at less than optimal capacity. (Recall that the optimization process described in Section 5 and in Appendix 6 shows a relatively flat energy cost over a wide range of possible energy output.) As demand grows in future years, additional turbines could be installed accordingly--provided, of course, that provision has been made in the barrage to accommodate such expansion.

(ii) Industries may be identified which can operate effectively on intermittent but regular pulses of energy. (For example, hydrogen production is possible by electrolysis. The hydrogen can then be stored for industry use as appropriate.) Proposed Phase II studies should examine potential industrial users and the compatability of their requirements with tidal energy production.

(iii) A large multi-reservoir hydroelectric project could be operated effectively in the same system as a tidal power plant. In a two dam system, for example, the powerhouse at the lower dam generates energy and releases water in accordance with downstream flow

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* While technically possible, environmental constraints may preclude the storage of saline waters in natural or man-made reservoirs on mountains near Cook Inlet.

regulations established in concert with resource agencies. The powerhouse at the upper dam could operate during periods when no tidal energy is produced and be turned off when tidal energy is being fed into the system. The proposed Susitna Hydroelectric Project could serve well in this role. Definition of appropriate capacities at Watana (the upper dam in the Susitna Project) and net benefits associated with combined operations can be accomplished by merging tidal energy production programs developed in this study with hydroelectric energy generation programs used on Susitna. (Note that in this Phase I study of Cook Inlet tidal power, it was not assumed that the Susitna Project would exist in the late 1990's. Tidal power was evaluated as an alternative whose benefits would be measured against the conventional generation system which would probably evolve in the Railbelt in the absence of the Susitna Project--corresponding to the "without Susitna" case in the Susitna studies.)

(iv) In addition to identifying industries which can absorb intermittent energy (see (ii) above), it is also true that encouragement of electrical energy-intensive industries in general would result in increased demand (corresponding to the high ISER forecast or higher). In the sample system illustrated in Figure 10-1, the net effect would be to raise the energy demand curve and possibly reduce the "excess" tidal energy.

(v) Depending upon the extent of industrial growth, it is possible to contemplate an unconstrained case wherein the Rainbow site on Turnagain Arm and the Eagle Bay site on Knik Arm are operated on alternate tides (one turbining on ebb tide and one on flood tide). The resultant total tidal energy generation would be such that cyclic "pulses" of energy from one would occur roughly at times when the other is not producing energy. Even so, some periods of no energy production would remain. Double-effect operation is also possible and may offer advantages in the unconstrained case over the two single-effect basins. The value to potential industrial users should be tested during Phase II industrial studies.

A subtle but important issue insofar as energy storage is concerned is the fact that variations from spring to neap tides occur over much longer periods than conventional storage systems are normally equipped to accommodate. That is, the excess energy which may have been available during a period of high tidal range must be held for a week or more to offset later lower tidal ranges.

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* These values are consistent with those specified by the Alaska Power Authority for economic evaluation of potential hydroelectric developments.

10.3 - Project Economics

Preliminary estimates were made of the way in which tidal energy costs compare with those associated with more conventional generating plants. An economic analysis in 1981 dollars (0 percent inflation, 3 percent real cost of capital) suggests that in the absence of retiming (energy storage) tidal energy costs would likely be competitive with thermal generation costs in the late 1990's.

A "worst case" analysis suggests that if a tidal plant were developed to its optimal capacity by about 2000, if the mid-range forecast were followed, and if all of the calculated "excess" energy must be retimed, tidal energy may be initially about 50 percent to 75 percent more expensive than energy generated by more conventional means. Based on the alternatives for reducing energy storage requirements cited in the preceding paragraph, this "worst case" is not likely to be realized. Phase II studies of industrial users would assist in defining the extent to which retiming costs might be avoided or reduced. Phase III engineering studies could then include a more precise site specific retiming facility (if required) together with associated costs.

10.4 - Constrained and Unconstrained Cases

It was noted in Section 4 that during the site selection process, Rainbow and Eagle Bay were chosen as likely candidates to meet Railbelt System demand without major industrial growth (the constrained case). Point MacKenzie was selected because it had the potential for supporting industrial energy needs over and above those assumed in ISER's "most likely" forecast (the unconstrained case). As the analysis proceeded, however, certain important changes occurred:

(i) The potential requirement to accommodate closure velocity limitations at Point MacKenzie resulted in a reduction from the original gross estimate of 6000 GWh annual energy to 3937 GWh, putting Point MacKenzie near the arbitrary 4000 GWh borderline which had been selected to divide constrained from unconstrained cases. Even if the closure constraint were removed (possibly by stacking two turbines vertically where depths permit), the at-site optimum energy would only be about 5000 GWh at Point MacKenzie.

