Corps of Engineers
New England Div.

PASSAMAQUODDY—ST. JOHN

HEARING

BEFORE A

SUBCOMMITTEE OF THE COMMITTEE ON PUBLIC WORKS UNITED STATES SENATE

EIGHTY-EIGHTH CONGRESS

SECOND SESSION

ON

S. 2573

A BILL TO AUTHORIZE THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT, INCLUDING HYDROELECTRIC POWER DEVELOPMENT OF THE UPPER ST. JOHN RIVER, AND FOR OTHER PURPOSES

AUGUST 12, 1964

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PASSAMAQUODDY—ST. JOHN

WEDNESDAY, AUGUST 12, 1964

U.S. SENATE,
SUBCOMMITTEE ON FLOOD CONTROL—RIVERS AND HARBORS
OF THE COMMITTEE ON PUBLIC WORKS,
Washington, D.C.

The subcommittee met, pursuant to call, at 9:03 a.m., in room 4200, New Senate Office Building, Senator Edmund S. Muskie, presiding.

Present: Senators Muskie, Randolph, Gruening, Metcalf, Jordan, Bayh, Salinger, and Fong.

Also present: Representatives Clifford G. McIntire and Stanley R. Tupper.

Senator MUSKIE. The committee will be in order.

I would like to take this opportunity to welcome the Secretary of the Interior and the distinguished gentlemen who have accompanied him here this morning, Congressman McIntire of Maine who has a deep interest in this project in common with the rest of us, and Congressman Tupper of Maine.

I have a brief opening statement designed to define the scope of this hearing here this morning.

Today's hearing opens a new chapter in the long history of the Passamaquoddy tidal power project proposal and the related development of the hydroelectric resources of the Upper St. John River. I want to take this opportunity to thank the chairman of the full Committee on Public Works, Mr. McNamara, for making this hearing possible.

Quoddy and the Upper St. John River have a special meaning for the State of Maine, New England, New Brunswick, and the Maritime Provinces. These two projects represent natural resources of great magnitude, challenging to the mind of man.

We recognize that there is almost a romantic urge to harness the tides of the Bay of Fundy and to tame the power of one of the mighty river systems of the eastern area of this continent.

There is, also, the desire to restore an area beset by adversity, where the unemployment rate ranges as high as 25 percent. Here is one of the most beautiful sections of our country, peopled by hearty pioneers, suffering in a stagnant economy rather than enjoying the benefits of our national economic growth.

Those of us who are concerned with the future of this corner of the United States and of Canada see the Quoddy-St. John project as a vital link in the long-term expansion of our economy.

It makes sense as resource utilization, it is essential to the revitalization of a sagging local economy, and it opens the door to the integration of a natural economic unit, including the New England States and the Canadian Maritime Provinces.

But we recognize that a project of this magnitude must be based on facts, not hope; on practical plans, not dreams. This project must stand or fall on its merits. That is why we have had the professional engineering studies. That is why we are opening congressional hearings. Today's hearing is limited to the consideration of the technical studies completed by the Department of the Interior and of the U.S. Corps of Engineers. In the next Congress, we plan to expand these hearings to encourage comments by other Government departments and to hear public witnesses. We intend to make as complete a record as possible and to leave no doubt in the minds of reasonable men and women as to the feasibility and desirability of this project.

As the record of these hearings will make clear, we will assemble all of the background material that is pertinent to this project with a view to using it in an educational campaign not only among Members of the Congress but also in the public at large.

There has been a great deal of interest on the part of many groups and people in testifying before this committee. We have not opened this up to general testimony for the reason that the purpose of this hearing is simply to complete the record, particularly with respect to the work which has been undertaken by the Department of the Interior and the Corps of Engineers and other Federal agencies in developing this project. At subsequent hearings all who are interested, both those who suport the project and those who oppose it, will be heard. As I indicated in my prepared remarks, this project must rise or fall on its merits. Those of us who support it feel it has that merit, but we realize we must prove our case, and this hearing this morning is the beginning of that proof.

I would like to again express my appreciation, Mr. Secretary, to you and to the three distinguished gentlemen who are with you, Secretary Holum, Mr. Dubrow, and Mr. Guidry for the dedicated efforts and interests you have given this project since the spring of 1961. We know that we would not be here this morning, that the project would not have been developed as it has been, without that help and interest.

Speaking for the people of Maine, I again want to express my wholehearted and deep-seated appreciation.

Many members of the committee have indicated an interest in these hearings this morning. This is the end of the session when we are driving toward adjournment at as early a date as possible. Since there is other urgent business, many will not be able to sit through the hearing this morning, but a number of them have indicated that they would drop by in the course of the morning, and I hope that particularly as many of them will be present as possible to see the slide presentation which will follow the Secretary's testimony this morning.

Good morning, Senator Metcalf. It is a pleasure to welcome you this morning.

Senator METCALF. Good morning, Mr. Chairman.

Senator MUSKIE. Congressman McIntire is here this morning, and although he comes from the other body, which we do not usually mention in these hearings, I think it would be appropriate to invite him to make any comments he may wish at this point.

Mr. MCINTIRE. Thank you, Mr. Chairman. Certainly as one who initiated the original legislation which established the survey upon which a great bulk of the information in the subsequent report since

1961 has been predicated, I am deeply interested in this supplemental report this morning and appreciate the opportunity to be present to listen to the presentations made by the Department of the Interior and the Department of the Army.

I share the deep interest in this which is evidenced by my early work back in 1952 and 1953. And I am deeply appreciative of the technical information which has been supplied and have been very anxious to get on with the legislative hearings in order that this project might be brought into an area of complete and adequate discussion by the appropriate committees of the Congress.

Thank you, Mr. Chairman, for the privilege of being here this morning.

Senator MUSKIE. Senator Metcalf?

Senator METCALF. Mr. Chairman, I am looking forward to this testimony this morning and to hearing about this very thrilling project. Secretary Udall will recall that when he and I were on President Kennedy's plane on an inspection trip, his last trip out West, we talked about this project, and some of the preliminary plans were presented at that time, and I want to assure you, Mr. Chairman, that this is a very thrilling and important project even though it is far from the West, and I am looking forward to hearing the testimony.

Senator MUSKIE. Thank you, Senator Metcalf.

Without objection there will be printed at this point in the record a copy of the legislation which is pending and the Department of the Interior's August 1964 supplemental report to its July 1963 Report on the International Passamaquoddy Project, upon which this hearing is based. Other background material which will be presented in the course of this hearing will be printed in appendix I and will constitute a part of the hearing.

(S. 2573 and the supplemental report with introductory statement of the Department of the Interior, follows:)

[S. 2573, 88th Cong., 2d sess.]

A BILL To authorize the international Passamaquoddy tidal power project, including hydroelectric power development of the upper Saint John River, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That, for the purposes of utilizing the power potential of the tides of Passamaquoddy Bay and the flows of the Saint John River in the State of Maine, United States of America, and the Province of New Brunswick, Canada, promoting economic development, providing flood control, and for allied purposes, the Secretary of the Army, acting through the Chief of Engineers, is hereby authorized to construct, operate, and maintain the international Passamaquoddy tidal power project and the Dickey and Lincoln School projects substantially in accordance with plans set forth in the July 1963 report of the Secretary of the Interior to the President entitled "The International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development" with such modifications as the Chief of Engineers deems advisable. The United States shall finance and construct the projects. Transmission and marketing facilities shall be constructed by the Department of the Interior.

SEC. 2. Construction of the projects shall not be initiated until the Governments of the United States and Canada shall have executed a special agreement or agreements providing for (1) acquiring easements and flowage rights in Canada necessary for the construction, operation, and maintenance of the projects; (2) equitable apportionment between the United States and Canada of downstream benefits provided by the projects; and (3) sale at an equitable price to Canadian authorities, or entities designated by them, of an equitable portion of the power and energy generated at the international Passamaquoddy tidal power project.

SEC. 3. Electric power and energy generated at the projects and in the opinion of the Secretary of the Army not required in the operation of such projects shall be delivered to the Secretary of the Interior, who shall transmit and dispose of such power and energy to Canada in accordance with agreements under section 2 hereof, and in the United States in such manner as to encourage the most widespread use thereof at the lowest possible rates to consumers consistent with sound business principles. The Secretary of the Interior shall prepare rate schedules having regard to the recovery (upon the basis of the application of such rate schedules to the capacity of the electric facilities of the projects) of the cost of producing and transmitting such electric energy, including the amortization of the capital investment allocated to power, over a reasonable period of years. Preference in the sale of such power and energy shall be given to public bodies and cooperatives. The Secretary of the Interior is authorized, from funds to be appropriated by the Congress to acquire by purchase or other agreement such additional transmission lines and related facilities as may be necessary in order to make the power and energy generated at the projects for use in the United States available in wholesale quantities for sale on fair and reasonable terms and conditions to facilities owned by the Federal Government, public bodies, cooperatives, and privately owned companies, and he is further authorized to enter into agreements with other electric power systems for the sale, transmission, wheeling, exchange, or purchase of electric power and energy and to provide for interconnection of the projects with one another and with other electric power systems in the United States and Canada. All moneys received from sales of electric power and energy shall be deposited in the Treasury of the United States as miscellaneous receipts. Downstream benefits provided by the projects and received in the United States from Canadian authorities in the form of power and energy shall be received, transmitted, and disposed of by the Secretary of the Interior pursuant to this section.

INTERIOR DEPARTMENT INTRODUCTORY STATEMENT TO SUPPLEMENTAL REPORT

Early authorization and construction of the Passamaquoddy international tidal power project and concurrent development of the St. John River in Maine was strongly recommended today to Secretary of the Interior Stewart L. Udall by the Passamaquoddy-St. John River Study Committee.

"We are firmly convinced that construction of the Passamaquoddy-Dickey project as a Federal development will benefit Maine, New England, the Maritime Provinces, Canada, and the United States of America," the committee reported.

The report—culmination of an intensive 3-year economic and engineering study recommended by Senator Edmund S. Muskie of Maine to the late President Kennedy—is being transmitted to the Governors of New England States, interested Federal agencies, and appropriate national and provincial representatives of the Dominion of Canada for comment prior to final approval by Secretary Udall and subsequent transmittal to President Johnson.

The committee pointed out that this procedure is in accord with established Federal criteria for water resource development as specified in Senate Document No. 97, 87th Congress.

In making its recommendations, the committee said:

"Under established Federal financial procedures and criteria, we have found the proopsed Passamaquoddy-Dickey project, Maine and New Brunswick, engineeringly and financially feasible. For the first time in the history of this Nation, it would harness the enormous energy of the ocean's tides for the production of relatively low cost and abundant electricity in the New England area. It would provide immediate and sustained employment opportunities, flood control, recreation, an international employment opportunities, flood control, recreation, an international tourist attraction, hydroelectric generation on the upper St. John River in Maine and downstream benefits in Canada."

Highlights of the report follow:

Initial installation of 500,000 kilowatts at Passamaquoddy Bay to harness the now-wasted energy of the tides with ultimate installation of 1 million kilowatts when future power requirements warrant such development. Reversible turbines would be used at Passamaquoddy to pump water for power generation during infrequent neap tide intervals, thus assuring full utilization of the full installed capacity at all times.

Installation of 760,000 kilowatts and 34,000 kilowatts of capacity at Dickey Dam and Lincoln School reregulating dam, respectively. Dickey Dam would be located above the confluence of the St. John River and the Allagash River in order to preserve the wilderness character of the Allagash. The committee said the Allagash "is a major recreation resource of great potential significance to the Nation. If the Allagash is not preserved, it will mean that the Nation has lost access to an adventuresome outdoor experience which it has treatsured since early times."

Initial installation will provide 1,294,000 kilowatts of dependable capacity and 3 billion kilowatt-hours of electrical energy annually. Of this dependable capacity, approximately 1,100,000 kilowatts would be available to supply a 2-hour peak daily, approximately 200,000 kilowatts of base-load power, plus substantial quantities of off-peak energy. Because of the flexibility of the project, alternative methods of operation are possible. Power would be marketed at $19.75 per kilowatt-year for capacity and 3 mills per kilowatt-hour for energy—substantially less than composite costs of thermal generation in New England as estimated by the Federal Power Commission.

Transmission lines would be constructed to interconnect these project facilities and to deliver power to load centers in Maine and Massachusetts.

The Passamaquoddy-Dickey project would require a Federal resource investment of $896 million. Excluding nonreimbursible allocations to flood control, recreation, and area redeveolpment benefits—approximately 10 percent—the investment will be fully repaid with prescribed Federal interest from power revenues within 50 years after each power feature becomes revenue producing, the usual repayment procedure for Federal water resource projects. The benefit-cost ratio was found to be 1.47 to 1, more attractive than that reported a year ago.

Privately financed modern steamplants, nuclear plants, and pumped storage plants are not realistic economic alternatives to Passamaquoddy-Dickey in terms of power costs and efficient, economical operation. Such plants also would not provide equivalent values in water resource development, flood control, recreation, and area redevelopment benefits.

Federally financed modern fossil fuel or nuclear plants and pumped storage plants, which could produce power cheaper than Quoddy-Dickey, were similarly rejected. Such plants do not provide maximum benefits as required in Senate Document 97, 87th Congress, and in no case could they develop the energy of the tides or the energy of the uncontrolled flows of the St. John River. In the case of a Federal fossil fuel or nuclear plants, the committee noted the lack of basic congressional authority or clear history of congressional preference.

Substantial area redevelopment benefits and national economic benefits consist of 15,000 man-years of on-site employment for skilled and semiskilled workers, many thousands of additional man-years of employment in the manufacturing and transportation of materials and equipment, and sustained economic benefit derived from the availability of abundant, relatively low-cost power.

Basic project features would be constructed by the Corps of Engineers, U.S. Army, and the Department of the Interior would construct transmission lines and market project power. The basic congressional authority for general construction, operation, and power marketing by the two agencies is contained in the Flood Control Act of 1944.

The committee also noted that the Passamaquoddy-Dickey project—which requires Canadian approval—intrinsically contains "a concept of an international intertie between Canada and the United States in Northeast whereby the full economic potential of each nation could be fully realized to mutual maximum benefits."

It also said that the Department of the Interior, the major power marketing agency of the Federal Government, is "convinced that, in New England in the ensuing years, the development of pumped storage, conventional hydroelectric power, modern steam generation, and nuclear plants—whether public or private—will be required."

"New capital investment by private industry in baseload plants will be absolutely essential. We are equally convinced that the Passamaquoddy-upper St. John project is a first and necessary step toward vitally needed economic rejuvenation" in New England, the committee concluded.

The report issued today was prepared under the supervision of Kenneth Holum, Assistant Secretary of the Interior for Water and Power Development, by a special committee established in 1961 and chaired by Morgan D. Dubrow, chief engineering adviser and assistant to Mr. Holum.

Concurrently, Mr. Dubrow also served as a member of a three-man Pacific Northwest-Pacific Southwest intertie negotiating team which recommended an 11 State combined public-private-Federal extra high voltage electric interconnection, recently endorsed by President Johnson as "launching a new era of cooperation between private and public power in the United States."

In receiving the committee's report, Secretary Udall stated: "The committee met its exacting assignment on a rational, scientific basis, and I hope the Nation will accept their findings on an equally rational, nonemotional basis.

"The race for the moon has many scientific ramifications, but none so challenging in terms of immediate benefit to man than the harnessing of the ever-wasting tides to generate electricity. This endeavor and the utilization of nuclear energy to desalt the ocean's waters will be important tests of our ability to create a great scientific society.

"The committee also took realistic cognizance of the importance of the Allagash River which has been recommended for national riverway status within the national park system. Its destruction would be a national loss. The Federal Government could not permit destruction of the Allagash, the last remaining wild river in the Northeastern United States, in order to develop the St. John River when prudent resource development will enhance the value of both. All conservationists should rejoice in this aspect of Mr. Dubrow's report," Secretary Udall said.

In 1961, Senator Edmund S. Muskie, of Maine, asked the late President Kennedy for a "careful and rigorous analysis" of an International Joint Commission report which found the Passamaquoddy-upper St. John River project to be engineeringly feasible but not financially sound under then assumed conditions of operations.

On President Kennedy's request, Secretary Udall instructed the committee to review the International Joint Commission report in light of changing patterns in electric generation and transmission technology, fuel costs, engineering advances, and electric demand.

The report also includes the detailed engineering and cost analysis for project construction prepared by Brig. Gen. P. C. Hyser, New England division engineer for the Corps of Engineers, and approved by Lt. Gen. W. K. Wilson, Jr., Chief of Engineers, U.S. Army.

SUPPLEMENT TO JULY 1963 REPORT

The International Passamaquoddy Tidal Power Project and Upper St. John River Hydroelectric Power Development, August 1964

REPORT TO STEWART L. UDALL, SECRETARY, U.S. DEPARTMENT OF THE INTERIOR BY PASSAMAQUODDY-ST. JOHN RIVER STUDY COMMITTEE

LETTER OF TRANSMITTAL

U.S. Department of the Interior,
Office of the Secretary,
Washington, D.C., August 3, 1964.

Memorandum to: Secretary of the Interior.
From: Passamaquoddy-St. John River Study Committee.
Subject: The international Passamaquoddy tidal power project and upper St. John River hydroelectric power development.

We submit herewith the report which supplements the earlier report which was transmitted to President John F. Kennedy on July 1, 1963, entitled "The International Passamaquoddy Tidal Power Project and Upper St. John River Hydroelectric Power Development." This report was prepared under the supervision of Assistant Secretary Kenneth Holum, Water and Power Development.

Under established Federal financial procedures and criteria, we have found

the proposed Passamaquoddy-Dickey project, Maine and New Brunswick, engineeringly and financially feasible. For the first time in the history of this Nation, it would harness the enormous energy of the ocean's tides for the production of relatively low cost and abundant electricity in the New England area. *It would provide immediate and sustained employment opportunities,* flood control, recreation, an international tourist attraction, hydroelectric power genedation on the upper St. John River in Maine and downstream power benefits in Canada.

This report contains the findings from the additional investigations completed by the Corps of Engineers, U.S. Army, and this Department since President Kennedy's acceptance of the previous report on July 16, 1963. In directing these studies be undertaken, the late President recognized that since the project involves international waters, equitable agreements must be reached with the Canadian Government before its construction could be started. The Department of State was directed to proceed toward accomplishing such agreements. We have been, and will continue, to assist as necessary in this endeavor.

Lt. Gen. W. K. Wilson, Jr., Chief of Engineers, U.S. Army, by letter of July 29, 1963, proposed the establishment of an eight member Army-Interior advisory board on the Passamaquoddy and upper St. John River project composed of four representatives from each agency. The purpose of this board was to advise and guide both agencies in the additional work required to supplement the July 1 report. By letter of July 30, 1963, the Department accepted the proposal. Later the board was augmented to include representatives of the Department of Commerce and the Federal Power Commission as participating members, and representatives of the Bureau of the Budget, the President's Office of Science and Technology, the President's Council of Economic Advisers, and the Atomic Energy Commission, as observers.

The board contributed immeasurably in both the evaluation and investigation of the project and in perfecting the report. Each of the agency representatives contributed generously of his talents and time, but have not yet concurred in this report. The results of this joint effort are embodied in this report.

The basic project would be comprised of the Passamaquoddy tidal power development with an initial installation of 500 megawatts and an ultimate installation of 1,000 megawatts; the Dickey Reservoir and powerplant with an installed capacity of 760 megawatts; the Lincoln School reregulating reservoir and powerplant with an installed capacity of 34 megawatts; and a transmission system interconnecting these plants and delivering power to load centers in Maine and in the vicinity of Boston, Mass. The Passamaquoddy powerplant would utilize the two-pool plan proposed and described in the International Joint Commission's report of April 1961 and all features would be identical with the exception of the powerplants.

In the International Joint Commission plan, an installed capacity of 300 megawatts was proposed and the powerplant was to be operated to produce load factor power to serve a local area. In the present proposal, an initial capacity of 500 megawatts would be installed and ultimately 1,000 megawatts, and the plant would be operated to provide peaking power to supply an expanded marketing area of New England and New Brunswick. The powerplant would incorporate reversible features in the turbines which would enable the generating units to be operated as pumps during the periods of neap tide so that the dependable capacity would be determined by the installed capacities in the powerhouses and not by the magnitude of the neap tide. An insignificant increase in the investment cost and in the cost of energy for pumping would be required to accomplish this improvement.

The Dickey and Lincoln School powerplants on the Upper St. John River would be electrically interconnected with the Passamaquoddy powerplant and coordinated so as to produce the optimum benefits. The operation would be extremely flexible and considerable quantities of load factor power could be provided for the local areas and, in addition, very substantial quantities of peaking power. In the current analysis, a peak of 2 hours' duration was considered a very likely occurrencce and this was selected for the basis of the analysis.

The total power output of the project would be 1,794 megawatts as the ultimate installed capacity. However, in the initial plan, only 1,294 megawatts is recommended, which can be installed in stages to meet the load demands. Generation will be provided at-site of about 3 billion kilowatt-hours and downstream benefits in Canada of 656 million kilowatt-hours, annually. The cost of the project is approximately $896 million, including a transmission system at a cost of

$87 million. This investment would provide annual benefits of $46.86 million, of which $42.51 million would be power, $2.03 million recreation, $2.28 million area redevelopment and $0.04 million flood control benefits within the United States, with significant flood control benefits to Canada which have not been evaluated in the project benefits.

The recommended benefit-cost ratio of the Passamaquoddy-Dickey project is 1.47 to 1, of which the Dickey and Lincoln School benefit-cost ratio is 2.25 to 1, and the Passamaquoddy tidal power project's benefit-cost ratio is 1.04 to 1. The segments of this project complement each other and together create values which are greater than would be obtained from either operating independently. These benefit-cost ratios were determined for a 100-year period of analysis with interest at 3 percent.

With an allocation of about 10 percent to the nonpower features, the investment in the project can be repaid with interest at 3 percent within a 50-year period after each unit becomes revenue producing from revenues from the sale of power at the following rates:

Capacity: $19.75 per kilowatt-year.
Energy: 3 mills per kilowatt-hour.

The above prices are lower than power that can be produced by privately financed new modern conventional steamplants, nuclear powerplants using light water reactors, and pumped storage plants with the transmission essential to deliver power to the load centers.

In accordance with the established procedures and criteria for project formulation and evaluation, we have also considered the least costly alternative. If federally financed, conventional steam, nuclear powerplants, and pumped storage plants would cost less than the project. However, the proposed development of the Passamaquoddy-Dickey project will provide more benefits than just power supply. The enormous and perpetual energy of the ocean's tides will be utilized instead of wasted. The construction of this project will provide greatly expanded employment opportunities as well as attractive recreational opportunities for an expanding population, with a resulting impact on the economy of the State of Maine and surrounding areas.

In view of the extensive previous investigations made on the project dating back to 1922 and the additional studies made in connection with the review of the report requested by the late President Kennedy, plus the work accomplished under the advice of the Passamaquoddy Advisory Board, we are firmly convinced that the construction of the Passamaquoddy-Dickey project as a Federal development will benefit Maine, New England, the Maritime Provinces, Canada, and the United States of America. Agreements, of course, must be reached with the Canadian Government.

We recommend early consideration moving toward possible authorization of the international Passamaquoddy tidal power project and the upper St. John River developments for construction by the Corps of Engineers, U.S. Army, and marketing of power and construction of transmission lines by the Department of the Interior.

As specified in Senate Document 97, 87th Congress, we are transmitting this report to the interested Federal agencies, the Governors of the New England States, as well as to the appropriate national and provincial representatives of the Dominion of Canada for comment. Such comments as are received will be reviewed and incorporated in your final report to the President of the United States.

MORGAN D. DUBROW, *Chairman.*
JOSEPH E. GUIDRY, *Project Engineer.*

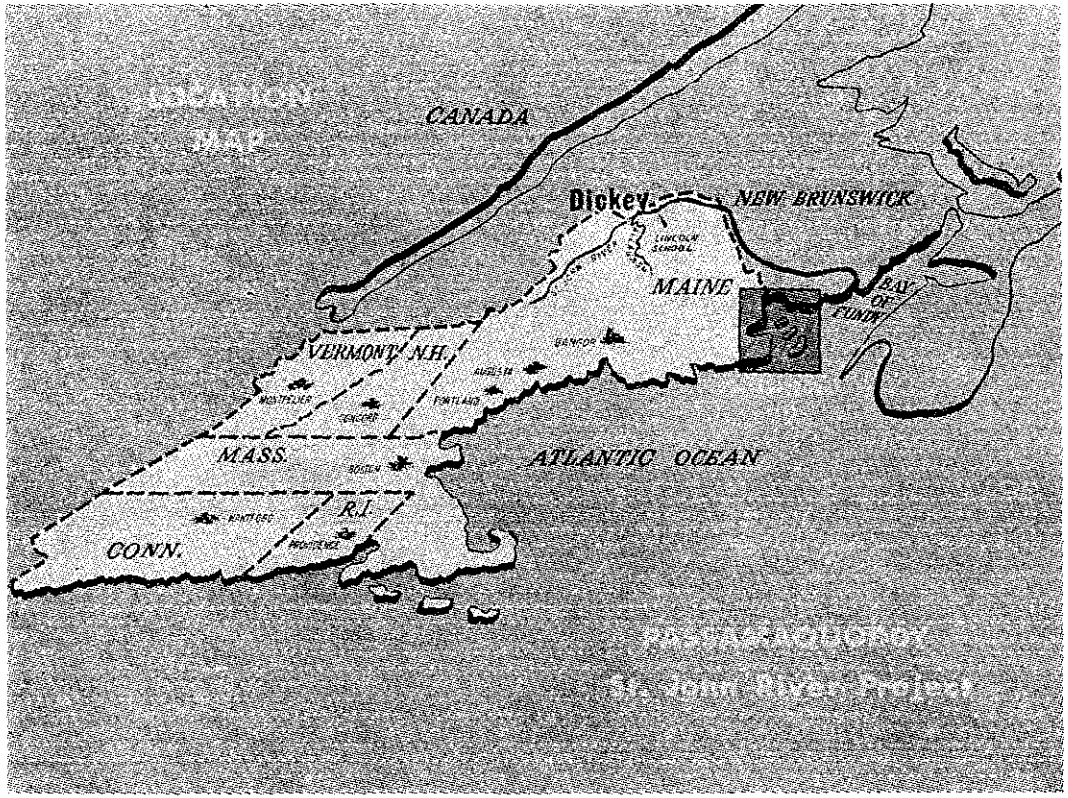
CANADA
Dickey
NEW BRUNSWICK
LINCOLN SCHOOL
MAINE
BAY OF FUNDY
BANGOR
AUGUSTA
PORTLAND
VERMONT
N.H.
MONTPELIER
CONCORD
MASS.
BOSTON
ATLANTIC OCEAN
R.I.
PROVIDENCE
CONN.
HARTFORD

FIGURE 1

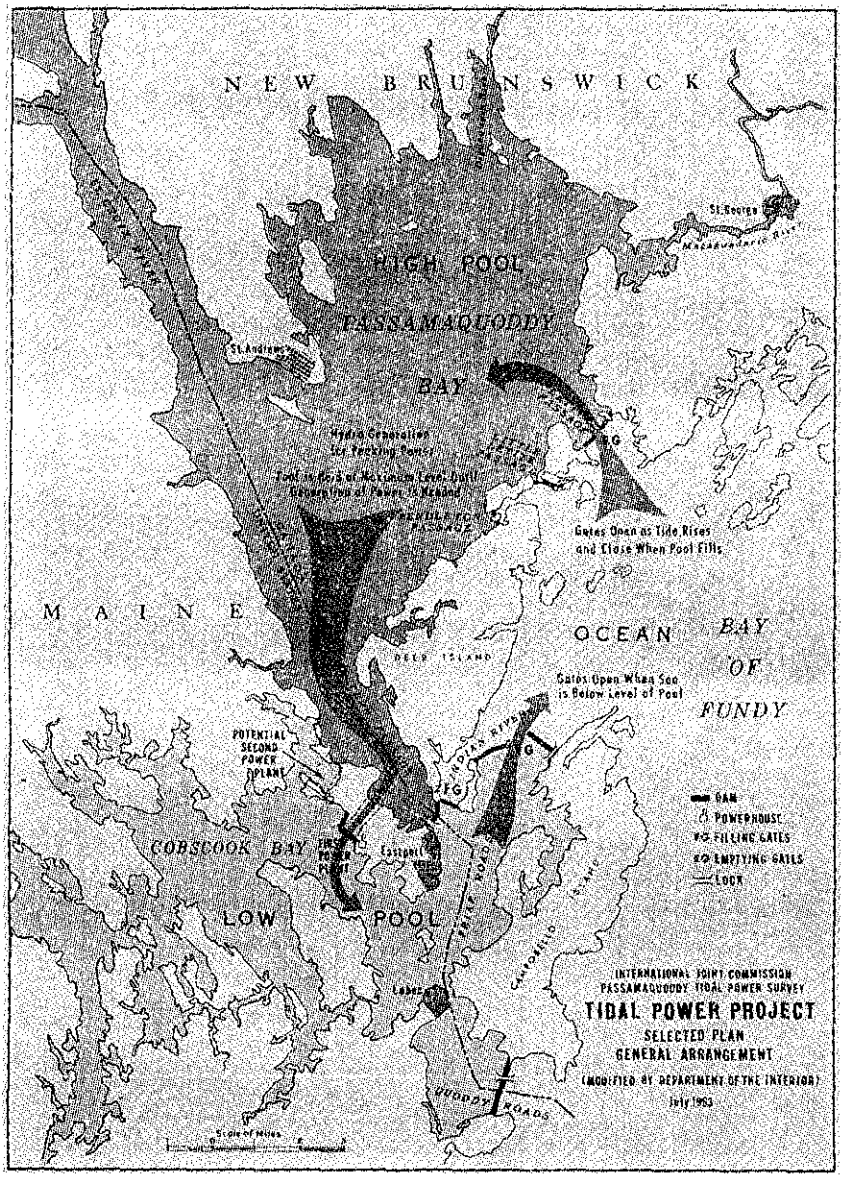
NEW BRUNSWICK
HIGH POOL
PASSAMAQUODDY
BAY
St. Andrews
St. Croix
Hydro Generation
for Pumping Power
Gates Open as Tide Rises
and Close When Pool Fills
MAINE
OCEAN
BAY
OF
FUNDY
DEER ISLAND
Gates Open When Sea
is Below Level of Pool
POTENTIAL
SECOND
POWER
PLANT
INDIAN RIVER
DAM
POWERHOUSE
FILLING GATES
EMPTYING GATES
LOCK
COBSCOOK BAY
Eastport
LOW
POOL
Lubec
CAMPOBELLO ISLAND
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
TIDAL POWER PROJECT
SELECTED PLAN
GENERAL ARRANGEMENT
(MODIFIED BY DEPARTMENT OF THE INTERIOR)
July 1963
WOODY ROADS
Scale of Miles

FIGURE 2

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SUPPLEMENT TO JULY 1963 REPORT—THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER ST. JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

CHAPTER I. PURPOSE AND SCOPE OF REPORT

The purpose of this report is to present additional conclusions of the Department of the Interior's review of the International Joint Commission's report on the international Passamaquoddy tidal power project, April 1961. It suppplements the report of July 1963 entitled "The International Passamaquoddy Tidal Power Project and Upper St. John River Hydroelectric Power Development."

The report embraces the considerations and suggestions of the Joint Army-Interior Advisory Board, which was created shortly after President Kennedy's acceptance of the Department's report on July 16, 1963. This Board consists of representatives from the Corps of Engineers, the Department of the Interior, the Department of Commerce, and the Federal Power Commission as participating members, with representatives of the Bureau of the Budget, the President's Office of Science and Technology, the President's Council of Economic Advisers, and the Atomic Energy Commission as observers.

The suggestions of all representatives on the Board were considered, but since the Board's function was advisory, the views of the individuals might not necessarily fully conform with the agencies' position in commenting on the report.

The following contributions by the Corps of Engineers are included:

(*a*) Geologic investigations and field explorations at the sites of all structural components.

(*b*) Field surveys.

(*c*) Hydrologic investigations of the St. John River.

(*d*) Layout and design of facilities for powerplants at Passamaquoddy; power dam and closure dikes at Dickey; and reregulating and power dam at Lincoln School.

(*e*) Studies of use of inclined axis turbines at Passamaquoddy in cooperation with the Bureau of Reclamation.

(*f*) Planning appraisal of all lands and damages for the entire project.

(*g*) Cost estimates of facilities.

The Department of Interior in its traditional role for water resource development accepts the basic responsibility for this report which portrays a feasible and workable plan for utilization of this unique water power resource—the tides. The Department conducted the economic analysis and marketing studies and provided the cost estimates for the transmission facilities.

The Department of State is working toward an agreement with the Canadian Government. A technical briefing session was held in Ottawa, Canada, December 4–5, 1963, as well as other meetings between officials of the two countries.

CHAPTER II. SUMMARY—FINDINGS

The results accomplished since completion of the July 1, 1963, report confirm the engineering and economic feasibility and the desirability of constructing, by the United States, the proposed international Passamaquoddy tidal power project, the Dickey storage reservoir and powerplant, and the Lincoln School reregulating reservoir and powerplant on the upper St. John River and the associated transmission system. These include firm geologic data and more detailed economic analyses than previously applied as well as updated cost estimates.

The proposed project offers a practical plan for harnessing, for the first time in the history of this Nation, the energy of the tides for the economic benefit of a large section of the country. The coupling of this resource with development of the hydroelectric power potential of the upper St. John River provides a multipurpose project with very significant electric power, flood control, recreation, and

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area redevelopment benefits. Each of these will constitute a significant element in the area's economy. Wasting of the energy in the tides and in the flows of the upper St. John River would be eliminated and changed to economic gain.

A major contribution from the project would be hydroelectric power. The project would provide a large block of peaking and load factor power which can be utilized advantageously in the New England-New Brunswick area. It is in the production of peaking power that the present Passamaquoddy proposal differs from the previous concepts in which an attempt was made to match the tidal power which follows the lunar day of 24 hours and 50 minutes with the electric power pattern which follows our living habits on a solar day of 24 hours.

The installed capacity of the ultimate project would total 1,794 megawatts. However, the second 500-megawatt powerplant at Passamaquoddy is deferred for future installation. The initial project would provide 1,294 megawatts of dependable capacity and approximately 3 billion kilowatt-hours of electrical energy annually. The two-pool plan envisioned in the International Joint Commission's report for Passamaquoddy would be used with a 500-megawatt powerplant instead of the 300-megawatt plant originally contemplated. The powerhouse would be located at Carryingplace Cove, the site originally chosen for the 300-megawatt plant. The 500-megawatt plant would be interconnected through a transmission system with two powerplants on the Upper Saint John River, Dickey with 760-megawatt capacity, and Lincoln School with an installation of 34 megawatts.

The project could be constructed in stages as the load demands grow. Initial operation of the first powerhouse at the Passamaquoddy Tidal Power Development would require about 6 years after construction is started. The second powerhouse at Passamaquoddy would take about 5 years. Dickey would require 3½ years and Lincoln School 2 years after the start of construction.

The estimated investment in the project, with Passamaquoddy, 500 megawatts; Dickey, 760 megawatts; and Lincoln School, 34 megawatts, would total approximately $896 million, including the transmission system with a cost of $87 million. The annual benefits would be $46.86 million of which $42.51 million is power, and $2.03 million recreation, $2.28 million area redevelopment and $0.04 million flood control benefits within the United States. With an allocation of about 10 percent to the recreation, area redevelopment and flood control benefits, the cost assigned to power could be repaid from power revenues within a period of 50 years after each unit becomes revenue producing, with interest at 3 percent per annum on the unpaid balance. The power would be marketed at load centers for $19.75 per kilowatt-year for capacity and 3 mills per kilowatt-hour for energy. This is lower than the cost of power provided by new modern steam electric powerplants, privately financed.

The logical development of the Upper Saint John River and the Passamaquoddy project with the entire project financed by the United States as visualized in this report is engineeringly feasible and economically sound. It has a benefit-cost ratio of 1.47 to 1 of which the Upper Saint John River plants are 2.25 to 1 and Passamaquoddy is 1.04 to 1. These are based on current principles utilizing a 100-year project formulation period with interest at 3 percent. The repayment analysis is also based on 3 percent interest, with a payout period of 50 years after each power unit becomes revenue producing.

Equivalent power could be provided by alternative federally financed thermal power developments using either conventional fossil fuels or nuclear energy, which would be generally contrary to present practice and incompatible with the fundamental purposes of this report. Furthermore, it would not be a true alternative in conformance with the requirements of Senate Document 97, of which the following is quoted:

"* * * There is no more economical means, evaluated on a comparable basis, of accomplishing the same purpose or purposes which would be precluded from development if the plan were undertaken. This limitation refers only to those alternative possibilities that would be physically displaced or economically precluded from development if the project is undertaken * * *."

Such a Federal steamplant, if attainable, would waste the Nation's resources because it would lack the following fundamental benefits:

(*a*) It would fail to utilize a significant undepletable resource and source of energy which is constantly being wasted to the sea by the rise and fall of the tides in Passamaquoddy Bay and in the flow of the Upper Saint John River on its course to the sea.

(*b*) It would fail to provide the human appeal and economic impact so essential to stimulating the economy of the Maine area. It would lose the great catalytic effect of developing this tidal resource.

(*c*) It would not provide the needed immediate employment opportunities to alleviate poverty in the seriously distressed conditions of Washington County and Aroostook County as would be accomplished from the Saint John and Passamaquoddy developments.

(*d*) It could never attract and sustain recreational resource value for the area.

The tidal and river resource developments would be operated practically in perpetuity as all wearable parts can be replaced as necessary. At the end of the repayment period, the project will be in practically the same operating condition as it is in the start and the power can then be produced for only the cost of operation and interim replacements. Appropriate funds are being included in the project analysis to cover the operation and maintenance expense and to provide for the necessary replacements.

The Passamaquoddy Bay is not subject to siltation and filling, so its value will never be reduced from this cause. Its dams likewise for all practical purposes do not deteriorate in time.

The United States would fail in one facet of its leadership in overall energy development by neglecting to develop the vast energy in the Quoddy tides. Meanwhile, France will complete the La Rance project and Russia is forging ahead in the development of its tidal projects.

Chapter III. Recommendations

We recommend that immediate steps be taken toward the following:

1. Early authorization of the International Passamaquoddy tidal power project, the Upper Saint John River developments, and the transmission system, for construction by the United States. The Corps of Engineers should be authorized to construct the basic project features and the Department of the Interior should construct the transmission lines and market the power.

2. Early construction of the project to develop low-cost firm power for Maine and peaking power for the remainder of the New England States, combat poverty, develop recreation resources, and utilize the now-wasted water resources of Maine.

Chapter IV. Project Features

The project combination selected consists of the Passamaquoddy development with reversible pump turbines, the Dickey Reservoir and Powerplant, the Lincoln School reregulating reservoir and powerplant, and a transmission system interconnecting these powerplants and delivering power to load centers in Maine and in the vicinity of Boston, Mass. Each feature is discussed in the following paragraphs:

A. PASSAMAQUODDY

The designs and engineering studies for the Passamaquoddy tidal power development are based on the International Joint Commission's report of April 1961. It includes Passamaquoddy Bay as the high pool and Cobscook Bay as the low pool with two identical powerhouses, one at Carryingplace Cove and the second at Bar Harbor. The powerhouses are the only features which differ from the International Joint Commission's plan.

Nearly 7 miles of rockfilled dams will be required, a small portion of which would vary in depths ranging from 125 to 300 feet. The tidal velocities will range as high as 10 feet per second during the 26-foot high tide presenting engineering and design challenges without precedent. The Corps of Engineers, the Bureau of Reclamation, the Bureau of Yards and Docks, the principal Federal engineering and construction agencies are confident that the tidal project can safely be constructed as concluded in the International Joint Commission's report.

As described in the International Joint Commission's report, outstanding specialists in the fields of hydraulic engineering and soils mechanics were consulted and model studies were made to determine the best and most economical designs and methods of construction.

The project plan includes 90 filling gates, 40 in Letite Passage and 50 between Western Passage and Indian River. In the reach between Pope and Green Inlets, 70 emptying gates similar to the filling gates, but set at a lower elevation, would empty the lower pool.

Four navigation locks would be provided. The dimensions and locations were selected to accommodate present traffic in Passamaquoddy and Cobscook Bays with an allowance for a modest increase in the size of ships using the area.

The initial 50-unit powerplant will be at Carryingplace Cove and the second identical unit at Bar Harbor. The locations are shown in the Corps of Engineers' report included in this document. A closure dam would connect the west end of the powerhouse to the mainland.

Reversible pump turbine units were selected for installation in the powerhouses between the upper and lower pool in order to provide flexibility in operation and utilization of the full installed capacity of the project. This is described in chapter V (a) and in the Corps of Engineers' report.

B. DICKEY

The site selected for the Dickey Dam and 760-megawatt powerplant is on the upper St. John River near Dickey, Maine, above the confluence of the Allagash River.

The main dam across the river and the dikes across the adjoining saddles would be of the earthfill type. All structural features would be located on the right bank and in general founded on rock; the lower level outlet tunnels, which would, be used for diversion during construction; the powerhouse, with tailrace discharging into the St. John River; and the spillway which would discharge during severe floods through a stilling basin into the lowermost 1¼-mile segment of the 100-mile Allagash River.

The Allagash River, located in the backwoods of northern Maine, is one of the few remaining free-flowing streams of importance in the Eastern United States. It is a major recreation resource of great potential significance to the Nation.

If the Allagash is not preserved, it will mean that the Nation has lost access to an adventuresome outdoor experience which it has treasured since early times.

C. LINCOLN SCHOOL

The Dickey powerplant, with an ultimate installed capacity of 760 megawatts, will have an average regulated flow of 4,370 cubic feet per second with a maximum discharge of about 48,000 cubic feet per second. In order that the Dickey discharge might be better controlled and utilized, a reregulating reservoir would be required. An ideal site was found approximately 11 miles downstream on the St. John River at Lincoln School. Here a dam will be constructed, including a 34-megawatt powerhouse, that will impound the Dickey discharges and where the discharge will be regulated for more effective use by existing and proposed downstream hydroplants at Grand Falls and Beechwood, New Brunswick.

D. TRANSMISSION

A strong transmission system is of the utmost importance to this project. It is required for electrical interconnection of the generating plants to permit fully coordinated and integrated operation and for delivery of power to load centers. Since the quantities of power involved are large and the distances are great, it is necessary to use extra high voltages.