(ii) The favorable nature of the site conditions at Eagle Bay is such that the initial gross estimate of 3500 GWh was increased in the simulation runs to 4037 GWh.

Eagle Bay is favored over Point MacKenzie for consideration as the unconstrained case. It would have lower energy costs, would not require navigation locks to support ocean traffic, would be further removed from areas sometimes frequented by Beluga whales and would not impose major changes on important habitat at Eagle Bay and Goose Bay.

Insofar as the constrained case is concerned, Rainbow at 2664 GWh lies within the expected forecast range. On the other hand, the installed capacity at Eagle Bay can be reduced below the apparent optimum if less energy is needed.

A reduced capacity project at Eagle Bay was considered. A 30 powerhouse project there would have a total capital cost of $2,803,000,000 and would produce 2300 GWh annual energy. Mill rates for the reduced capacity Eagle Bay are competitive with an optimally developed Rainbow project if the need for some retiming is found in succeeding phases.

10.5 - Fuel Escalation

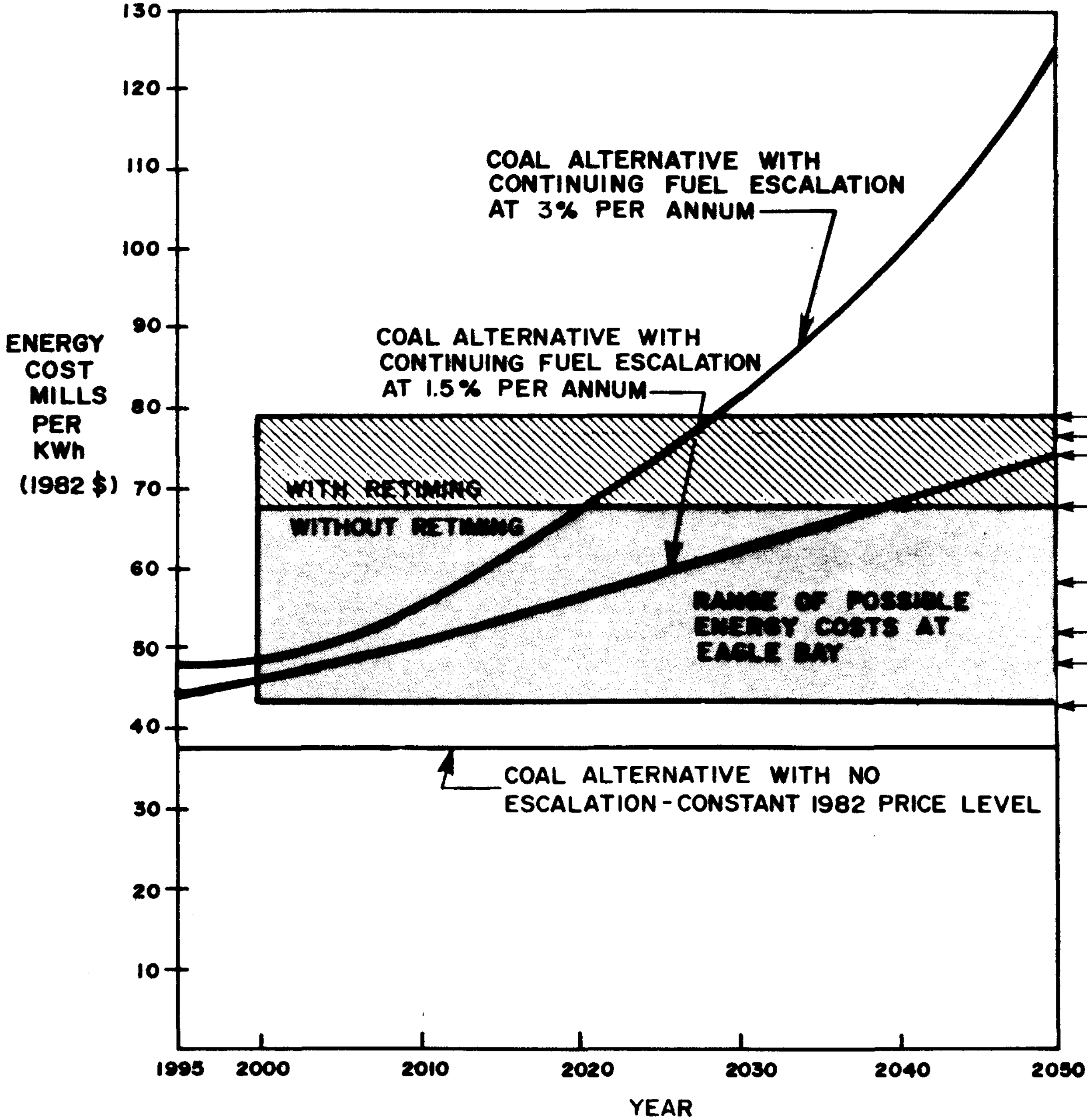
If the price of coal continues to escalate after 1995, a variety of possible Eagle Bay developments will become increasingly more attractive from an economic standpoint. The attractiveness is dependent upon the rate of real escalation. At a real rate of 1.5 percent, suggested in the Battelle Energy Alternative Study, coal costs are at or below tidal power costs for project life. At double this rate or 3 percent, the tidal plant has some advantage in later years of project life. Figure 10-2 compares energy costs of the coal alternative (including fuel escalation) to Eagle Bay energy costs for 50 years of project life, and for fuel escalation which continues perpetually. (Note that the levelized coal energy costs appearing in tables in Section 2 were based on an assumption of zero escalation after 2005.)