The transmission system, as shown on figure 3, would consist of two 345-kilovolt transmission lines for the 410 miles from the Dickey-Lincoln School powerplants to the Boston area via Bangor, Augusta, and Portland, Maine, and two 230-kilovolt lines 90 miles between Passamaquoddy and Bangor, Maine. These transmission facilities would be required for a 500-megawatt development at Passamaquoddy, with the full development of the 760-megawatts at Dickey and 34 megawatts at Lincoln School.

The transmission system was designed by the Bureau of Reclamation based on network analyzer studies. Appropriate reactive correction has been added to assure stable operation under fault conditions. The design visualized interconnections with the power systems in the New England area, as well as with Canada; however, no transmission lines have been included in the cost estimates for interconnection with the New Brunswick Electric Power Commission pending interconnection agreements with the Canadian Government for construction of the project and sharing of the power benefits.

The transmission system linking the New Brunswick system with the New England power systems will increase the reliability of both systems. This could reduce the amount of system reserve required and provide other economies

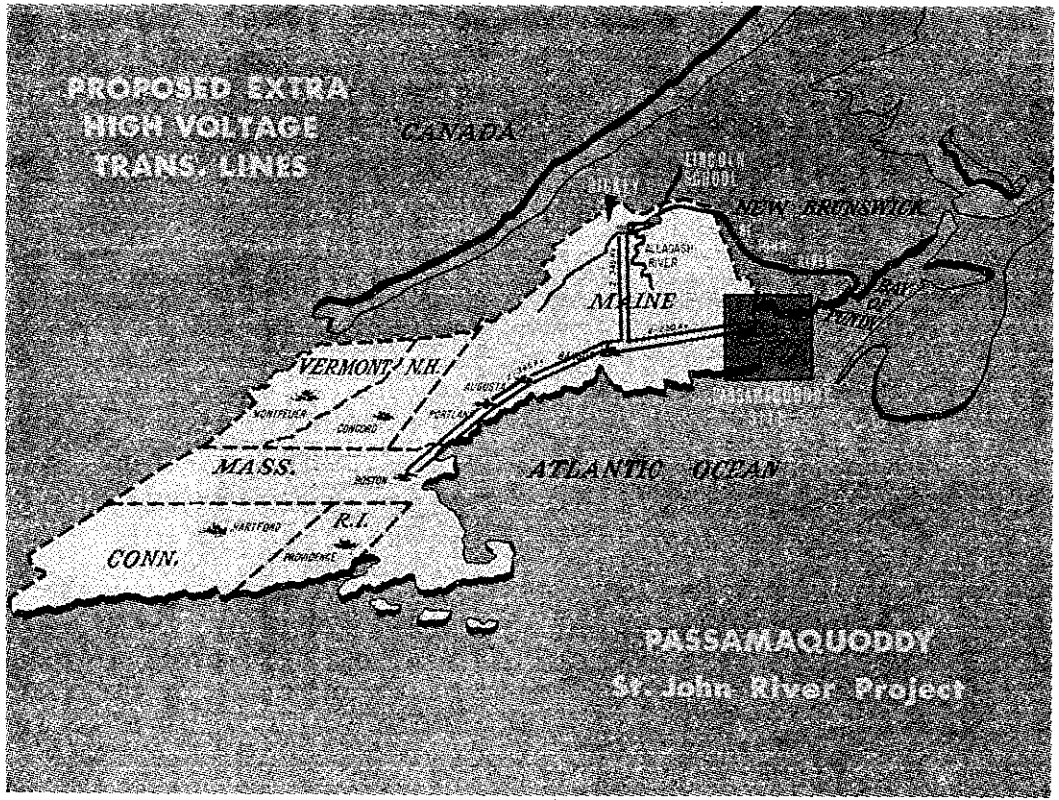
PROPOSED EXTRA
HIGH VOLTAGE
TRANS. LINES
CANADA
NEW BRUNSWICK
MAINE
VERMONT
N.H.
MASS.
R.I.
CONN.
ATLANTIC OCEAN
PASSAMAQUODDY
St. John River Project

FIGURE 3

which accrue from interconnected and integrated operation. While the values of such an interconnection are significant, none of these benefits were evaluated or included in the current analysis.

The transmission system was designed and the cost estimates were prepared *on the basis of a reconnaissance field survey and broad assumptions as to dis*tribution of power to the load centers. Certain portions of the lines can be utilized for wheeling and will provide additional revenues for the project. These revenues were not evaluated. This fact will be recognized and considered as contracts for the sale of power are negotiated. The transmission system design should include such excess capacity as can be judiciously included to provide for potential revenue from the sale of "excess" peaking ca-capacity and "offpeak" capacity.

CHAPTER V. HYDROLOGY AND OPERATING PLAN

The tides of Passamaquoddy Bay and the streamflows of the upper St. John River in Maine constitute the energy source for this project. The tides being astronomic in origin are dependable as to occurrence and predictable in magnitude depending upon the relative positions of the earth, moon, and sun. The streamflows on the other hand follow no fixed pattern and depend on the rainfall and other hydrologic factors.

The basic operating plan envisions using the two-pool plan generally as set forth in the IJC report for the tidal development and utilizing storage control to regulate the releases and provide head for the river development. In the tidal plan, the upper pool is filled during the rising tide and water is allowed to flow from the upper pool to the lower pool through turbines for the generation of power. Evacuation of the lower pool will occur during the low tides. The river plan consists of controlling the streamflow, thereby diminishing flood hazards and allowing the water to flow through turbines for power generation. The power generated would depend on the streamflow and the head through which the water falls, which in turn depends upon the topography of the area.

A. PASSAMAQUODDY

The Department's report of July 1963 envisioned the use of the two-pool plan for Passamaquoddy and the operation of the project to produce peak power of 1 hour's duration in the magnitude of 1,000 megawatts. As a result of the further studies concerning marketing possibilities, the engineering and economic analysis in this report was made for a power peak of 2 hours' duration.

Hydrologic studies using high-speed electronic computers indicated that dependable capacities as shown in table 5–1 could be obtained for 2 hours' duration with installed capacities of 300 to 1,000 megawatts. Limitations are *placed on this operation during the period of neap tide. By using reversible* pump-turbine units, the water level between the pools can be raised during the neap tide beyond that obtainable from the tides alone. This increases the head available for generation of power during the neap tides. Thus, the Passamaquoddy powerplant can be operated at the full installed capacity at the powerplant during all peaking periods.

Table 5–2 shows the results of operation with pumping under the following criteria:

1. The low pool is drawn down during the low tide occurring before the peaking periods.
2. During the high tide preceding this low tide, the low pool is filled from the ocean and water pumped from the low pool to the high pool.
3. A 30-percent pumping efficiency was used.

Should the Passamaquoddy project be operated for the generation of the maximum amount of energy rather than peaking power, the following quantities in millions of kilowatt hours should be obtained:

[1 million kilowatt-hours]

	Energy production in GWH	
	Annual	9-month period
Number of turbine units:		
30	1,840	1,380
50	2,170	1,630
70	2,280	1,710
100	2,360	1,770

Assuming the Passamaquoddy powerplant is operated to produce the maximum energy for 9 months of the year and peaking for 3 months as suggested by the FPC, which is considered a practical operation, the following would be obtained for an installation of 500-megawatts:

Peaking capacity	mw	500
Generation:		
9 months' energy	GWH	1,630
3 months' peaking energy	GWH	85
3 months' off-peak energy	GWH	217
Total, GWH		1,932

TABLE 5-1.—*Passamaquoddy power generation (no pumping)*

	Installed capacity—megawatts (2-hour peaking)			
	300	500	700	1,000
October 1937: [1]				
1	300	440	530	610
2	300	500	620	720
3	300	500	670	780
4	300	500	700	840
5	300	500	700	1,000
6	300	500	700	1,000
7	300	500	700	1,000
8	300	500	660	820
9	260	370	500	610
10	220	300	380	440
11	190	260	320	370
12	170	240	290	330
13	180	260	310	350
14	220	300	370	430
15	250	350	420	490
16	300	400	480	560
17	300	500	580	670
18	300	500	700	820
19	300	500	700	950
20	300	500	700	1,000
21	300	500	700	1,000
22	300	500	700	1,000
23	300	500	700	1,000
24	300	500	700	890
25	300	500	560	640
26	300	410	480	530
27	300	410	500	590
28	300	440	530	620
29	300	440	530	610
30	300	450	540	630
31	300	490	580	680
ENERGY FOR MONTH (MILLIONS OF KILOWATT-HOURS)				
Peak	17.380	27.120	35.100	43.960
Off-peak	79.288	100.868	95.759	91.625
Total	96.668	127.988	130.859	135.585

[1] October 1937 was selected because the mean tide range, as well as the frequency distribution of the ranges, approximates the long-term observed values.

TABLE 5-2.—*Passamaquoddy tidal power project pumping power requirements for pumping from low pool to high pool during periods of neap tide*

[50 turbine units, 2-hour peaking duration]

	Assumed placement of days	Energy production in megawatt-hours		Energy requirement for pumping in megawatt-hours
		Peak	Off peak	
October 1937:				
1	Saturday	800	1,390	0
2	Sunday	1,000	3,812	0
3	Monday	1,000	4,101	0
4	Tuesday	1,000	4,185	0
5	Wednesday	1,000	4,209	0
6	Thursday	1,000	3,130	0
7	Friday	1,000	3,074	0
8	Saturday	1,000	1,259	0
9 [1]	Sunday	0	0	1,950
10	Monday	1,000	0	550
11	Tuesday	1,000	0	2,250
12	Wednesday	1,000	0	2,100
13	Thursday	1,000	0	1,700
14	Friday	1,000	0	1,050
15	Saturday	585	0	0
16	Sunday	756	725	0
17	Monday	1,000	3,697	0
18	Tuesday	1,000	4,153	0
19	Wednesday	1,000	4,830	0
20	Thursday	1,000	5,245	0
21	Friday	1,000	5,368	0
22	Saturday	1,000	4,027	0
23	Sunday	1,000	4,443	0
24	Monday	1,000	4,494	0
25	Tuesday	1,000	2,072	0
26	Wednesday	1,000	0	450
27	Thursday	1,000	0	800
28	Friday	1,000	630	700
29	Saturday	880	2,300	0
30	Sunday	980	2,776	0
31	Monday	1,000	3,680	0
Total		29,001	73,600	11,550
3-month period, 91.249 days		85,365	216,643	33,997

[1] No peaking power needed.

The Passamaquoddy operation is extremely flexible. Computer studies prepared by the Bureau of Reclamation indicate that this operation can be coordinated and integrated with the Dickey powerplants to produce significant blocks of load factor power. The quantities of power will depend on the installed capacity in the Dickey unit and the installed capacity in Passamaquoddy. The following tabulation indicates the quantities of load factor power which could be obtained under these operations without utilizing the internal pumping features on the Passamaquoddy development.

2-hour peaking

[In megawatts]

Capacity		Load factor power, 50 percent	Peaking power
Dickey	Passamaquoddy		
475	300	130	300
570	500	260	500
760	500	159	1,111

B. DICKEY

The drainage area above the Dickey site is 2,725 square miles. At maximum elevation of 910 the reservoir area would be 88,600 acres and its capacity 8,080,000 acre-feet. At drawdown level of 870 the reservoir area would be 58,500 acres and its capacity 5,180,000 acre-feet.

The regulated flow available at the Dickey site was developed for periods of deficient streamflow, using records of flow at the Dickey gaging station. The critical periods were 1947 to 1948 and 1955 to 1958. The storage and regulated flow for various values of drawdown are:

Maximum drawdown (feet)	Active storage (acre-feet)	Regulated flow (cubic feet per second)
10	845,000	2,520
20	1,600,000	3,560
30	2,300,000	4,100
40	2,900,000	4,370

In computing the regulated flows, an allowance of 50 cubic feet per second was made for losses by evaporation and leakage. For the selected maximum drawdown of 40 feet, the active storage would be 2.9 million acre-feet, and the regulated flow 4,370 cubic feet per second.

The annual energy generated with the full installation of 760 megawatts is 750 million kilowatt-hours annually.

C. LINCOLN SCHOOL

The active storage capacity of 16,000 acre-feet at Lincoln School would be sufficient for reregulation of the discharges from Dickey on a monthly basis. The controlled average outflow from Lincoln School would equal the regulated flow from Dickey plus the minimum flow, 200 cubic feet per second, from the Allagash River drainage area of 1,361 square miles. The 2,900,000 acre-foot active storage, 40-foot maximum drawdown, at Dickey would permit a regulated average flow of 4,370 cubic feet per second after deducting 50 cubic feet per second for evaporation and leakage. Thus the regulated average flow from Lincoln School would be 4,570 cubic feet per second.

The average energy generated with an installation of 34 megawatts at Lincoln School is 260 million kilowatt-hours annually.

CHAPTER VI. PROJECT PURPOSES

Substantial power, flood control, recreational, and area redevelopment benefits will be provided by this multipurpose project. Each of these will have a significant impact on the area.

A. POWER

Electric power will constitute the major benefit from this project and will provide the revenues for repayment of all costs except the approximate 10 percent allocated to area redevelopment, recreation, and flood control. The need and marketability of the power generated is described in the chapter on "Marketing." The economics are covered under "Economic and Financial Analysis."

The power generated will be predominantly "peaking" power but substantial quantities of both load factor and off-peak power can be produced. The operation is quite flexible and can be coordinated readily with other generation sources in the area. Its long-term predictability enhances the effective utilization of the tidal resource for the peaking power.

B. FLOOD CONTROL

The St. John River rises in the Appalachian Mountains at Little St. John Lake on the international boundary between the United States and Canada. The total fall from its source in Little St. John Lake and tidewater at Fredericton is about 1,578 feet. The total drainage area is about 21,300 square miles, of which 7,600 square miles is in the State of Maine. There are 2,725 square miles in the drain-

age area above the Dickey site and 1,500 square miles in the Allagash River Basin.

The Dickey reservoir, with a capacity of 8,080,000 acre-feet, of which 2,900,000 acre-feet is active storage at a maximum draw-down of 40 feet, will provide full regulation of the streamflow at the Dickey site.

Snowmelt, sometimes in combination with rainfall, annually produces spring floods along the upper St. John River. These would be controlled by the proposed reservoir. Since the area has been sparsely settled, significant damages have only occurred at Fort Kent, which is located about 28 miles downstream from the Dickey Dam. The Fort Kent urban area has experienced seven consequential floods during the past 36 years of record. Two of the largest floods have occurred within the past 5 years, the most damaging being in 1961, a recurrence of which would cause damages at today's prices of $450,000.

Damages at Fort Kent start at a river discharge of 100,000 cubic feet per second. The 1961 discharge was 131,000 cubic feet per second. Inasmuch as the Dickey Dam controls 47.5 percent of the contributing drainage areas, impoundment of floodwaters would reduce discharges to well below the damage stage.

The alternate method for prevention of damages, without reservoirs, would be a local protection project. A recent study investigation by the New England Division, Corps of Engineers, in 1963 indicated that such a project would cost $1,060,000. Dickey Dam could make such a project unnecessary and the flood control benefits at Fort Kent would average $40,000 annually.

The flood protection afforded by Dickey Dam will also benefit the lower St. John River. The actual extent of flood protection afforded along the lower St. John River should be studied in detail and evaluated in the course of negotiations with the Canadian Government.

C. RECREATION

The recreational values of the potential Passamaquoddy tidal power project have been studied by the Department of the Interior's Bureau of Outdoor Recreation and are described in the July 1963 report.

The principal attraction to tourists would be the tidal project. This unique attraction and engineering marvel would feature the rise and fall of the tides, the impounding of water in two natural pools, navigation locks for unrestricted movement of boats, emptying and filling gates, and power transmission. Parking areas, picnic sites, and boat-launching ramps would be provided. Service roads to the various features would offer sightseeing opportunities to the area. Representative statistics on recreational use of several water resource projects in other parts of the Nation are as follows:

Project and State	*Total visitor-days, 1962*
Central Valley, Calif	5,209,923
Boulder Canyon, Ariz.-Nev	3,200,739
Colorado-Big Thompson, Colo	1,593,653
W. C. Austin, Okla	1,295,079
Rio Grande, New Mex	1,210,000
Solano, Calif	865,720
Rapid Valley, S. Dak	605,300

Recreational facilities could also be provided at the Dickey Reservoir site as camping areas and boat-launching ramps.

D. AREA REDEVELOPMENT BENEFITS

Washington County, the location of the Passamaquoddy tidal powerplant, and Aroostook County, where the Dickey site is located, have been declared areas of substantial and persistent unemployment. Washington County's population has declined for the decade 1950 to 1960, while Aroostook County's population increased only by 9.4 percent—as contrasted to a national growth rate of 19.2 percent.

Economic opportunity has been denied to the youth of both counties with subsequent migration to other cities and States, thus breaking down the traditional family solidarity characteristic of New England. Industry has moved to other areas, thereby causing many retail and service establishments to close. The high cost of electric power has been a significant contributing factor in the industrial decline of the area. Fish-processing plants in Washington County—

an important local industry—have gone out of business, and the county's agricultural economy has been declining. In Aroostook County, agricultural conditions are uncertain, and the lumber industry is subject to wide fluctuation.

A national sampling conducted by the Department of Labor in 1959 shows that an annual income of approximately $6,000 is required to maintain a modest but adequate level of living for a typical family of four. In Washington County, 34 percent of the families have incomes of less than $3,000 annually, and in Aroostook County over 30 percent of the families have incomes of less than $3,000. In Washington County, nearly 17 percent of the family units receive some form of public assistance, and in Aroostook County nearly 12 percent of the family units receive public assistance. Using this yardstick, one-third of the people in the area live in poverty, as contrasted with a national projection of one-fifth.

By providing substantial on-site employment, the Passamaquoddy-Dickey project will do much to alleviate human misery. The area redevelopment values, however, go much further than employment opportunity. The Department of the Interior's experience in 60 years of water resource development has conclusively demonstrated that for each dollar of Federal investment an additional $2 of private business is stimulated. Furthermore, a rejuvenated economy normally follows completion of water resource projects.

More important, perhaps, for longer term is the new ray of hope which will be instilled in the people of the area—men, women, and children who have lived with a mounting sense of despair for years. The psychological exit from poverty provided by Quoddy-Dickey, as well as its material benefits, will again offer the self-reliant people of the area a new opportunity to advance themselves to the limits of their capabilities.

E. EFFECT ON FISHERIES

The International Joint Commission's report of April 1961 described in detail the effect of the two-pool tidal powerplant operated on the basis of producing continuous power and evaluated the damages to fishing under the project's operation. The general conclusion of the previous report was as follows:

"On the basis of the extensive studies of the Fisheries Board, the Commission finds that by providing for relocation and modification of existing fisheries facilities and by including appropriate remedial measures in the design of the tidal power structures, construction and operation of the tidal power project would have very little effect on the important sardine industry in the region and only a minor effect on other fisheries."

In answer to the question as to how the changes in the present proposal might affect the fisheries of the Passamaquoddy area, a working party of United States and Canadian fishery scientists was formed at a meeting in Ottawa, Canada, December 4 to 5, 1963, and asked to study the problem. This group, composed of Drs. J. L. Hart and L. Chenard of Canada, and Messrs. D. L. McKernan and L. W. Scattergood of the United States, report the following:

"*Changes in the fisheries.*—Although the Interior plan will produce minor differences in oceanographic conditions compared to the IJC proposed, and the overall influence may be slightly less favorable, it is concluded that previous predictions contained in the IJC report concerning the effect of the project on the fisheries of the area are generally valid."

This report was forwarded to the Canadian and United States Governments. The report to the Secretary of the Interior was dated April 21, 1964.

CHAPTER VII. COST ESTIMATES

This chapter summarizes the estimates of cost, as of January 1964, prepared by the Corps of Engineers for the Passamaquoddy tidal power project and the hydroelectric powerplants on the upper St. John River at Dickey, Maine, and Lincoln School. It also summarizes the estimates of cost for the transmission system prepared by the Bureau of Reclamation.

The layout and design of the tidal project is the same as proposed by the International Joint Commission with the exception of the powerplant. Four sizes of powerplants are considered; namely, 30, 50, 70, and 100 units of 10,000 kilowatts each. Thirty or 50 units would be located in powerhouse No. 1 and the additional units to make up the 70 or 100 units would be located in powerhouse No. 2.

The proposed dam at Dickey, along with the reregulating dam at Lincoln School, are new layouts and designs.

The transmission system estimate includes the lines and substation necessary to market the power generated from the project in the United States. Depending upon agreements with Canada for sharing of power, the transmission system could be modified to include other lines interconnecting the United States and Canadian systems.

Estimate of cost, tidal power project

Item	Cost in thousands, installed capacities			
	300 megawatts	500 megawatts	700 megawatts	1,000 megawatts
Powerplant	$119,189	$204,491	$302,287	$427,162
Switchyard	1,780	2,370	3,160	3,950
Filling gates	62,634	62,634	62,634	62,634
Emptying gates	57,627	57,267	57,627	57,627
Locks	18,917	18,917	18,917	18,917
Dams	77,309	63,664	64,454	64,454
Lubec Channel	634	634	634	634
Fishways	888	1,298	1,748	2,324
Service facilities	1,670	1,870	2,070	2,470
Relocations	3,929	4,931	7,431	9,631
Lands and damages	1,870	1,870	1,960	2,030
Subtotal	346,447	420,306	522,922	651,833
Contingencies	49,520	58,967	72,728	89,616
Subtotal	395,967	479,273	595,650	741,449
Engineering, design supervision, and administration	43,478	50,581	61,221	74,482
Total first cost	439,445	529,854	656,871	815,931
Interest during construction	33,225	39,267	45,966	53,824
Grand total	472,670	569,121	702,837	869,755

Estimate of cost, Dickey project

Item	Cost in thousands, installed capacities			
	190-megawatts	380-megawatts	475-megawatts	760-megawatts
Lands and damages	$4,469	$4,469	$4,469	$4,469
Relocations	1,363	1,363	1,363	1,363
Reservoir clearing	2,000	2,000	2,000	2,000
Dams	72,919	72,919	72,919	72,919
Penstocks	3,624	7,249	9,062	14,503
Powerplant	28,531	39,093	44,591	60,229
Switchyard	1,583	1,940	2,787	3,466
Buildings, grounds, and facilities	560	560	560	560
Access roads	728	728	728	728
Subtotal	115,777	130,321	138,479	160,237
Contingencies	16,935	18,691	19,700	22,321
Subtotal	132,712	149,012	158,179	182,558
Engineering, design supervision, and administration	14,954	16,559	17,476	19,880
Project first cost	147,666	165,571	175,655	202,438
Interest during construction	6,500	7,036	7,337	8,128
Grand total	154,166	172,607	182,992	210,566

Estimate of cost, Lincoln School project

Item	*Cost in thousands*
Lands and damages	$400
Relocations	1,238
Reservoir clearing	40
Dams	4,323
Powerplant	6,290
Switchyard	387
Buildings, grounds, and facilities	208
Access roads	50
Subtotal	12,936
Contingencies	1,776
Subtotal	14,712
Engineering, design, supervision, and administration	1,553
Project first cost	16,265
Interest during construction	480
Grand total	16,745

Passamaquoddy operation, maintenance, and replacement cost

	Installed capacity, 300 megawatts	Installed capacity, 500 megawatts	Installed capacity, 700 megawatts	Installed capacity, 1,000 megawatts
Operation and maintenance	$1,126,000	$1,340,000	$1,540,000	$1,910,000
Replacements	333,000	508,000	693,000	970,000
Total	1,459,000	1,848,000	2,233,000	2,880,000

Dickey and Lincoln School projects—Operation, maintenance, and replacement cost

	Installed capacity, 190 megawatts	Installed capacity, 380 megawatts	Installed capacity, 475 megawatts	Installed capacity, 760 megawatts
Operation and maintenance	$400,000	$580,000	$670,000	$940,000
Replacements	38,000	74,000	92,000	145,000
Total	438,000	654,000	762,000	1,085,000

Lincoln School project

	Installed capacity 34 megawatts
Replacements	$12,800
Transmission	
Investment	$84,492,000
Interest during construction	2,535,000
Total investment	87,027,000
Annual operation and maintenance	489,000
Replacements	87,000
Operation, maintenance, and replacements	576,000

Passamaquoddy powerplant: Added cost for inclusion of reversible turbine features

Investment (50 units, including interest during construction	$12,880,000
Amortization, annual	407,650
Operation, maintenance, and replacements	62,350
Annual costs	470,000

Chapter VIII. Economic and Financial Analysis

The economic justification and financial feasibility of the potential project have been analyzed using current evaluation procedures. A 100-year period of analysis and a 3-percent Federal interest rate were used in the economic studies. In accordance with the provisions of Senate Document No. 97, recreation and area redevelopment were included as project purposes.

A. PROJECT FORMULATION

The optimum development for the Passamaquoddy-Dickey project under current evaluation criteria was determined to consist of the following project segments:

(1) Dickey Dam, Reservoir, and powerplant with eight generating units having a total installed capacity of 760 megawatts;

(2) Lincoln School regulating reservoir and powerplant with two generating units of 17 megawatts each;

(3) Passamaquoddy tidal basin facilities and powerplant with fifty 10-megawatt generating units; and

(4) Transmission facilities required to distribute project-produced power and energy to load centers in Maine and Massachusetts.

The proposed Dickey development represents maximum utilization of the Saint John River in Maine consistent with preservation of the wild river characteristics of the Allagash. The proposed development of Passamaquoddy represents only an initial step toward development of the full power potential. Construction of Passamaquoddy as proposed in this report envisions the construction of the second powerplant when future conditions warrant such development.

Well-established project formulation procedures were followed in determining the optimum economic development of the project. The objective of these procedures is to insure that the benefits for each added segment of the project bear a favorable relationship to the cost for including the segment. Futhermore, the project is formulated at a level of development that will result in maximization of project benefits over costs.

Comparison of project benefits and costs for various size power installations at Dickey indicates that the installation of eight generating units is amply justified. Additional units were not considered because physical limitations preclude the installation of more than eight units.

Lincoln School Regulating Reservoir and Powerplant were included in all plans analyzed for Dickey because these facilities are essential operational features needed to avoid impairment of power generation at downstream plants in Canada. Comparison of benefits and costs for 2-unit, 4-unit, 6-unit, and 8-unit power installations at Dickey is shown in table 8–1. On the basis of this analysis, the 8-unit power development at Dickey plus the Lincoln School Regulating Reservoir and Powerplant were adopted as the initiating point in the development of the plan formulation studies.

TABLE 8-1.—*Project formulation, Dickey analyzed without Passamaquoddy*

Item	Power installation at Dickey			
	2 units	4 units	6 units	8 units
	(Megawatts)			
Installed capacity:				
Dickey	190	380	570	760
Lincoln School	34	34	34	34
Total	224	414	604	794
	Thousands of dollars			
Annual benefits:				
Power	10,398	15,162	19,924	24,688
Flood control	40	40	40	40
Area redevelopment	247	271	343	409
Total	10,685	15,473	20,307	25,137
Incremental	----------	4,788	4,834	4,830
Annual project costs:				
Dickey	5,267	6,067	6,941	7,699
Lincoln School	593	593	593	593
Transmission system	671	2,018	2,870	2,870
Total	6,531	8,678	10,404	11,162
Incremental	----------	2,147	1,726	758
Benefit-cost ratio:				
Total	1.64	1.78	1.95	2.25
Incremental	----------	2.23	2.80	6.37

Passamaquoddy was then analyzed as an increment to the Dickey unit development. The result of this analysis is shown in table 8-2. It will be noted that Passamaquoddy with a power instalation of 500 megawatts constitutes a justifiable increment to the project. Power installations of 700 megawatts and 1,000 megawatts were also considered but it was concluded that these should be reappraised at some future time when the power demand grows and further experience is gained by the utility systems in meeting peaking power requirements. Since the initial 500-megawatts powerplant does not preclude later additions in the second powerplant, considerations of the full development can readily be deferred.

Internal pumped storage features were included in the proposed plan of development for Passamaquoddy because the analysis of incremental benefits and costs associated with these features revealed that for a relatively small expenditure, project benefits would be enhanced greatly.

Information was obtained on the cost of developing equivalent supplies of energy and capacity by alternate means. The estimated cost of producing power by the proposed Dickey-Passamaquoddy project is significantly lower than modern conventional steamplants under private financing. Nevertheless, it would be possible to produce the equivalent power at less cost in federally financed conventional steamplants. However, the two types of developments would not be at all comparable in terms of the effects on water resource development, flood control, recreation, and area redevelopment.

Passamaquoddy, in particular, constitutes a unique resource potential. Construction of steamplants would still leave this unique resource undeveloped and the highly significant impact of recreation and area redevelopment on the economy of the State of Maine would be foregone. Therefore, it can be concluded the interests of the United States would not be served nearly as well by the construction of federally financed steamplants in New England.

The basic objective in the formulation of plans is to provide the best use, or combination of uses, of water and related land resources to meet all foreseeable short- and long-term needs. National and economic development and the development of each region within the country are essential to the maintenance of national strength and the achievement of a satisfactory level of living. Water and related land resource development and management are essential to these aims. The well-being of all people shall be the overriding determinant in con-

sidering the best use of water and the related land resources. Construction of a steamplant as an alternate to the Passamaquoddy-Dickey project would not contribute to the foregoing aims.

TABLE 8-2.—*Project formulation, integrated operation—Dickey and Passamaquoddy with pumped*[1] *storage (2-hour peaking)*

[Based on 100-year project formulation]

Item	8-unit Dickey with transmission[2]	Integrated operation Dickey plus—	
		30-unit Quoddy	50-unit Quoddy
	Megawatts		
Installed capacity:			
Dickey plus Lincoln School	794	794	794
Quoddy		300	500
Total	794	1,094	1,294
	Thousands of dollars		
Annual benefits:			
Power	24,688	36,732	42,511
Flood control	40	40	40
Area redevelopment	409	1,845	2,278
Recreation		2,030	2,030
Total	25,137	40,647	46,859
Incremental		(15,510)	21,722
Annual project costs:			
Dickey plus Lincoln School	8,292	8,292	8,292
Quoddy		16,700	20,334
Transmission system	2,870	3,330	3,330
Total	11,162	28,322	31,956
Incremental		(17,160)	20,794
Benefit-cost ratio:			
Total	2.25	1.44	1.47
Incremental		(.90)	1.04

[1] Pumping to upper pool from lower pool during periods of neap tides, only.
[2] Transmission to Boston, Mass., area.

B. BENEFITS AND COSTS

Construction of the proposed Passamaquoddy-Dickey power development would create annual equivalent benefits of $46,859,000. (This includes power benefits analyzed under a 2-hour peaking operation at Dickey and Passamaquoddy.) The associated annual equivalent Federal project costs are $31,956,000. The resulting benefit-cost ratio is 1.47 to 1.

C. PURPOSES

Benefits creditable to the project were analyzed for five project purposes—power, recreation, area redevelopment, flood control, and fish and wildlife. A discussion of the benefits for each of these purposes follows.

1. Power benefits

The annual power benefits creditable to the proposed Passamaquoddy-Dickey developments are estimated to be $42,511,000 based on the standard energy-capacity approach. The annual value of capacity and energy that would be produced by the project was computed using energy and capacity unit values furnished by the Federal Power Commission. These unit values represent the alternative costs of producing energy and capacity in New England from highly efficient, large-scale, conventional steamplants under private financing. Inasmuch as transmission system costs have been included in the project cost estimates, power benefits have been computed for at-market conditions. Transmission losses of 9.5 percent for capacity and 7.1 percent for energy were deducted in the power benefit analysis.

Composite at-market unit power values of 3 mills per kilowatt-hour of energy and $27.70 per kilowatt of dependable capacity were adopted for use in evaluating power benefits. These composite values reflect the projected amounts of energy and capacity produced by the project that would be marketed in Boston and Maine powerload centers.

Energy values

	Mills per kilowatt-hour
Maine	3.31
Boston	2.79
Composite	3.00

Capacity values

	Dollars per kilowatt
Maine	29.51
Boston	26.02
Composite	27.70

Estimates of dependable capacity, average annual energy generation, and power benefits are summarized in table 8–3.

TABLE 8–3.—*Power benefits and related data proposed Passamaquoddy-Dickey power developments 2-hour peaking operation*

Item	*Amount*
Installed capacity (megawatts):	
Dickey	760
Lincoln School	34
Passamaquoddy	500
Dependable capacity	1,294
Average annual energy (megawatt-hours):	
At-site production	[1] 2,908,000
Downstream production	656,000
Annual power benefits (thousands of dollars):	
Capacity	32,439
Energy	10,072
Total	42,511

[1] *Net production after deducting pumping energy used in pumped-storage operation at* Passamaquoddy, during neap tide periods.

2. Recreation benefits

The recreational aspects of the potential Passamaquoddy tidal development have been studied by the Bureau of Outdoor Recreation. This Bureau estimates the annual recreational visitation to Passamaquoddy would be 500,000 visitor-days under 1975 conditions. The number of visitors is expected to increase to 4,675,000 by the year 2025. The average annual benefits associated with this recreation activity adjusted for changes over time are estimated to be $2,030,000 based on recreational values of $0.80 per visitor-day.

3. Area redevelopment benefits

Both the Passamaquoddy and Dickey power developments are located within counties which are designated as "redevelopment areas" based on criteria set forth in the Area Redevelopment Act of 1961 (75 Stat. 47); therefore, construction of the potential project would significantly reduce unemployment in these two areas.

Current evaluation procedures require the measurement of benefits attributable to the value of labor required for the construction and operation of a project that otherwise would not be fully utilized. Such benefits are identified in this analysis as area redevelopment benefits.

In evaluating the benefits which would accrue from area redevelopment, wages paid to skilled and unskilled labor required for project construction and salaries paid to personnel for project operation were considered. Labor inputs necessary for the construction of the potential project were estimated through use of information obtained from the Corps of Engineers. Information on the present extent of unemployment in the affected labor market areas and the character of the unemployed labor force was obtained from the Employment Security Commission, State of Maine. Utilizing this information, the available local unemployed labor force was compared with the projected construction work requirements by construction years to estimate the amount of increased employment of the local labor force creditable to project construction. The associated construction wages converted to annual equivalent values for a 100-year period of analysis were used as the construction employment component of the area redevelopment benefits.

Salaries and wages paid to the permanent operating personnel were estimated and used in evaluating the contribution of project operation to local employment. However, in accordance with current procedures of the Department of Commerce, the overall employment period was established at 20 years from initiation of construction at the Dickey and the Passamaquoddy sites, and a declining scale of values reaching zero in the 21st year was utilized. The employment benefits associated with project operation were evaluated as the annual equivalent of this series of declining values when spread over the 100-year period of analysis for the project. The annual area redevelopment benefits creditable to the Passamaquoddy-Dickey power development, as estimated in the manner described, are $2,278,000, annually.

Additional information relating to the area redevelopment analysis is presented in table 8–4.

TABLE 8–4.—*Area redevelopment benefits, Passamaquoddy-Dickey power development*

	Dickey	Passamaquoddy	Project total
Local labor utilized, construction:			
Man-years	2,200	9,900	12,100
Total wages	$9,630,000	$54,080,000	$63,710,000
Operation and maintenance: Annual wages and salaries	$562,000	$810,000	$1,372,000
Annual equivalent benefits:			
Construction	$305,000	$1,712,000	$2,017,000
Operation and maintenance	$104,000	$157,000	$261,000
Total benefits	$409,000	$1,869,000	$2,278,000

4. Flood control benefits

Construction of Dickey dam and reservoir is expected to provide local flood control benefits at Fort Kent of $40,000 annually.

5. Fish and wildlife benefits

Fish and wildlife benefits are not included in the project. The costs for mitigating damages to fish and wildlife have been included as project costs and have been allocated as joint costs of the project.

6. Summary of project benefits

Purpose	*Annual equivalent benefits*
Power (2-hour peaking)	$42,511,000
Recreation	2,030,000
Flood control	40,000
Area redevelopment	2,278,000
Total	46,859,000

D. FEDERAL POWER COSTS

Annual Federal costs associated with the benefits for the potential Passamaquoddy-Dickey power development are estimated at $31,956,000 based on a 100-year analysis and 3-percent interest. The derivation of this estimate is shown in the following tabulation:

Item	*Costs (thousands)*
Construction costs:	
Dickey	$202,438
Lincoln School	16,265
Passamaquoddy (with pumping modifications)	541,881
Transmission system	84,492
Interest during construction:	
Dickey	8,128
Lincoln School	480
Passamaquoddy	40,170
Transmission system	2,535
Total investment	896,389
Annual equivalent investment costs	28,370
Annual operating costs:	
Dickey and Lincoln School	1,098
Passamaquoddy	1,912
Transmission system	576
Total annual equivalent costs	31,956

E. COST ALLOCATION

The costs of the potential project have been allocated among the four functions of power, recreation, flood control, and area redevelopment, using the separable costs-remaining benefits method of allocation, a 100-year period of analysis and 3-percent interest. The costs to be allocated are summarized below:

[In thousands]

Project facilities	Project investment costs			Annual operating costs
	Construction	Interest during construction	Total	
Dickey	$202,438	$8,128	$210,566	$1,035
Lincoln School	16,265	480	16,745	63
Passamaquoddy	541,881	40,170	582,051	1,912
Transmission system	84,492	2,535	87,027	576
Total	845,076	51,313	896,389	3,586

The results of the cost allocation are summarized in table 8-5, and the basic allocation is shown in table 8-6.

TABLE 8-5.—*Summary of project cost allocation*

Project purpose	Construction	Interest during construction	Operation, maintenance, and replacement
Power	$751,077,000	$45,215,000	$3,505,000
Area redevelopment	49,259,000	3,191,000	42,000
Recreation	43,887,000	2,844,000	38,000
Flood control	853,000	63,000	1,000
Total project	845,076,000	51,313,000	3,586,000

TABLE 8-6.—*Cost allocation, Passamaquoddy-Dickey power developments*

[In thousands]

Item	Project functions				Total project
	Power	Area redevelopment	Recreation	Flood control	
Costs to be allocated:					
Construction					$845,076
Interest during construction [1]					51,313
Operation, maintenance, and replacement					3,586
Annual equivalent values:					
Benefits	$42,511	$2,278	$2,030	$40	46,859
Alternative costs	31,956	(2)	(2)	(2)	
Justifiable expenditure	31,956	2,278	2,030	40	36,304
Separable costs:					
Construction	14,982				14,982
Interest during construction	863				863
Operation, maintenance, and replacement	3,266				3,266
Total	19,111				19,111
Remaining justifiable expenses	12,845	2,278	2,030	40	17,193
Percentage	(74.71)	(13.25)	(11.81)	(.23)	(100.00)
Remaining joint costs:					
Construction	8,789	1,559	1,389	27	11,764
Interest during construction	568	101	90	2	761
Operation, maintenance, and replacement	239	42	38	1	320
Total	9,596	1,702	1,517	30	12,845
Total allocated costs:					
Construction	23,771	1,559	1,389	27	26,746
Interest during construction	1,431	101	90	2	1,624
Operation, maintenance, and replacement	3,505	42	38	1	3,586
Total	28,707	1,702	1,517	30	31,956
Summary of allocated costs:					
Construction	751,077	49,259	43,887	853	845,076
Interest during construction	45,215	3,191	2,844	63	51,313
Operation, maintenance and replacement	3,505	42	38	1	3,586

[1] 3 percent annum.
[2] Cost of alternative exceeds benefits, hence the justifiable expenditure is limited to the benefits.

F. REPAYMENT

Reimbursable costs

The construction costs and interest during construction allocated to power is $796,292,000 and is asumed to be fully reimbursable with interest. For fiscal year 1964, the applicable interest rate is 3 percent per annum.

The balance of the project construction costs and interest during construction, $100,097,000, is assumed to be nonreimbursable. Under existing statutes, costs allocated to flood control are nonreimbursable. It is proposed that the costs allocated to area redevelopment and recreation be authorized as fully nonreimbursable. However, if the costs allocated to recreation were made nonreimbursable only within the limits established in the proposed bill, H.R. 9032, only $26,256,000 of the construction costs and $1,701,000 of the interest during construction allocated to recreation would be reimbursable.

Power repayment

Power payout studies for the potential Passamaquoddy-Dickey power development were made to determine the rates at which the power would have to be marketed to achieve reimbursement of the power investment costs in 50 years. The power payout studies disclosed that power rates as shown below would be adequate to achieve repayment of the total power investment, including the transmission system, in 50 years after each unit becomes revenue producing. Moreover, the power payout studies disclosed that the rates would be adequate to achieve repayment of the power investment allocations for each stage of the development within its own 50-year repayment period.

The at-market power rates used in the power payout analysis are:

Energy: 3 mills per kilowatt-hour.

Dependable capacity: $19.75 per kilowatt-year.

An annual revenue credit of $2 million for downstream generation in Canada was assumed in the power payout analysis for planning purposes only. However, unlike the analysis prepared for the July 1963 report, no credit was taken for wheeling revenues in the current power payout studies.

COMPARISON OF DICKEY AND PASSAMAQUODDY-DICKEY PROJECT COSTS WITH A FEDERALLY FINANCED STEAM ALTERNATE

The following cost estimates and comparisons were made to determine the cost of an equivalent quantity of power provided by the project, if generated from comparably financed (Federal) conventional steamplants.

Item	Annual project costs federally financed		Alternate costs, steam, federally financed
	Total	Adjusted	Total
760-megawatt Dickey, plus 34-megawatt Lincoln School	$11,162,000	[1] $10,713,000	$14,645,000
500-megawatt Passamaquoddy plus 760-megawatt Dickey and 34-megawatt Lincoln School	31,956,000	[2] 27,608,000	26,231,000

[1] Annual cost less flood control benefits of $40,000 annually and area redevelopment, $409,000 annually.
[2] Annual cost less flood control benefits of $40,000 annually, recreation $2,030,000 annually, and area redevelopment $2,278,000 annually.

CHAPTER IX. MARKETING

A project is valuable only to the extent of the need and demand of the goods or services produced. With this principle as a guide, the Passamaquoddy-Dickey project functions were evaluated. This discussion is directed to the major revenue-producing feature—power. Flood control, area redevelopment, and recreational benefits are discussed under other chapters of the report.

The Department of the Interior's load and resources study, dated December 1961, recognized the merits and made the initial proposal for the Passamoquoddy tidal power project operating primarily as a peaking powerplant to supply a large market area. These conclusions were based on a review of the International Joint Commission's report of April 1961 and studies utilizing data obtained from the Washington and Boston offices of the Corps of Engineers, U.S. Army, the Washington and New York offices of the Federal Power Commission, and the headquarters office of the New Brunswick Electric Power Commission at Fredericton, New Brunswick.

The market area selected in the current studies embraces the New England States and the Maritime Provinces of Canada. The division of power will depend upon the agreements reached with Canada for construction of the project. In these studies, it is assumed that the additional power produced as downstream benefits will be marketed by the New Brunswick Electric Power Commission and all the other power will be marketed by the United States.

A. LOAD STUDIES

The Federal Power Commission Advisory Committee Report No. 13 forecast the electric utility power requirements in New England to the year 1980. It indicates that the State of Maine will experience a peak demand of 1,750 megawatts in 1980, with an energy requirement of 9.6 billion kilowatt-hours annually. The balance of New England, less the State of Maine, would have a peaking requirement in 1980 of 18.700 megawatts with 95 billion kilowatt-hours of associated energy. The load growth and generation required to meet the peakloads are shown in the following tabulation.

New England load growth and resources, Federal Power Commision and Edison Electric Institute data

[Megawatts]

	1960	1965	1970	1975	1980
Maximum demand:					
PSA 1 (Maine)	565	800	1,010	1,350	1,750
PSA 2 (Massachusetts, Vermont, Rhode Island, Connecticut, New Hampshire)	5,616	7,900	10,400	14,050	18,700
Total	6,181	8,700	11,410	15,400	20,450
Installation required (15 percent reserve)	[1] 7,280	10,000	13,200	17,700	23,600

[1] Actual.

	Megawatts
Installed capacity, Dec. 31, 1963	7,958
Additions planned through 1967 (taken from Edison Electric Institute Publication No. 63-65 dated October 1963):	
Bangor hydro	29
Boston Edison	395
Central Maine Power	125
Connecticut Light & Power	172
Connecticut Yankee	460
Hartford Electric Light	235
New England Power Co	496
Total additions	1,912
Grand total	9,870

B. CHARACTERISTICS OF POWER MARKETS

The growth of utility power markets in New England and New Brunswick, as in the rest of the United States and Canada, is influenced by a number of economic and technological factors. These include growth of population and households; expansion of industrial production; growth of activities associated with service, trade, and professional establishments; greater application of known processes and devices using electricity; and the development and introduction of new uses for electricity in the home, industry, and other fields. Under the impact of these influences, the utility markets have grown steadily over a long period. The growth of these markets is expected to continue in the future.

At present there are 31 electric utilities operating in the State of Maine and 126 in the remaining New England States. In Canada, the principal utilities are the New Brunswick Electric Power Commission, the Nova Scotia Power Commission, and the Nova Scotia Light & Power Co., Ltd.

The load shape forecast for New England, based on Federal Power Commission data projected for 1980, is indicated on the following chart:

FEDERAL POWER COMMISSION

ESTIMATED ELECTRIC UTILITY LOADS IN NEW ENGLAND

WEEK OF DECEMBER 7, 1962

EXPANDED TO

ESTIMATED ANNUAL PEAK LOAD IN 1980

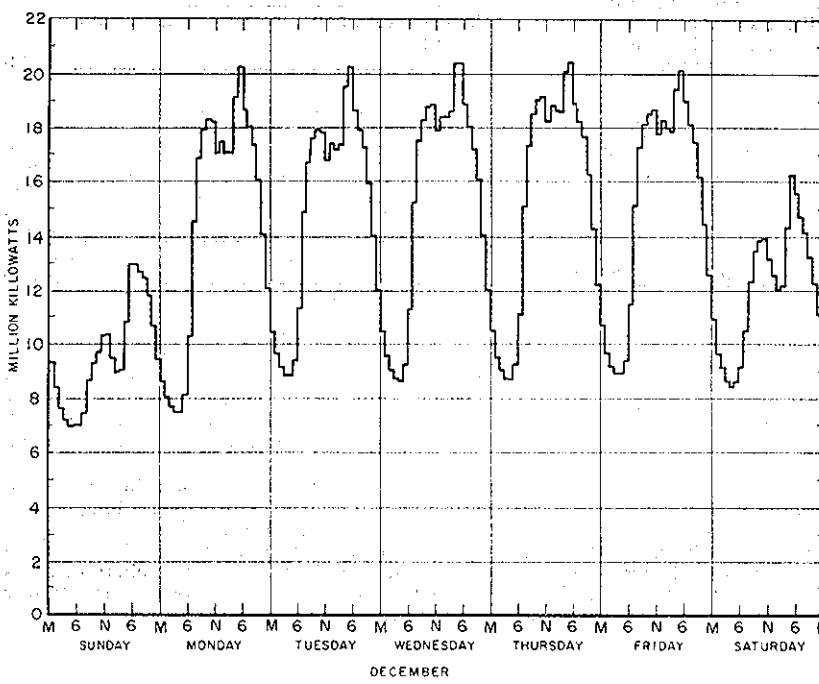

FIGURE 4

This shows the predominantly high peakloads which must be met and indicates the potential for sale in excess of 1 million kilowatts for a peak of 2 hours' duration. This is predicated on load growth based on current expansion factors and does not take into account the economic impact of the project on the area.

Since the project's total capacity of 1,294 megawatts will provide 2.94 billion kilowatt-hours of energy annually, the project has 2,274 kilowatt-hours associated with each kilowatt of generating capacity. The cost associated with kilowatt of capacity would be as follows:

Passamaquoddy-St. John—Federal

Capacity	$19.75
Energy	6.82
Total	26.57

Thermal (fossil fuel)—Private

Capacity	$27.70
Energy	6.82
Total	34.52

Nuclear—Private

Capacity	$30.89
Energy	4.09
Total	34.98

Pumped storage—Private

Capacity	$30.00
Energy	13.64
Total	43.64

C. POWER COSTS

The power studies indicate the following comparison of the cost of peaking capacity from various sources and attest to the marketability of the project's power (2-hour peak):

[Dollars per kilowatt]

	Federal—Passamaquoddy-Dickey	Private financing			
		Fossil fuel	Nuclear	Conventional pumped storage	
				Maine	New Hampshire
Capacity	19.75	27.70	30.89	25.32	28.18
Energy	1.56	1.56	.94	1.66	1.64
Total	21.31	29.26	31.83	26.98	29.82

D. MARKETING POLICY

In marketing the electric power generated at the project the Secretary of the Interior shall transmit power and energy to Canada in accordance with agreements reached, and the remaining power will be sold in the United States in such a manner as to encourage the most widespread use thereof at the lowest possible rates consistent with sound business principles. The Secretary of the Interior shall prepare rate schedules having regard to the recovery of the cost of producing and transmitting such electric energy, including the amortization of the capital investment allocated to power, over a reasonable period of years. Preference in the sale of such power and energy shall be given to public bodies and cooperatives.

All moneys received from sales of electric power and energy shall be deposited in the Treasury of the United States as miscellaneous receipts. Downstream benefits provided by the projects and received in the United States from Canadian authorities in the form of power and energy shall be received, transmitted, and disposed of by the Secretary of the Interior.

CHAPTER X. POWER COSTS BY ALTERNATIVE MEANS

The Passamaquoddy-upper St. John project is singularly unique in its potential for providing immediate beneficial economic impact and sustained economic benefit for the people of seriously distressed areas of Maine and New Brunswick—areas which compare to any other region in both countries in the roots and consequences of prolonged poverty.

For the first time in history, this imaginative and conclusively demonstrable economic water resource development will provide Canada, the United States, and the world with full-scale generation of electric power from the tides of the ocean. In addition, it will encompass comprehensive development of an important international river in the Northeast, an unparalled international recreational attraction, and significant and continuing new employment opportunities directly and indirectly.

Power, however, is a major feature and function of the project.

From this source comes the revenues which must repay the basic cost of natural resource development, as well as the costs of operation, maintenance, replacement, and interest—the requirements of Federal policy and congressional directive for water resource development.

In order to evaluate properly the value of power from the Passamaquoddy-upper St. John project, a comparison of the cost of power generated by likely alternative sources, in conjunction with due regard for their alternate merits and demerits, must be considered.

The first, and more probable equivalent alternative, would be a modern steam-generating plant fired by fossil fuels and operated to provide equivalent power. The cost estimates for such plants, Federal or non-Federal, were furnished by the Federal Power Commission. The economic studies and financial analyses in this report were made on this basis.

Estimates were also made of the cost of generating power from generating plants located in the New England area, with transmission to the Boston area.

Although it was recognized that conventional hydroelectric powerplants, jet engine peaking plants, gas turbine peaking plants, steam-topping units or diesel engines are also peaking power sources, the Advisory Board concluded that for the purpose of evaluating power of the magnitude, and characteristic of flexibility and perpetuity of the Passamaquoddy-Dickey project, it would be sufficient to restrict the comparison to thermal plants, both fossil fuels and nuclear fired, and conventional pumped storage plants.

This decision was made by the Board on the basis that these other alternative sources could not provide peaking power on the magnitude offered by the Passamaquoddy-St. John River project, either on a historical basis in New England in case of conventional hydroelectric power or by long-term operating experience in the case of other alternatives mentioned above.

A. THERMAL POWER-FOSSIL FUELS

The Federal Power Commission furnished the following values for the project's power delivered to load centers in the Maine and Massachusetts areas—the logical markets. These power values include the generating cost, plus the cost of a step-up substation to a high voltage transmission system.

Private financing

	Massachusetts	Maine
Unit size, megawatts	325	100
Capital cost (kilowatts):		
Generation	$150	$180
Stepup transmission	$8	$12
Fixed charges (percent)	12.12	13.42
Capacity costs (kilowatts)	$24.78	$28.10
Capacity value adjustment:		
Percent	5	5
Amount	$1.24	$1.41
At-market capacity value (kilowatts)	$26.02	$29.51
At-market energy value, mills per kilowatt-hour	2.79	3.31

NOTE.—Composite value for area: Capacity (kilowatts), $27.70; energy-mills (kilowatt-hour), 3.0.

The comparable composite values on Federal financing of a similar modern steamplant are $13.90 per kilowatt for capacity and 3 mills per kilowatt-hour for energy, based on the current Federal rate of 3 percent interest.

B. NUCLEAR POWER

The Atomic Energy Commission supplied cost estimates for nuclear powerplants which could provide power roughly equivalent to that which would be generated by the Passamaquoddy-Dickey project. The comparison recognized the fact that nuclear powerplants, as in the case of thermal powerplants using conventional fuels, are essentially baseload plants. Thus, when operating as a peaking powerplant such as is envisioned from the Passamaquoddy-upper St. John project, the full economic potential for nuclear energy generation is not realized. However, with this recognition, the capacity and energy costs were furnished by the Atomic Energy Commission for units of 625-, 430-, and 300-megawatt capacity using light water reactors. To these costs which are noted on the following table the costs of the step-up substation were added to provide costs at the high-voltage bus. Thus, the costs are comparable to the estimates by the Federal Power Commission for fossil fuel plants.

Capacity and energy cost of nuclear power light water reactor

	Private financing [1]			Federal financing [2]		
Unit size ... megawatts	625	430	300	625	430	300
Investment ... kilowatts	$130	$150	$185	$130	$150	$185
	Dollars per kilowatt-year					
Annual capacity costs:						
1. Fixed charges on plant	17.6	20.4	25.1	7.0	8.1	10.0
2. Fuel stock investment	2.6	2.6	2.7	.8	.8	.8
3. Fixed operating cost (operations, maintenance, administration, and insurance)	3.4	3.5	3.6	3.4	3.5	3.6
Total generation	23.6	26.5	31.4	11.2	12.4	14.4
Step-up transmission	1.2	1.4	1.5	1.2	1.4	1.5
Total at high-voltage bus	24.8	27.9	32.9	12.4	13.8	15.9
	Mills per kilowatt-hour					
Variable operating costs:						
1. Energy fuel	1.40	1.45	1.50	1.40	1.45	1.50
2. Operation and maintenance	.20	.25	.30	.20	.25	.30
Total variable	1.60	2.70	1.80	1.60	1.70	1.80

[1] Cost in percent:

	Percent
Cost of money	6.25
Depreciation, 35 years S.F	.85
Interim replacement	.35
Property insurance	.40
Taxes (Federal—3.33—State and local—2.39	5.72
Total	13.57

[2] Cost in percent:

	Percent
Cost of money	3.0
Depreciation, 35-year S.F	1.65
Interim replacement	.35
Property insurance	.40
Total	5.40

C. PUMPED STORAGE

The Passamaquoddy-Dickey project contemplates delivery of peaking power to meet a peak of 2 hours' duration in the Boston, Mass., area. Studies were made to determine the cost of providing peaking power in this area by construction of pumped storage plants and the necessary transmission facilities, under both private financing and Federal financing.

The Federal Power Commission supplied information on several pumped storage sites. The Bureau of Reclamation prepared estimates of the cost of pumped storage developments at these sites. The results of the studies are shown on the attached table for the following possible plants:

Rowe pumped storage powerplant (Maine)

This powerplant site is located near Bingham, Maine. It would utilize the Rowe Pond for a forebay and the Kennebec River as an afterbay. The average static head is 775 feet. Installed capacities of 250 and 500 megawatts were considered. Based on 85-percent efficiency, it would be necessary to use 4,500 cubic feet per second with a 250-megawatt plant and 9,000 cubic feet per second for a 500-megawatt plant. To provide for 2 hours of peaking, 750 acre-feet of storage would be required for the 250-megawatt plant and 1,500 acre-feet for the 500-megawatt plant. The cost estimates include the cost of a forebay structure.

Woodstock pumped storage powerplant (New Hampshire)

This pumped storage powerplant would be located near Woodstock, N.H. The information submitted by the Federal Power Commission indicated that this plant would have a head of 960 feet and an installed capacity of 800 megawatts. Examination of the quadrangle sheet in the vicinity of Elbow Pond indicated that it would not be possible to develop enough storage to provide that head. Estimates were therefore made by proportionately reducing the installed capacity from 800 to 670 megawatts and the ratio of a head of 960 feet to a head of 800 feet. A flow of 11,600 cubic feet per second and storage capacity of approximately 2,000 acre-feet would be required to meet a 2-hour peak. The estimates include a dam on Elbow Pond and a dam on the Pemigewasset River for an afterbay structure. The estimates provide for relocations that would be required in the afterbay structure.

Mountain Tom pumped storage powerplant (Massachusetts)

This site is located on the Connecticut River near Holyoke, Mass. The head on this powerplant is estimated to be 490 feet for an installed capacity of 400 megawatts. The flow required would be 1,400 cubic feet per second and about 1,900 acre-feet of storage would be required to provide 2 hours of peaking. The cost estimates for this plant include an afterbay structure on the Connecticut River.

Pumped storage operation

It must be recognized that pumped storage is an energy-conversion device and not an energy-creating device. It acts much the same as a storage battery. Electric energy must be supplied for pumping water from a lower level to a higher level during periods of excess energy on the transmission system. In fact, it requires 3 kilowatt-hours of energy to produce 2 kilowatt-hours by pump storage. Thus, power is generated during peaking periods by releasing water through generators from the higher level to the lower level. The operation of pumped storage presupposes a source of low-cost dependable power or self-contained energy for pumping during off-peak periods.

In the case of alternative pumped storage projects in New England and in specific comparison to the Passamaquoddy-upper St. John project, the availability of other sources of low-cost off-peak power or self-contained power is a definite consideration. None of the three alternate pumped storage projects have the advantage of Passamaquoddy's self-contained source of off-peak, low-cost dependable power. Furthermore, pumping at this project will be necessary only for very short periods during any given month when minimum tides occur, rather than daily, thus requiring only nominal amounts of energy.

Pumped storage: Selected sites in New England—Reconnaissance estimates

	Rowe, Maine		Woodstock, N.H.	Mount Tom, Mass.
Summary:				
Installed capacity (in megawatts)	250	500	610	400
Capital cost (in dollars per kilowatt)	144	135	150	196
Private financing:				
Generation (in dollars per kilowatt year)	22.44	21.55	23.28	32.91
Transmission	14.22	9.29	3.70	3.35
Total (in dollars per kilowatt-year)	36.66	30.84	26.98	36.26
Federal financing:				
Generation (in dollars per kilowatt-year)	9.74	9.35	9.92	11.79
Transmission	4.87	3.35	1.27	1.00
Total (in dollars per kilowatt-year)	14.61	12.70	11.19	12.79

NOTE.—2-hour daily peak, 5 days per week. Energy assumed to be available at 4 mills per kilowatt-hour.

Analysis of alternatives

Economic analysis alone precludes all privately financed fossil fuel, nuclear, or pumped storage projects as an alternative to the Passamaquoddy-upper St. John River project. In no instance of feasible alternatives can privately financed electric generation provide an equivalent amount of power at a lower cost. The economic alternatives are as follows:

A. FEDERAL STEAMPLANTS

The charges of $13.90 for capacity and 3 mills for energy are less than the equivalent cost for the Passamaquoddy-upper St. John River project. However, no legislative authority exists for the Corps of Engineers or the Department of the Interior to construct or operate conventional steamplants in the continental United States; nor has the Congress elected to adopt such a policy. In any event, this alternative offers no development of regional water resources as specified in Senate Document 97, 87th Congress; nor does it provide any significant area redevelopment or outdoor recreational benefits comparable to the Passamaquoddy-upper St. John River project. And, in the analysis, a Federal steamplant so operated would be inefficient in providing power such as that available from the Passamaquoddy-upper St. John project.

B. FEDERAL NUCLEAR POWER

A federally financed and operated nuclear powerplant could again under certain conditions supply power of the same magnitude at a lower cost. However, legislative history provides conclusively that the Congress does not envision wholly financed and wholly operated Federal nuclear plants. Furthermore, a Federal nuclear plant would not result in any water resource development, flood control, river regulation, area redevelopment, or outdoor recreational benefits.

Again, as in the case of a Federal steamplant operating on fossil fuels, a federally owned and operated nuclear powerplant would have to be operated uneconomically to provide equivalent power.

C. PUMPED STORAGE

Federally constructed and operated pumped storage projects could produce equivalent peaking power at a lower cost than the Passamaquoddy-upper St. John River project. Furthermore, under the Flood Control Act of 1944, and under subsequent interpretation and practice, the Federal Government could conceivably construct such projects upon congressional authorization.

This alternative suffers in that none of the three alternate pumped storage sites have a source of dependable low-cost power available from an independent entity nor do they have the capability of self-contained power for pumping. Also, a pumped storage project would need outside power daily while Passamaquoddy is dependent upon off-peak generation for pumping for only a few days each month. Nor does pumped storage offer equivalent benefits in water resource development, flood control, river regulation, area redevelopment, and outdoor recreation.

Summary of alternatives

None of the three economic alternatives—Federal steam, Federal nuclear, or Federal pumped storage—offers the equivalent in new employment and sustained economic opportunity.

Also, intrinsic in the Passamaquoddy-upper St. John River project is the concept of an international intertie between the United States and Canada in the Northeast whereby the full economic potential of each nation could be fully realized to mutual maximum benefit. Ignoring the other inherent limitations of alternatives, the full development of water resources—a national goal—would be retarded through adoption of other economic alternatives.

There is no alternative to Passamaquoddy to conserve the ever-wasting energy of the tides and putting it to beneficial use.

In the ensuing years, the Department of the Interior is convinced that, in New England, the development of pumped storage, conventional hydroelectric power, modern steam generation, and nuclear plants—whether public or private—will be required. New capital investment by private industry in baseload plants will be absolutely essential.

We are equally convinced that the Passamaquoddy-upper St. John River project is a first and necessary step toward vitally needed economic rejuvenation for people whose ancestors did so much to help frame our national heritage.

SUPPLEMENT TO JULY 1963 REPORT

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER ST. JOHN RIVER HYDRO-ELECTRIC POWER DEVELOPMENT

SUPPLEMENTARY ENGINEERING REPORT

CORPS OF ENGINEERS

APRIL 1964

PREPARED BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS

WALTHAM, MASS.

LETTERS OF TRANSMITTAL

HEADQUARTERS, DEPARTMENT OF THE ARMY,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D.C., April 13, 1964.

Hon. STEWART UDALL,
Secretary of the Interior.

DEAR MR. SECRETARY: In compliance with the instructions of the late President Kennedy, as expressed at the White House meeting of July 16, 1963, and in accord with our agreement, I am pleased to transmit herewith my report on the cost and engineering aspects of supplemental studies pertaining to the international Passamaquoddy tidal power project and upper St. John River hydroelectric power development.

Sincerely yours,

W. K. WILSON, JR.,
Lieutenant General, U.S. Army,
Chief of Engineers.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND,
CORPS OF ENGINEERS,
Waltham, Mass., April 10, 1964.

Subject: Transmittal of supplementary engineering report to the Secretary of the Interior's report entitled "The International Passamaquoddy Tidal Power Project and Upper St. John River Hydroelectric Development."

To: Chief of Engineers. Attention: ENGCW-E, Washington, D.C.

1. Pursuant to instructions outlined in your letter of July 23, 1963, and in accord with your agreement with the Secretary of the Interior, a supplementary engineering investigation has been undertaken in support of the Secretary of the Interior's report of July 1963 to the late President Kennedy. The investigation covers engineering layouts and cost estimates for various sizes of powerplants with ultimate installed capacity of 1 million kilowatts at Passamaquoddy, Eastport, Maine; and hydroelectric development at Dickey, Maine, on the upper St. John River with ultimate installed capacity of 760,000 kilowatts and a reregulating dam and powerplant with 34,000 kilowatts installed capacity 11 miles downstream at Lincoln School, Maine. The investigation and report were accomplished with the advice and guidance of the Army-Interior Advisory Board on Passamaquoddy and upper St. John River.

2. The supplementary engineering investigation is complete and the report is transmitted herewith.

P. C. HYZER,
Brigadier General, U.S. Army,
Division Engineer.

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PERTINENT DATA

Tidal Power Project

Location: Passamaquoddy Bay and Cobscook Bay, in New Brunswick and Maine.

Highpool: Passamaquoddy Bay, New Brunswick and Maine; area	square miles	101
Low pool: Cobscook Bay, Maine, and Friar Roads, New Brunswick; area	square miles	41

Powerhouse: Two separate 50-unit plants. Powerhouse No. 1 located in Carryingplace Cove, Maine; powerhouse No. 2 located in Bar Harbor, Maine. Each with 50 300-inch diameter adjustable-blade, adjustable-gate, propeller-type, inclined-axis turbines, speed 45 revolutions per minute connected through a speed increaser to 10,000-kilowatt, 13,800-volt, 3-phase, 60-cycle generators turning at 450 revolutions per minute.

Dams—Earth and rockfill type:		
Total length	feet	35,700
Maximum height	do	315
Crest elevation	feet, mean sea level	25

Filling and emptying gates: 90 30- by 30-foot vertical-lift, submerged venturi filling gates; 70 30- by 30-foot vertical-lift, submerged venturi emptying gates.

Navigation locks:		
Head Harbor passage	feet	415 by 60 by 21
Western passage	do	415 by 60 by 21
Little Letite	do	95 by 25 by 12
Quoddy Roads	do	95 by 25 by 12
Principal quantities:		
50-unit development (including gates and locks):		
Dams	cubic yards	53,000,000
Cofferdams:		
Steel sheeting	tons	62,000
Dikes	cubic yards	11,000,000
Waste from excavation	do	4,500,000
Concrete	do	1,700,000
Steel, reinforcing	tons	82,000
Steel, structural	do	190,000
50-unit powerplant No. 2, increment:		
Cofferdams:		
Steel sheeting	do	11,000
Dikes	cubic yards	3,500,000
Waste from excavation	do	45,000,000
Concrete	do	950,000
Steel, reinforcing	tons	47,000
Steel, structural	do	10,000

Dickey Project

Location: St. John River, Maine, 300 miles above mouth.

Streamflow:		
Average annual runoff	acre feet	3,331,000
Maximum discharge	cubic feet per second	71,700
Minimum discharge	do	129
Average discharge	do	4,600
Reservoir:		
Drainage area	square miles	2,725
Maximum operating level	feet, mean sea level	910
Limit of drawdown	do	870
Usable storage	acre-feet	2,900,000
Total storage	do	8,080,000
Area, at maximum operating level	acres	88,600
Main embankment:		
Crest length	feet	9,200
Maximum height	do	340
Top elevation	feet, mean sea level	925
Spillway:		
Crest length	feet	500
Crest elevation	feet, mean sea level	910
Design discharge	cubic feet per second	50,000

Low level outlets: Two 24-foot diameter tunnels controlled by four 90-inch fixed-cone dispersion valves.

Powerhouse: Indoor type, concrete. Eight Francis-type, vertical-axis turbines, average head 293 feet, direct-connected to 95,000-kilowatt, 13,800 volt, 3-phase, 60-cycle generators turning at 128.6 revolutions per minute.

Principal quantities:		
Rock and earthwork	cubic yard	65,000,000
Concrete	do	500,000
Reinforcing steel	tons	20,000

Lincoln School Project

Location: St. John River, Maine, 289 miles above mouth.

Streamflow:		
Average annual runoff	acre-feet	4,981,000
Maximum discharge	cubic feet per second	101,000
Minimum discharge	do	249
Average discharge	do	6,880
Reservoir:		
Drainage area	square miles	4,086
Maximum operating level	feet, mean sea level	605
Limit of drawdown	do	597
Usable storage	acre-feet	16,000
Total storage	do	52,500
Area, at maximum operating level	acres	2,200
Main embankment:		
Crest length	feet	1,290
Maximum height	do	87
Top elevation	feet, mean sea level	620
Spillway:		
Four 30- by 40-foot taintor gates:		
Crest elevation	feet mean sea level	575
Design discharge	cubic feet per second	92,005

Powerhouse: Indoor type, concrete. Two Kaplan-type vertical-axis turbines, average head 61 feet, direct-connected to 17,000-kilowatt, 13,800-volt, 3-phase, 60 cycle generators turning at 138.5 revolutions per minute.

Principal quantities:		
Rock and earthwork	cubic yard	2,200,000
Concrete	do	85,000
Reinforcing steel	tons	4,000

SUPPLEMENT TO JULY 1963 REPORT

CHAPTER I. INTRODUCTION

1-01 Authority

At Eastport, Maine, the large tidal range has long intrigued observers as a natural resource that could be used for the development of electric power. There are two large natural tidal bays that are connected by water passages between a string of islands which stand between the bays and the open ocean. Passamaquoddy Bay, the larger of the two, is mainly located across the international boundary in Canada while Cobscook Bay lies entirely in the United States. By connecting the islands with a series of dams in designed pattern separate tidal pools can be formed and water elevations regulated to maintain the pools at different levels. If a powerhouse is placed between the two pools and water permitted to pass from the higher to the lower the induced head differential will produce power.

The development of tidal power at Passamaquoddy has been studied periodically since 1919 by both private and public engineers. The most comprehensive report undertaken was that of the International Joint Commission completed in April 1961 after 3 years of study and a cost of $3 million. The project was developed as a two-pool scheme interconnected with a powerplant that would operate continuously but with varying output. The powerhouse was a 30-unit plant with vertical-axis turbine and generator units with a capacity of 10,000 kilowatts each. The Commission found the project not economically feasible under the then existing conditions.

In early July 1963, as a result of an earlier request to review the International Joint Commission (IJC) report to ascertain whether developments in engineering techniques and/or economic conditions would make the project feasible, the Secretary of the Interior presented to President John F. Kennedy a report on "The International Passamaquoddy Tidal Power Project and Upper St. John River Hydroelectric Power Development." This report proposes to use the power output to meet the demand for peak power in the New England area, and when coupled with the advancement in engineering techniques and integrated with a hydroelectric plant on the upper St. John River would make the project economically feasible. The same structures were used for the tidal project, except for the powerhouse where an inclined-axis turbine was substituted for the more conventional vertical-axis turbine. From the studies made of power potential, it was proposed that an ultimate installation of 100 to 10,000 kilowatt units could be installed at Passamaquoddy. Integration with another source of power is necessary since tidal output varies with the tide range, a minimum occurring about every 2 weeks at periods of neap tides when the available head is lowest. In order to supplement and maintain power output at these periods an auxiliary hydroelectric plant with an ultimate capacity of 750,000 kilowatts would be established on the St. John River at Dickey. The Dickey Dam site was selected by the Department of the Interior in lieu of the Rankin Rapids project considered by the IJC in order to preserve the recreational values of the Allagash River. Integrated operation of the two plants would assure dependable peaking capacity of the planned magnitude of 1 million kilowatts and 250,000 kilowatts capacity at 60 percent load factor for energy output.

On July 16, 1963, the President directed the Departments of the Interior and Army to proceed immediately with such additional studies and plans as are necessary and that the studies be coordinated in all respects by the Secretary of the Interior. Pursuant to this general understanding, Lt. Gen. W. K. Wilson, Jr., the Chief of Engineers, by letter of July 29, 1963, proposed an eight-member Army-Interior Advisory Board on Passamaquoddy and upper St. John River, with four representatives from each agency. The purpose of the Board is to advise and guide both field agencies in their preparation of additional studies, plans, and reports to supplement the July 1963 report to the President by the Secretary of the Interior on the international Passamaquoddy tidal power project and upper St. John River hydroelectric power development. By letter of July 30, 1963, Mr. Kenneth Holum, Assistant Secretary, Department of the Interior, agreed

to this procedure. The Board was later increased to 14 members by adding representatives from the Federal Power Commission, Department of Commerce, Bureau of the Budget, Office of Science and Technology, Council of Economic Advisers, and the Atomic Energy Commission. Membership of the Board is given in appendix I.

1-02 Scope of engineering studies

The division of work between the Corps of Engineers and the Department of the Interior, as indicated by the initial agreement between the agencies and confirmed by the Advisory Board, was to the effect that power studies, power transmission, marketing, benefits, and other economic aspects of the project would be the responsibility of the Department of the Interior and that the development of the physical components, other than transmission lines, would be the responsibility of the corps. The detailed engineering studies and requisite field work were to be performed by the division engineer, New England Division, Waltham, Mass.

The studies undertaken for this report to attest to the engineering feasibility and soundness of the engineering structures of this project were as follows:

(*a*) Geologic investigations and field explorations at the sites of all structural components.

(*b*) Field surveys.

(*c*) Hydrologic investigations of the St. John River.

(*d*) Layout and design of facilities for powerplants at Passamaquoddy; power dam and closure dikes at Dickey: and reregulating and power dam at Lincoln School.

(*e*) Studies of use of inclined-axis turbines at Passamaquoddy in cooperation with the Bureau of Reclamation.

(*f*) Planning appraisal of all lands and damages for the entire project.

(*g*) Cost estimates of facilities, except transmission facilities.

The layouts of the construction proposed and the cost estimates for the entire project are presented in the following chapters.

Chapter II. Site Investigations and Foundation Conditions, Passamaquoddy

2-01 General geology

Bedrock of the project area includes sedimentary and igneous rocks of upper Silurian age known as the Eastport formation. The sedimentaries are shales and conglomerates and the igneous rocks are represented by rhyoltic and diabasic varieties and associated volcanic tuffs. These rocks have been much folded to present a complex distribution of alternating beds of igneous and sedimentary rocks.

Prior to glaciation, the bedrock topography was subjected to a long period of erosion featured by development of deep-stream valleys. The land was greatly depressed by the advance of thick glacial ice in Pleistocene time, and with retreat of the ice came invasion by the sea. Since glaciation full emergence has not been attained and the preglacial stream valleys are partly drowned to form the deep marine channels, while the numerous islands are high areas of the old erosional surface.

The preglacial topography was slightly modified by movement of the ice mass in the removal of the weathering mantle and in the plucking and smoothing of the rock surface. More pronounced modification resulted from deposition of rock debris carried in and on the ice. Materials that were deposited directly from the ice generally occur as a veneer over the rock surface in the form of glacial till, a compact mass mixture of all sizes of rock and earth materials. Coarse materials that were outwashed from the ice occur as remnant deposits of sorted sands and gravels. The fine materials that were outwashed to settle in quiet waters of the invading sea occur as thick deposits of marine clay and silt. Since glacial time, the outwash deposits exposed to sea attack have been reworked by waves and transported by currents to form bars and beaches. Minor deposition by streams has occurred and peat has locally accumulated in bogs and marshes.

2-02 Explorations

Investigations previously made over a number of years for powerhouse No. 1 and channels are sufficiently complete as to preclude need for further exploratory work. These investigations, which include concrete aggregate studies applicable to powerhouse No. 2, are detailed in "Report to the International Joint Commission, 1959," Appendix 2: Geology, Foundations, and Materials.

Previous subsurface explorations pertinent to the areas of powerhouse No. 2 and channels have consisted of the following:

(*a*) Eight scattered wash borings indicating elevation of bedrock made for the Cooper study of 1926–28.

(*b*) Three drive-sample and core borings made by the Corps of Engineers in 1935 on alinements of the Carlow Island and Pleasant Point Dams.

(*c*) Marine geophysical exploration extending into a portion of the tailrace channel in the vicinity of Spectacle Island, cooperatively made on a trial basis in 1951 by the Corps of Engineers and U.S. Geological Survey.

Current explorations made for the purpose of this report specifically for powerhouse No. 2, included geological reconnaissance on land and water and the drilling of two test borings recovering 2-inch drive samples and 2⅛-inch diameter rock cores made to investigate foundation and excavation conditions for the powerhouse structure. Boring FD–1 was drilled and hydraulically pressure-tested in rock to elevation minus 89 mean sea level or slightly below maximum required depth of structure excavation. Although this boring is located off the structure because of subsequent adjustment in layout, the conditions encountered are considered pertinent. Boring FD–2, which was made to establish depth to bedrock on the west end of the original layout for the powerhouse, is now located nearly 1,000 feet southwest where it becomes more applicable to excavation conditions in the tailrace channel. Other explorations consisted of 29 machine-driven probings to preliminarily determine division of earth and rock materials to be excavated in the headrace and tailrace channels. These probings were distributed in water areas of the channels lacking in surficial and subsurface data and were driven to below proposed grades or to refusals above grades.

The locations and records of previous and current explorations and the distribution of bedrock exposures for powerhouse No. 2 are shown on plate No. 4 entitled "Plan and Record of Explorations."

2–03 Structure excavations and foundations, powerhouse No. 2

Ground elevations will vary from a few feet to nearly 60 feet above mean sea level on the powerhouse alinement. Structure excavation will amount to over 2 million cubic yards, principally rock, and deepest excavation will be about 140 feet in reaching lowest invert of about 80 feet below mean sea level.

Overburden excavation will vary from a skimming to an estimated maximum depth of 30 feet to reach the rock surface. Overburden is principally glacial till with the major exception of the marsh area along about the southeasterly third of alinement where marine clay attains a thickness of 15 or more feet.

Reconnaissance geologic mapping and the rock cores recovered from boring FD–1 indicate that rock excavations will principally encounter igneous rocks, rhyolite and diabase in flows, sills and dikes with subordinate occurrences of sedimentary rock (shale) and tuffs (cemented volcanic fragments). These rocks singly or in their various complex associations present no apparent problems as to their competency for bearing heavy foundation loads. However, the many contacts of rock types, occasional fault zones and the presence of numerous open and healed fractures and cracks may relate to problems of water pressures and inflows requiring grouting during and after excavation, and to difficulties in producing any close tolerances that may be required for precise or shaped excavations. The fractured condition of the rock as recovered in cores from the deep test boring FD–1 is pictured on figure 1 (p. 52) and a graphic record of tests for holed leakage using water under pressure is shown on plate No. 4. These tests indicate openness in some zones by flows of up to 16 gallons per minute under maintained pressures of 20 to 50 pounds per square inch.

2–04 Channel excavations

Excavations for the headrace and tailrace channels will involve over 50 million cubic yards with a greater proportion in the headrace channel where grade is constant at minus 40.7 mean sea level. Deepest excavation, to minus 67 mean sea level and mainly in rock, will occur in the beginning of the tailrace channel near the southerly shore of Moose Island.

Overburden of the land and islands and their fringes is glacial till, except for localized marsh areas and clay deposits. The overburden of the water areas is clay overlying the till which veneers the rock surface.

All of the igneous and sedimentary rock types previously discussed will be encountered. From available surficial and subsurface geologic data, it is preliminarily estimated that 50 percent of channel excavations will involve rock.

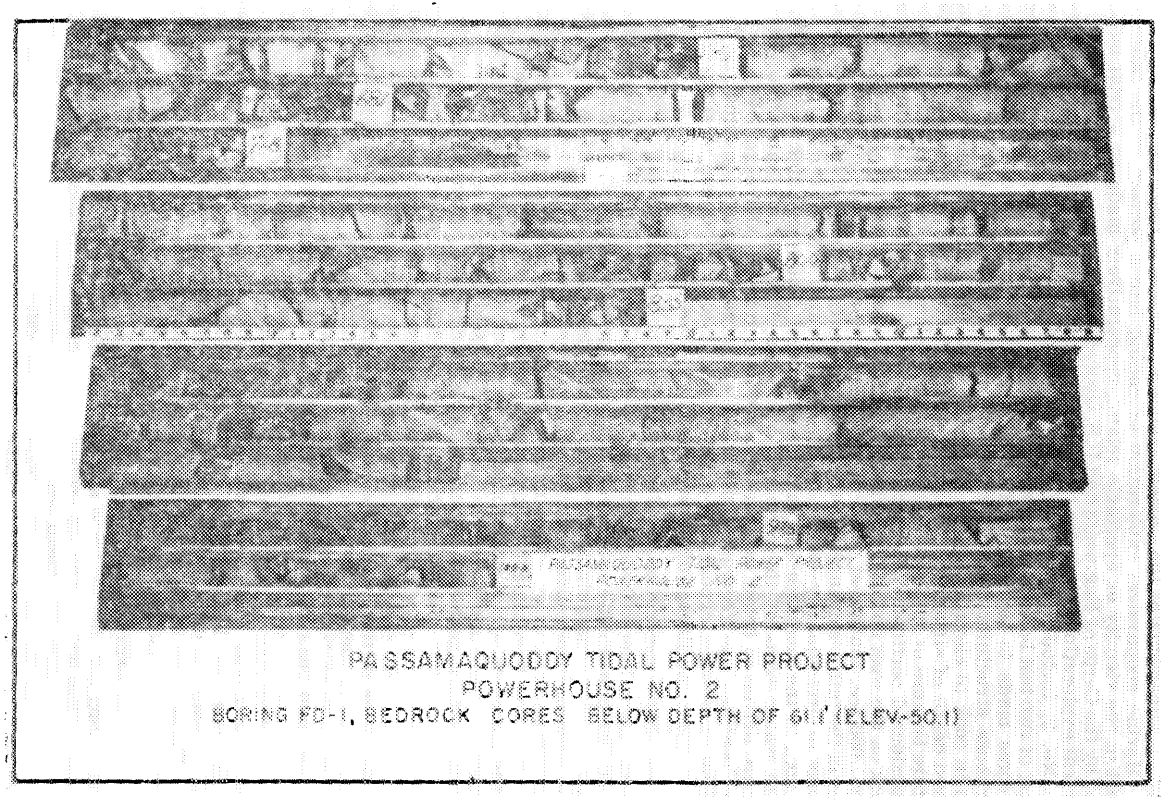

PASSAMAQUODDY TIDAL POWER PROJECT
POWERHOUSE NO. 2
BORING FD-1, BEDROCK CORES BELOW DEPTH OF 61.1' (ELEV-50.1)

FIGURE 1

2–05 Tidal dam

A low tidal dam would connect from the powerhouse westerly across Bar Harbor to the Perry mainland. The elevation of bottom near midchannel is about minus 30 mean sea level making maximum height of embankment about 50 feet. A single machine-driven probing near this point shows about 4 feet of soft material, followed by increasing resistance to penetration and refusal indicative of bedrock at minus 38.3 mean sea level. Materials required for embankment construction amount to approximately 400,000 cubic yards and perhaps except for special gravel requirements can be selectively obtained from required excavations for powerhouse and channels.

DICKEY DEVELOPMENT

2–06 General geology

The wilderness area which comprises much of the upper St. John River basin in the United States, was not mapped topographically until 1953. Geologic mapping has been only of limited reconnaissance scope except for the published detailed investigations in the igneous rock area at Deboullie Mountain. In the Canadian part of the upper basin, detailed geologic mapping of correlative value is available for the area bordering the St. Francis River in Quebec.

The upper St. John River basin is a maturely dissected upland region which has been modified by glaciation. The headwaters area is predominantly a region of low relief with wide, flat plains, mostly swamps, and low, broadly domed hills with occasional, widely scattered monadnocks. Downstream from the headwaters of the reservoir along the main river and throughout the Allagash and Little Black River drainage areas, the relief is greater and the topography is rougher with steep hills and narrow-crested, broken ridges rising above generally narrow, trough-like valleys. Till consisting of variable, gravelly, silty to clayey sand with cobbles and boulders, deposited by the last glacier blankets the bedrock throughout most of the region. The till is generally thin on the upper slopes and crests of the hills and in these areas bedrock is occasionally exposed. The valley botton and lower hillsides are generally deeply filled with till and outwash left by the wasting glacier. The outwash deposits composed of variable, roughly stratified, silty sands and gravels occur in thick outwash plains in the valley bottoms and extensive terraces on the lower valley walls. Because the St. John River drains northward, it was dammed at successive locations against the retreating ice front. In the sluggish pools thus formed, thick deposits of laminated fine sand, silt and clay were laid down. As a consequence of the thick filling in the valley bottoms, the rivers now flow high above the deep preglacial valleys in bedrock, and rock is exposed only in uncovered bedrock spurs high on the old valley walls.

Bedrock throughout the basin consists of slaty shale with local thin beds of sandstone and limestone. These Silurian sediments have been folded so that ciently so that the shale in many areas grades to poor slate. The only major occurrence of igneous rocks in the upper basin is the syenite and granodiorite in the vicinity of Deboullie Mountain.

No occurrences of mineral deposits of economic value have been reported in the upper basin.

2–07 Explorations

At the initiation of work on the Dickey project, reports of all previous investigations on the upper St. John River were reviewed. The review included study of reports of sites at Lincoln School, Rankin Rapids, Cross Rock Rapids, and Big Rapids. Reports of investigations by Canadian agencies at Glazier Lake on the St. Francis River were also reviewed. Field investigations were made initially for a designated dam alinement immediately downstream from the Dickey highway bridge. At this location, hereafter discussed as the upper site, explorations consisted of a total of 11 borings including 3 borings made for the Dickey highway bridge by the Maine State Highway Commission in 1950. Unfavorable foundation conditions developed by these explorations led to investigation of an indicated more favorable site approximately 1½ miles downstream and just above the mouth of the Allagash River. Seven borings were completed at this site for preliminary exploration of foundation conditions. The locations of explorations and bedrock outcrops at both sites are shown on plan of exploration, plate No. 11. Foundation conditions at the Fall Brook dike site were explored by three borings, and one boring was completed at the Hafey Brook dike site. Subsurface explorations were not made at the Campbell Brook dike site or at the very remote minor dike sites.