10.6 - Marketing and Financing

A review of the existing La Rance tidal power plant and of proposed installations at Passamaquoddy and in the Bay of Fundy resulted in the identification of important finance and marketing issues. Results of this effort are provided in Appendix 15.

Perhaps the most important considerations have to do with the high front-end loading of a capital intensive project. Simply stated, major investments have to be made well in advance of project revenues and high debt services will impact the costs of power. Long-term stability in tidal energy costs is possible, but costs in the early years of operation are likely to exceed the costs of alternative energy generation.

The State has recognized this problem and has established a program of financial assistance for power projects. Further analysis of financial issues should be closely coordinated with the State.



MILL RATE	NO. TURBINES	CAUSEWAY BENEFIT	RETIMING
79	60	NO	YES
76	30	NO	YES
74	60	YES	YES
68	30	YES	YES
58	30	NO	NO
52	30	YES	NO
48	60	NO	NO
43	60	YES	NO

FIGURE 10-2
THE EFFECTS OF COAL COST ESCALATION ON ECONOMICS OF ALTERNATIVE EAGLE BAY DEVELOPMENTS

SECTION 11 - RISK ASSESSMENT

Because field investigations specifically oriented toward tidal power production have not yet been made, much of the technical evaluation in this study relied upon extrapolations from available data and upon rational assumptions. While a conscious effort was made to maintain a degree of conservatism in the selection of preliminary design criteria, it is nonetheless true that uncertainty as to actual conditions must be reduced significantly before construction of a tidal plant is ever started.

One example of the importance of reducing uncertainties may be found in assumptions regarding the depth at which competent foundations will be found. The total direct costs of dredging at the Rainbow site amount to nearly $190 million. When this figure is adjusted for contractor costs and indirect costs, it becomes about $290 million--more than 10 percent of the total capital cost at the site. Subsurface exploration is essential to verify the validity of assumed quantities and costs. Results obtained from a drilling program have the potential for introducing significant changes in project economics--in either direction.

Risks in this preliminary assessment stage are viewed primarily in terms of uncertainties in data and assumptions. During a later feasibility study, it would be possible to assess total project risks.

Appendix 16 provides a preliminary risk assessment as the basis for identifying certain investigation programs which should be undertaken if a detailed feasibility study is conducted. Table 11-1 lists proposed investigation programs which are expected to be required in future.