Field surveys were made to obtain baseline profiles and to establish boring locations at the upper and lower Dickey sites and at the Falls Brook and Hafey Brook dike sites. All borings were drive-sampled in overburden, and the bedrock, where encountered, was drilled with coring diamond bits. The classification of overburden samples and description of bedrock cores recovered from borings at the selected downstream damsite and the Falls Brook and Hafey Brook dike sites are shown on record of explorations, plate No. 14.

2–08 Site selection

Explorations indicated that subsurface conditions encountered at the upper site were not favorable for construction of a high dam. As shown on geologic section, plate No. 13, the very thick deposits of soft silt and clay which occur throughout the valley bottom, would necessitate very flat slopes on the dam, and the relatively pervious materials which occur to depths of more than 40 feet would require a deep cutoff and elaborate downstream drainage. The very thick, relatively pervious materials in the left abutment extend to depths of more than 150 feet below the valley bottom, making cutoff impractical and control of seepage very difficult. Because bedrock is inaccessible in the left abutment and valley bottom, it would be necessary to concentrate the diversion tunnels, penstocks, powerhouse and spillway in a relatively limited area of the right abutment.

It was found by reconnaissance, which continued during the exploration of the upper site, that at a lower site bedrock outcrops occurred on the top and upper slopes of the prominent hill immediately above the mouth of the Allagash River and at other locations along the Allagash River bank and the south side of the valley as shown on plan of exploration, plate No. 11. On the north side of the valley, a gully was found which formed a deep reentrant in the continuous pervious terrace deposits so that cutoff to till is possible. In view of the feasibility of cutoff in the left abutment and the availability of bedrock for structure foundations at several locations, a dam alinement at this location, the lower Dickey site, was finally selected. This selected site is hereinafter designated as the Dickey damsite.

2–09 Foundation conditions

(*a*) *Dickey Dam.*—In the valley bottom below the nominal channel deposits of silty, sandy gravel, outwash consisting of silty sand, sandy and clayey silt extends to a depth of approximately 40 feet as shown on geologic section, plate No. 13. Cutoff through the river channel deposits and into the upper part of the relatively impervious outwash materials is possible at reasonably shallow depths.

Beneath the fine outwash a zone of stratified silty sands and gravels with scattered till lenses approximately 50 feet thick overlies the basal till which extends to bedrock in the bottom of the valley at depths of more than 180 feet below the river. The fine outwash deposits in the valley bottom extend up the left abutment in a deep gully to a height of more than 100 feet above the river, but throughout the gully area the outwash is blanketed by up to 40 feet of till. Upstream and downstream adjacent to the gully the prominent terraces on the abutment form very thick deposits of silty sands and gravels with beds of sandy silt and zones of till. Above the terraces the upper slopes of the abutment are blanketed with till. The fine-grained outwash which occurs in the valley bottom also extends up the right abutment of the river section to heights above the highway, but again these materials are blanketed by till with thin beds of sand and gravel so that cutoff to relatively impervious material is available at reasonable depths. Throughout the upper slopes of the right abutment the till extends to bedrock at depths estimated at about 30 feet.

On both abutments at the south section of the dam, the overburden is generally thin and consists of till composed of gravelly, silty sand. Along the lower part of the left abutment, as shown on geologic section, plate No. 13, it is expected that the thickness of the till cover increases to 40 feet or more and grades into a more silty, clay till. The bottom of the broad, flat valley is largely a peat bog with organic deposits estimated to be about 10 feet in thickness. Underlying the organic material, stratified, silty sands and gravels occur to estimated depths of 60 to 75 feet. Cutoff through these relatively pervious outwash materials can be made to the underlying till which extends to bedrock. Although some fine-grained soils occur in the foundation, they appear to be dense and have relatively high shear strengths and would permit relatively steep design slopes for the embankment.

The bedrock is dark gray to black, relatively hard, slaty shale, generally calcareous and locally graphitic. Thin sandstone beds and occasional quartz stringers occur in the shale at widely scattered localities. The trend of the conspicuous cleavage is north 40° to 50° east. The dip of the cleavage ranges from vertical to 70° west. The photograph on figure 2 (p. 56) shows a typical outcrop of the shale. Although the shale is generally hard, weathering has commonly progressed along numerous open cleavage planes and joints to depths of more than 10 feet and locally to more than 20 feet. In boring FD–16 located at the intake area for the conduit tunnels, a thin zone of fault breccia was encountered at a depth of 17.1 feet below the rock surface. Photographs of representative bedrock cores from borings are shown on figure 3 (p. 57). Physical tests performed by others on similar rock from damsites on the Canadian side of the St. John River show a specific gravity range of from 2.73 to 2.79 and compressive strengths for saturated samples ranging from 8,330 pounds per square inch to 10,380 pounds per square inch.

Slaking tests performed on samples of similar slaty shale from the Rankin Rapids damsite showed no significant breakdown during 34 cycles of wetting and drying.

The alinement of structure excavations, spillway and tailrace channels and diversion tunnels is nearly normal to the trend of the bedrock structure. This favorable relationship of excavations to the attitude of the rock structure will assist materially in producing stable side slopes in open rock excavations and will minimize overbreak in both open excavations and in the diversion tunnels. Below the upper weathered zone the structure of the rock makes it generally adaptable to application of line drilling or presplitting where vertical slopes are required for structure excavations. In required excavations, some of which are up to 150 feet in depth, where structures are not involved, it may also prove to be economical to produce vertical slopes rather than conventional 4-on-1 slopes depending on refined estimates of rock quantities required from excavations.

Bedrock is generally sufficiently deeply buried and blanketed with thick deposits of relatively impervious till so that only a minor grouting program will be required. Provision for grouting is advisable in the cutoff near the penstock intake structure and in the vicinity of the spillway. Because of the relatively low heads occurring at these high elevations, only shallow grouting would be required. On the abutments of the south section of the dam where bedrock is exposed or close to the ground surface, deeper grouting will be done as necessary to provide adequate cutoff. In view of the character and condition of the bedrock, it is expected that the quantity of grout "take" will be nominal.

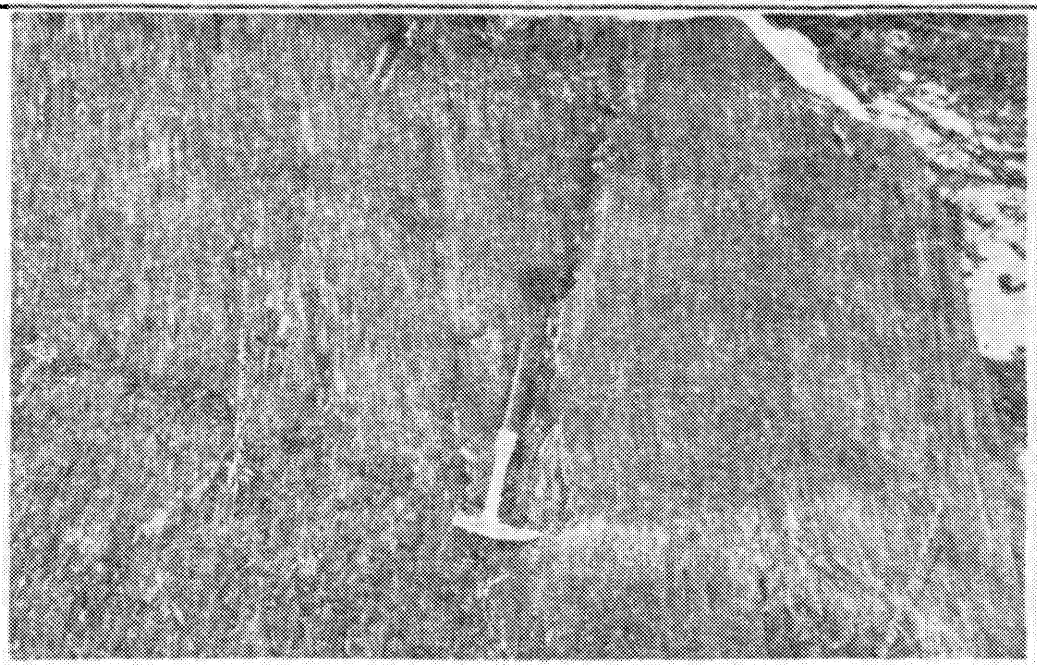
(*b*) *Falls Brook dike.*—At the Falls Brook dike site which is the major remote dike, the overburden on the abutments is till as shown on geologic section, plate No. 13. On the left abutment the till cover is very thin near the bedrock outcrops high on the slope. On the upper slope of the right abutment, the till is also thin, but the thickness of the till blanket increases down the abutments to the deeply filled valley bottom, where the till rests on bedrock at depths of more than 90 feet. In the valley bottom the till is covered by outwash consisting of silty sands and gravels with minor lenses of till. The outwash is generally less than 10 feet thick, although local accumulations up to 25 feet occur. Cutoff through the relatively pervious outwash deposits to the till is therefore possible at generally shallow depths. The bedrock is the common slaty shale with characteristics similar to the rock at the damsite.

(*c*) *Hafey Brook dike.*—At Hafey Brook dike site the overburden on the right or east abutment is till generally about 10 feet in thickness as shown by boring FD–10. Although subsurface information is not available in the valley bottom or west abutment, reconnaissance indicates that it is quite possible for a deeply filled valley in the bedrock to occur in this area. Immediately north of the dike site there is an extensive outwash plain floored with sands and gravels. If a deep buried valley does occur at the site, it is probably filled with similar sands and gravels.

Bedrock encountered in the boring at the site is andesite with scattered quartz stringers and shale inclusions. The bedrock exposed in extensive outcrops immediately south of the site is slaty shale.

(*d*) *Campbell Brook dike.*—The overburden on the abutments at Campbell Brook dike is till. It is assumed that the organic materials, probably superficial in depth which occur in the valley bottom, are underlain by thin deposits of sand and gravel resting on till.

Bedrock was not found outcropping in the vicinity of the site. Outcrops on the valley wall south of the site, however, indicate that the bedrock is the regional slaty shale.



DICKEY DEVELOPMENT
DICKEY DAM
SHALE OUTCROP SHOWING TYPICAL SLATY CLEAVAGE

FIGURE 2

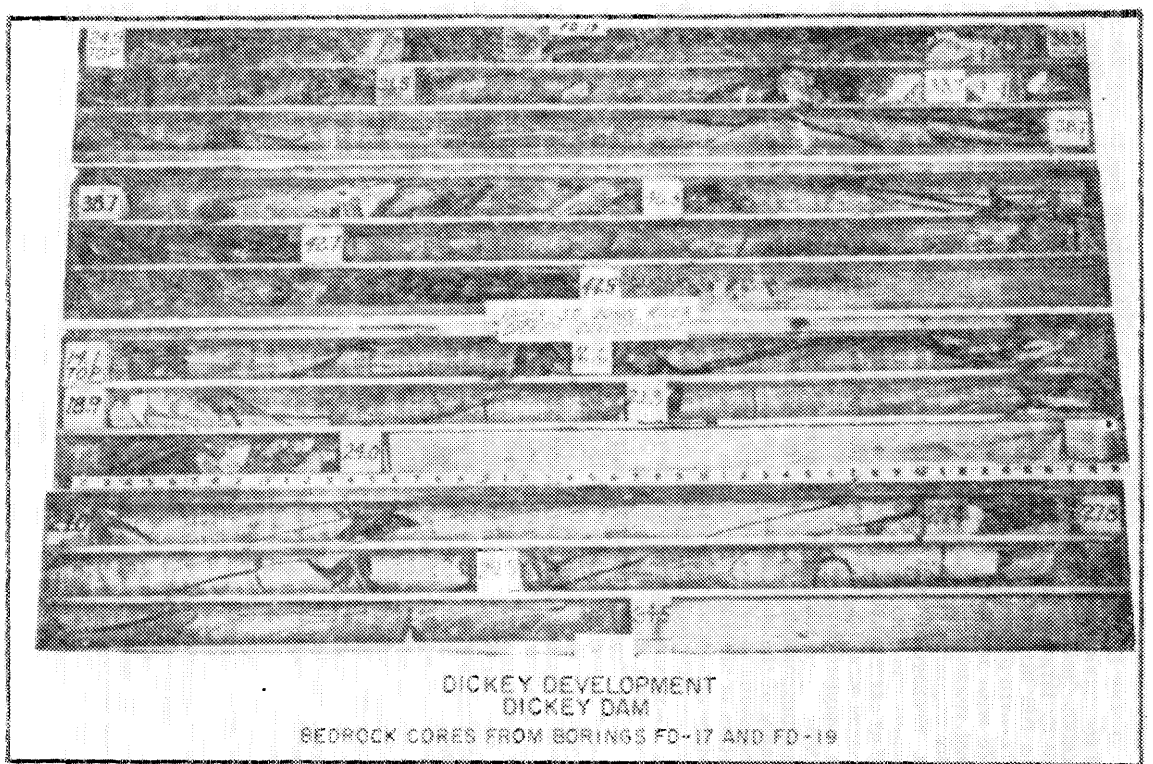

DICKEY DEVELOPMENT
DICKEY DAM
BEDROCK CORES FROM BORINGS FD-17 AND FD-19

FIGURE 3

(*c*) *Blue Brook dike and Cunliffe Brook dike.*—These remote minor dike sites have not been visited. It is assumed, however, that the overburden on the abutments at these locations is till. Superficial organic deposits probably occur in the valley bottoms overlying till. Bedrock at the sites is assumed to be the regional slaty shale.

2–10 Embankment and foundation designs

(*a*) *Dickey Dam.*—Typical sections of the embankment for Dickey Dam, designed for maximum utilization of available materials, are shown on plate No. 7. The section design provides for a minimum core section composed of glacial till, flanked by large relatively pervious zones. The large pervious zones not only enables full utilization of the more economically available earth borrow, but permits earth placement to be carried out over a longer construction season than possible with moisture sensitive materials. Also the internal design can be modified considerably in final design to suit the characteristics of materials actually available and adopted construction sequences without change in outer slopes. Seepage through the embankment is controlled by the arrangement of the impervious and pervious fill zones, and foundation seepage is, in general, controlled by carrying the impervious section of the dam to rock, glacial till, or other impervious stratum. At the left abutment, however, it may not be feasible to obtain complete foundation cutoff, and the cost estimate provides for inclusion of a short upstream impervious blanket and a drainage tunnel downstream for intercepting possible underseepage at this abutment.

Because of the slaty nature of rock from required excavations, and the need for processing to remove the expected large quantity of excess fines, rock slope protection is provided only on the upstream slopes. Below minimum pool, the rock slope protection will consist of processed rock from required excavation and a select granitic rock transported from the Deboullie Mountain area will be used above. Downstream slopes will be protected by gravel and cobbles from the pervious borrow and site excavations.

(*b*) *Falls Brook dike.*—The only known sources of large quantities of embankment materials in the vicinity of the dike site appear to be deposits of relatively impervious glacial till. This dike has therefore been designed as an essentially homogeneous impervious fill section, with impervious cutoff carried through shallow pervious deposits to rock or impervious glacial till. An internal pervious wick drain and downstream horizontal pervious blanket are provided for controlling through and under seepage. Slope protection on the upstream slope above the minimum pool will consist of select granitic rock from the Deboullie Mountain area and processed gravel below. The downstream slope protection will consist of locally quarried rock.

(*c*) *Hafey Brook dike.*—Materials indicated to be available in the area for embankment construction are pervious sands and gravel sand impervious glacial till. Cutoff to bedrock or other impervious stratum does not appear feasible in the valley bottom and at the west abutment. A horizontal upstream impervious blanket connected to the core, a pervious fill drainage trench downstream of the core, and a downstream rock toe are provided for control of seepage. However, the upstream impervious blanket is eliminated where cutoff to rock or glacial till appears feasible on the east abutment. Upstream slope protection will consist of select granitic rock from the Deboullie Mountain area above minimum pool and processed gravel below. The downstream slope protection will consist of locally quarried rock on gravel bedding.

(*d*) *Campbell Brook, Cunliffe Brook and Blue Brook dikes.*—These dikes which are of relatively low height are designed as essentially homogeneous impervious fill sections, utilizing the local glacial till, with pervious downstream toes, for control of seepage. Cutoff to impervious glacial till is assumed at relatively shallow depth. Upstream slope protection for the Campbell Brook dike will consist of select granitic rock from the Deboullie Mountain area. Downstream protection will consist of processed rock from required excavations at Dickey Dam. Local rock will be used for all slope protection at Cunliffe Brook and Blue Brook dikes.

2–11 Construction materials

(*a*) *General.*—Quantity estimates of borrow materials required for construction of the dam and dikes are based on available topography and geology for the various sites and preliminary designs appropriate to this stage of investigations. Estimated volume of the main dam and dike at Dickey including rock slope protection and rockfill is approximately 56 million cubic yards. The volume of earth and rock materials in the Falls Brook dike is about 7,300,000 cubic yards.

At Hafey Brook dike approximately 2 million cubic yards of earthfill and rock are required. The minor dikes have small volumes ranging from 40,000 to 200,000 cubic yards.

(*b*) *Impervious materials.*—Foundation testborings made high on the left abutments at both the sites investigated at Dickey indicate that thick and extensive deposits of till occur generally above elevation 900. The till is compact, relatively impervious and characteristically variable. It contains scattered boulders and ranges in gradation from gravelly, silty sand to gravelly, sandy clay. Preliminary estimates indicate that an area extending upstream along the valley 2 miles or more from Dickey Dam site could provide all impervious materials required for the impervious sections of the dam. Other localities where extensive deposits of relatively impervious till occur within 2½ miles of the site include the high slopes on the north valley wall downstream from the site and the higher hillside on the south side of the valley between the upper and lower Dickey sites.

At the Falls Brook dike impervious materials are available in nearby extensive till deposits on the east side of the Falls Brook Valley both upstream and downstream from the site. Sources of impervious materials for the other dikes were not specifically located. However, it is expected that deposits of till suitable for use as impervious fill can be found in proximity to all the sites.

(*c*) *Pervious materials.*—Pervious materials for construction of the Dickey Dam occur in extensive terrace deposits of silty sands and gravels which extend from river level to about elevation 800 along the north side of the valley. In some areas the terrace materials are mantled by till. Within these deposits, till also occurs in scattered small masses and thin lenses. The total thickness of the pervious materials, including the relatively minor till zones, is generally more than 100 feet. It is expected that adequate exploration of these deposits would permit delineation of suitable areas where it would be feasible to obtain very large quantities of relatively pervious material. Without some selection, these deposits would probably provide material which overall would be classified as random fill.

Foundation explorations for the southern section of the dam at the lower Dickey site and in the valley bottom at the upper site encountered more than 40 feet of relatively pervious silty sands and gravels, and similar materials occur in the extensive outwash plain at the mouth of the Little Black River. The water table is generally less than 20 feet deep in these areas so that subaqueous borrow operations would be required to realize more than a nominal percentage of an indicated large potential.

Other potential sources of pervious borrow occur in a large terrace approximately 11 miles downstream from the Dickey site and in less extensive terraces on the east side of the Allagash River from Three Mile Island to Twin Brook Rapids about 4 miles from the Dickey site.

A nearby source of pervious materials has not been found in the vicinity of Falls Brook dike. For purposes of this report it is assumed that pervious materials will be obtained from deposits in the vicinity of the damsite.

Immeriately north of the Hafey Brook dike site, there is an extensive outwash plain indicated to be underlain by gravelly sands in sufficient quantity for pervious fill requirements.

At Campbell Brook dike all pervious materials required will be obtained from pervious deposits at Dickey. At Blue Brook and Cunliffe Brook dike requirements for pervious fill have been kept to a minimum in preliminary designs and it is assumed that they can be found within 5 miles haul distance of the sites.

(*d*) *Gravel bedding, slope protection, and road gravel.*—It might be possible to obtain these materials by selective excavations in the areas considered as potential sources for pervious material. Considering the large quantities required, however, it is believed more realistic at this time to assume that all gravel for bedding, slope protection, and roads will be obtained by processing materials from the most suitable pervious borrow areas. Campbell Brook dike is only a short-haul distance from the Dickey site and could be supplied from a processing plant at Dickey. Select gravel materials for the dikes at Falls Brook and Hafey Brook likewise could probably be supplied most readily from a central processing plant located at Dickey.

(*e*) *Rock slope protection and rockfill.*—The slaty shale bedrock will provide most of the required rock for slope protection and rockfills. The shale bedrock from the required rock excavations will be utilized at the dam and adjacent dike. At the remote dikes most of the required slope protection or rockfill will be provided by quarrying in nearby areas.

Cleavage is very well developed in the shale so that it will split easily into thin plates and wafers, and shapes produced by blasting will be elongate, flat slabs. Breakdown of the rock during blasting and handling will result in production of a high proportion of undesirable fines. Processing will, therefore, be required to obtain satisfactory rock for use in rock slope protection. It is expected that the excavated rock will increase in volume by a factor of 1.3 over in situ volume but losses incurred during blasting, handling, and processing will reduce the quantity of available rock so that for in place volume on the embankment a balance factor of 0.8 of the in situ volume is considered reasonable for quantity estimates. A very large volume of shale will be available from required rock excavations so it is planned to incorporate unprocessed excesses in a rolled, rockfill section in the cofferdam or internally in the dam embankment.

Because of the tendency of the shale to break down during freezing and thawing, it will be necessary to use a more durable type of rock where the slope protection will be exposed to fluctuating water levels and atmospheric conditions. Granitic rocks, mainly granodiorite, suitable for this purpose are available in the vicinity of Deboullie Mountain located approximately 12 miles southeast of the Dickey site as shown on plate No. 5. The granodiorite is massive, hard, durable and generally uniform in texture, color, and composition. Access to the Deboullie area is possible for most of the distance on existing poor logging roads but extension by several miles of new road will be required. Total haul distance from the Deboullie area to Dickey is about 18 miles.

(*f*) *Concrete aggregates.*—All the natural deposits of sand and gravel in the region contain a high proportion of flat, elongate and friable shale fragments derived from the local bedrock. Because of the slaty character of the shale, both the bedrock and the natural sand and gravel deposits are not considered suitable for use as aggregates in concrete.

At Deboullie Mountain, as previously discussed in conjunction with producing high quality rock slope protection, rock for production of suitable fine and coarse aggregates could be obtained by quarrying. In view of the large volume of concrete required, amounting to approximately 500,000 cubic yards, and the long haul distance from the Deboullie area, consideration will be given to the feasibility of also obtaining fine aggregates from the nearby sand and gravel deposits in the vicinity of the damsite. As a subsidiary operation to processing for selected gravels or by selective excavations, it may be possible, by adequate processing, to eliminate or reduce to tolerable limits the percentage of shale fragments in the natural materials to produce an acceptable fine aggregate.

Chapter III. Tidal Power Project—Department of the Interior Plan

3–01 General description

The basic plan envisioned by the Department of the Interior proposes Passamaquoddy developed as a peaking powerplant supplying a substantial portion of the peaking power requirements of an extensive marketing area embracing the New England States and New Brunswick. The plan utilizes the basic two pool concept developed in the IJC's report with the significant modification that inclined shaft turbines would be used in the powerplant in lieu of conventional vertical shaft turbine-generator units, and that the installed capacity would be 1 million kilowatts instead of 300,000 kilowatts.

The components of the IJC's plan, except the powerhouse, are incorporated into the Department of the Interior's plan without change. The unchanged features include tidal dams, the navigation locks, and all filling and emptying gates.

POWERHOUSES

3–02 Layout

The adopted plan proposes the construction of two identical 50-unit powerhouses, one at Carryingplace Cove and the second at Bar Harbor, as shown on plate No. 1. Powerhouse No. 1 would be located on Mathews Island, as in the IJC's plan, with the headrace excavated across a narrow isthmus of Moose Island between Kendall Head and Redoubt Hill. A closure dam would connect the northwest end of the powerhouse to Moose Island. Powerhouse No. 2 would be located on the western peninsula of Moose Island near Bar Harbor with the

headrace excavated across the causeway for Route 190 between Carlow and Moose Islands. A closure dam would connect the west end of the powerhouse to the mainland.

For economic studies cost estimates were required for installations of 30, 50, 70, and 100 power units. The 30-unit powerplant would be located at the same site as powerhouse No. 1. Headrace and tailrace would be narrower to correspond to the smaller powerhouse. The 50 units would be installed in powerhouse No. 1. The 70 units would include an additional 20-unit powerhouse at the location of powerhouse No. 2 with appropriate headrace and tailrace. The 100 units would be contained in the two powerhouses as already described.

The switchyard would be built on an artificial fill near the northwest end of powerhouse No. 1 as shown on plate No. 1 where it would serve both powerhouses.

The powerhouses developed would be identical, and further description of one powerhouse will apply to both. The powerhouse would have 50 main unit bays, each 62 feet wide; two 83-foot assembly bays, one at each end; and four 55-foot service bays, located between groups of 10 units. The total length of the powerhouse would be 3,486 feet. Plate No. 2 shows the general plan of the powerhouse.

The powerhouse would be a reinforced concrete structure. The intake side of the structure housing the turbines is planned as a semioutdoor type of structure with the deck at elevation 20 feet above mean sea level. Access roads and railroad would meet the powerhouse at deck level. Most of the mechanical and electrical equipment would be housed inside the powerhouse. Two outdoor-type 85-ton gantry cranes would travel on the concrete deck to unload, install, and service the 50 turbines, and operate the intake gates. Large openings in the deck, each covered with a removable hatch cover, would provide access to the turbines. The portion of the powerhouse over the draft tubes, containing the speed increasers and generators, would be of the indoor type. It would have reinforced concrete walls and a flat roof on steel trusses. Two 100-ton bridge cranes, traveling the full length of the powerhouse, would install and service the 50 speed increasers and generators. Five step-up transformers would be spaced along the deck at 10-unit intervals between the gantry crane tracks and the powerhouse roof. Two 20-ton gantry cranes would travel the deck over the draft tube openings and operate the draft tube gates.

3–03 Turbines and generators

Plate No. 2 shows the equipment setting and water passages which are in accordance with a manufacturer's submitted proposal and considered reasonable. The main unit includes a turbine, speed increaser, and generator all on an inclined axis.

The slightly inclined propeller-type turbine would have adjustable blades, adjustable wicket gates, and fixed stay vanes. Wicket gates are required to prevent leakage. Turbine would have a full-gate rating of 14,000 horsepower at a 13.2-foot head and 45 revolutions per minute. A governor and operating mechanism are included with the turbine.

The speed increaser with a 10-to-1 ratio, would increase the shaft speed from 45 to 450 revolutions per minute, permitting the use of a smaller diameter, more efficient, and less costly generator and results in a better design.

The generator would be rated at 11,100 kilovolt-amperes, 0.90 power factor, 3 phase, 60 cycle, 13,800 volts, 450 revolutions per minute, complete with exciter. The generator and direct connected exciter would be complete with bearing relays, thermometers, waterflow indicators, generator field shunt, space heaters, current transformers, etc. Included are also air-to-water heat exchangers, a carbon dioxide fire protection system, and thrust bearing to absorb the generator thrust due to inclination of the shaft.

3–04 Main unit bay

The inclined axis turbine, with centerline at elevation —20, is set at a slight angle to the horizontal so as to permit the lacating of the generator and speed increaser in the dry. Preliminary structural analysis indicated a thickness requirement of 6 feet for the end piers and 5 feet for the center pier. This requirement plus the water passage exist width of 45 feet established the width of the main unit bays at 62 feet. The generator floor is established at elevation —4 and as such provides 4 feet of concrete, minimum, over the draft tube. The

floor level over the turbines was established at elevation +3 and provides mass concrete around the turbine for the inertia block.

The powerhouse deck was established at elevation 20 which provides 6.5 feet of freeboard above the upper pool maximum elevation of 13.5, and which also provides a working headroom of 14 feet in the mechanical and electrical equipment galleries. The walls for the generator room would extend the entire length of the powerhouse, and support the bridge cranes. The walls for the turbine area would extend the entire length of the powerhouse, and support the deck slab and gantry cranes.

The indoor-type structure over the generator has the advantage that it would provide suitable electrical clearances for the high voltage equipment and transmission line takeoff structures. The indoor-type structure also offers the advantage of a dry inside area for the construction, operation, and maintenance of the major electrical equipment. The powerhouse roof would consist of multiple-ply roofing laid over "Q" decking supported by a steel truss framework.

3–05 Assembly bays

The 83-foot assembly bay provided at each end of the powerhouse would have two floor levels, elevation —4 and +20, as shown on plate No. 3. The lower level would provide two assembly areas. One area for the erection of turbines and transformers would be serviced by one 85-ton gantry crane operating through metal-covered hatches in the deck. The other assembly area for the erection of speed increasers and generators would be serviced by one 100-ton bridge crane. A transfer car operating on transverse rails would be used for moving equipment between the two erection areas. The assembly bays would provide space for oil storage and purification, maintenance shop, washroom, and first aid and storage area. An office building, 24 feet by 83 feet, would be located on the elevation 20 floor as shown on plate No. 3. The building at the southeast end would be used for offices for project administrative personnel and facilities for visitors. The building at the northwest end would be used for additional office space and for the powerplant supervisory control room.

3–06 Service bays

A 55-foot service bay would be provided between each group of 10 units as shown on plates Nos. 2 and 3. These four areas, at elevation —4 would provide space for station service auxiliary equipment and space for repair of main unit equipment. These repair areas would be used during construction as additional assembly areas for erection of turbines, generators, and speed increasers. The central portion of the area would be used for station service air compressor rooms. The powerhouse drainage and unwatering sumps and pumps would be located in the downstream area of these service bays.

3–07 General arrangement

The general arrangement of the powerhouse equipment is shown on plate No. 3. The mechanical and electrical systems would be arranged in 5 groups of 10 units each. A group control center would be located on the generator floor at the midpoint of each group. This control center would provide all necessary features for the remote control and operation of each of the 10 units in the group. The generator and station service switchgear for each group of 10 units would be located in the electrical equipment gallery, elevation 3, at the midpoint of the group. The main power transformer for a group would be located on the main deck, elevation 20 directly above the generator switchgear. The mechanical equipment gallery would be used for locating the governors, heat exchangers, piping systems, and other mechanical equipment. A transverse utility gallery would be provided between each unit for the routing of mechanical piping and electrical circuits from the generator room to the mechanical and electrical equipment galleries. The powerhouse roof area would be used for location of high voltage equipment and takeoff structures for aerial lines to the switchyard.

3–08 Gates, trashracks, and stoplogs

Five sets of intake gates would be provided for the 50 units. This would permit the simultaneous unwatering of three units while leaving two reserve sets for emergencies. Each set would consist of one wheeled and one slide gate. The gates, approximately 34 feet 6 inches high by 16 feet 6 inches wide, would each

be constructed in two sections. The gates would be handled by the 85-ton powerhouse gantry crane and when not in use would be stored in the gate slots and supported by latches. The gates would be designed for emergency closure under full flow conditions with wide-open wicket gates. Under these conditions, the slide gate would first be placed in one passage, then the wheeled gate would be placed in the remaining passage. Under these conditions the gates would close under their own weight.

Similarly five sets of draft tube gates would be provided for the 50 units to permit the simultaneous unwatering of three units, leaving two reserve sets. This quantity would be adequate to meet the requirement of project maintenance for a 50-unit plant. Each gate, approximately 53 feet 6 inches high by 22 feet 6 inches wide, would be constructed in six sections. The gate sections would be handled by the draft tube 20-ton gantry crane and when not in use would be stored in the gate slots and supported by latches. Because these gates would always be placed under a balanced-head condition, all would be slide gates.

One set of trashracks would be provided for each of the 50 units plus 1 spare set for use in maintenance work. The trashracks would be placed in structural steel guides fastened to the upstream pier noses of the intake and would be handled by a 10-ton auxiliary jib hoist located on the 85-ton powerhouse, gantry crane. This hoist would be equipped with a grab hook for use in removal of trash gathered in front of the trashracks.

One set of intake stoplogs would be provided for the 50 units and would be used for closure under a balanced-head condition of any one of the intake passageways. This would permit maintenance of the intake gate slots. The stoplogs would be designed to operate in the trashrack guide slots and would be of such dimension and weight as to permit their handling by the 10-ton jib hoist on the 85-ton powerhouse gantry crane.

3–09 Cranes

Two 85-ton gantry cranes with a 52-foot span would be provided for the 50 units and would operate along the entire length of the powerhouse including the unloading areas at each end. The principal function of the cranes would be to handle the turbines and intake gates during construction and maintenance of the powerplant. The cranes would also be used to untank transformers, to unload railroad cars, and to handle trashracks and intake stoplogs. Each crane would have large rolling doors to permit complete enclosure of the area under the crane for use when servicing the turbines during inclement weather. A 115-kilowatt diesel generator set would be installed in each crane to provide power for hoisting and propulsion.

Two 100-ton bridge cranes, having a 70-foot span, would be provided in the generator room and would operate along the entire length of the powerhouse including the assembly and service bays. The cranes would handle the generators, speed increasers, turbine shafts, and miscellaneous equipment during the construction and maintenance of the powerplant. They would take their power from a trolley bus located on the downstream side of the powerhouse.

There would also be two 20-ton draft tube gantry cranes to handle the draft tube gates for the 50 units. Each would be powered by a 115-kilowatt diesel generator set mounted on the crane.

3–10 Powerhouse control and operation

When required for load the powerplant would be operated to generate maximum power during short periods of time and would be under automatic control. The sequence of stopping and starting units could be preprogramed by electronic computer from tide cycle predictions and recorded on punched cards or tapes for use by the automatic controller. The main supervisory control board would be equipped with a 50-unit status board permitting the witholding of selected units from automatic control if required.

A central supervisory board would be located in the west assembly bay of the plant and would provide equipment for automatic or manual control of all 50 units. Controls would also permit remote manual operation of switchyard breakers and disconnects. A unit-group control center would be located adjacent to each of the 5 groups of 10 generators. From this center, an operator could control all operations for starting, loading, and stopping the generators in his group.

3–11 Auxiliary electrical and mechanical systems

All auxiliary electrical and mechanical systems for the tidal powerhouse described in the IJC report of April 1961 were studied and estimated in detail. The systems for the present powerhouses are similar, and further detailed study is not warranted, since the overall estimates are quite accurately made by adjusting the previous estimate.

3–12 Main power transformers

At each powerhouse the generators would be combined in 5 groups of 10 each with a stepup transformer for each group. The transformers would all be three-phase, forced oil-air-type, delta-wye, rated at 111,100 kilovolt-amperes with BIL characteristics as described in the IJC report. At each powerhouse four transformers would have a high-voltage rating of 345 kilovolt and the fifth a rating of 230 kilovolt.

3–13 Station service

Station service electrical system for service areas would be taken from each of the five groups of generators by means of a 13.8-kilovolt feeder cable, when the powerhouse is in operation. The service for the aerial lines feeding the navigation locks and the tide gates, which form a part of the tidal power project, would be fed from a 13.8-kilovolt generator bus.

Inasmuch as the tidal powerplants will not operate continuously, it will be necessary to use power from the interconnected system for station service and auxiliary power when the tidal plants are not operating. The station service in each group of 10 units would be served by a 1,000-kilovolt-amperes, three-phase, 13,200–480-volt transformer. Each transformer would be connected to a group bus which would furnish the auxiliary power to the 10 units connected to the bus. Each transformer would be capable of carrying the load of its group as well as that of an adjacent group.

3–14 Switchyard

The transmission lines in their entirety are included in the Department of the Interior report. Switchyard estimates were provided by the Bureau of Reclamation of the Department of the Interior and are included in the cost summaries of this report. The cost of main transformers is included with the powerhouse estimate, and the switchyard estimate, which had included it, is reduced by like amount in this report.

3–15 Corrosion control

All metal in the water passageways, including the runner hub and turbine shaft, will have a minimum one-eighth inch stainless steel type 316 cladding, welded overlay or sleeves. It is noted that the International Passamaquoddy Engineering Board report of October 1959 contemplated that the turbine runner and certain other turbine parts would be fabricated of type 316 stainless steel.

All estimates are based on the corrosion prevention coatings and cathodic protection systems recommended in the IJC report.

3–16 Fishways

At the request of the International Passamaquoddy Fisheries Board, fishways for anadromous fish were planned in the IJC report at the tidal powerhouse and emptying gates. In accordance with this request similar fishways have been provided at each end of powerhouse No. 1 and No. 2 with a collection gallery along the downstream side of each powerhouse. The fishway at the emptying gates at Pope Islet would be the same as shown in the IJC report.

HEADRACE AND TAILRACE

3–17 Design

The headrace channels were designed to minimize hydraulic losses without requiring excessive excavation. The bottom of the channel for powerhouse No. 1 varies from elevation —44 at the entrance, to elevation —50 at the narrowest part of the channel and to elevation —40.7 at the powerhouse. The bottom of the headrace channel for powerhouse No. 2 is level at elevation —40.7.

The bottoms of the tailrace channels for both powerhouses vary from elevation —67 at the powerhouse to about elevation —35 in Cobscook Bay.

Average velocities in the headrace channels would be about 3.5 feet per second and in the tailrace channels about 3 feet per second.

3–18 Excavation

The part of the excavation of the channels above high tide would be used for cofferdams. Cofferdams would be constructed, the work areas in the channels unwatered, and the work continued in the dry. It is planned to use the material excavated from the channels for powerhouse No. 1 in the permanent features of the project. Since construction of powerhouse No. 2 will be scheduled in the last phase of development, only a small portion of the material excavated from the channels could be used; the remainder would be wasted.

3–19 Cofferdams

In estimating the cost of cofferdams the same design is used as in the IJC report. The quantities of materials vary with the number of units, 30, 50, 70, or 100, to be installed. Sources of materials for cofferdams also vary, being dependent upon what materials would be available in the early stages of construction. The length of cofferdams at powerhouse No. 2 exceed those of powerhouse No. 1 because of greater distances between suitable abutments.

MISCELLANEOUS ITEMS

3–20 Service facilities

The service facilities consist of maintenance shops, warehouse, utilities, land plant, floating plant, housing facilities, parking areas, service and access roads, and an access railroad spur to each powerhouse. The warehouse and storage area would be at Carryingplace Cove as in the IJC report.

3–21 Relocations

All public and private facilities interrupted by the proposed construction would be relocated to give the same service as before the project was started. The costs of the work necessary to make the owners whole would be included as project costs in accordance with established procedures. These costs for powerhouse No. 1 are increased from the IJC report for the extension to a wider headrace. The same bridge is used as the one in the IJC report for carrying the following facilities across the channel into Eastport; State Highway Route 190; a single track branch line of the Maine Central Railroad; the water supply line to the city of Eastport; two power circuits of the Bangor Hydroelectric Co.; 1 cable and 22 wires of the New England Telephone & Telegraph Co.; and Western Union communication wires.

The wider headrace for the waterway to powerhouse No. 1 requires removal of the sides of Kendall Head on the westerly side and Redoubt Hill on the eastern side. This would cut off the roads leading to the houses on the top of the two hills. Relocation of the access and utilities to both areas is included in the plans and cost estimates.

The same highway, railroad, and utilities would require relocation across the headrace of powerhouse No. 2 by means of a bridge similar to that across the headrace of powerhouse No. 1. The crossing of the water pipeline to Eastport is at Bar Harbor and along the line of the powerhouse. Since the relocation would not be completed before the construction for powerhouse No. 2 is started, a temporary waterline would be required prior to construction of the permanent replacement.

3–22 Lands and damages

The real estate costs have been prepared by an appraiser familiar with the area and are additive to the real estate costs included in the IJC report. The additional cost of widening the taking line for the wider approach channel to powerhouse No. 1 is added.

The western peninsula of Moose Island would be acquired for powerhouse No. 2, with a construction area on the southeastern end and another at the northwestern end. A strip along the southeast line of the approach channel will be

acquired, also areas for the abutments and approaches to the proposed replacement bridge. All of Carlow Island would be included in the taking; any remainder after the bridge construction would be developed for the use of visitors as described in chapter VI. All lands and damages in Canada remain the same as in the IJC report. Damages to waterfront property, caused by the tidal regime for the high and low pools, would appear to be unchanged from those developed in the IJC report.

3–23 Operation and maintenance

The operating and maintenance staff of a hydroelectric power installation is a large part of the annual costs. The estimate of operation and maintenance annual cost for the increments of size of the tidal powerhouses now under study is developed from the IJC report. The staff for locks, dams, and emptying and filling gates would be the same, with a cost increase in accordance with present wage rates. The staff for the varying sizes of powerhouse would increase with the number of units, as would the amount estimated for annual supplies. The staff would include a small executive section, an engineering section, an operating section to provide necessary around-the-clock service, and a maintenance section on an 8-hour-day basis plus emergency service.

SUBJECTS FOR FUTURE STUDY

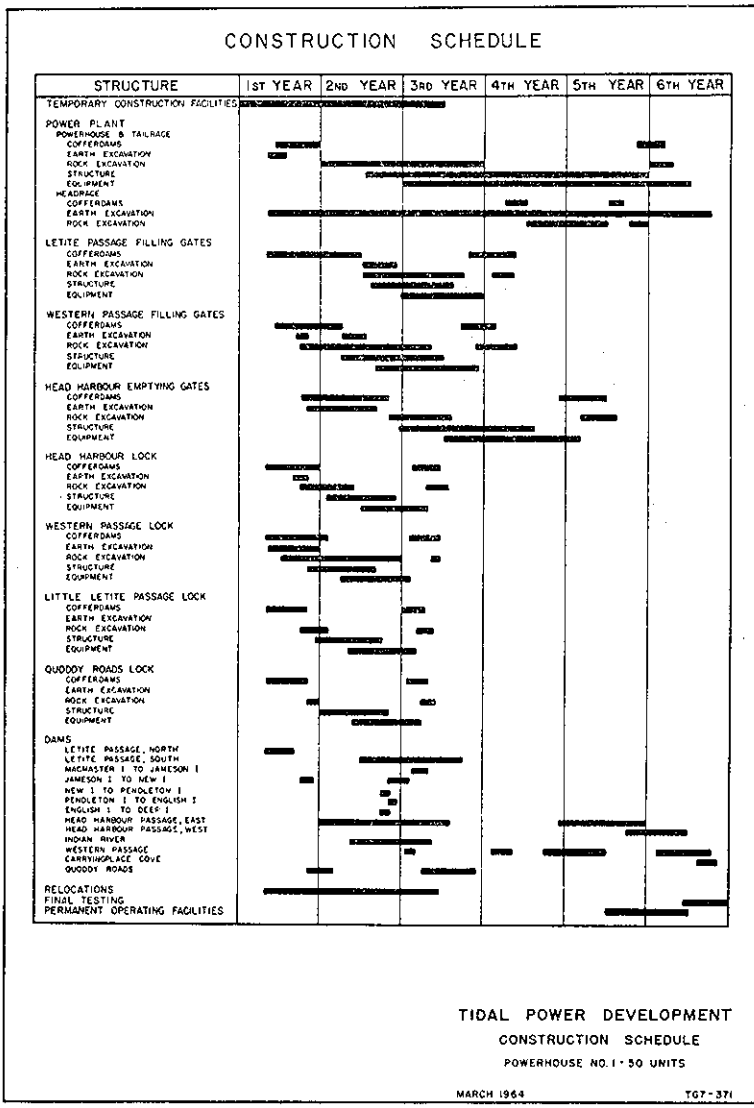
3–24 Pump-turbine units

In searching for ways and means to improve the economics of the tidal power project, various ideas have been conceived. One of these, which is worthy of further study, is that of using pump turbines to increase the peak power generation during periods of neap tides. Using off-peak power, available from 10 p.m. to 6 a.m., the reversible units would pump water from the low pool to the high pool.