TABLE 11-1

PROPOSED INVESTIGATION PROGRAMS

Proposed Investigation	Description of Items to be Investigated
1. Investigation of Regulatory Licensing Requirements	- Continued updating of the preliminary application - Preparation of required backup reports
2. Subsurface Exploration	- Geological conditions - Geotechnical conditions - Foundation physical parameters
3. Seismological Investigation	- Fault system - Seismic activity
4. Probability Analysis	- Maximum and minimum tides - Maximum wave height - Seismic event frequency and magnitude - Tsunami wave occurrence and magnitude
5. Investigation of Construction Approach	- Site conditions - Material sources and availability - Construction methods
6. Hydraulic Survey	- Tidal variations - Tide mode shape - Storm surge - Wave height - Shoaling and refraction - Water temperatures
7. Hydraulic Model Studies	- Barrier effect and impact on tides - Tidal current - Sedimentation - Erosion
8. Chemical and Biological Testing	- Identification of harmful chemical composition of existing material when moved to new areas - Determine presence and identify types of biological organisms - Determine presence or absence of endangered species
9. Energy Storage Study	- Storage sites - Storage type
10. System Model Study	- Capital cost - Interest rate - Escalation rates - Operation requirements - Electrical energy growth rates

SECTION 12 - PHASES II AND III

12.1 - Introduction

When the Office of the Governor, State of Alaska, requested proposals on September 23, 1980, to conduct a Phase I Preliminary Assessment of Cook Inlet Tidal Power, it was noted that two additional phases would be considered for future award as follows:

(i) "Phase II is intended to look in depth at the potential industries that appear to have a comparative advantage in association with a Cook Inlet tidal power source," and

(ii) "Phase III would involve a detailed engineering and environmental investigation of site-specific configurations, as well as the preparation of a conceptual development plan."

It was in light of these succeeding phases that a concept for the study of "constrained" and "unconstrained" cases was formulated (see paragraph 10.4). Briefly stated, it was envisaged at the start that tidal power development in the constrained case might be possible simply as an alternative means of satisfying most likely energy demand growth--without providing any unusual impetus for further industrialization in the Railbelt. On the other hand, if the State should choose to encourage industrial growth, some greater level of tidal power development in the unconstrained case might be possible.

As a result of the Phase I study, it has been concluded that tidal power development need not depend upon accelerated industrialization (Conclusion 7, Section 2). A low level development at the Eagle Bay site could be readily matched with anticipated system needs.

12.2 - Phase II Studies

An "in-depth look at potential industries that appear to have a comparative advantage" necessarily implies that an identification process is necessary--in effect, a screening to determine which industries might best use tidal energy in the amounts and at the costs determined in Phase I. Possibilities include aluminum production which may require on the order of 3000 GWh annually and up to 350 MW of power at nearly 100 percent capacity factor for a single modern plant. Industrial users may also be attracted by the possibility that hydrogen production from unretimed excess energy could be accommodated.

Once candidate industries are identified, there is a need to focus more directly upon their specific energy needs and to assess technical problems associated with energy distribution and conversion. Simply stated, there is some cost at which energy in the form acceptable to a particular industry becomes attractive. The costs and the technical difficulties of getting from raw (unretimed) tidal energy to the precise needs of selected industries become crucial considerations.

After initial screening and in-depth consideration of viable candidate industries, the next step in the Phase II studies would be selection of one or more preferred users. This selection would set the stage for choice of the most appropriate tidal plant energy production (which may be more or less than the apparent optimal raw energy of 4037 GWh, depending upon retiming needs, energy costs acceptable to the selected industry, and the like). It would also permit the selection of an appropriate capacity and storage time for an energy storage system if one is required.

This proposed Phase II work provides an important link between Phases I and III. The generic descriptions of energy storage in Phase I should be made site-specific in Phase III. Phase II is necessary as the basis for defining how much storage and what major features are sought.

12.3 - Phase III Studies

Studies proposed for Phase III have three major components:

(i) Development of conceptual site-specific characteristics and potentials of a retiming facility which meets the needs determined in Phase II or which meets the needs of the Railbelt system in the event that Alaska elects not to encourage industrial growth.

(ii) Preparation of a conceptual development plan which includes layouts and descriptions for the tidal plant, storage system, transmission system, road network, caisson prefabrication area, and ancillary facilities.

(iii) An environmental assessment of the proposed conceptual development plan for the entire tidal plant/retiming facility/vehicular crossing system.

Phase III can commence concurrently with Phase II since major portions of components (ii) and (iii) above can be developed in advance of the retiming plant (component (i)). Assuming an early concurrent start, Phases II and III could be completed before March 1, 1982.

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BIBLIOGRAPHY

BIBLIOGRAPHY

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LOCATION OF SELECTED SITES

N

0 5 10 MILES

SCALE 1" = 4 MILES

SELECTED SITES IN UPPER COOK INLET AREA

ACRES

PAINTED BY CHIP DEBELIUS