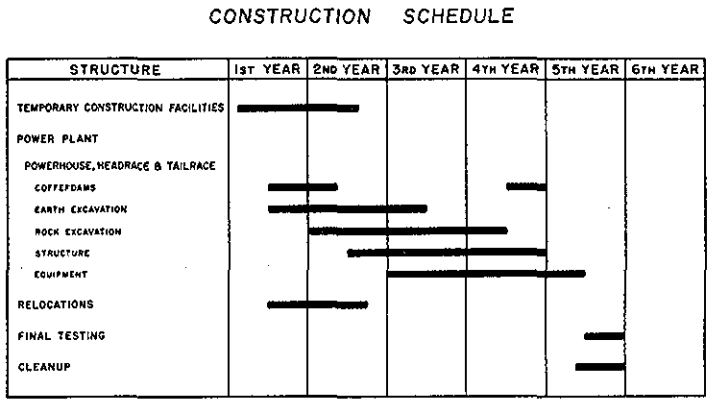
Then, during the daily period of peak demand, these same units would generate power as the water in the high pool would flow back through them into the low pool. By this means, the firm generating capability of Passamaquoddy could be realized, as the additional water and head could be used to extend the period of on-load operation, thus offering more flexibility in fitting tidal power to the load.

3–25 Dams, cofferdams, and gates

There are several features where study during the design phase of the project might result in a reduction of cost. The tidal dams and coffee dams present many problems of design and construction. General and detailed hydraulic model studies and extensive deep-water drilling would appear warranted. Further investigation may show that prefabrication of filling and emptying gates with a floated-in construction method would provide a saving.


CONSTRUCTION SCHEDULE
STRUCTURE
1ST YEAR
2ND YEAR
3RD YEAR
4TH YEAR
5TH YEAR
6TH YEAR
TEMPORARY CONSTRUCTION FACILITIES
POWER PLANT
POWERHOUSE & TAILRACE
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
STRUCTURE
EQUIPMENT
HEADRACE
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
LETITE PASSAGE FILLING GATES
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
STRUCTURE
EQUIPMENT
WESTERN PASSAGE FILLING GATES
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
STRUCTURE
EQUIPMENT
HEAD HARBOUR EMPTYING GATES
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
STRUCTURE
EQUIPMENT
HEAD HARBOUR LOCK
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
STRUCTURE
EQUIPMENT
WESTERN PASSAGE LOCK
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
STRUCTURE
EQUIPMENT
LITTLE LETITE PASSAGE LOCK
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
STRUCTURE
EQUIPMENT
QUODDY ROADS LOCK
COFFERDAMS
EARTH EXCAVATION
ROCK EXCAVATION
STRUCTURE
EQUIPMENT
DAMS
LETITE PASSAGE, NORTH
LETITE PASSAGE, SOUTH
MACHASTER I TO JAMESON I
JAMESON I TO NEW I
NEW I TO PENDLETON I
PENDLETON I TO ENGLISH I
ENGLISH I TO DEEP I
HEAD HARBOUR PASSAGE, EAST
HEAD HARBOUR PASSAGE, WEST
INDIAN RIVER
WESTERN PASSAGE
CARRYINGPLACE COVE
QUODDY ROADS
RELOCATIONS
FINAL TESTING
PERMANENT OPERATING FACILITIES
TIDAL POWER DEVELOPMENT
CONSTRUCTION SCHEDULE
POWERHOUSE NO. 1 - 50 UNITS
MARCH 1964
TG7-371

SCHEDULE I



TIDAL POWER DEVELOPMENT
CONSTRUCTION SCHEDULE
POWERHOUSE NO. 2 - 50 UNITS
MARCH 1964 TG7-372

SCHEDULE 2

Chapter IV. Dickey Project, St. John River

4–01 General plan

The site selected for the river hydroelectric project is on the main river immediately above the confluence with the Allagash River as shown on plate No. 5. The geologic features of the site have been described in a previous chapter. The general plan of the development is shown on plate No. 6. The main dam across the river and the dikes across the adjoining saddles would be of the earthfill type. All structural features would be located on the right bank and in general founded on rock: The low-level outlet tunnels, which would be used for diversion during construction; the powerhouse with tailrace discharging into the St. John River; and the spillway which would discharge at infrequent times through a stilling basin into the Allagash River. The maximum and minimum reservoir elevations would be 910 and 870 feet above mean sea level, thus providing a 40-foot drawdown.

4–02 Hydrology

The drainage area above the Dickey site is 2,725 square miles. Area and capacity curves for the Dickey site, shown on plate No. 10, were developed from the latest available U.S. Geological Survey quadrangle sheets, scale 1:62,500. At maximum elevation of 910 feet, the reservoir area would be 88,600 acres and its capacity 8,080,000 acre-feet. At drawdown level of 870 the reservoir area would be 58,500 acres and its capacity 5,180,000 acre-feet.

Tailwater rating curves were developed for the spillway and the powerhouse. Since the stilling basin at the end of the spillway chute would discharge into the Allagash River just above the cutoff, its tailwater would be controlled by the new channel. The estimated rating curve is shown on plate No. 10. The rating curve at the powerhouse shows that tailwater levels there would be controlled by the Lincoln School dam. The static maximum, minimum, and average tailwater elevations would be 605, 597, and 601, respectively.

Streamflow at the Dickey site was assumed to be the same as at the Dickey gaging station 2 miles upstream. Records at the gage indicate the following:

Drainage area, in square miles: 2,700 (approximately).
Period of record: October 1946 to September 1962.
Average discharge, in cubic feet per second: 4,600.
Minimum discharge, in cubic feet per second: 129.
Date: September 17, 1948.
Maximum discharge, in cubic feet per second: 71,700.
Date: May 15, 1961.

Two important hydrologic events have occurred since the IJC study: The most critical 3-year drought, 1955–58; and the greatest flood, May 1961. These events are taken into consideration in the present study.

The streamflow follows a normal annual pattern. Melting snow produces high rates of runoff in April and May after which the flow diminishes gradually and then remains quite uniform until the following spring, except for occasional rises due to rainfall. Then the cycle repeats. The following tabulation of mean monthly discharge illustrates this cycle:

Month	*Mean discharge, cubic feet per second*	*Month*	*Mean discharge, cubic feet per second*
April	12,460	October	3,350
May	16,300	November	4,340
June	5,290	December	2,450
July	3,040	January	1,210
August	2,360	February	740
September	2,150	March	1,330

In order to determine the regulated flow available at the Dickey site storage-draft curves were developed for periods of deficient streamflow, using records of flow at the Dickey gaging station. The critical periods were found to be 1947 to 1948 and 1955 to 1958. The following tabulation gives the storage and regulated flow for various values of drawdown:

Maximum drawdown (feet)	*Active storage* (acre-feet)	Regulated *flow (cubic* feet per second)
10	845,000	2,520
20	1,600,000	3,560
30	2,300,000	4,100
40	2,900,000	4,370

In computing the regulated flows, an allowance of 50 cubic feet per second was made for losses by evaporation and leakage. For the selected maximum drawdown of 40 feet, the active storage would be 2.90 million acre-feet, and the regulated flow 4,370 cubic feet per second.

An analysis was made of the time required to fill the Dickey Reservoir. With the intakes built as shown on plate No. 7, the reservoir would have to be filled to elevation 870 before power generation could begin. This would require the accumulation of 5,180,000 acre-feet of water. In filling the reservoir consideration would need to be given to the water requirements of downstream plants, of which Beechwood, with 102,000 kilowatts installed, requires the most water. Assuming that Beechwood operates at 60 percent load factor and an average net head of 58 feet, its average water requirement is 14,600 cubic feet per second. It was assumed that the flow at Beechwood could be reduced to this average, 14,600 cubic feet per second, as a minimum, by storing water at Dickey except that a minimum discharge of 500 cubic feet per second would be released at all times to maintain a reasonable low water riverflow immediately below the dam. It is also assumed that water in storage would not be drawn on during the filling period to make up any deficiency should natural flow at Beechwood fall below the 14,600-cubic-feet-per-second level. Under average flow conditions, filling of the reservoir would begin in April and be completed in about 2 years.

4-03 Reservoir

The extent of the proposed Dickey Reservoir at full pool elevation 910 is shown on plate No. 5. It would extend about 47 miles up the St. John River and cover an area of 88,600 acres. A more detailed description will be given later under the subject of "Lands and Damages," in paragraph 4-09. The reservoir would be contained by the main dam and saddle dikes at five scattered locations, required to prevent flow into adjacent watersheds.

4-04 Embankment and saddle dikes

The top of the main embankment was set at elevation 925 to provide 15 feet of freeboard over the maximum normal operating pool. A 60-mile-per-hour wind (velocity over water) acting on the effective fetch of 3.14 miles from the northwest, would generate 4.6-foot waves. These waves would run up 3.8 feet on the 1-on-3, riprapped slope. In addition, there would be a setup of 0.7 foot, on an effective reservoir length of 23 miles. The sum of setup plus wave runup would be 4.5 feet, leaving a freeboard of 10.5 feet. The freeboard provided above maximum spillway surcharge of 8.6 feet, an extremely rare condition, is 6.4 feet without wind and wave action.

Typical cross sections of the main embankment across the river and the secondary dam on the right bank are shown on plate No. 7. Transition zones between different materials, details of surface protection and control of seepage follow conventional practice.

The upstream face of the embankment would have 4 feet of rock slope protection placed on a 2-foot layer of gravel bedding. Above elevation 860, where the pool is subject to fluctuation, the rock for slope protection would be selected. The downstream slopes would be faced by 3 feet of processed gravel above elevation 610, below elevation 610, the downstream toe would be protected by 4 feet of "select" rock on a 2-foot gravel bedding.

To prevent overflow into the St. Francis River Basin a dike would be required on Falls Brook, and another on Hafey Brook. Dikes would also be required on

Campbell Brook, Blue Brook, and Cunliffe Brook to prevent overflow into the Allagash River Basin. All dikes would be earthfill type, constructed of materials found within 3 or 4 miles of the respective sites. The locations of the dikes are shown on plate No. 5.

4–05 Low-level outlets and river diversion

Two 24-foot tunnels driven through the right abutment would be used during construction to pass riverflows after the spring freshet recedes. A study shows that the 10-year construction-season flood passing through the tunnels would raise the level in the reservoir to elevation 627.2. A closure section across the river would have to be raised above this elevation as rapidly as possible after the spring breakup. The following spring flood could be passed through the tunnels and over a saddle at elevation 662.5 to the right of the powerhouse location. With a gap of about 1,000 feet in the embankment across the saddle the maximum spring flood would raise the level in the reservoir to elevation 672.6. With the flow confined to the two 24-foot tunnels the maximum flood of record would raise the reservoir to elevation 699. The section of the dam closing the 1,000-foot gap would be raised to above this elevation during the construction season.

The two 24-foot tunnels described in the previous paragraph would also be used for releases during reservoir filling. Two 90-inch fixed-cone dispersion valves would be installed in each tunnel to control the discharge. The valves and their vertical-lift emergency gates would be located in a shaft immediately upstream from the centerline of the dam as shown on plate No. 7.

4–06 Spillway

The spillway design flood for the Dickey site was developed in the same way as the spillway design flood for the Big Rapids site. (See report of the International Passamaquoddy Engineering Board; app. 12, "Auxiliary River Hydro Developments"; par. 12–08, f, pp. 12–27). The maximum possible rainfall over the Dickey drainage area is very nearly the same as for the Rankin Rapids drainage area. Figure 5, plate 12–6, same reference, shows the component hydrographs of the Rankin Rapids spillway design flood. The two component hydrographs representing flow from the drainage area of St. John River were added together. Then the ordinates were adjusted to the drainage area above the Dickey site, and base flow was added. This gave the natural hydrograph at the damsite. The hydrograph of inflow to a full reservoir would have a higher and earlier peak because of loss of valley storage and shorter travel time. Accordingly, the peak of the hydrograph was increased by 35,000 cubic feet per second and the hydrograph was reshaped, retaining the same runoff volume, to obtain the inflow hydrograph, show on plate No. 10.

An ungated overflow spillway rather than a gated control structure was chosen for the Dickey development to provide better flood control. In addition, an ungated structure would not require a power supply or operating personnel.

A relationship was developed between maximum surcharge and length of spillway crest by trial routings of the spillway design flood through the Dickey Reservoir. On the basis of this relationship, a crest length of 500 feet was selected. After the shape of the spillway crest and the spillway rating curve was determined, the spillway design flood was again routed through the spillway to check the design. It was assumed that all other outlets would be closed. The routing was started with the reservoir 0.75 foot above spillway crest, corresponding to a spillway discharge equal to the base flow. The maximum surcharge was 8.6 feet, and the maximum discharge was 50,000 cubic feet per second, which were satisfactory.

Since the control structure would be subject to ice thrust, the upstream face of the control weir would have a slope of 1 on 1. The crest would be shaped to conform to the lower nappe of a freely falling sheet of water. A design head of 7 feet was used. Heads in excess of the design head would produce pressures somewhat less than atmospheric on the crest of the weir.

The crest structure would discharge into a rock chute which would gradually converge from a width of 500 feet, spillway crest length, to a width of 250 feet in about 1,500 feet. The upstream 800 feet of the chute would have a slope of 0.2 percent, then 700 feet at a slope of 13.8 percent, then 1,650 feet at a slope of 11.8 percent into a stilling basin with floor at elevation 590. The chute would be unpaved where it is in sound rock and the lower 1,600 feet and stilling basin would be paved with concrete and have concrete sidewalls.

A standard hydraulic jump stilling basin would be provided at the downstream end of the chute, as shown on plate Nos. 6 and 7 to give necessary control of the high flow velocities which would occur in the chute. The horizontal apron at the basin would be at elevation 590, sufficiently below river tailwater elevation to assure the formation of a hydraulic jump at all levels of tailwater. Concrete walls of the stilling basin would rise 50 feet above the floor to provide ample freeboard above spillway design flood tailwater and to serve as abutments for the highway bridge.

The channel of the Allagash River would be improved from the stilling basin to its mouth, a distance of about 8,700 feet. The bottom width would be 400 feet, and the side slopes 1 on 2. The bottom slope would be about 1 foot per thousand feet.

4–07 Intake and penstocks

The most economical arrangement of penstocks and intake structure was found to be with the intake through a high rock knob on the right bank. The invert of the 18-foot penstocks was set at elevation 835, an elevation determined by an economic relationship between width and depth of the approach channel referred to the drawdown level of 870. This elevation provides 17 feet of submergence over the top of the penstocks. The excavated channel from the reservoir to the intake structure would be 10 feet lower in accordance with common practice.

The intake would be a concrete gravity structure with the top elevation the same as the dam crest, elevation 925. The service road across the dam would cross the top of the intake structure. Each intake would have a single water passage with an 18- by 30-foot trashrack and a 12.5- by 25-foot emergency vertical-lift headgate. The gates would be remotely controlled from the powerhouse. Stoplogs, placed in the trashrack slots, would be used when inspection or repair of the gate slots is necessary.

The penstocks from the intake to the powerhouse would be constructed of welded steel. The eight main unit penstocks would be 18 feet in diameter and the station service units would be supplied through a single 4-foot 3-inch penstock which would branch at the powerhouse to the two units. Maximum velocity in the main unit penstocks would be 23 feet per second. Plate thickness would be designed for maximum pressures accompanying emergency interruption of full turbine load with maximum pool head. The length of the penstocks was made as short as possible, 1,230 feet, to obviate the need for surge tanks and thus avoid the problems of icing that would occur with peaking operation of a hydroplant during the extremely cold winters at the Dickey site.

To prevent icing of the penstocks, they would be located in a cut and backfilled to a depth of 5 feet over the top. This would place the centerline well below the frostline with a depth of 6 feet.

4–08 Powerhouse

As stated earlier the powerhouse would have an ultimate capacity of 760 megawatts with eight 95,000-kilowatt generators. The cost estimate includes the structure for the ultimate development in the initial 190-megawatt installation. For the 380-megawatt, 475-megawatt, and the 760-megawatt installations the costs for turbines, generators, penstocks, and accessories are added. The powerhouse would be of the indoor concrete type with ultimate installation of eight generating units driven by vertical shaft, Francis-type, hydraulic turbines spaced 63 feet on centers. Each turbine would be connected by an 18-foot-diameter steel penstock extending approximately 1,230 feet to the intake structure. The switchyard would be located downstream from the powerhouse on the right bank of the tailrace channel and connected by aerial lines to the power transformers on the draft tube deck of the powerhouse. Access would be heavy-duty road from the railhead at St. Francis, Maine, to the south end of the plant where the assembly, control, service, and office areas are located. The powerhouse layout is shown on plate No. 8. The bridge crane would have a rated capacity of 375 tons.

The centerline of turbine distributors would be set at elevation 601. Each of the eight vertical, Francis-type, steel-spiral-case, hydraulic turbines would develop 130,000 horsepower at full gate, at the rated head of 275 feet and at 128.6 revolutions per minute. The governors would be equipped with means for adjusting the rate of gate movement to any value between 5 and 30 seconds for full gate opening or full gate closing stroke.

The generators, directly connected by vertical shafts to the turbines, would each be rated at 105,500 kilovolt-amperes, 60° C. temperature rise, class B insulation, 13.8 kilovolt, 0.90 power factor, 3-phase, 60-cycle and with a direct-connected exciter. Reactances, WR^2, runway speed, and thrust bearing loading would not exceed values available in standard design machines. Power for the station service system would be supplied by two station service generators driven by hydraulic turbines. The generators would be rated at 1,250 kilovolt-amperes, 480 volts, 0.80 power factor, 3-phase, 60-cycle and with a speed of 720 revolutions per minute. Conventional fire protection, cooling, heating, and utility systems would be provided.

Four, 3-phase, 243,000 kilovolt-ampere, 13.2–13.2–230 kilovolt, three winding, delta-delta-star connected, type FOW transformers would be provided. Each transformer would be connected to two generators and sized for 115 percent of the rated generator output. The transformers would be located on the tailrace deck, and each transformer would be connected to the switchyard by an aerial line.

The switchyard would be a 230-kilovolt yard and would be remote controlled from the powerhouse.

4–09 Lands and damages

The site of the Dickey Dam and Reservoir is located at Aroostook County, Maine, as shown on plate No. 5. The damsite is about 13 miles above the town of St. Francis, Maine, and just above the point where the Allagash River enters the St. John River. The reservoir extends from the damsite 57 miles to the farthest point of flooding on the St. John River. The backwater extends 25 miles up the Little Black River and 23 miles up the Shields Branch of the Big Black River. (The Shields Branch is called Riviere St. Roche in Canada.)

Land required for the project is approximately 110,000 acres which consists of water area of approximately 88,600 acres at maximum pool elevation 910, and 2,000 acres for work areas at the dam and saddle dikes with necessary access and adjacent borrow areas. The total area includes some islands that would be formed by the reservoir and a 300-foot buffer and access strip around the perimeter. A separate borrow area of 20 acres at Deboullie Mountain is included as a source for concrete aggregate and stone facing.

The reservoir would extend into the Province of Quebec, Canada, at three places. On the Shields Branch (Riviere St. Roche) of the Big Black River about 1,200 acres in Canada would be flooded. This area is developed with farms, roads, and bridges. On two branches of the Little Black River about 2,400 acres of forest would be flooded. The costs of relocation of the public facilities in Canada are included in the relocation costs.

Most of the land required for the Dickey project is in large tracts of timber held mainly for pulpwood cutting. There are some abandoned farms reverting to woodland. There is a built-up area in the hamlet of Dickey about 1½ miles above the damsite. Highway No. 161 serves the community and terminates above the hamlet of Dickey. The population of the entire project area is estimated at 700. About 240 tracts of land would have to be acquired for the project.

An appraisal of the woodland required for the project was made by an appraiser familiar with timberlands in the region. All land was classified according to its highest and best use, and appraised on the basis of fair market value in January 1964. An allowance was made for the value of standing wood growth on all timberland, and also for severance. Severance costs provide an equal access in cases where present access would be flooded out. To avoid isolation of timberlands on the north side of the St. John River, a ferry with landings on the north and south side of the reservoir is included in the estimate. An access road leads from the ferry landing to connect with the road along the Allagash River and with Route 161 just below the damsite. Improvements on the land were estimated separately. They include dwellings, barns, lumber mills, churches, schools, etc. There are no known mineral rights.

Water rights include two breached dams on the St. John River. International water rights on the St. John River arise from the treaty of August 9, 1842, between the United States and Britain (the Webster-Ashburton Treaty), which provides for common use of the waters of the St. John River to promote commerce and transportation for the benefit of the United States and Canada. The only use made of the river in the sense of the treaty is the floating of logs and pulpwood to downstream points. The design of the dam provides for a logway to maintain this traffic. No fishways would be required since the upstream movement of anadromous fish is blocked downstream by natural obstacles.

4–10 Road nets and relocations

Access roads and relocations necessary in connection with the construction of the Dickey project are shown on plate No. 5. The Dickey site is reached from St. Francis by Route 161. The bridge over Allagash River would be reconstructed for heavy loads for project purposes. The road leading up the north side of the Allagash River will be relocated within the work area and carried across the stilling basin by a bridge, as shown on plate No. 6.

Access to the sites of the Falls Brook and Hafey Brook dikes would be by means of a road across the Lincoln School Dam and existing and relocated tote roads, as shown on plate No. 5. Access to the site of the Campbell Brook dike would be by a new road connecting to the tote road along the north side of the Allagash River. This road would also serve the ferry landing and recreation area to be constructed on the south side of the reservoir. There are no known roads near the sites of the Blue Brook and Cunliffe Brook dikes. Access would be by haul roads which are a project cost. Access roads for woods operations are included as severance costs in lands and damages.

There is a power pole line of the Maine Public Service Co. on Route 161, and a pole line of the Fort Kent Telephone Co. which require removal within the Dickey project. There is a single-wire telephone line of the Maine Forest Service in the reservoir area. It is understood that future communications of this service are to be handled by radio and no relocation would be necessary. There are about 250 graves in 3 cemeteries which will require relocation of an estimated cost of $50,000.

4–11 Service facilities

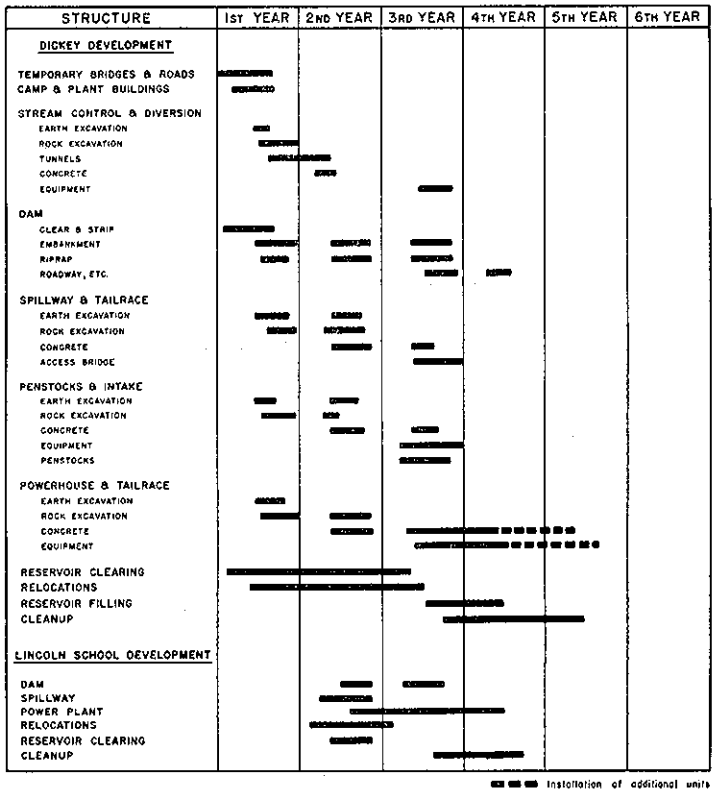
Since the Dickey project is about 180 air miles from the tidal project, it will be practically independent for operating services and most maintenance work. Therefore, the project would be provided with maintenance shops, vehicle servicing shops, warehousing, housing for key employees, land vehicles and equipment, and marine plant. The service facilities at the Dickey project would also serve the reregulating dam about 11 miles downstream at Lincoln School.

4–12 Operation and maintenance

An operating and maintenance staff of approximately 45 would be required to operate the full development at Dickey; about two-thirds would be engaged on maintenance work. A high degree of automatic control and centralized operation is anticipated. The maintenance force would handle all preventive maintenance. The operation of the Lincoln School project would be controlled from the Dickey project. A common maintenance force would be used. The estimate for operation and maintenance is based on the study made in the IJC report, adjusted to present conditions.

4–13 Future considerations

There are other possibilities for developing power on the upper St. John River which may be investigated for comparative purposes during the project design stage. One is a power reservoir at elevation 910 at Big Rapids, coupled with one at Lincoln School with maximum pool elevation 630. This combination was studied in the preparation of the IJC report. Another would be a dam at Dickey with maximum pool elevation about 910, but with intake and powerhouse on the left bank of the St. John River at Lincoln School. This scheme would require a high dam on Falls Brook about 5 miles downstream of the present dike, a 2-mile tunnel through the mountain to the Lincoln School damsite and a slightly higher reregulating dam at Lincoln School. The high-head powerplant at Lincoln School would discharge two turbines into the St. John River for continuous power, and six turbines into the Lincoln School Reservoir for peak demands. Flow from the Allagash and the discharge from the six high-head turbines would be utilized by two turbines in the Lincoln School powerhouse.



DICKEY & LINCOLN SCHOOL
CONSTRUCTION SCHEDULES

MARCH 1964 AG7-135

SCHEDULE 3

Chapter V. Lincoln School Project, St. John River Reregulation

5–01 Function of Lincoln School

The average regulated flow from the Dickey powerplant would be 4,370 cubic feet per second with a maximum discharge of about 48,000 cubic feet per second. In order that the Dickey discharge might be better controlled and utilized a reregulating reservoir would be desirable. An ideal site was found approximately 11 miles downstream on the St. Johns River at Lincoln School. Here a dam will be constructed, including a powerhouse, that will impound the Dickey discharges and where the discharge will be regulated for more effective use by existing downstream hydroplants at Grand Falls and Beechwood. New Brunswick. Coincidentally it will have the capability of generating power. The general plan of the proposed dam is shown on plate No. 9.

5–02 Hydrology

The active storage capacity of 16,000 acre-feet at Lincoln School would be sufficient for reregulation of the discharges from Dickey on a monthly basis but not enough to regulate the flow from the uncontrolled drainage area. The controlled average outflow from Lincoln School would equal the regulated flow from Dickey plus the minimum flow, 200 cubic feet per second, from the uncontrolled drainage area of 1,361 square miles. The 2,900,000 acre-foot active storage, 40-foot maximum drawdown, at Dickey would permit a regulated average flow of 4,370 cubic feet per second after deducting 50 cubic feet per second, for evaporation and leakage. Thus the regulated average flow from Lincoln School would be 4,570 cubic feet per second.

The tailwater rating curve for natural conditions at the Dickey site shows that the head loss between the two sites would be negligible, even when the Lincoln School pool is drawn down. The pool level at Lincoln School would vary from a maximum of 605 feet to a minimum of 597 feet above mean sea level. Area and capacity curves determined from U.S. Geological Survey quadrangle maps, scale 1:62,500, are shown on plate No. 10.

5–03 Reservoir

The Lincoln School reregulating reservoir would extend 11 miles upstream on the St. John River to the Dickey Dam and up the Allagash River to the Dickey spillway discharge channel, as shown on plates No. 5 and No. 6. It would have an area of 2,200 acres at full pool elevation of 605 feet above mean sea level.

5–04 Embankment

Because rock is deeply buried below the bed of the river, an earth dam is the most economical structure. The top of the embankment was set at elevation 620 to provide 15 feet of freeboard over the maximum normal operating pool level and spillway design flood pool level, which are at the same elevation. A 60-mile wind from the direction of maximum fetch (SW, 1½ miles) would result in 3.5-foot high waves which would ride up 5 feet on the upstream slope. There would remain 10 feet of freeboard above the level of wave action.

The design of the earth embankment is similar to that used by the IJC for the Lincoln School project. Plate No. 9 shows a typical embankment section.

5–05 River diversion

It is assumed that construction of the Dickey Dam would be started in advance of the Lincoln School Dam so that the Dickey Reservoir would be available to control floods from its drainage area. In this case, the flood discharge at the Lincoln School site during construction would be only the discharge from the uncontrolled drainage area. On the other hand, construction of Lincoln School Dam might be scheduled to start some time after two units have been installed in the Dickey powerhouse. In the latter case, the discharge from two units, 10,000 cubic feet per second, would be added to floods from the uncontrolled area. The record spring flood on the Allagash River is 28,800 cubic feet per second from a drainage area of 1,260 square miles. On the basis of drainage area ratios, it is estimated that the maximum discharge from the total uncontrolled area of 1,361 square miles was 31,300 cubic feet per second. The total estimated discharge to be passed at the Lincoln School site would thus be 41,300 cubic feet per second.

It is planned that the river would be diverted initially over the partly completed powerhouse foundation and later over the spillway. The powerhouse, plate No. 9, would be constructed in two stages, the first of which would consist of the intake up to its final elevation, and the powerhouse substructure to the

bottom of the spiral case. Piers would be constructed above the draft tube outlet. Closure of the main embankment across the river channel would be initiated by a rockfill cofferdam upstream which would force the river flow through the partially completed powerhouse. The discharge capacity of the powerhouse would be 41,300 cubic feet per second with the pool at elevation 562, which would pass the record spring flood from the uncontrolled area, 31,300 cubic feet per second plus the discharge from the Dickey powerhouse, 10,000 cubic feet per second.

On completion of the main embankment and the spillway, the headgates and downstream bulkheads would be installed in the powerhouse area, the area pumped out, and the powerhouse construction resumed. After closure of the headgates, the pool would have to rise from about elevation 540 to elevation 580 (5 feet above spillway crest) before the river flow could be passed over the spillway in sufficient quantity for downstream requirements. Since only 13,000 acre-feet would be involved in this operation, it might be advantageous to draw on Dickey storage to raise the pool rapidly. If desired, some flow could be released through the intake gates during the filling operation.

In view of the foregoing, and the low head at the project, plus the fact that all releases for reregulation could be made through the spillway, no low-level outlets are planned.

5–06 Spillway

The spillway would be designed to meet the following requirements:

(*a*) It must pass river flows while construction of the powerhouse is being completed.

(*b*) It must, together with the powerhouse, reregulate the discharge from the Dickey powerhouse, and pass flood flows in excess of the capacity of the Lincoln School powerhouse.

(*c*) It must pass the spillway design flood.

The spillway design flood for the Lincoln School spillway was computed by adding the ordinates of four hydrographs shown on plate No. 10 and described as follows:

(*a*) *Dickey powerhouse discharge.*—The power output at Dickey required to supplement the Passamaquoddy output is shown on figure 9 of the report of the Department of the Interior dated July 1963. The load pattern of the first Wednesday was followed, assuming a maximum load of 760,000 kilowatts from 5 to 6 p.m. The average discharge for each hour of the day was computed. For simplicity, it was assumed that this pattern of discharge would repeat daily during the spillway design flood.

(*b*) *Dickey spillway discharge.*—The spillway design flood inflow was routed through Dickey Reservoir, assuming powerhouse discharge as described above, to obtain the Dickey spillway discharge.

(*c*) *Upper Allagash.*—The flow from the upper Allagash drainage area of 720 square miles, which is completely regulated by lakes, was assumed to be 6,000 cubic feet per second.

(*d*) *Lower Allagash plus local.*—The hydrograph representing runoff from the lower part (540 square miles) of the Allagash drainage area is shown on plate 12–6, of appendix 6, of the International Passamaquoddy Engineering Board's report, dated October 1959. It was assumed that the runoff from the local area of 101 square miles would follow the same pattern. Therefore, the ordinates of the hydrograph were increased by the ratio of the drainage areas to represent the runoff from the lower Allagash plus local drainage area of 641 square miles.

During the design flood, the spillway would be operated so as to reregulate the flow from the Dickey powerhouse as shown on plate No. 10. The average flow from the Dickey powerhouse would be 6,225 cubic feet per second. The regulated outflow would be equal to the sum of flood inflows plus this amount as shown by the dashed line. The pool elevation would vary between 602.5 and 605, as shown.

The spillway would consist of an approach channel, a control structure, a chute, a stilling basin, and a discharge channel as shown on plate No. 9.

The control structure would be a gated spillway having four 30-by-40-foot taintor gates. Its discharge capacity would be 100,000 cubic feet per second at full pool, which is 8 percent more than spillway design discharge.

The chute would have a relatively level grade for a distance of about 250 feet, on which velocities would be faster than critical. This length was selected for economy of excavation. The flat chute would be followed by a steep chute down into the stilling basin.

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The stilling basin would be designed to produce a hydraulic jump to safely dissipate the energy of the water. It would be provided with two rows of baffle blocks and an end sill to stabilize the jump. An excavated channel would convey spillway discharges back to the St. John River.

5-07 Powerhouse

The powerhouse would be integral with the intake structure and would be located on the left bank of the river in an excavated channel as shown on plate No. 9.

The general project considerations, previously described, established the minimum net head as 56 feet, rated net head as 61 feet, and the maximum net head as 67 feet. The plant dependable capacity of 34,000 kilowatts would be required at the minimum net head of 56 feet with the turbines operating at full gate. The plant was sized on the basis of the regulated flow of 4,570 cubic feet per second and a 60-percent load factor. Preliminary studies made by the International Joint Commission for Kaplan and fixed-blade propeller-type turbines in one-, two-, and three-unit plants indicated that a two-unit plant with Kaplan-type turbines would be most favorable. Each of the two turbines would be rated at 25,900 horsepower at full gate, with a head of 61 feet and a speed of 138.5 revolutions per minute. Each generator would be rated at 90-percent power factor, a 60° centigrade rise at 18,900 kilovolt-amperes and an 80° centigrade rise at 21,700 kilovolt-amperes.

The powerhouse would be of the indoor type. Units would be on 55-foot centers with a 70-foot assembly and station service area provided at the southeast end of the plant. Access level would be at elevation 550, which provides a freeboard of 5 feet above spillway design flood tailwater. The one main power transformer would be located on the tailrace deck, elevation 550. Generators would be located at elevation 560. Scroll case and draft tube access galleries would be provided at elevations 533 and 516.5 respectively. The scroll case would be of formed concrete with centerline at elevation 537.

Conventional mechanical equipment and electrical systems normally included in powerhouses of this type would be provided. One, three-phase, 43,400-kilovolt-ampere transformer would serve both generators through 13.8-kilovolt air circuit breakers. The transformer would be connected to the 230,000-volt transmission line through a conventional switchyard. Governors and switchboards would be located between the units at elevation 560. This area would serve as the station control room. Station service power supply would be from two transformers connected to terminals of the generators.

5-08 Road nets

Construction of the Lincoln School project will include some changes to existing roads, as follows:

Access to timberlands east of Little Black River, blocked by the Dickey Reservoir, would be provided by a road on top of Lincoln School Dam to the north side of St. John River and thence to the proposed Falls Brook dike, as shown on plate No. 9. Access to the powerhouse is by service road from Highway 161 to the south end where the maintenance area is located.

Portions of State Route 161 between Lincoln School and the Dickey Dam site, which would be inundated by the Lincoln School Reservoir, would be relocated on higher ground as shown on plate No. 5. The power pole line of the Maine Public Service Co. and the Fort Kent Telephone Co. pole line would require relocation along with Highway 161.

5-09 Lands and damages

In addition to the land acquired for the Dickey Dam work area, there are about 2,150 acres of land and improvements that would be required at elevation 605, plus a 300-foot buffer and access strip. The estimate for the acquisition of this land is in the cost schedule of Lincoln School. A logway is provided at the Lincoln School Dam to provide for passage of timber and pulpwood.

5-10 Service facilities

Joint service facilities will be provided for the Dickey and Lincoln School projects and would be located at Dickey.

5-11 Operation and maintenance

The operating staff at Dickey would be responsible for the operation and maintenance of Lincoln School.

5-12 Construction schedule

Construction of the Lincoln School project would begin after the Dickey Dam had been raised to sufficient height to control flows from the St. John River. Sequence of construction is shown on schedule 3 accompanying chapter IV of this report.

Chapter VI. Flood Control and Recreation

6-01 Flood control on St. John River

Snowmelt, sometimes in combination with rainfall, annually produce spring floods along the St. John River. The area, being sparsely settled, has not been exposed to significant damages with the exception of Fort Kent located about 28 miles downstream of the Dickey Dam. The Fort Kent urban areas has experienced seven consequential floods during the past 36 years of record. Two of the largest floods have occurred within the past 5 years, the most damaging being in 1961 a recurrence of which would cause damages at today's prices of $450,000.

Damages at Fort Kent start at a river discharge of 100,000 cubic feet per second. The 1961 discharge was 131,000 cubic feet per second. Inasmuch as the Dickey Dam controls 47.5 percent of the contributing drainage areas, impoundment of floodwaters would reduce discharges to well below the zero damage stage.

The alternate method for prevention of damages, without reservoirs, would be by a local protection project. A recent study investigation by the New England Division, Corps of Engineers in 1963 indicated that such a project would cost $1,060,000. Dickey Dam makes such a project unnecessary and results in average annual benefits at Fort Kent of $40,000.

6-02 Incidental construction for recreation

Plans for construction of facilities at the Passamaquoddy project for the convenience of visitors are as follows:

A parking area for visitors would be provided at powerhouse No. 1. A parking area and picnic grounds would be provided at Carlow Island. A visitors' gallery and exhibit area would be provided in the tidal powerhouses. The service roads to the tidal dams, locks, and gates could be used by visitors to obtain an overall view of the tidal project. It is expected that sightseeing tours would be conducted by suitable members of the operating staff.

Plans for recreation facilities at the Dickey Reservoir consist of a camping area and boat-launching ramps. They would be located on the east side of the Campbell Brook arm of the Dickey Reservoir adjacent to the proposed ferry landing as shown on plate No. 5. The 30-acre camping area would be cleared of underbrush, campsites laid out, gravel roads constructed, and toilet and water provided. A ramp for small boats would be constructed. Access to the area would be provided by a new road about 2.7 miles long which would connect to the existing roads along the Allagash River. Picnic areas will be scattered throughout the reservoir.

6-03 Tidal plant fishways

Plans of the tidal powerhouses, plate Nos. 1, 2, and 3, indicate fishways to provide for the passage of eastern salmon, shad, and alewives. This is in accordance with the desires of the authorities interested in sport fishing and wildlife. The fish ladders and collection galleries are similar to those shown in the IJC report.

Chapter VII. Cost Estimates

7-01 General

This chapter covers the estimates of cost, as of January 1964, of the Passamaquoddy tidal power project together with the proposed hydroelectric auxiliary plant on the St. John River at Dickey, Maine. The layout and design of the tidal project remains the same as proposed in the 1959 report to the International Joint Commission with the exception of the powerplant, which is based on the use of inclined turbines and generators instead of the vertical type. The powerplant proposed in 1959 comprised thirty 10,000-kilowatt units for a total installed capacity of 300,000 kilowatts. In this report four sizes of powerplants are proposed for study; namely, 30, 40, 70, and 100 units of 10,000 kilowatts each, with the 30 or 50 units located in powerhouse No. 1 and the additional capacities to make up the 70 or 100 units in powerhouse No. 2.

The proposed dam at Dickey, together with the reregulating dam at Lincoln School, comprise new layouts as required by the concept of developing peaking power and the preservation of the Allagash River as a white-water recreational area.

7-02 Basis of estimates

The estimates herein have been prepared to provide usability in economic analysis of the ultimate plan of development and incremental units thereof.

Four separate estimates have been prepared for the Passamaquoddy tidal power project. The dams, gates, and navigation locks are common to each and are, therefore, the same in each, except for amount of excavation available for dams. The variation is applicable to the powerplant and the headrace and tailrace required.

At Dickey there are four separate estimates based on installations of 190-, 380-, 475-, and 760-megawatt installations. The estimate for the 190-megawatt installation includes the dam, outlet works, spillway, closure dikes, the powerhouse for the ultimate development of 760, but the installation of only two turbines and generators (two, at 95 megawatts) together with two penstocks and necessary auxiliary equipment. The variation of the other estimates results from the incremental addition of subsequent turbines and generators to the base installation.

The Lincoln School estimate is predicated on total construction at one time.

7-03 Criteria for unit costs

Unit costs that make up the various elements for the project have been developed on current construction knowledge and information. The unit costs used in the International Joint Commission Report of 1961 developed from detailed research have been carefully reviewed and have been utilized as far as possible subject to necessary adjustments due to changes in the costs of equipment, materials, and of rates of wages, as well as in the continuing economy of more efficient construction machinery and methods of construction operations.

The labor rates used as a basis for the cost estimates are the rates that it is believed a contractor would be required to pay even though they may be higher than prevailing rates of wages in the localities. A typical list of such wages are listed in appendix II, table 1.

Ownership rates of construction equipment have been revalued based on a long service concept on large projects. Typical rates of land and marine equipment are listed in appendix II, table 2.

7-04 Project features

The designs of the tidal plant remain the same as in the 1961 International Joint Commission Report except for the powerplant which is based on the concept of inclined turbines and generators. However, since the amount of excavated rock for the proposed powerplants will vary from the 30-unit plant in the IJC report, the costs of the tidal barriers will be changed due to the necessity of having more usable rock and thus requiring less material from expensive borrow areas.

Materials obtainable at the proposed Dickey Dam site are somewhat different from those found at the IJC report location of Rankin Rapids. Sources of materials for the dam are based on an average haul of 2½ miles; concrete aggregates as well as select armor stone are to come from Deboullie Mountain, a distance of about 18 miles, and imported materials and equipment are expected to arrive by rail to St. Francis and thence by restrengthened highway to the site.

7-05 Contingency allowance

An allowance for contingencies is commonly made in estimating project costs to allow for unforeseen conditions that may arise during the construction. The uncertainty about site conditions is greater than the variation in quoted prices for equipment from manufacturers. For installed equipment items, the allowance is carried at 10 percent. For all remaining construction items, the contingency allowance is carried at 15 percent. The percentage is applied to the sum of direct, indirect, distributive, and overhead costs.

7-06 Government costs

The allowance for Government costs which cover engineering, design, supervision, inspection, and administration, have been increased from that used in the IJC report, which was a straight 9 percent. A study of major Government contracts for similar type projects indicate a higher average cost. This allowance, therefore, has been increased to 12 percent, except for the costs of power-

plants where the allowance will remain at 9 percent. This 9 percent is being used on these structures due to the repetitive nature of the work of design which should show a saving in the cost. The percentage for Government costs is applied to the sum of the construction costs and contingencies.

7-07 Tidal power project

The estimate that follows is made up by computation of costs based on present-day unit prices applied to the quantity surveys. The estimate contemplates the use of excavated materials to the maximum extent possible. Further breakdown is given in tables 3 to 6 of appendix II. It will be noted that the construction schedule indicated in chapter III is essentially the same as the one in the International Joint Commission Report of 1961. The description of construction operations by features is also the same as in the International Joint Commission Report. Necessary changes and additions to all features are made as entailed by the larger number of units. Powerhouse No. 1 includes the 300- and 500-megawatt plants and powerhouse No. 2 the additional units for a total of 700- and 1,000-megawatts installation. As it is contemplated that powerhouse No. 2 will be a later stage of construction, the excavation therefrom has been wasted. In the estimates that follow the main power transformers are included in the powerhouse costs and have been deducted from switchyard costs supplied by the Department of the Interior. Separate estimates are given for the various sizes of powerhouse in appendix II, tables 3 to 6. The project features that are common to all sizes of powerhouse are estimated in appendix II, tables 7 to 19, inclusive. Those common feature items that vary somewhat because of powerhouse size are given for a 500-megawatt plant, they are: "Table 14: Dams," "Table 16: Fishways," "Table 17: Service Facilities," "Table 18: Relocations," and "Table 19: Lands and Damages." The increase or decrease from the 500-megawatt plant is included in the cost estimate for the various sizes of project powerhouse.

Estimate of cost, tidal power project

[Megawatts—Cost in thousands]

Item	Installed capacities			
	300	500	700	1,000
Powerplant	$119,189	$204,491	$302,287	$427,162
Switchyard	1,780	2,370	3,160	3,950
Filling gates	62,634	62,634	62,634	62,634
Emptying gates	57,627	57,627	57,627	57,627
Locks	18,917	18,917	18,917	18,917
Dams	77,309	63,664	64,454	64,454
Lubec Channel	634	634	634	634
Fishways	888	1,298	1,748	2,324
Service facilities	1,670	1,870	2,070	2,470
Relocations	3,929	4,931	7,431	9,631
Lands and damages	1,870	1,870	1,960	2,030
Subtotal	346,447	420,306	522,922	651,833
Contingencies	49,520	58,967	72,728	89,616
Subtotal	395,967	479,273	595,650	741,449
Engineering, design, supervision, and administration	43,478	50,581	61,221	74,482
Total 1st cost	439,445	529,854	656,871	815,931

7-08 Dickey project

(*a*) *General.*—The dam and powerplant at Dickey are generally of a conventional river hydroelectric pattern. The construction is adapted to the terrain making full use of natural materials available locally. Access is by Maine State Highway Route No. 161 which would terminate at the project site. Areas for the contractor's work area would be on the right bank of the St. John River above the Allagash River. The real estate included in the project costs would provide ample area for warehouses, garage, shops, and minimum housing for Government operators and maintenance staff.

(*b*) *Reservoir clearing.*—There are about $1,000 acres of forested land within the Dickey and Lincoln School Reservoir area. The present estimated value of standing wood growth is approximately the full value of the woodland area.

The residual land value is low. If the timberland acquisition is completed in the first part of the construction period, then the full standing value of the wood growth would be realized and would be sufficient to cancel cost of reservoir clearing. In the actual work, there may be scheduling difficulties that would prevent full realization of the standing growth value, or the timber may be cut off by owners, which would reduce the cost of the land but leave a clearing operation necessary. A sum is carried in the estimates for clearing which reflects reduction for the standing wood growth.

(*c*) *Estimate of cost.*—The detailed estimate of cost is shown in appendix II, table 20. It is based on the initial development of two 95,000-kilowatt units. The switchyard costs furnished by the Department of the Interior are reduced by the estimate for main transformers, which are included with the powerhouse costs. The Department of the Interior requested that the construction cost estimate provide for the ultimate development of eight units, but further, that the cost of building the powerplant in increments of two, four, and five units be shown in the estimate. Accordingly, the cost by increments is provided.

Estimate of cost, Dickey project

[Megawatts—Cost in thousands]

Item	Installed capacity			
	190	380	475	760
Lands and damages	$4,469	$4,469	$4,469	$4,469
Relocations	1,363	1,363	1,363	1,363
Reservoir clearing	2,000	2,000	2,000	2,000
Dams	72,919	72,919	72,919	72,919
Penstocks	3,624	7,249	9,062	14,503
Powerplant	28,531	39,093	44,591	60,229
Switchyard	1,583	1,940	2,787	3,466
Buildings, grounds, and facilities	560	560	560	560
Access roads	728	728	728	728
Subtotal	115,777	130,321	138,479	160,237
Contingencies	16,935	18,691	19,700	22,321
Subtotal	132,712	149,012	158,179	182,558
Engineering, design, supervision, and administration	14,954	16,559	17,476	19,880
Project 1st cost	147,666	165,571	175,655	202,438

7–09 Lincoln School project

The Lincoln School reregulating dam would be built during the latter part of the construction period of the Dickey Dam. It would be started when the dam at Dickey is high enough to control riverflow. The estimate for Lincoln School is given below:

Estimate of cost, Lincoln School project

Item	*Cost in thousands*
Lands and damages	$400
Relocations	1,238
Reservoir clearing	40
Dams	4,323
Powerplant	6,290
Switchyard	387
Buildings, grounds, and facilities	208
Access roads	50
Subtotal	12,936
Contingencies	1,776
Subtotal	14,712
Engineering, design, supervision, and administration	1,553
Project 1st cost	16,265

7-10 Annual maintenance and operation costs

The yearly operation and maintenance costs for the tidal project are estimated as follows:

300 megawatts	$1,126,000
500 megawatts	1,340,000
700 megawatts	1,540,000
1,000 megawatts	1,910,000

The yearly operation and maintenance costs for the Dickey and Lincoln School projects combined are estimated to be:

For units at Dickey:	
190 megawatts	$400,000
380 megawatts	580,000
475 megawatts	670,000
760 megawatts	940,000

Lincoln School project would be an automatic station and be operated and maintained from Dickey.

7-11 Annual cost of major replacements

The estimated cost of yearly replacements is computed assuming that about 25 percent of the major equipment will be replaced every 30 years.

Tidal project:	
300 megawatts	$333,000
500 megawatts	508,000
700 megawatts	693,000
1,000 megawatts	970,000
Dickey project:	
190 megawatts	38,100
380 megawatts	74,200
475 megawatts	92,000
760 megawatts	145,000
Lincoln School project:	
34 megawatts	12,800

7-12 Interest during construction

As requested by the Department of the Interior a brief analysis was made of the proposed construction schedules to determine the approximate amount of funds needed per year to prosecute the work. Based on the interest rate of 3 percent, the total interest required during the construction period is given below.

Tidal power project:	
300 megawatts	$33,225,000
500 megawatts	39,267,000
700 megawatts	45,966,000
1,000 megawatts	53,824,000
Upper St. John River development:	
Dickey project:	
190 megawatts	$6,500,000
380 megawatts	7,036,000
475 megawatts	7,337,000
760 megawatts	8,128,000
Lincoln School project:	
34 megawatts	480,000

7-13 Added cost estimate if turbine hub is lowered 5 feet for reverse pumping

It should be noted that when the turbines and water passages of the tidal power units are lowered 5 feet, the sidewalks of the draft tube of the power units would be increased from 6 feet to 6 feet 6 inches making the spacing of units 63 feet in the tidal powerhouse. The estimates are for lowering all 50 units of 1 tidal powerhouse. These estimates are to be added to the powerhouse estimates given elsewhere in this report, if pumping is selected for operation.

The following estimate is based on using the draft tube gate guides for the trashracks. A trashrack in three sections would be provided for each opening. The racks would be stored in an enlarged slot over each opening and would be placed in the draft tube openings each time the units are pumping.

	Quantity	Unit	Unit price	Amount
Excavation	440,000	Cubic yard	$1.90	$836,000
Concrete, lowering main powerhouse	45,000	do	$49	2,205,000
Concrete, extend powerhouse to provide rack slots.	27,000	do	$49	1,323,000
Trashracks	100	Each	Lump sum	1,700,000
Draft tube gantry cranes	2		do	120,000
Dogging devices			do	30,000
Grating			do	100,000
Machinery modification (4 percent)				2,987,000
Subtotal				9,301,000
Contingencies				1,395,000
Subtotal				10,696,000
Engineering, design, supervision, and administration.				1,284,000
Total, added 1st cost				11,980,000

Interest during construction is estimated to be $900,000 which added to the construction first cost would give a total added investment cost of $12,880,000.

The yearly added cost of operation, maintenance, and replacements for one 50-unit tidal powerhouse is estimated to be $62,350.

Automatic lifting and lowering devices for trashracks would be investigated during the design stage of the project. Further investigation of riparian damages would also be necessary if reverse pumping maintains a high elevation upper pool and a low elevation lower pool for a period of one to several days, since holding of water levels might affect daily business activities.

SUPPLEMENT TO JULY 1963 REPORT

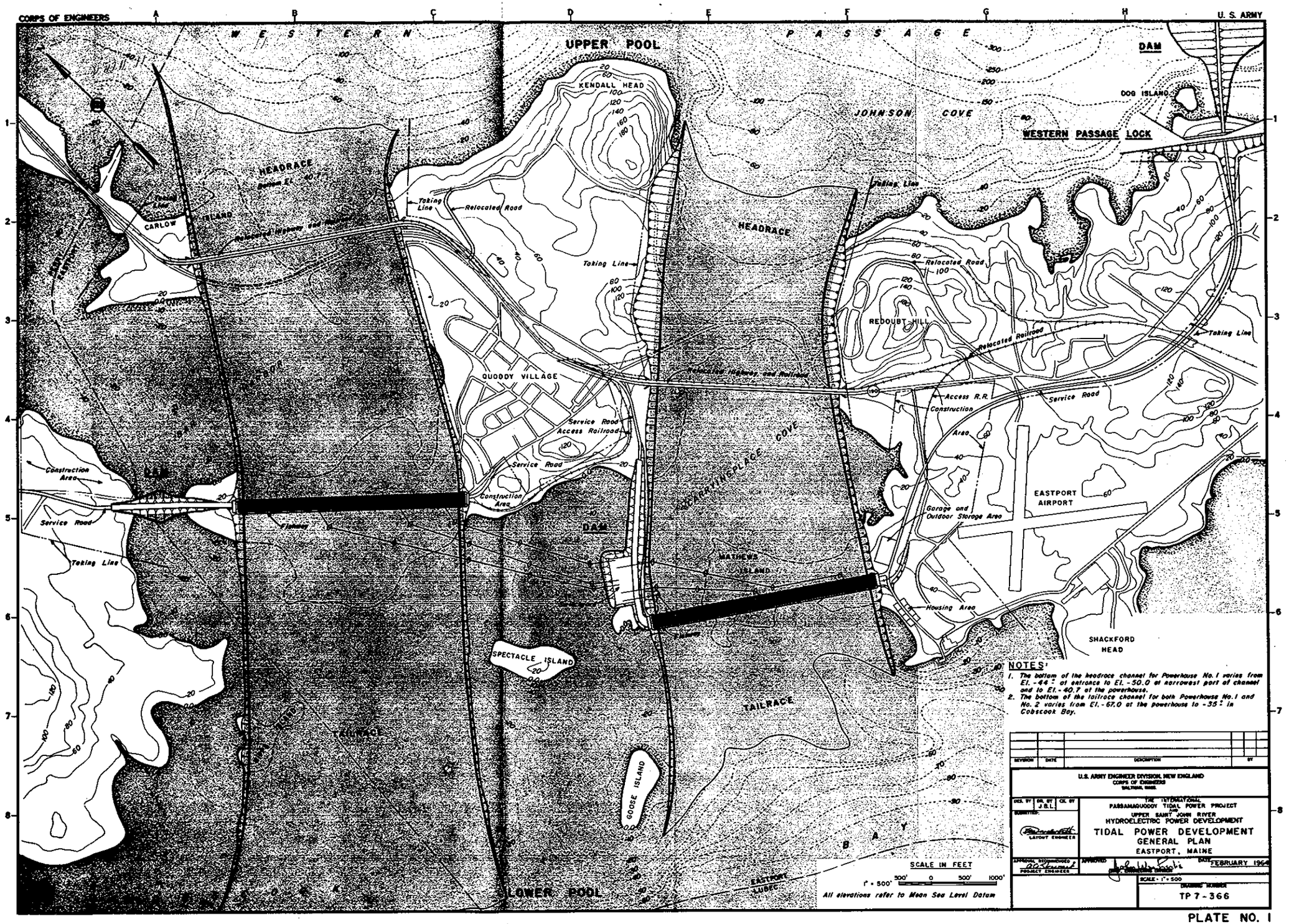
THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER ST. JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

Engineering Report

DRAWINGS

Plate No. *Title*

1. Tidal power development, general plan, Eastport, Maine.
2. Tidal power development, powerhouse, general plan, typical main unit bay.
3. Tidal power development, powerhouse general arrangement.
4. Tidal power development, powerhouse No. 2, plan and record of explorations.
5. Dickey and Lincoln School, reservoir map.
6. Dickey development, general plan.
7. Dickey development, embankment-spillway-intake, profile and sections.
8. Dickey development, powerhouse-dam-spillway, plan and sections.
9. Lincoln School development, powerhouse-dam-spillway, plan and sections.
10. Dickey and Lincoln School, hydrology.
11. Dickey development, plan of explorations.
12. Dickey development, Dickey Dam-Falls Brook dike, geologic sections.
13. Dickey development, upper damsite, geologic sections.
14. Dickey development, record of foundation explorations.



NOTES:

1. The bottom of the headrace channel for Powerhouse No. 1 varies from El. -44 ± at entrance to El. -50.0 at narrowest part of channel and to El. -40.7 at the powerhouse.
2. The bottom of the tailrace channel for both Powerhouse No. 1 and No. 2 varies from El. -67.0 at the powerhouse to -35 ± in Cobscook Bay.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY J.B.L. | CK. BY

SUBMITTED: LAYOUT ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT
UPPER SAINT JOHN RIVER
HYDROELECTRIC POWER DEVELOPMENT

TIDAL POWER DEVELOPMENT
GENERAL PLAN
EASTPORT, MAINE

APPROVED: PROJECT ENGINEER

APPROVED: DATE FEBRUARY 1964

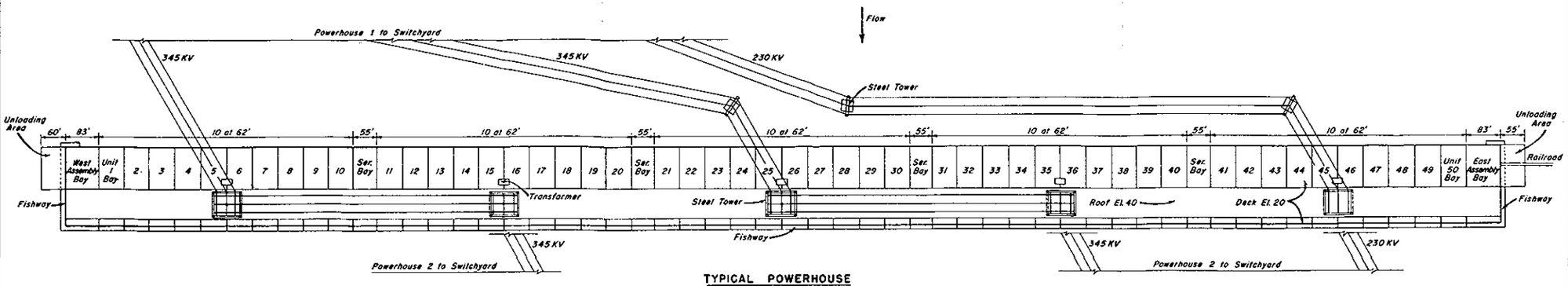
SCALE: 1" = 500

DRAWING NUMBER TP 7-366

PLATE NO. 1

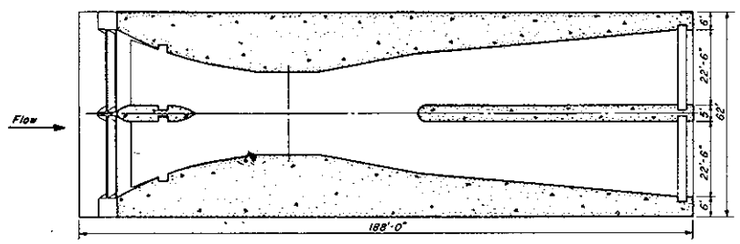
36-941 O - 64 (Face p. 84) No. 1

CORPS OF ENGINEERS — U. S. ARMY

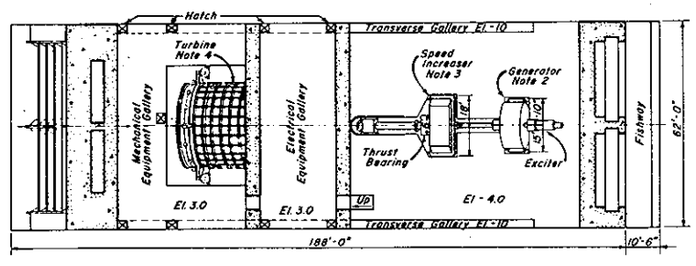


TYPICAL POWERHOUSE
GENERAL PLAN

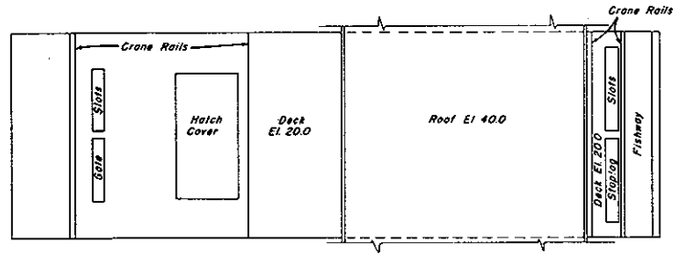
SCALE IN FEET
1" = 100'-0"



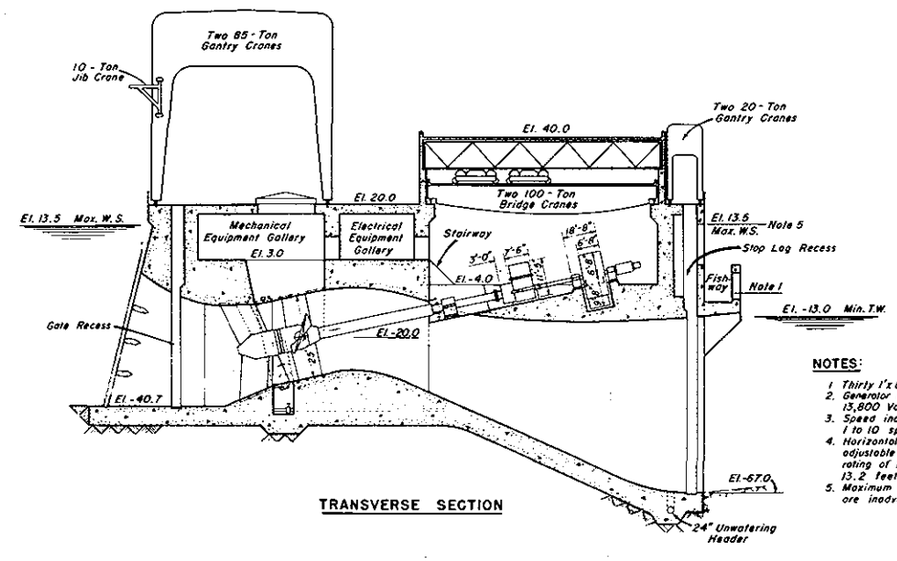
WATER PASSAGE - PLAN



OPERATION AREA - PLAN



DECK - PLAN



TRANSVERSE SECTION

NOTES:

1. Thirty 1'x 8' fishway openings for each powerhouse.
2. Generator rated 11,111 KVA, 0.9 power factor, 3-phase, 13,800 Volts and 450 R.P.M.
3. Speed increaser with integral thrust bearing and having a 1 to 10 speed ratio.
4. Horizontal tube turbine with adjustable blade runner, adjustable wicket gates, stationary stay vanes and having a rating of 14,000 horsepower, 45 R.P.M. at a head of 13.2 feet.
5. Maximum water surface in low pool if emptying gates are inadvertently left open.

TYPICAL MAIN UNIT BAY

SCALE IN FEET
1/16" = 1'-0"

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY JL-MS | CK. BY

SUBMITTED: A.C. Gatin, LAYOUT ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

TIDAL POWER DEVELOPMENT
POWERHOUSE
GENERAL PLAN
TYPICAL MAIN UNIT BAY

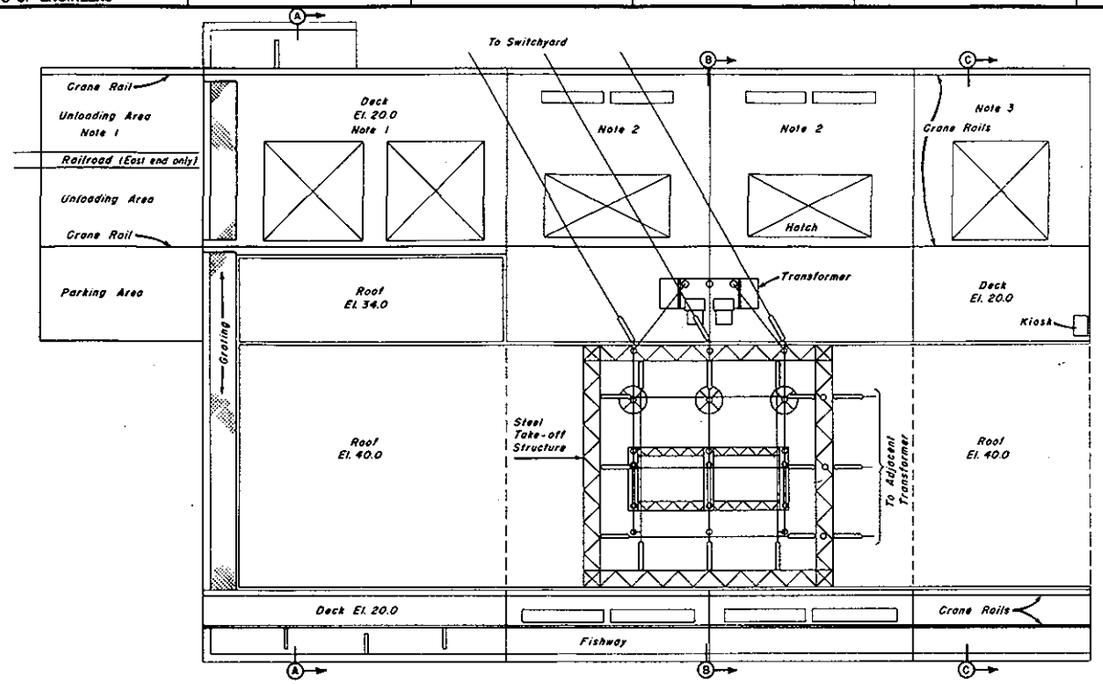
APPROVAL RECOMMENDED: PROJECT ENGINEER
APPROVED: CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964

SCALE: AS SHOWN
DRAWING NUMBER TG7-367

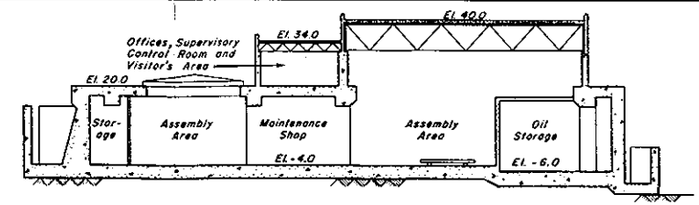
36-941 O - 64 (Face p. 84) No. 2

PLATE NO. 2

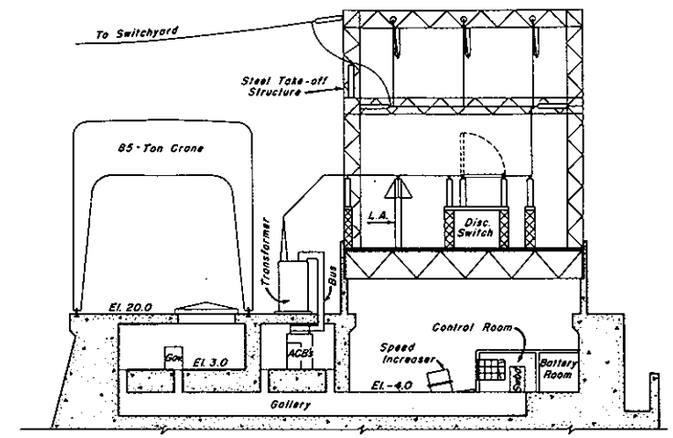
CORPS OF ENGINEERS — U. S. ARMY



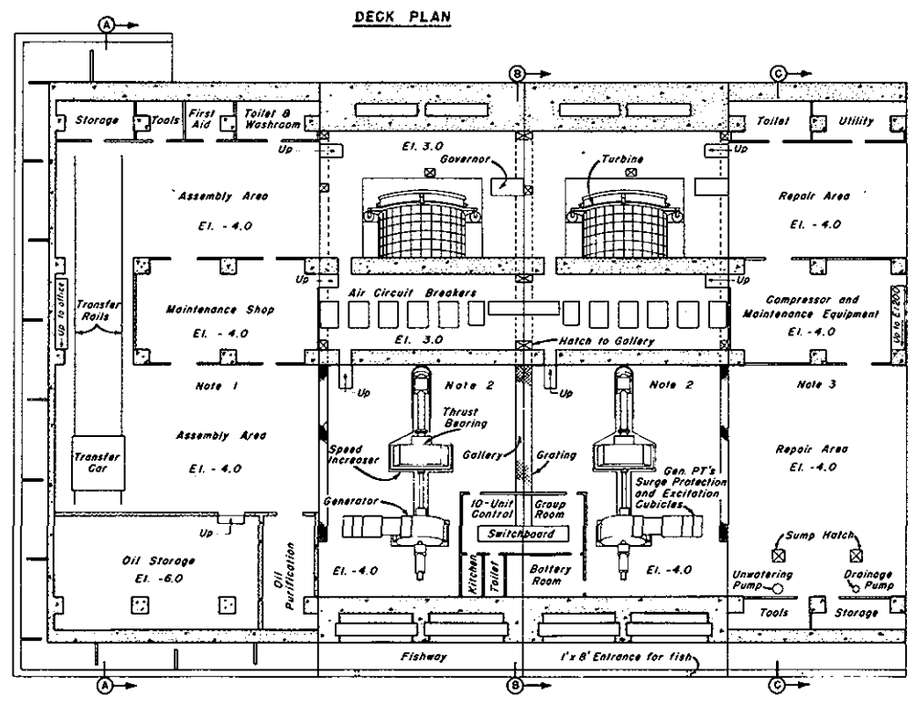
DECK PLAN



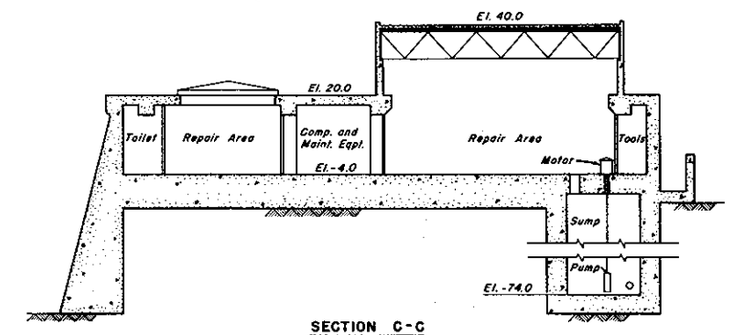
SECTION A-A



SECTION B-B



OPERATING FLOOR PLAN



SECTION C-C

SCALE IN FEET
1/16" = 1'-0" 8' 0 8' 16' 24' 32' 40'

NOTES:

1. Typical assembly bay except opposite hand for east end.
2. Typical main unit bay except that take-off structure, transformer, oil circuit breakers and 10-unit group control area occur only at middle of each of 5 groups of 10-units.
3. Typical service bay that occurs between each group of 10-units.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY MS-JL | CK. BY
SUBMITTED: LAYOUT ENGINEER

THE INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT
AND
UPPER SAINT JOHN RIVER
HYDROELECTRIC POWER DEVELOPMENT

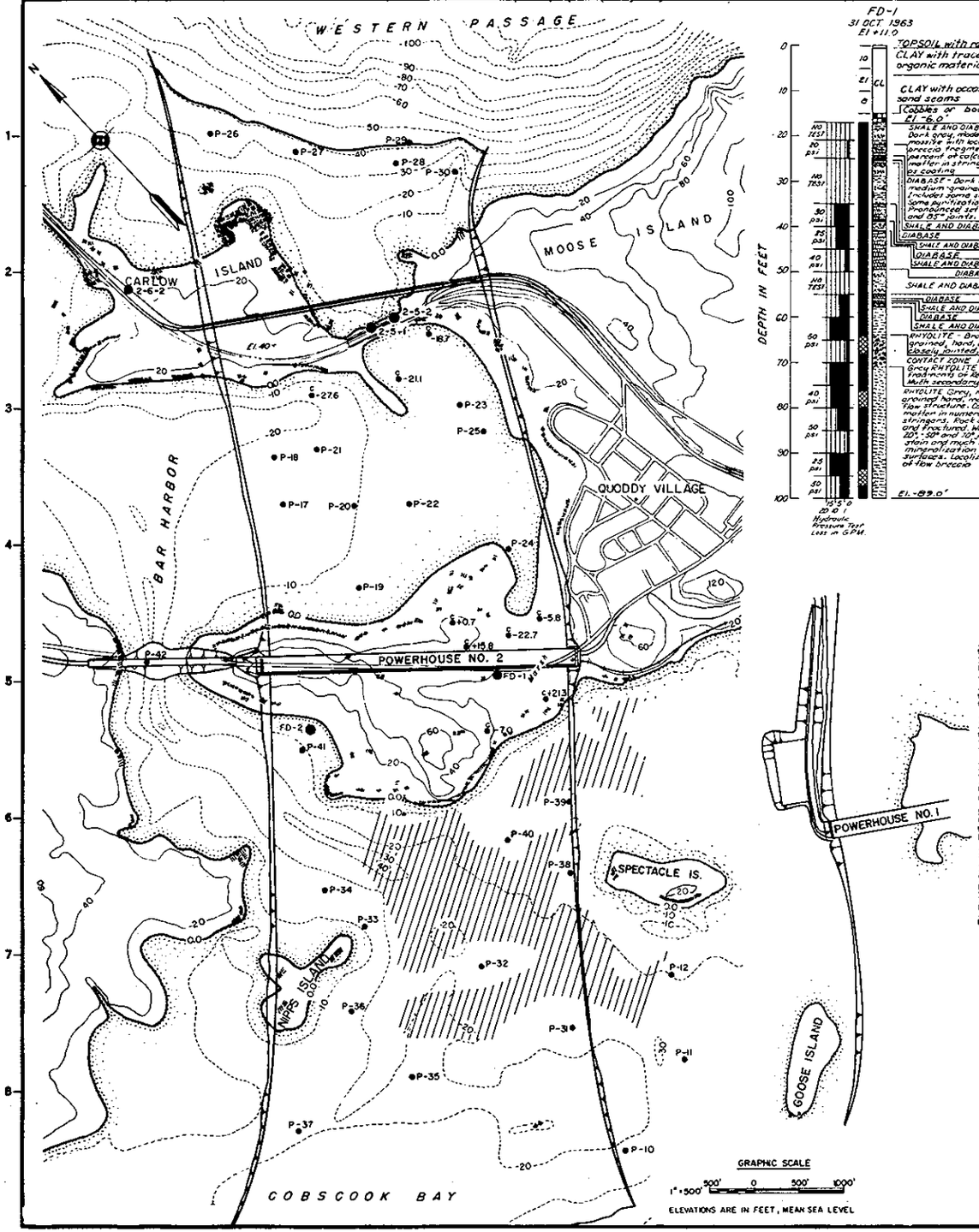
TIDAL POWER DEVELOPMENT
POWERHOUSE
GENERAL ARRANGEMENT

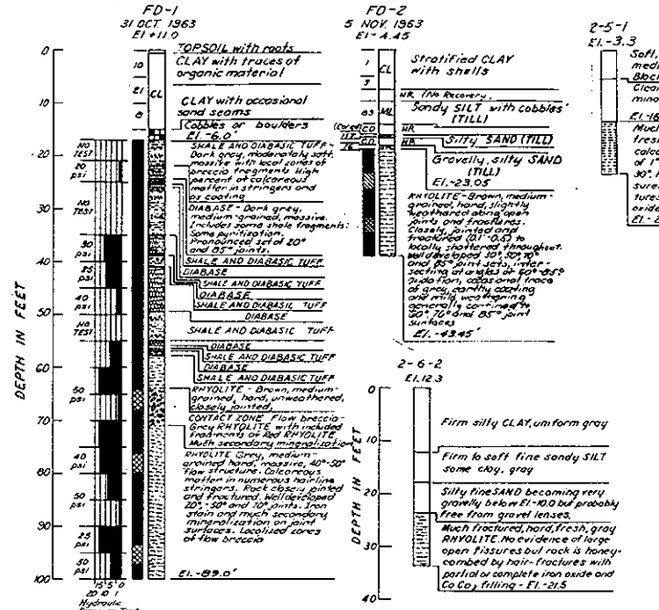
APPROVAL RECOMMENDED: PROJECT ENGINEER
APPROVED: CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964
SCALE 1/16" = 1'-0"
DRAWING NUMBER TG7-368

36-941 O - 64 (Face p. 84) No. 3

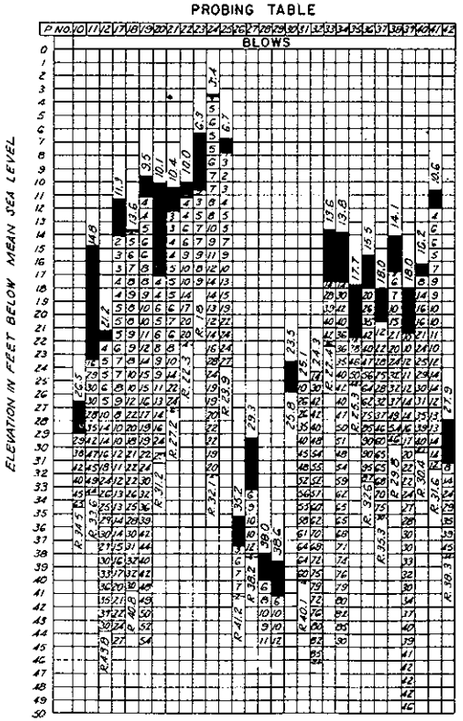
PLATE NO. 3

CORPS OF ENGINEERS — U. S. ARMY





PROBING TABLE



PROBING NOTES

Probings were made by driving 1 5/8" O.D. drill rods using a 343 lb. drop weight with a free fall of about one foot.

Shaded portion of table denotes penetration by weight of rods or weight of rods plus pressing by 2 men.

"R" denotes refusal, 200 blows with no appreciable advance.

LEGEND FOR PLAN

- FD — Foundation Test Boring - 1963
- 2-5 — Test Boring - 1935
- -18.7 — Test Boring, Cooper Study - 1928. Elevation indicates bedrock.
- P — Machine Probing - 1963
- Hatched areas denote bedrock surface below El. -40.0' MSL as determined by Sonic Method in 1951.
- Denotes outcropping of bedrock, principally the Eastport Formation of Silurian age. Volcanics predominate as rhyolite, diabase and tuffs. Sedimentaries are shale limestone and conglomerate.

NOTES AND LEGEND FOR FD LOGS

Figures on left side of column are blow counts per foot of penetration considered representative for sample drive using a drop weight of 300 lbs. falling freely 18 inches to drive a 5 foot standard sample spoon equipped with beveled and sharpened drive shoe.

Letters in column are group symbols according to Unified Soil Classification System.

- Core Recovery 50-75 %
- Core Recovery 75-90%
- Core Recovery 90-100%

NOTES

Hydrography from surveys by Cooper made in 1928

Topography from surveys by U.S.C.&G.S. made in 1949

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY C.G.H. | DR. BY P.D.B. | CK. BY R.C.G.

SUBMITTED: CHIEF, GEOLOGY SECTION

APPROVAL RECOMMENDED: CHIEF, PWR. & MAT'LS BRANCH

APPROVAL RECOMMENDED: PROJECT ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

TIDAL POWER DEVELOPMENT

POWERHOUSE NO. 2

PLAN AND RECORD OF EXPLORATIONS

APPROVED: CHIEF, ENGINEERING DIVISION

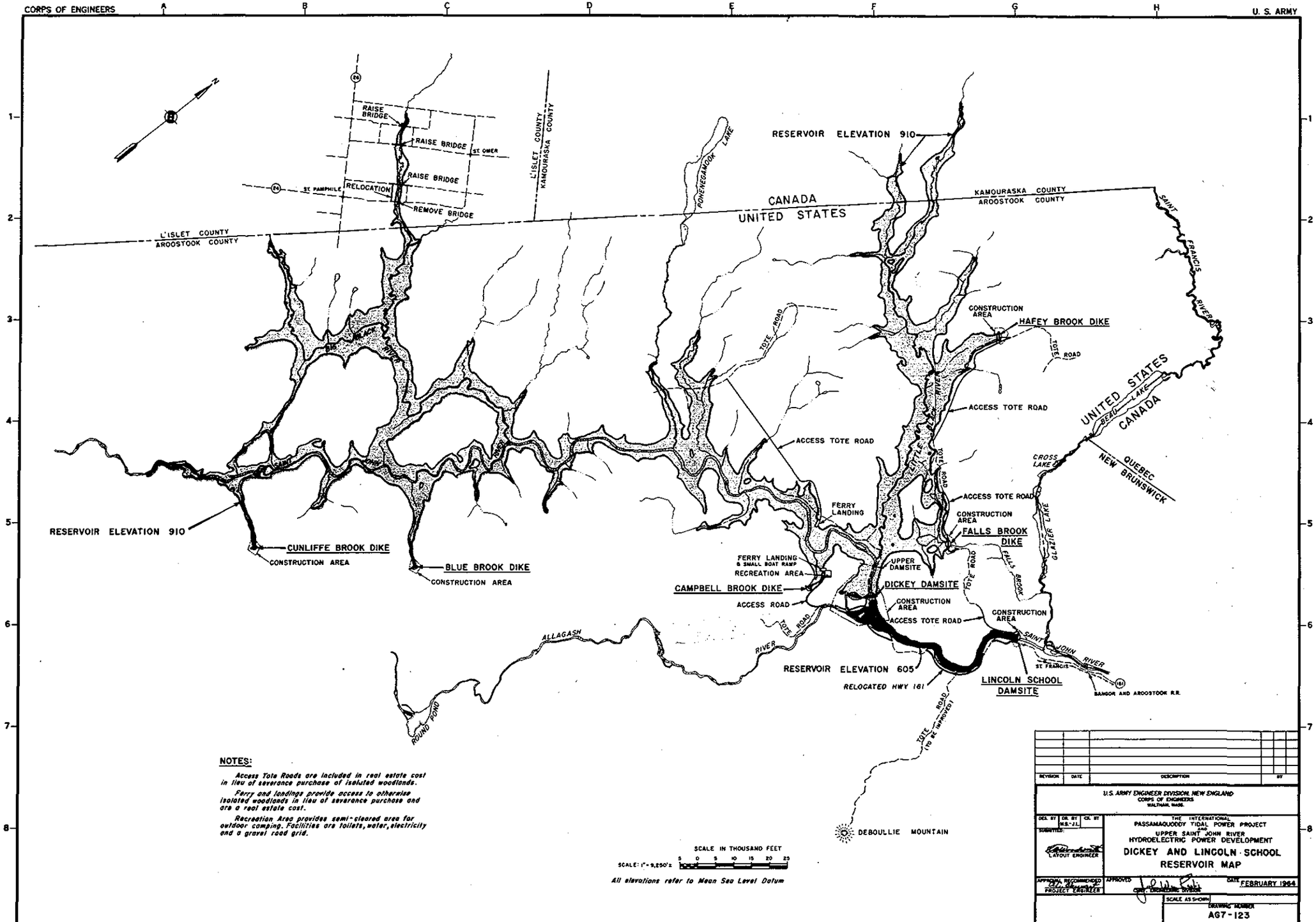
DATE FEBRUARY 1964

SCALE 1" = 500'

DRAWING NUMBER TG7-369

PLATE NO. 4

36-941 O - 64 (Face p. 84) No. 4



NOTES:

Access Tote Roads are included in real estate cost in lieu of severance purchase of isolated woodlands.

Ferry and landings provide access to otherwise isolated woodlands in lieu of severance purchase and are a real estate cost.

Recreation Area provides semi-cleared area for outdoor camping. Facilities are toilets, water, electricity and a gravel road grid.

PLATE NO. 5

36-941 O - 64 (Face p. 84) No. 5

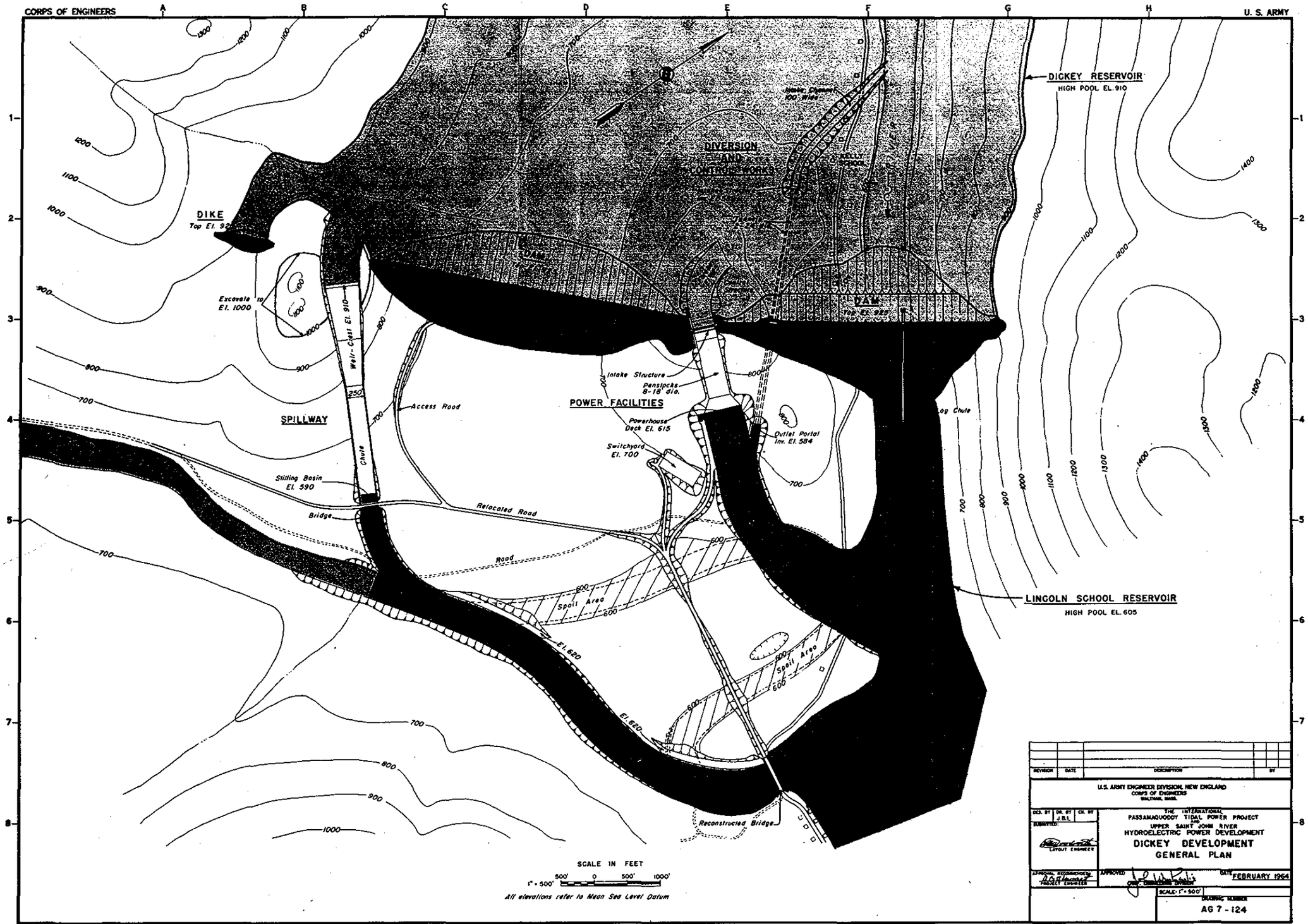
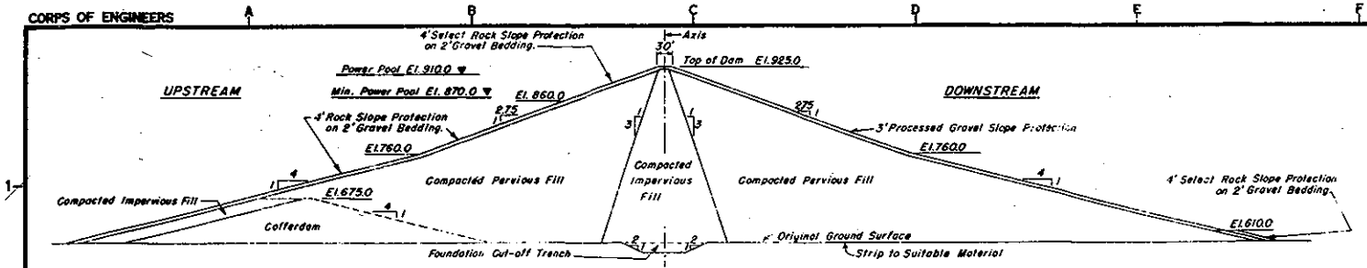


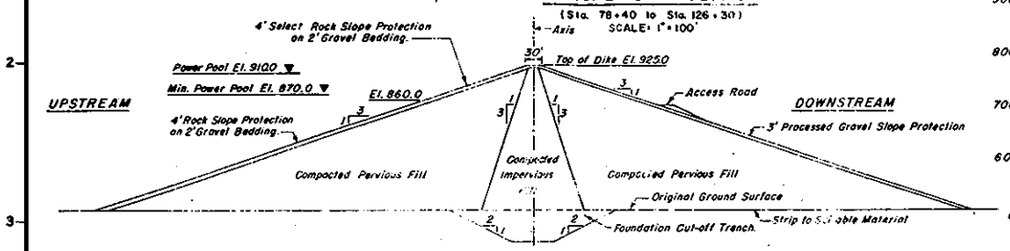
PLATE NO. 6

36-941 O -64 (Face p. 84) No. 6

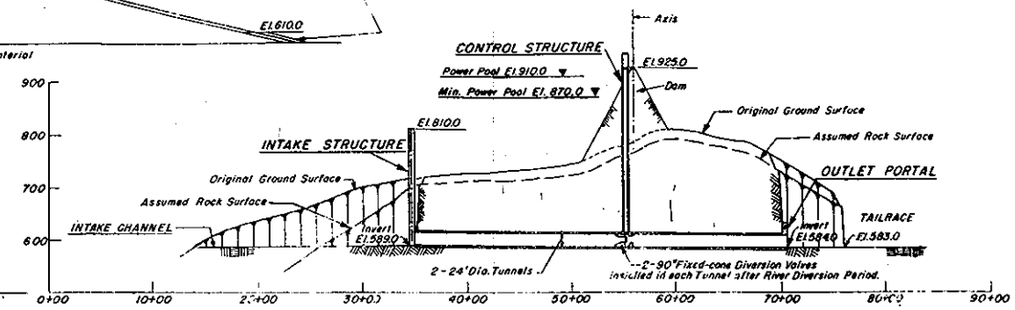
CORPS OF ENGINEERS U. S. ARMY



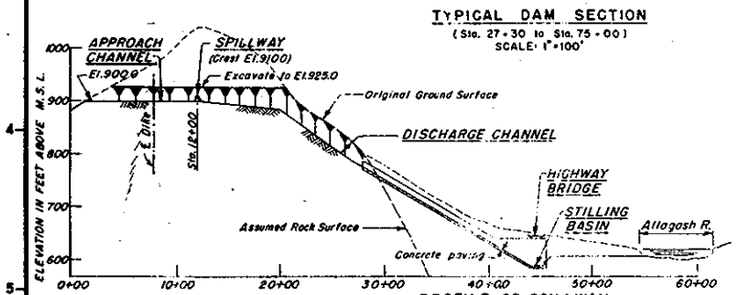
TYPICAL DAM SECTION
(Sta. 78+40 to Sta. 126+30)
SCALE: 1" = 100'



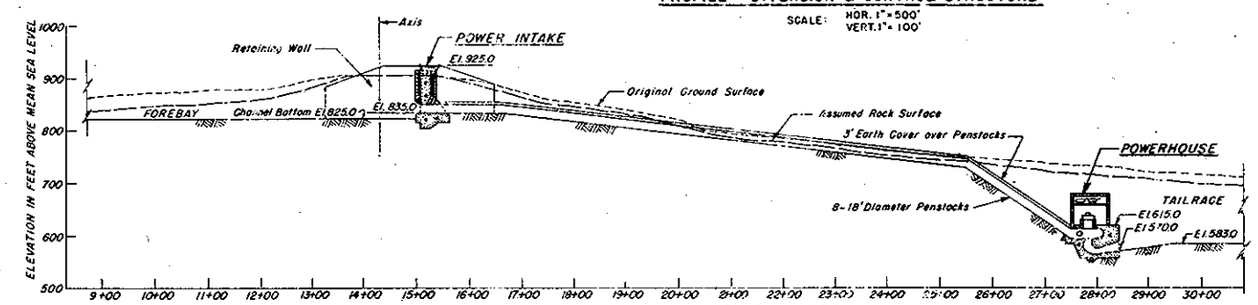
TYPICAL DAM SECTION
(Sta. 27+30 to Sta. 75+00)
SCALE: 1" = 100'



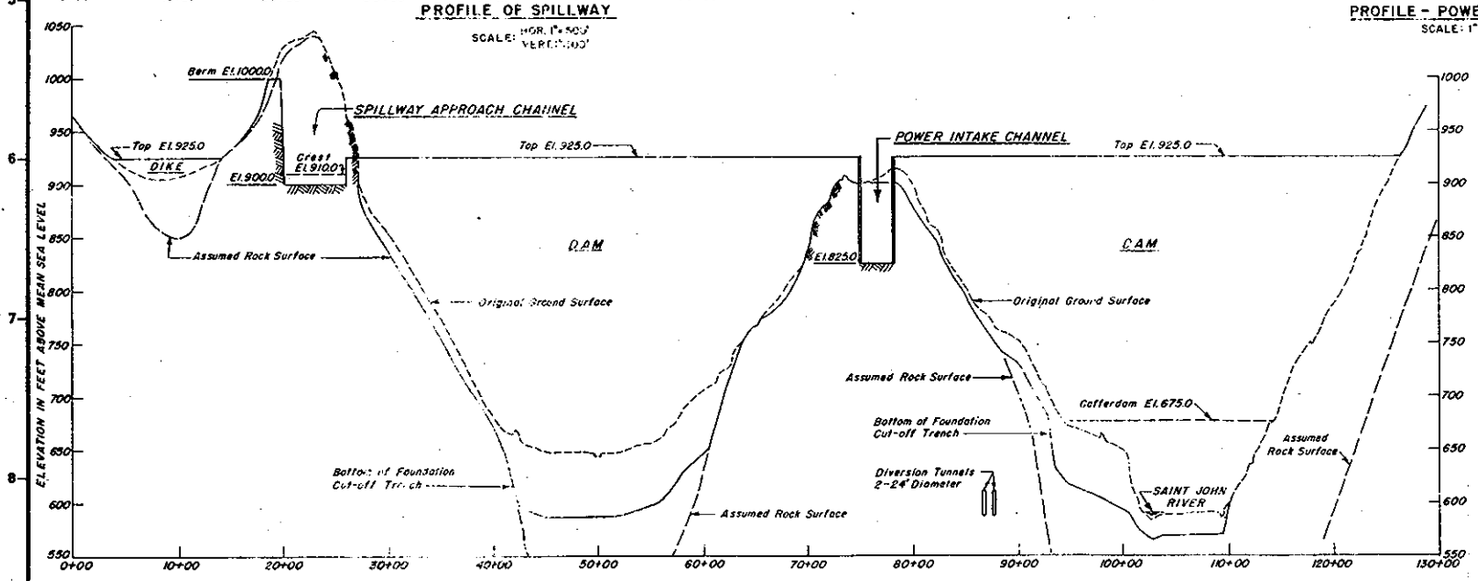
PROFILE — DIVERSION & CONTROL STRUCTURE
SCALE: HOR. 1" = 500'
VERT. 1" = 100'



PROFILE OF SPILLWAY
SCALE: HOR. 1" = 500'
VERT. 1" = 100'



PROFILE - POWER FACILITIES
SCALE: 1" = 100'



PROFILE ALONG AXIS
SCALE: HOR. 1" = 500'
VERT. 1" = 50'

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY C.A. | CK. BY

SUBMITTED: LAYOUT ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

DICKEY DEVELOPMENT

EMBANKMENT-SPILLWAY-INTAKE

PROFILE AND SECTIONS

APPROVAL RECOMMENDED: PROJECT ENGINEER

APPROVED: CHIEF, ENGINEERING DIVISION

DATE: FEBRUARY 1964

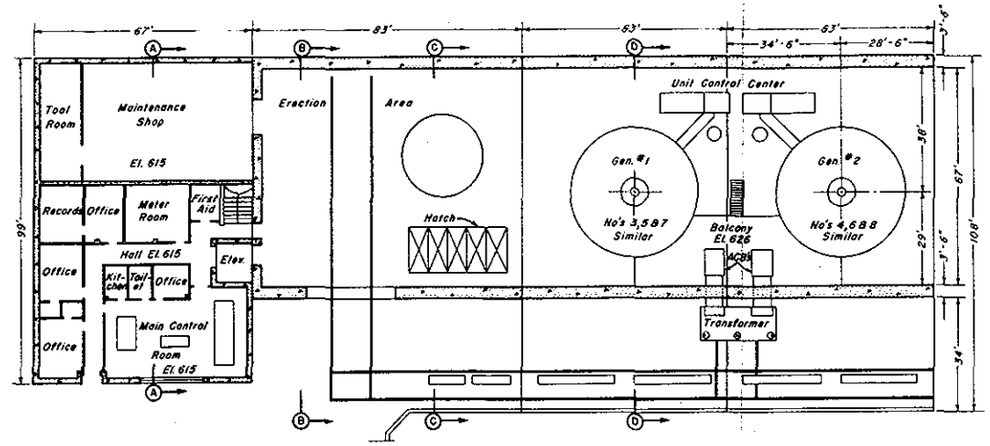
SCALE AS SHOWN

DRAWING NUMBER AG 7-125

PLATE NO. 7

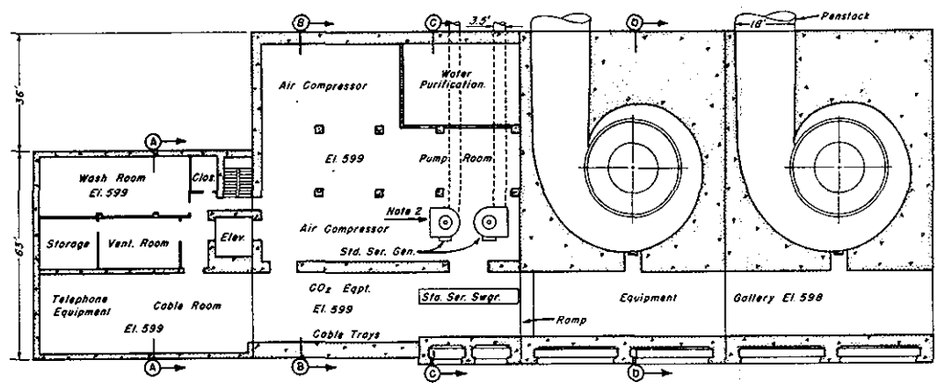
36-941 O - 64 (Face p. 84) No. 7

CORPS OF ENGINEERS — U. S. ARMY



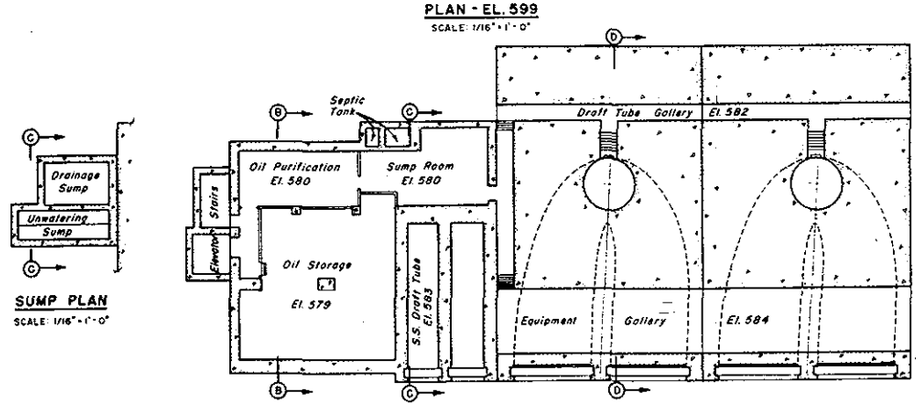
PLAN - EL. 615

SCALE: 1/16" = 1'-0"



PLAN - EL. 599

SCALE: 1/16" = 1'-0"



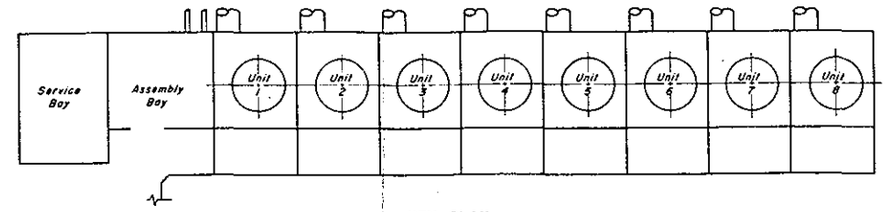
SUMP PLAN

SCALE: 1/16" = 1'-0"

PLAN - EL. 580

SCALE IN FEET

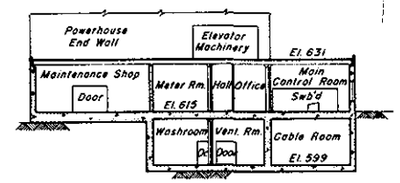
1/16" = 1'-0" 8' 0 8' 16' 24' 32' 40'



KEY PLAN

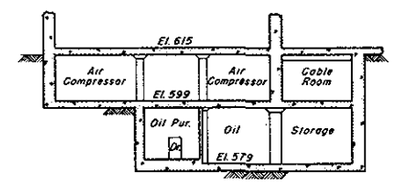
SCALE IN FEET

1" = 40'-0" 40' 0 40' 80'



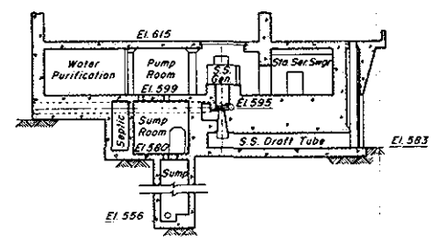
SECTION A-A

SCALE: 1/16" = 1'-0"



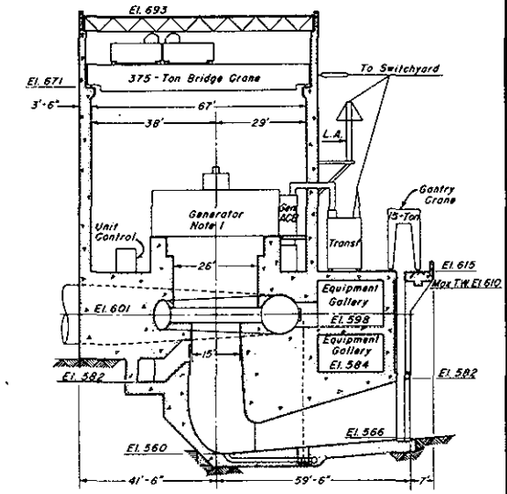
SECTION B-B

SCALE: 1/16" = 1'-0"



SECTION C-C

SCALE: 1/16" = 1'-0"



SECTION D-D

SCALE: 1/16" = 1'-0"

NOTES:

1. Eight main unit generators, each rated at 105,500 KVA, 0.9 power factor, 13,800 volts, 3-phase, 60 cycles and 128.6 r.p.m.
2. Two station service generators, each rated at 1250 KVA, 0.8 power factor, 480 volts, 3-phase, 60 cycles and 720 r.p.m.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY — DR. BY N.S. — CK. BY

SUBMITTED: LAYOUT ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

DICKEY DEVELOPMENT
POWERHOUSE
PLAN AND SECTIONS

APPROVAL RECOMMENDED: PROJECT ENGINEER

APPROVED: CHIEF, ENGINEERING DIVISION

DATE FEBRUARY 1964

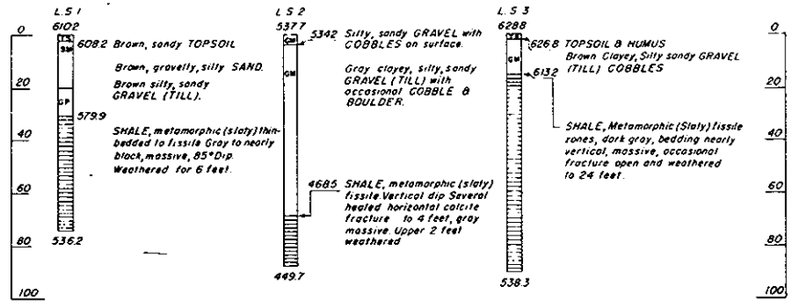
SCALE: AS SHOWN

DRAWING NUMBER AG7-126

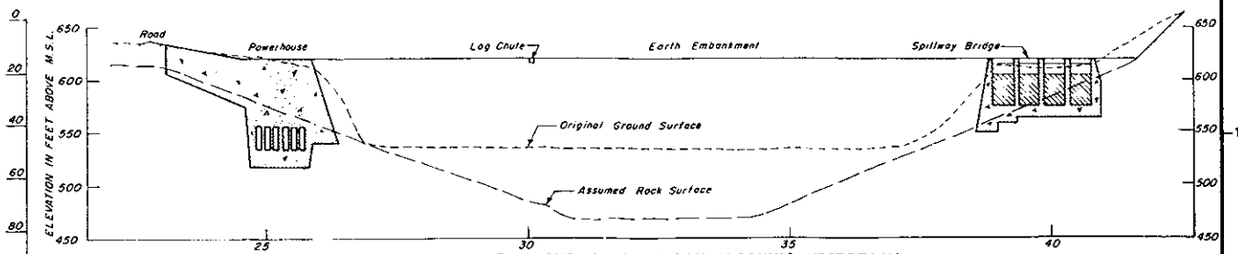
PLATE NO. 8

36-941 O - 64 (Face p. 84) No. 8

CORPS OF ENGINEERS — U. S. ARMY



FOUNDATION EXPLORATIONS



PROFILE ALONG AXIS OF DAM (LOOKING UPSTREAM)

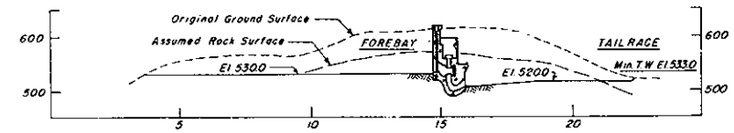
SCALE: VERT. 1"=50' HOR. 1"=100'

NOTES:

Two main unit generators each rated at 18,900 K.V.A., 0.9 power factor, 13,800 volts, 3-phase, 60 cycles and 138.5 r.p.m.

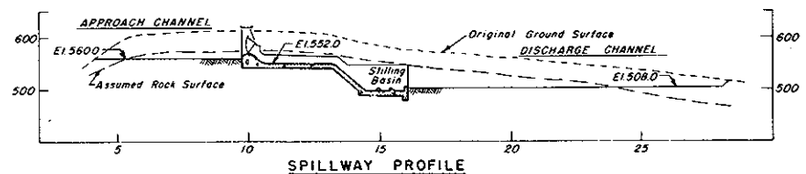
Units are spaced 55 feet on centers and there is a 70 foot service and erection bay.

All elevations refer to Mean Sea Level Datum.



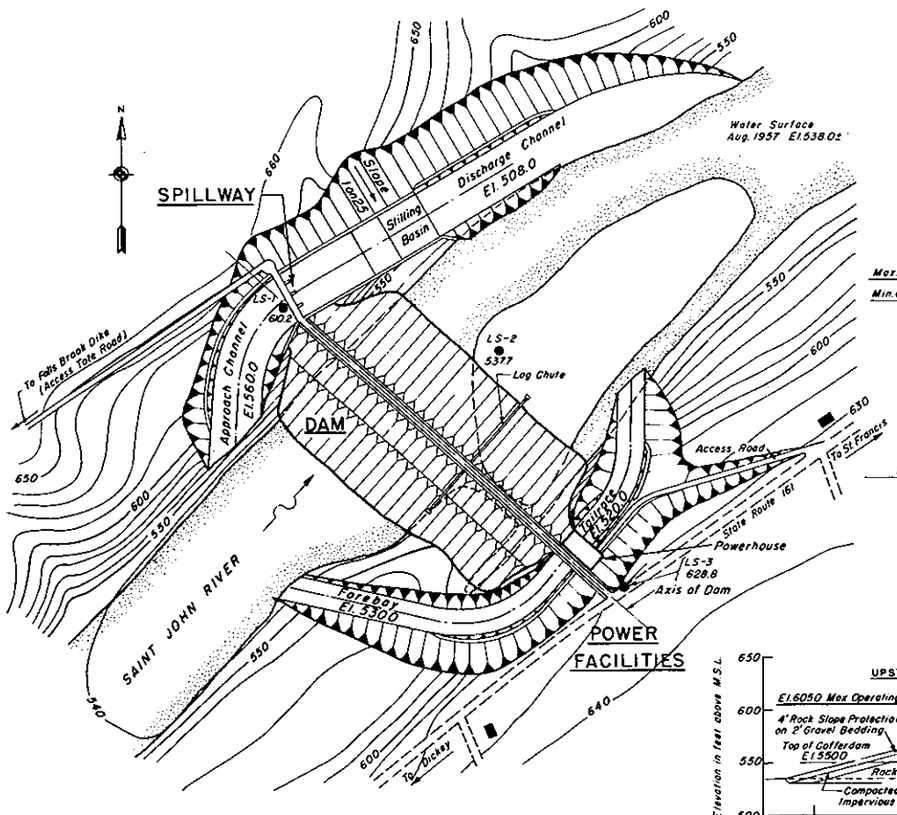
POWER FACILITIES PROFILE

SCALE: VERT 1"=100' HOR. 1"=200'



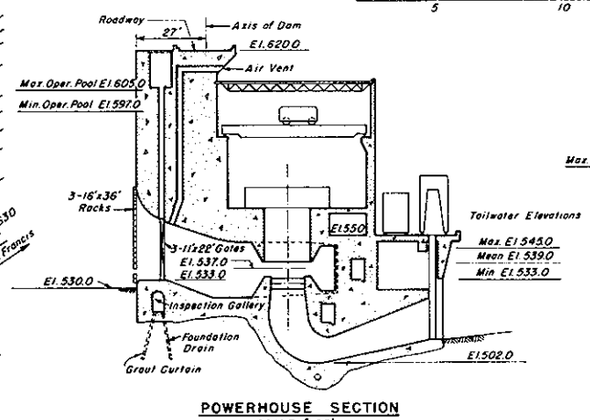
SPILLWAY PROFILE

SCALE: VERT. 1"=100' HOR. 1"=200'



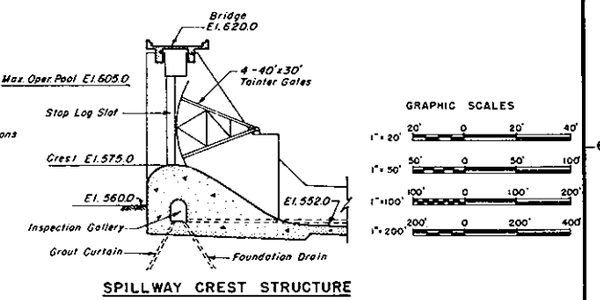
PLAN

SCALE: 1"=200'



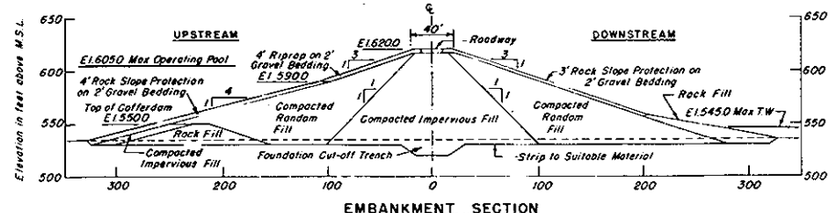
POWERHOUSE SECTION

SCALE: 1"=20'



SPILLWAY CREST STRUCTURE
SECTION THRU TAINTER GATE BAY

SCALE: 1"=20'



EMBANKMENT SECTION

SCALE: 1"=50'

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY — DR. BY — CK. BY — SUBMITTED: — CHIEF DESIGN ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT
UPPER SAINT JOHN RIVER
HYDROELECTRIC POWER DEVELOPMENT
LINCOLN SCHOOL DEVELOPMENT
POWERHOUSE-DAM-SPILLWAY
PLAN AND SECTIONS

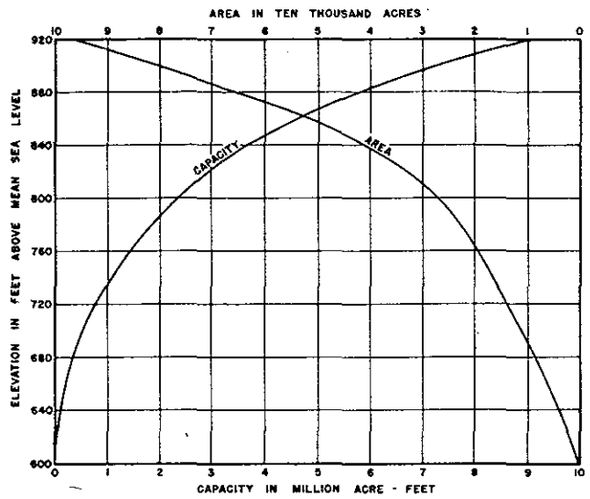
APPROVAL RECOMMENDED: PROJECT ENGINEER — APPROVED: CHIEF, ENGINEERING DIVISION — DATE FEBRUARY 1964

SCALE AS SHOWN

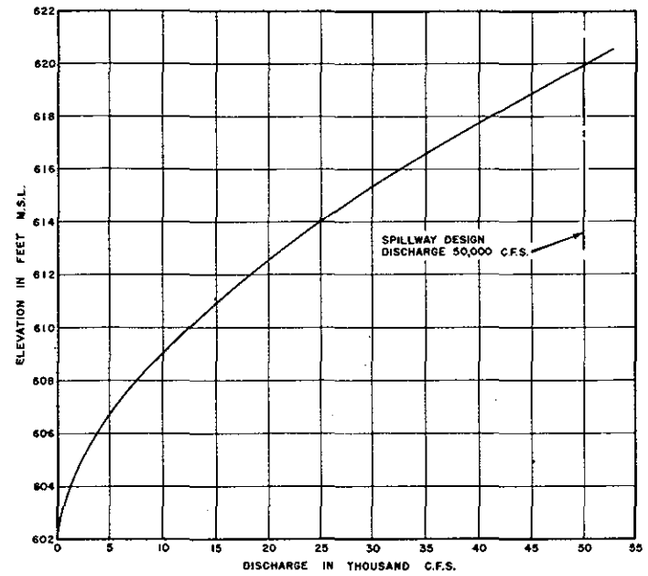
DRAWING NUMBER AG 7-127

36-941 O - 64 (Face p. 84) No. 9

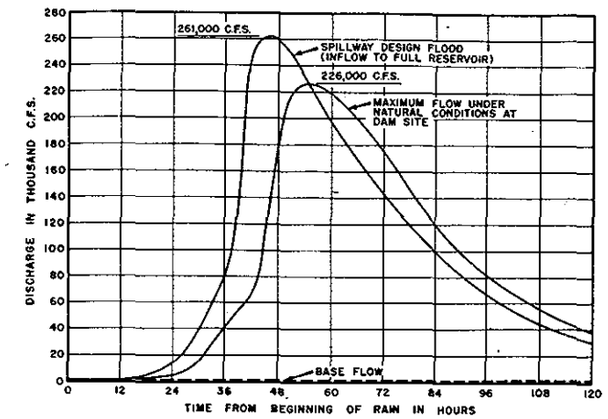
PLATE NO. 9



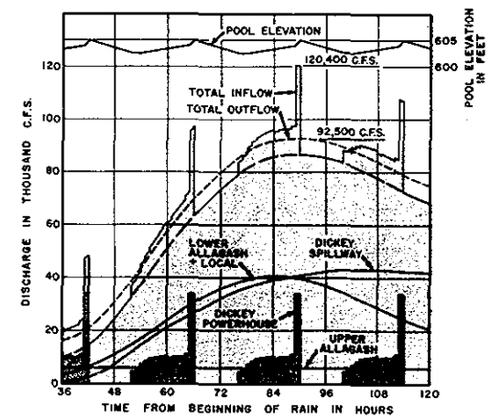
DICKEY RESERVOIR



DICKEY SPILLWAY

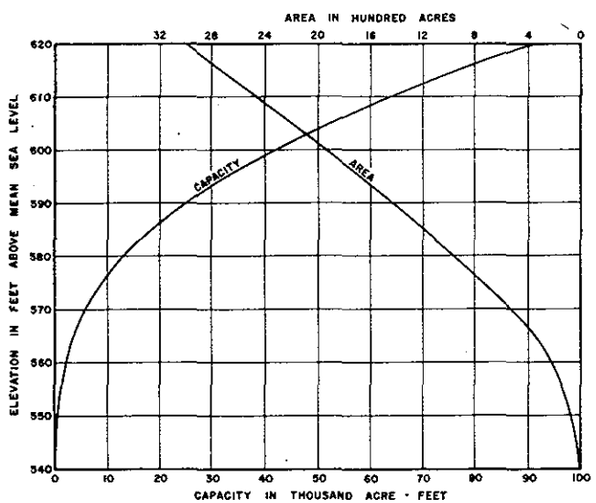


DICKEY RESERVOIR



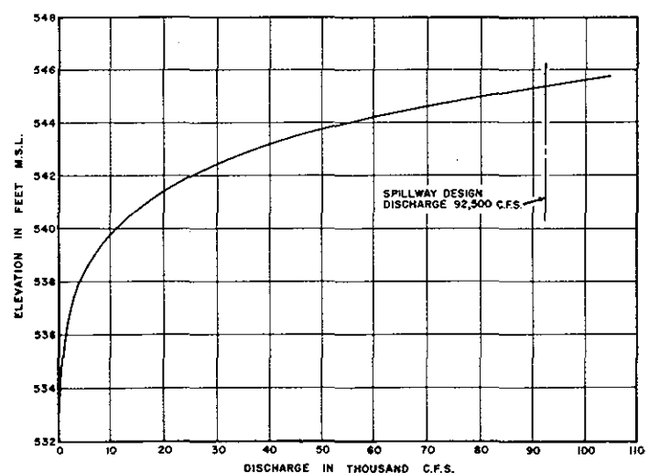
LINCOLN SCHOOL POOL

SPILLWAY DESIGN FLOOD HYDROGRAPHS



LINCOLN SCHOOL POOL

AREA AND CAPACITY CURVES



LINCOLN SCHOOL DAM

TAILWATER RATING CURVES

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY E.A.W. | DR. BY M.S. | CK. BY
SUBMITTED: L. Reid HYDRAULIC ENGINEER

THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT AND UPPER SAINT JOHN RIVER HYDROELECTRIC POWER DEVELOPMENT

DICKEY AND LINCOLN SCHOOL
HYDROLOGY

APPROVED AND RECOMMENDED: PROJECT ENGINEER
APPROVED: CHIEF, ENGINEERING DIVISION
DATE FEBRUARY 1964
SCALE: AS SHOWN
DRAWING NUMBER AG7-128

PLATE NO. 10

36-941 O - 64 (Face p. 84) No. 10

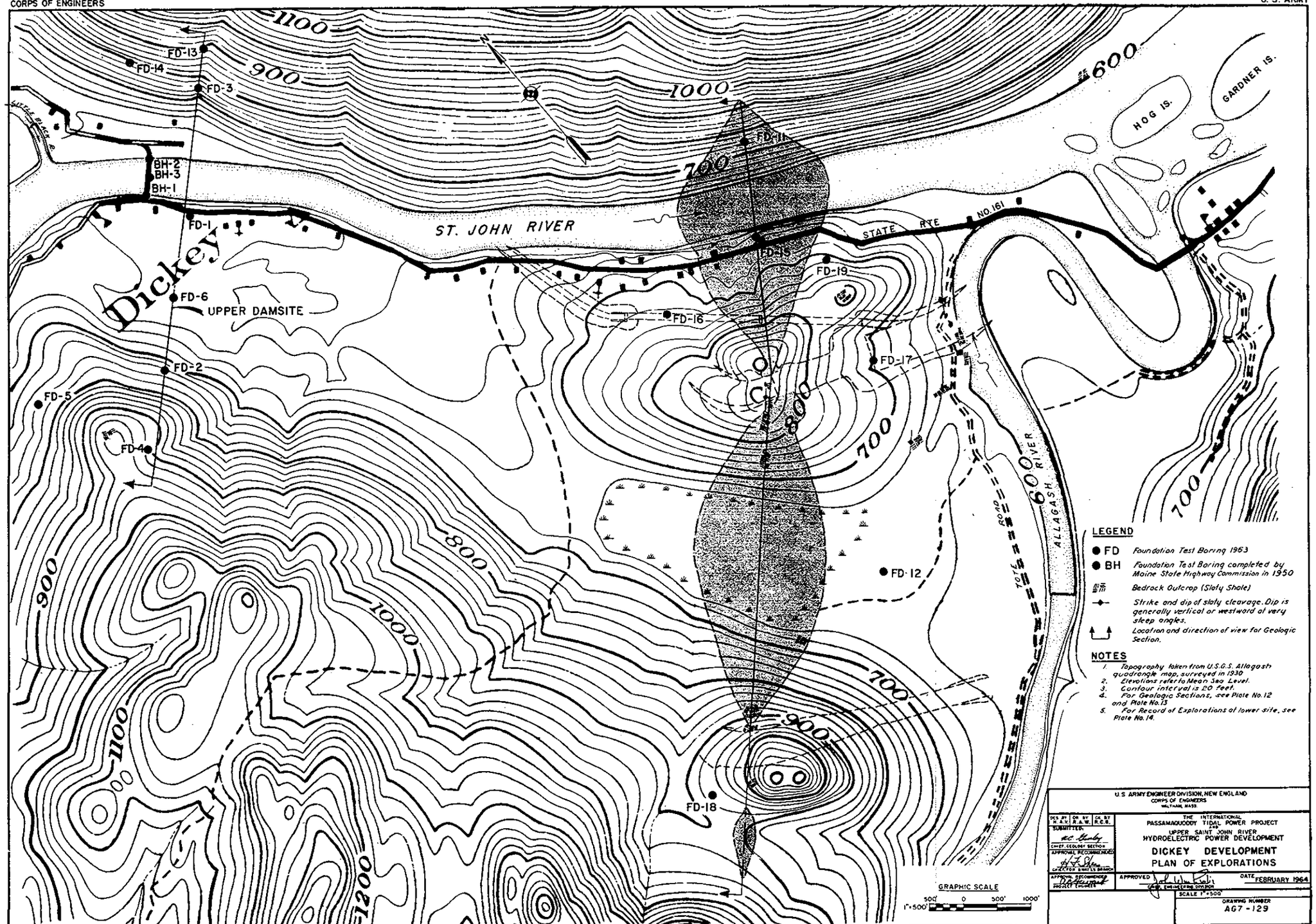
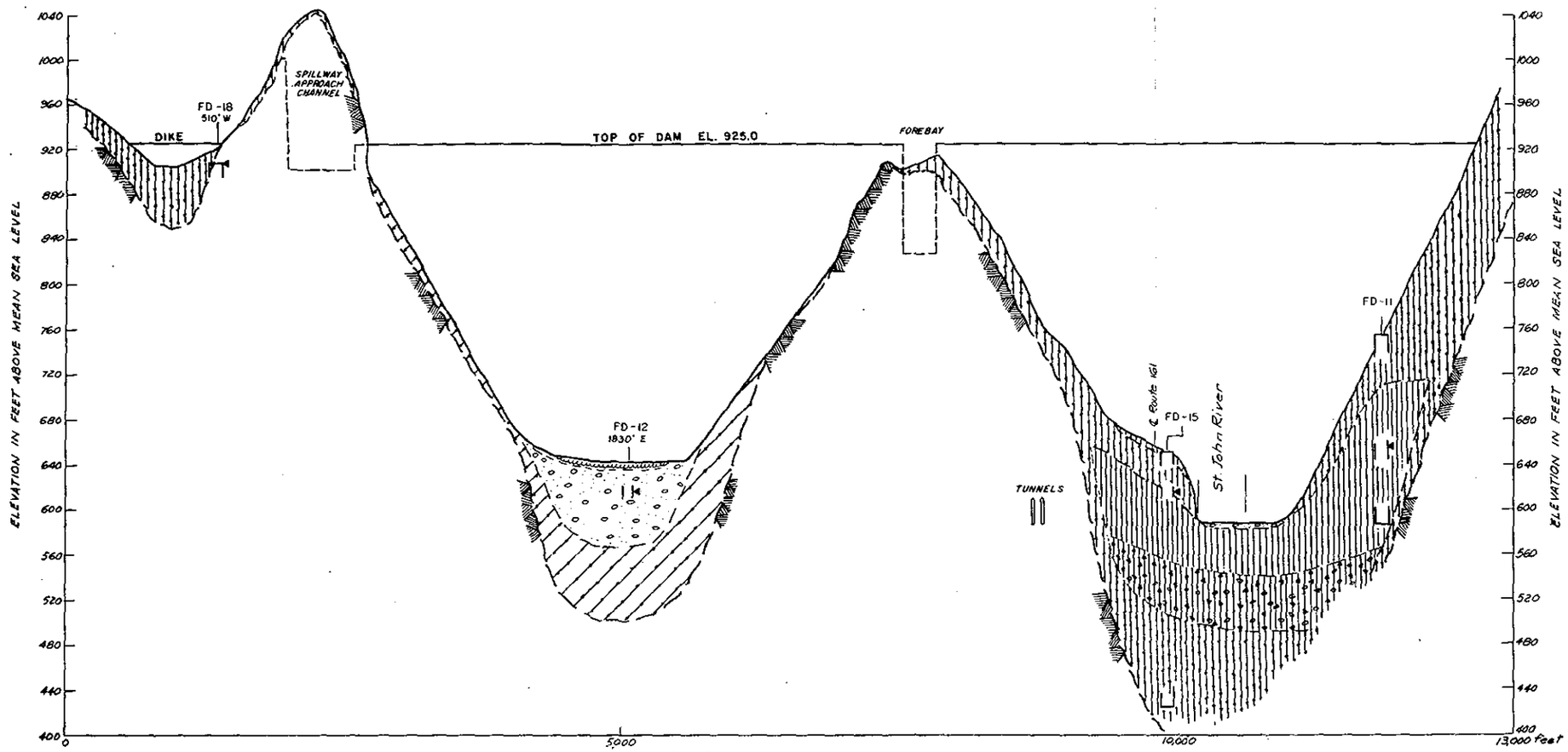


PLATE NO. 11

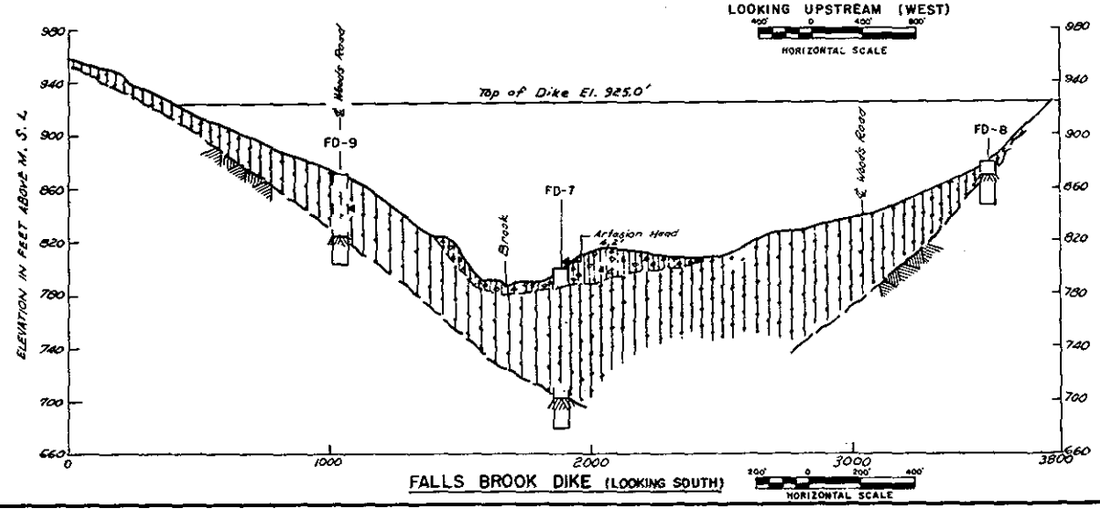
36-941 O - 64 (Face p. 84) No. 11



DICKEY DAM

LOOKING UPSTREAM (WEST)

HORIZONTAL SCALE



FALLS BROOK DIKE (LOOKING SOUTH)

HORIZONTAL SCALE

LEGEND

- Gravelly, silty SAND (TILL)
  Gravelly, silty, clayey SAND (TILL)
  Silty, sandy Gravel (TILL)
- Gravelly sandy SILT (TILL)
  Gravelly, silty, sandy CLAY (TILL)
  Silty, sandy, gravelly CLAY (TILL)
  Sandy CLAY (TILL)
- Silty SANDS and GRAVELS in part TILL
  Silty gravelly SAND in part TILL
- Silty SANDS and GRAVELS
  Silty gravelly SANDS
- Silty SAND and SILT
  Silty SAND, sandy SILT, clayey SILT
- SILT and CLAY
- PEAT
- Assumed Rock Surface
  Bedrock is dark gray, hard slaty SHALE generally slightly calcareous. Strike generally N 40° to 50° East. Dip vertical to 70° Westward.

NOTES

1. All sections taken along surveyed profiled lines. Locations of sections for Lower and Upper Damsites are shown on Plate No. 11. General location of Falls Brook Dike is shown on Plate No. 5.
2. Elevations refer to Mean Sea Level.
3. FD Foundation Test Boring
4. Symbol denotes level of Subsurface water boring during drilling.
5. Denotes bottom of boring.
6. For Record of Explorations see Plate No. 14

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY N.A.V. | DR. BY L.W.I. | CK. BY R.C.B.

SUBMITTED: CHIEF, GEOLOGY SECTION

APPROVAL RECOMMENDED: CHIEF, FOR & SMT'LS BRANCH

APPROVAL RECOMMENDED: PROJECT ENGINEER

THE INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT
AND
UPPER SAINT JOHN RIVER
HYDROELECTRIC POWER DEVELOPMENT

DICKEY DEVELOPMENT
DICKEY DAM - FALLS BROOK DIKE
GEOLOGIC SECTIONS

APPROVED: CHIEF, ENGINEERING DIVISION

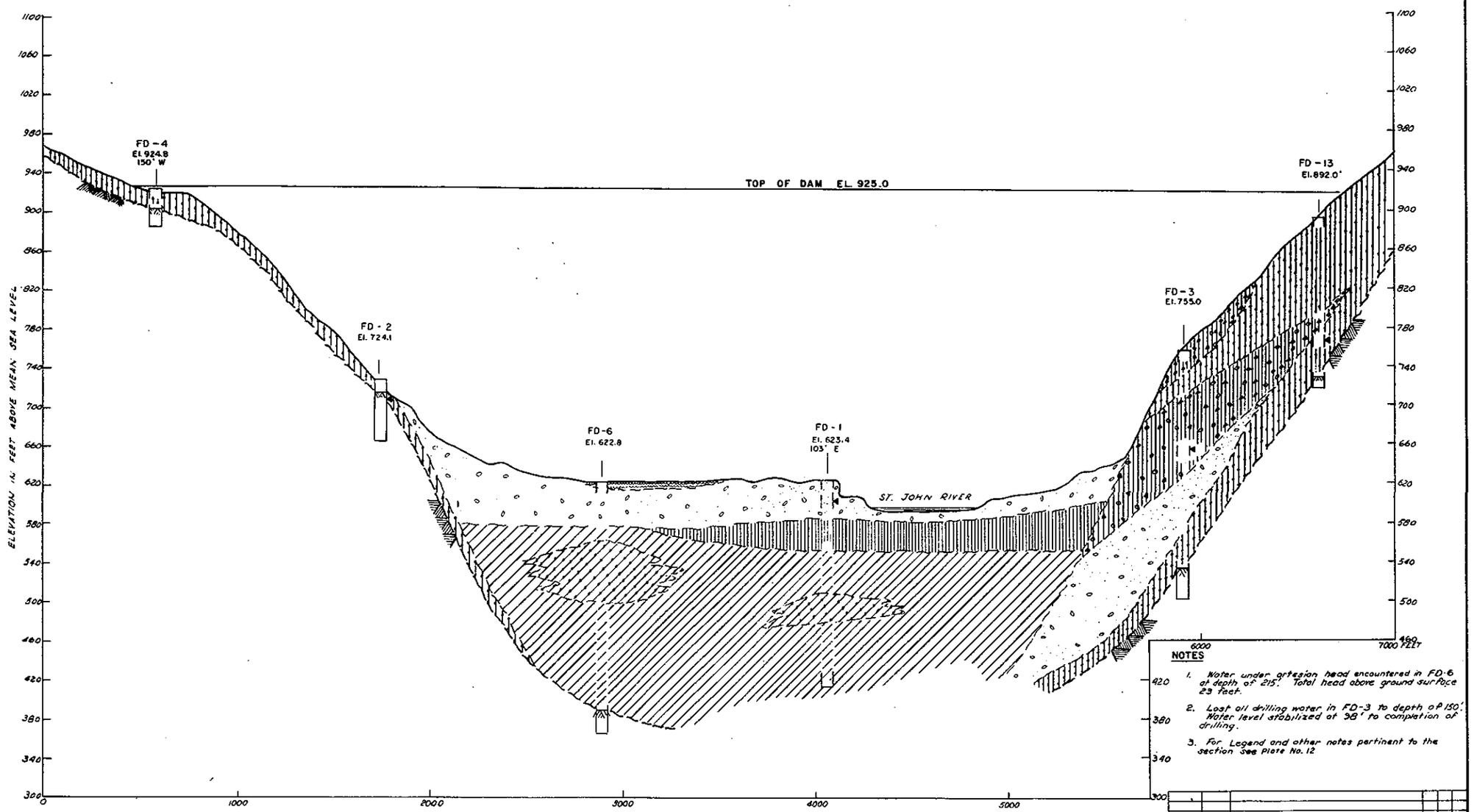
DATE FEBRUARY 1964

SCALE AS SHOWN

DRAWING NUMBER AG7-130

PLATE NO. 12

36-941 O - 64 (Face p. 84) No. 12



NOTES

1. Water under artesian head encountered in FD-6 at depth of 215'. Total head above ground surface 23 feet.
2. Lost all drilling water in FD-3 to depth of 150'. Water level stabilized at 98' to completion of drilling.
3. For Legend and other notes pertinent to the section see Plate No. 12

DAM - UPPER SITE

LOOKING UPSTREAM (WEST)

200' 0 200' 400'

HORIZONTAL SCALE

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY N.D.V. | DR. BY L.H.S. | CK. BY E.C.G.

SUBMITTED: M.C. Gurley, CHIEF, GEOLOGY SECTION

APPROVAL RECOMMENDED: H.J. Shea, CHIEF, FOR. & MAT'LS BRANCH

APPROVAL RECOMMENDED: A.C. Stewart, PROJECT ENGINEER

THE INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT
AND
UPPER SAINT JOHN RIVER
HYDROELECTRIC POWER DEVELOPMENT

DICKEY DEVELOPMENT
UPPER DAMSITE
GEOLOGIC SECTION

APPROVED: [signature], CHIEF, ENGINEERING DIVISION

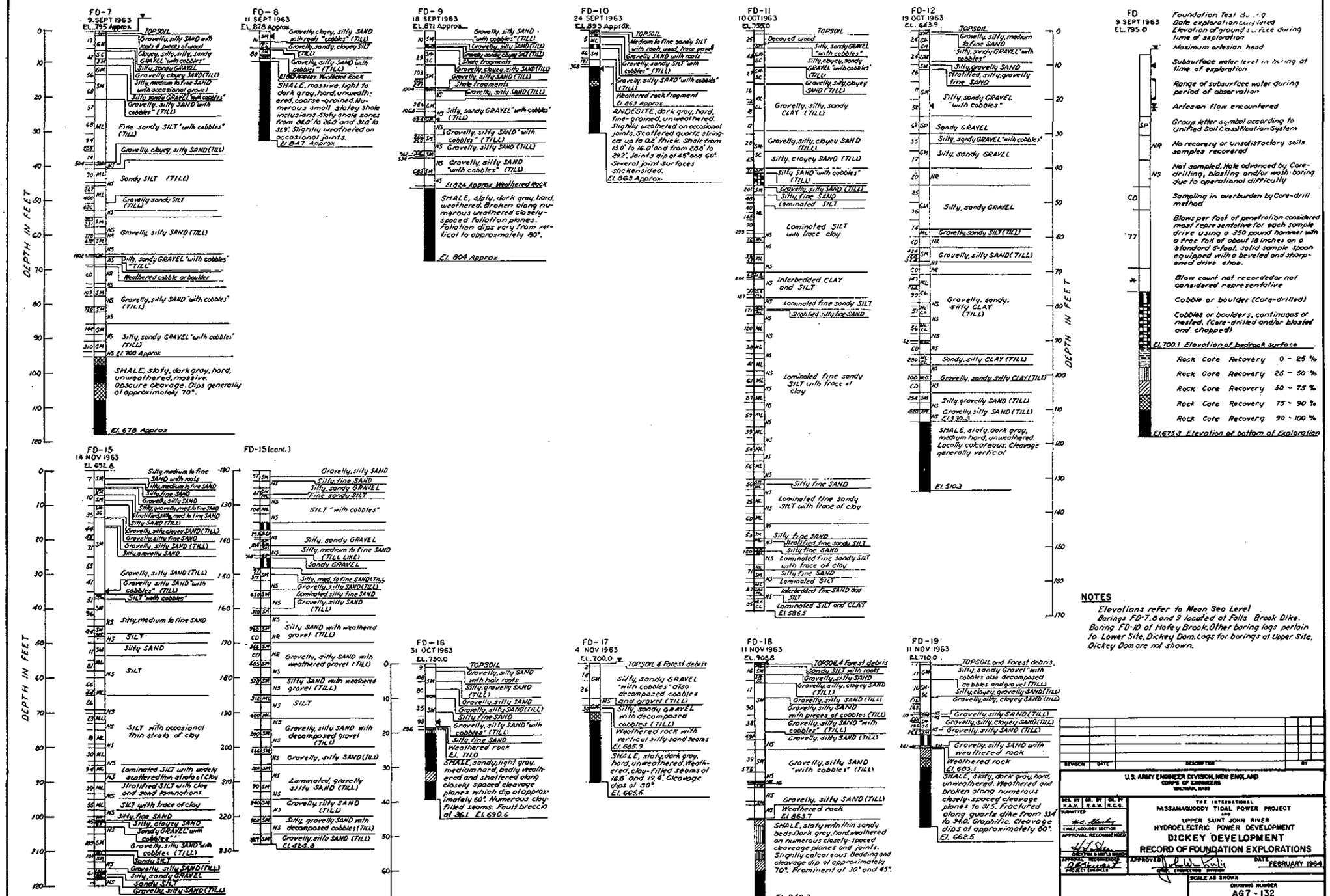
DATE: FEBRUARY 1964

SCALE AS SHOWN

DRAWING NUMBER: AG7-131

PLATE NO. 13

36-941 O - 64 (Face p. 84) No. 13



36-941 O - 64 (Face p. 84) No. 14

PLATE NO. 14

Appendix I. Army-Interior Advisory Board

Name, position, and agency

W. E. Johnson, Chairman, Chief, Engineering Division, Directorate of Civil Works, Office of the Chief of Engineers, Department of the Army, Washington, D.C.

H. C. C. Weinkauff, Chief, Planning Division, Directorate of Civil Works, Office of the Chief of Engineers, Department of the Army, Washington, D.C.

F. L. Thrall, engineer, Multiple Use Coordination Branch, Directorate of Civil Works, Office of the Chief of Engineers, Department of the Army, Washington, D.C.

J. W. Leslie, Chief, Engineering Division, U.S. Army Engineer Division, New England, Waltham, Mass.

M. D. Dubrow, assistant and chief engineering research adviser, Department of the Interior, Washington, D.C.

N. B. Bennett, Assistant Commissioner, Bureau of Reclamation, Department of the Interior, Washington, D.C.

J. E. Guidry, engineer, Office of Assistant Secretary for Water and Power, Department of the Interior, Washington, D.C.

B. P. Belport, Chief Engineer, Bureau of Reclamation, Department of the Interior, Denver, Colo.

F. S. Brown, Chief Engineer, Federal Power Commission, Washington, D.C.

D. A. Portner, Deputy Assistant Administrator for Industrial Analysis, Business and Defense Services Administration, Department of Commerce, Washington, D.C.

T. W. Barry, Resources and Civil Works Division, Bureau of the Budget, Executive Office, Washington, D.C.

M. Kaplan, Council of Economic Advisers, Executive Office, Washington, D.C.

R. Barlow, Office of Science and Technology, Executive Office, Washington, D.C.

A. Giambusso, Atomic Energy Commission, Washington, D.C.

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Appendix II. Estimates of Cost

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TABLE 1.—*Wage rates*

Listed below are the wage rates for key positions that have been used for the cost estimates in this report.

Classification	*Rate per hour*
Crane and shovel operators	$5.10
Oilers	3.65
Carpenters	2.75
Cement masons	4.00
Ironworkers, structural	4.45
Ironworkers, reinforcing	4.15
Truck drivers, heavy equipment	2.25
Laborers	2.00
Dipper dredge operator	3.93
Dipper dredge deck hand	2.74

TABLE 2.—*Construction equipment rates*

The ownership rates of typical pieces of construction equipment used as a basis for the cost estimates are listed below.

Land-based equipment	*Ownership rates per 8-hour day*
Air compressor, diesel, 900 cubic feet per minute	$32
Wagon drill, 4 inches	18
Crane, 30-ton diesel	55
Shovel, 4-cubic yard diesel	172
Bulldozer, 200 horsepower	72
Truck, 35-cubic yard	120
Truck, 15-cubic yard	60

Marine equipment	*Ownership rates per 24-hour day*
Derrick lighter, 25-ton, 2½-cubic yard	$300
Dipper dredge, 15-cubic yard	2,500
Hydraulic dredge, 28-inch	3,000
Dump scow, 1,500-cubic yard	250
Towboat, 450-horsepower	250
Towboat, 900-horsepower	400
Work or fuel boat, 150-horsepower	80

TABLE 3.—*Tidal power project, 300 megawatts*

Item	Quantity	Unit	Unit price	Amount
1. Powerplant No. 1, 300 megawatts:				
a. Cofferdams			Lump sum	$7,250,000
b. Excavation:				
(1) Earth:				
(*a*) By hydraulic dredge	16,000,000	Cubic yard	$0.60	9,600,000
(*b*) In dry	980,000	do	$1	980,000
(2) Rock	5,840,000	do	$1.90	11,096,000
Total, excavation				21,676,000
c. Powerhouse			Lump sum	30,447,000
d. Intake gates			do	1,679,000
e. Draft tube gates			do	1,574,000
f. Turbines and generators			do	48,949,000
g. Accessory electrical equipment			do	5,271,000
h. Miscellaneous powerplant equipment			do	1,593,000
i. Power transformers			do	750,000
Total, powerplant				119,189,000
2. Switchyard				1,780,000
3. Letite Passage filling gates (table 7)				27,472,000
4. Western Passage filling gates (table 8)				35,162,000
5. Head Harbor emptying gates (table 9)				57,627,000
6. Locks (tables 10–13)				18,917,000
7. Dams:				
a. Cost for 500-megawatt powerplant (table 14).			Lump sum	63,664,000
b. Extra cost to borrow, $10,660,000			$1.28	13,645,000
Total, dams				77,309,000
8. Lubec channel (table 15)				634,000
9. Fishways:				
a. Powerplant (table 16 mod.)			Lump sum	616,000
b. Head Harbour emptying gates (table 16).			do	272,000
Total, fishways				888,000
10. Service facilities (table 17 mod.)				1,670,000
11. Relocations:				
a. Relocations in United States:				
(1) Roads and bridges:				
(*a*) Highways				54,000
(*b*) Railroad				212,000
(*c*) Highway and railroad bridge (table 18 mod.)				3,153,000
Roads and bridges				3,419,000
(2) Waterlines				64,000
(3) Telephone and telegraph lines				30,000
(4) Electric lines				55,000
(5) Cemeteries				2,000
(6) U.S. Coast Guard				250,000
(7) International boundary monuments.				10,000
Total, relocations in United States.				3,830,000
b. Relocations in Canada				99,000
Total, relocations				3,929,000
12. Lands and damages (table 19)				1,870,000
Subtotal				346,447,000
Contingencies				49,520,000
Subtotal				395,967,000
Engineering, design supervision, and administration.				43,478,000
Project 1st cost (300 megawatts)				439,445,000

TABLE 4.—*Tidal power project, 500 megawatts*

Item	Quantity	Unit	Unit price	Amount
1. Powerplant, No. 1, 500 megawatts:				
a. Cofferdams			Lump sum	$9,700,000
b. Excavation:				
(1) Earth:				
(*a*) By hydraulic dredge	23,000,000	Cubic yard	$0.60	13,800,000
(*b*) In dry	2,000,000	do	$1	2,000,000
(2) Rock	15,000,000	do	$1.90	28,500,000
Total, excavation				44,300,000
c. Powerhouse:				
(1) Substructure:				
(*a*) Foundation preparation.	74,000	Square yard	$4	296,000
(*b*) Concrete	926,000	Cubic yard	$49	45,374,000
(*c*) Water stops and seals			Lump sum	305,000
(*d*) Miscellaneous blockouts.			do	234,000
(2) Superstructure:				
(*a*) Concrete	9,200	Cubic yard	$90	828,000
(*b*) Steel and ironwork:				
1. Steel for roof			Lump sum	670,000
2. Crane rails	1,483,000	Pound	$0.20	297,000
3. Miscellaneous items.			Lump sum	396,000
(*c*) Roof			do	350,000
(*d*) Architectural features			do	874,000
(*e*) Plumbing			do	229,000
(*f*) Heating and ventilating.			do	333,000
(*g*) Lighting			do	556,000
(*h*) Miscellaneous			do	3,000
Total, powerhouse				50,745,000
d. Intake gates:				
(1) Gates and guides			Lump sum	1,026,000
(2) Trash racks and stop logs			do	1,616,000
(3) Grating covers and frames			do	90,000
(4) Painting			do	67,000
Total, intake gates				2,799,000
e. Draft tube gates:				
(1) Gates and guides			Lump sum	2,473,000
(2) Grating covers and frames			do	76,000
(3) Painting			do	75,000
Total, draft tube gates				2,624,000
f. Turbines and generators:				
(1) Turbines, governors, speed increasers, and generators.	50	Each	$1,608,200	80,410,000
(2) Lube system			Lump sum	250,000
(3) Cooling system			do	670,000
(4) Fire protection system			do	252,000
Total, turbines and generators.				81,582,000
g. Accessory electrical equipment			Lump sum	8,785,000
h. Miscellaneous powerplant equipment			do	2,656,000
i. Power transformers			do	1,300,000
Total, powerplant				204,491,000

TABLE 4.—*Tidal power project, 500 megawatts*—Continued

Item	Quantity	Unit	Unit price	Amount
2. Switchyard:				
a. Circuit breakers			Lump sum	$557,000
b. Disconnect switches			do	235,000
c. Grading, structures, bus, etc			do	1,578,000
Total, switchyard				2,370,000
3. Letite Passage filling gates (table 7)				27,472,000
4. Western Passage filling gates (table 8)				35,162,000
5. Head Harbour Passage emptying gates (table 9).				57,627,000
6. Head Harbour Passage lock (table 10)				7,472,000
7. Western Passage lock (table 11)				6,943,000
8. Little Letite Passage lock (table 12)				1,756,000
9. Quoddy Roads lock (table 13)				2,746,000
10. Dams (table 14)				63,604,000
11. Lubec Channel (table 15)				634,000
12. Fishways (table 16)				1,298,000
13. Service facilities (table 17)				1,870,000
14. Relocations (table 18)				4,931,000
15. Lands and damages (table 19)				1,870,000
Subtotal				420,306,000
Contingencies				58,967,000
Subtotal				479,273,000
Engineering, design, supervision, and administration.				50,581,000
Project 1st cost (500 megawatts)				529,854,000

TABLE 5.—*Tidal power project, 700 megawatts*

Item	Quantity	Unit	Unit price	Amount
1. Powerplant:				
a. Powerplant No. 1, 500 megawatts (table 4).				$204,491,000
b. Powerplant No. 2, 200 megawatts:				
(1) Cofferdams			Lump sum	9,700,000
(2) Excavation:				
(*a*) Earth:				
1. By hydraulic dredge.	8,800,000	Cubic yard	$0.60	5,280,000
2. In dry	1,000,000	do	$1	1,000,000
(*b*) Rock:				
1. In dry	9,800,000	do	$1.90	18,620,000
2. Underwater	200,000	do	$15	3,000,000
Total, excavation.				27,900,000
(3) Powerhouse and equipment				60,196,000
Total, powerplant No. 2, 200 megawatts.				97,796,000
Total, powerplants, 700 megawatts.				302,287,000
2. Switchyard				3,160,000
3. Filling gates (tables 7 and 8)				62,634,000
4. Emptying gates (table 9)				57,627,000
5. Locks (tables 10 to 13)				18,917,000
6. Dams:				
a. For 500-megawatt project (table 14)				63,664,000
b. Bar Harbor Dam				790,000
Total, dams				64,454,000
7. Lubec Channel (table 15)				634,000
8. Fishways:				
a. For 500-megawatt project (table 16)				1,298,000
b. For PII number 2, 200-megawatts				450,000
Total, fishways				1,748,000
9. Service facilities:				
a. For 500-megawatt project (table 17)				1,870,000
b. For 200-megawatts addition				200,000
Total, service facilities				2,070,000
10. Relocations:				
a. For 500-megawatt project (table 18)				4,931,000
b. For 200-megawatts addition:				
(1) Highway and railroad bridge				2,250,000
(2) Highways				150,000
(3) Waterlines				100,000
Total, relocations				7,431,000
11. Lands and damages:				
a. For 500-megawatt project (table 19)				1,879,000
b. For 200-megawatts addition				90,000
Total, lands and damages				1,960,000
Subtotal				522,922,000
Contingencies				72,728,000
Subtotal				595,650,000
Engineering, design, supervision, and administration				61,221,000
Project 1st cost (700 megawatts)				656,871,000

TABLE 6.—*Tidal power project, 1,000 megawatts*

Item	Quantity	Unit	Unit price	Amount
1. Powerplant:				
a. Powerplant No. 1, 500 megawatts (table 4).				$204,491,000
b. Powerplant No. 2, 500 megawatts:				
(1) Cofferdams			Lump sum	11,200,000
(2) Excavation:				
(*a*) Earth:				
1. By hydraulic dredge.	20,500,000	Cubic yard	$0.60	12,300,000
2. In dry	2,000,000	do	$1	2,000,000
(*b*) Rock:				
1. In dry	22,200,000	do	$1.90	42,180,000
2. Underwater	300,000	do	$15	4,500,000
Total, excavation.				60,980,000
(3) Powerhouse and equipment				150,491,000
Total, powerplant No. 2, 500 megawatts.				222,671,000
Total, powerplants, 1,000 megawatts.				427,162,000
2. Switchyard				3,950,000
3. Filling gates (tables 7 and 8)				62,634,000
4. Emptying gates (table 9)				57,627,000
5. Locks (tables 10 to 13)				18,917,000
6. Dams:				
a. For 500-megawatt project (table 14)				63,664,000
b. Bar Harbor Dam				790,000
Total, dams				64,454,000
7. Lubec Channel (table 15)				634,000
8. Fishways:				
a. For 500-megawatt project (table 16)				1,298,000
b. For 500-megawatt addition				1,026,000
Total, fishways				2,324,000
9. Service facilities:				
a. For 500-megawatt project (table 17)				1,870,000
b. For 500-megawatt addition				600,000
Total, service facilities				2,470,000
10. Relocations:				
a. For 500-megawatt project (table 18)				4,931,000
b. For 500-megawatt addition				4,700,000
Total, relocations				9,631,000
11. Lands and damages:				
a. For 500-megawatt project (table 19)				1,870,000
b. For 500-megawatt addition				160,000
Total, lands and damages				2,030,000
Subtotal				651,833,000
Contingencies				89,616,000
Subtotal				741,449,000
Engineering, design, supervision and administration				74,482,000
Project first cost (1,000 megawatts)				815,931,000

TABLE 7.—*Tidal power project—Letite Passage filling gates*

Item	Quantity	Unit	Unit price	Amount
a. Cofferdams			Lump sum	$6,526,000
b. Excavation:				
(1) Earth, in dry	419,000	Cubic yard	$1	419,000
(2) Rock, in dry	1,695,000	do	$2	3,390,000
(3) Rock, under water	83,500	do	$15	1,253,000
(4) Backfill	10,900	do	$0.20	2,000
Total, excavation				5,064,000
c. Concrete:				
(1) Foundation preparation				128,000
(2) Foundation mat	16,800	Cubic yard	$25	420,000
(3) Gate structure	128,000	do	$59	7,552,000
Total, concrete				8,100,000
d. Gates and machinery:				
(1) Service gates and guides			Lump sum	3,807,000
(2) Machinery			do	772,000
(3) Emergency gates and guides			do	2,291,000
(4) Unwatering bulkheads			do	155,000
(5) Gantry crane and rails			do	257,000
(6) Electrical items			do	226,000
Total, gates and machinery				7,508,000
e. Operations building			Lump sum	56,000
f. Miscellaneous items			do	218,000
Total, Letite Passage filling gates				27,472,000

TABLE 8.—*Tidal power project—Western Passage filling gates*

Item	Quantity	Unit	Unit price	Amount
a. Cofferdams			Lump sum	$3,719,000
b. Excavation:				
(1) Earth, in dry	406,250	Cubic yard	$1	406,000
(2) Rock, in dry	4,325,000	do	$2	8,650,000
(3) Rock, under water	228,000	do	$15	3,420,000
Total, excavation				12,476,000
c. Concrete:				
(1) Foundation preparation			Lump sum	180,000
(2) Gate structure	158,000	Cubic yard	$58	9,170,000
Total, concrete				9,350,000
d. Gates and machinery:				
(1) Service gates and guides			Lump sum	4,750,000
(2) Machinery			do	965,000
(3) Emergency gates and guides			do	2,852,000
(4) Unwatering bulkheads			do	174,000
(5) Gantry crane and rails			do	271,000
(6) Electrical items			do	280,000
Total, gates and machinery				9,292,000
e. Operations building				55,000
f. Miscellaneous items				270,000
Total, Western Passage filling gates				35,162,000

TABLE 9.—*Tidal power project—Head Harbour Passage emptying gates*

Item	Quantity	Unit	Unit price	Amount
a. Cofferdams				$18,923,000
b. Excavation:				
(1) Earth, by dredge	410,000	Cubic yard	$1.10	451,000
(2) Rock, in dry	2,172,000	do	$2	4,344,000
(3) Rock, underwater	152,000	do	$15	2,280,000
(4) Backfill	82,400	do	$0.20	16,000
Total, excavation				7,091,000
c. Concrete:				
(1) Foundation preparation			Lump sum	237,000
(2) Foundation mat	90,735	Cubic yard	$25	2,268,000
(3) Gate structure	252,300	do	$58	14,633,000
Total, concrete				17,138,000
d. Gates and machinery:				
(1) Service gates and guides			Lump sum	7,203,000
(2) Machinery			do	1,351,000
(3) Emergency gates and guides			do	4,548,000
(4) Unwatering bulkheads			do	220,000
(5) Gantry crane and rails			do	301,000
(6) Electrical items			do	388,000
Total, gates and machinery				14,011,000
e. Operations building			Lump sum	57,000
f. Miscellaneous items			do	407,000
Total, Head Harbour Passage emptying gates				57,627,000

TABLE 10.—*Tidal power project—Head Harbour Passage lock*

Item	Quantity	Unit	Unit price	Amount
a. Cofferdams			Lump sum	$1,467,000
b. Excavation:				
(1) Earth, in dry	51,500	Cubic yards	$1.50	77,000
(2) Rock:				
(*a*) In dry	917,450	do	$2	2,835,000
(*b*) Underwater	48,000	do	$15	720,000
(*c*) Backfill	60,500	do	$0.20	12,000
(*d*) Fine rock grading	40,000	Square yard	$2.25	90,000
Total, excavation				2,734,000
c. Concrete:				
(1) Foundation preparation			Lump sum	28,000
(2) Lock structure	53,500	Cubic yard	$42	2,247,000
Total, concrete				2,275,000
d. Gates and machinery:				
(1) Gates			Lump sum	342,000
(2) Machinery			do	109,000
(3) Unwatering bulkheads			do	267,000
(4) Service bridge			do	100,000
(5) Electrical items			do	138,000
Total, gates and machinery				956,000
e. Operations building			do	16,000
f. Miscellaneous items			do	24,000
Total, Head Harbour Passage lock				7,472,000

TABLE 11.—*Tidal power project—Western Passage lock*

Item	Quantity	Unit	Unit price	Amount
a. Cofferdams			Lump sum	$1,934,000
b. Excavation:				
(1) Earth, in dry	303,840	Cubic yard	$1	304,000
(2) Rock:				
(*a*) In dry	578,070	do	$2	1,156,000
(*b*) Underwater	4,230	do	$25	106,000
(*c*) Backfill	52,800	do	$0.20	11,000
(*d*) Fine rock grading	52,000	Square yards	$2.25	117,000
Total, excavation				1,694,000
c. Concrete:				
(1) Foundation preparation			Lump sum	41,000
(2) Lock structure	57,500	Cubic yard	$40	2,300,000
Total, concrete				2,341,000
d. Gates and machinery:				
(1) Gates			Lump sum	342,000
(2) Machinery			do	109,000
(3) Unwatering bulkheads			do	267,000
(4) Service bridge			do	78,000
(5) Electrical items			do	138,000
Total, gates and machinery				934,000
e. Operations building			Lump sum	16,000
f. Miscellaneous items			do	24,000
Total, Western Passage lock				6,943,000

TABLE 12.—*Tidal power project—Little Letite Passage lock*

Item	Quantity	Unit	Unit price	Amount
a. Cofferdams			Lump sum	$212,000
b. Excavation:				
(1) Rock:				
(*a*) In dry	57,400	Cubic yard	$2	115,000
(*b*) Underwater	15,370	do	$15	231,000
(*c*) Backfill	6,000	do	$0.20	1,000
(*d*) Fine rock grading	7,700	Square yard	$2.25	17,000
Total, excavation				364,000
c. Concrete:				
(1) Foundation preparation			Lump sum	6,000
(2) Lock structure	14,150	Cubic yard	$52.50	743,000
Total, concrete				749,000
d. Gates and machinery:				
(1) Gates			Lump sum	116,000
(2) Machinery			do	89,000
(3) Unwatering bulkheads			do	56,000
(4) Service bridge			do	43,000
(5) Electrical items			do	103,000
Total, gates and machinery				407,000
e. Operations building			Lump sum	16,000
f. Miscellaneous items			do	8,000
Total, Little Letite Passage lock				1,756,000

TABLE 13.—*Tidal power project—Quoddy Roads lock*

Item	Quantity	Unit	Unit price	Amount
a. Cofferdams			Lump sum	$1,231,000
b. Excavation:				
(1) Rock:				
(*a*) In dry	14,000	Cubic yard	$4	56,000
(*b*) Underwater	5,900	do	$25	148,000
(*c*) Backfill	5,200	do	$2.35	12,000
(*d*) Fine rock grading	4,200	Square yard	$2.25	9,000
Total, excavation				225,000
c. Concrete:				
(1) Foundation preparation			Lump sum	7,000
(2) Lock structure	16,750	Cubic yard	$51	854,000
Total, concrete				861,000
d. Gates and machinery:				
(1) Gates			Lump sum	116,000
(2) Machinery			do	89,000
(3) Unwatering bulkheads			do	52,000
(4) Service bridge			do	43,000
(5) Electrical items			do	103,000
Total, gates and machinery			Lump sum	403,000
e. Operations building		Lump sum	do	16,000
f. Miscellaneous items		do		10,000
Total, Quoddy Roads lock				2,746,000

TABLE 14.—*Tidal power project—Dams*

Item	Quantity	Unit	Unit price	Amount
a. Letite passages	3,740,000	Cubic yards		$3,891,000
b. McMaster Island to Deer Island	1,241,000	do		2,531,000
c. Head Harbour Passage, East	20,311,000	do		21,098,000
d. Head Harbour Passage, West	7,203,000	do		9,591,000
e. Indian River	5,362,000	do		4,519,000
f. Western Passage	12,322,000	do		15,387,000
g. Carryingplace Cove	345,000	do		650,000
h. Quoddy Roads	2,750,000	do		5,997,000
Total, dams	53,274,000	do		63,664,000

TABLE 15.—*Tidal power project—Lubec Channel*

Item	Quantity	Unit	Unit price	Amount
a. Excavation:				
(1) By hydraulic dredge	345,000	Cubic yard	$0.90	$311,000
(2) By dipper dredge	170,000	do	1.90	323,000
Total, Lubec Channel				634,000

TABLE 16.—*Tidal power project—Fishways*

Item	Quantity	Unit	Unit price	Amount
a. Powerplant, 500 megawatts			Lump sum	$1,026,000
b. Head Harbour emptying gates			do	272,000
Total, fishways				1,298,000

TABLE 17.—*Tidal power project—500 megawatts*

Item	Quantity	Unit	Unit price	Amount
Service facilities:				
a. Service roads:				
(1) In United States			Lump sum	$210,000
(2) In Canada			do	522,000
Total, service roads				732,000
b. Buildings, grounds, and facilities:				
(1) Housing			Lump sum	170,000
(2) Service buildings			do	160,000
(3) Water supply			do	87,000
(4) Roads and railroad sidings			do	96,000
(5) Operating equipment			do	625,000
Total, buildings, grounds, and facilities				1,138,000
Total, service facilities				1,870,000

TABLE 18.—*Tidal power project—500 megawatts*

Item	Quantity	Unit	Unit price	Amount
Relocations:				
a. Relocations in United States:				
(1) Roads and bridges:				
(*a*) Highways			Lump sum	$54,000
(*b*) Railroad			do	212,000
(*c*) Highway and railroad bridge			do	4,155,000
Total, roads and bridges.				4,421,000
(2) Waterlines			Lump sum	64,000
(3) Telephone and telegraph lines			do	30,000
(4) Electric lines			do	55,000
(5) Cemeteries			do	2,000
(6) U.S. Coast Guard			do	250,000
(7) International boundary monuments.			do	10,000
Total, relocations in United States.				4,832,000
b. Relocations in Canada:				
(1) Electric lines			Lump sum	95,000
(2) Cemeteries			do	4,000
Total, relocations in Canada				99,000
Total, relocations				4,931,000

TABLE 19.—*Tidal power project—500 megawatts*

	Unit price	Amount
Land and damages:		
a. Lands and damages in United States:		
(1) Lands and improvements	Lump sum	$486,000
(2) Damages, modification of structures in low pool	do	557,000
Total, lands and damages in United States		1,043,000
b. Lands and damages in Canada:		
(1) Lands and improvements	Lump sum	359,000
(2) Modification of structures	do	468,000
Total, lands and damages in Canada		827,000
Total, lands and damages		1,870,000

TABLE 20.—*Estimate of cost, Dickey project, 190 megawatts*

Item	Quantity	Unit	Unit price	Amount
1. Lands and damages:				
a. Lands	109,850	Acre	Lump sum	$3,400,000
b. Improvements (210 buildings)			do	300,000
c. Severance			do	700,000
d. Resettlements			do	55,000
e. Water rights			do	10,000
f. Access roads easements			do	4,000
Total, lands and damages				4,469,000
2. Relocations:				
a. Roads and bridges			Lump sum	1,300,000
b. Power and telephone lines			do	13,000
c. Cemeteries			do	50,000
Total, relocations				1,363,000
3. Reservoir clearing			Lump sum	2,000,000
4. Dams:				
a. Stream control and diversion:				
(1) Inlet:				
(*a*) Earth excavation	1,020,000	Cubic yard	$0.50	510,000
(*b*) Rock excavation	235,000	do	$1.80	423,000
(*c*) Gates, racks, and guides	611,400	Pound	$0.50	306,000
(*d*) Concrete	6,020	Cubic yard	$55	331,000
Total, Inlet				1,570,000
(2) Gate structure:				
(*a*) Rock excavation shaft	20,000	Cubic yard	$20	400,000
(*b*) Gates and hoists			Lump sum	262,000
(*c*) Concrete	20,200	Cubic yard	$66	1,327,000
(*d*) Crane and structure			Lump sum	138,000
(*e*) Valves			do	300,000
(*f*) Elevator			do	80,000
Total, gate structure				2,507,000
(3) Tunnels:				
(*a*) Rock excavation	186,000	Cubic yard	$20	3,720,000
(*b*) Concrete lining	66,800	do	$45	3,006,000
(*c*) Miscellaneous items			Lump sum	146,000
Total, tunnels				6,872,000
(4) Outlet:				
(*a*) Earth excavation	97,000	Cubic yard	$0.60	58,000
(*b*) Rock excavation	325,000	do	$1.80	585,000
(*c*) Concrete	1,600	do	$47	75,000
(*d*) Miscellaneous items			Lump sum	6,000
Total, outlet				724,000
(5) Cofferdams			do	120,000
Total, stream control and diversion.				11,703,000
b. Embankment:				
(1) Preparation of site			Lump sum	76,000
(2) Excavation:				
(*a*) Stripping	1,825,000	Cubic yard	$0.50	913,000
(*b*) Cutoff trench	984,000	do	$0.60	590,000
(*c*) Foundation grouting			Lump sum	50,000
Total, excavation				1,553,000
(3) Fill:				
(*a*) Impervious fill	8,065,000	Cubic yard	$0.78	6,291,000
(*b*) Pervious fill:				
1. From earth excavation.	5,600,000	do	$0.13	728,000
2. From rock excavation.	11,000,000	do	$0.20	2,200,000
3. From borrow	28,800,000	do	$0.68	19,584,000
Total, pervious fill.				22,512,000
(4) Gravel bedding and slope protection.	1,100,000	Cubic yard	$1.25	1,375,000

TABLE 20.—*Estimate of cost, Dickey project, 190 megawatts*—Continued

Item	Quantity	Unit	Unit price	Amount
4. Dams—Continued				
b. Embankment—Continued				
(5) Rock slope protection:				
(a) From excavation	685,000	do	$0.40	$274,000
(b) From borrow	218,000	do	$4.50	981,000
Total, rock slope protection.				1,255,000
(6) Roadway across dam			Lump sum	216,000
(7) Drainage tunnel			do	150,000
Total, embankment	55,468,000			33,428,000
c. Saddle dams:				
(1) Falls Brook	7,310,000	Cubic yard		4,900,000
(2) Hafey Brook	1,980,000	do		2,507,000
(3) Blue Brook	38,000	do		142,000
(4) Campbell Brook	44,000	do		44,000
(5) Cunliffe Brook	211,000	do		396,000
Total, saddle dams	9,583,000	do		7,989,000
d. Spillway:				
(1) Preparation of site			Lump sum	75,000
(2) Excavation:				
(a) Earth	800,000	Cubic yard	$0.50	400,000
(b) Rock	4,500,000	do	$1.80	8,100,000
Total, excavation				8,500,000
(3) Concrete	92,600	Cubic yard	$45.00	4,167,000
(4) Miscellaneous items			Lump sum	103,000
Total, spillway				12,845,000
e. Intake:				
(1) Approach channel:				
(a) Earth excavation	320,000	Cubic yard	$0.60	192,000
(b) Rock excavation	375,000	do	$1.80	675,000
Total, approach channel				867,000
(2) Intake structure:				
(a) Rock excavation	69,500	do	$1.80	125,000
(b) Gates and hoists			Lump sum	680,000
(c) Concrete	61,000	do	$41.50	2,532,000
Total, intake structure				3,337,000
(3) Miscellaneous items				110,000
Total, intake				4,314,000
f. Allagash channel:				
(1) Stream control and diversion			Lump sum	50,000
(2) Earth excavation	4,000,000	Cubic yard	$0.60	2,400,000
(3) Slope protection			Lump sum	100,000
Total, Allagash channel				2,550,000
Total, dams				72,919,000
5. Penstocks:				
a. Excavation:				
(1) Earth	42,500	Cubic yard	$0.60	26,000
(2) Rock	107,000	do	$1.80	192,000
Total, excavation				218,000
b. Steel conduits	6,450,000	Pound	$0.32	2,060,000
c. Expansion joints			Lump sum	60,000
d. Anchors and supports:				
(1) Concrete	15,150	Cubic yard	$53	793,000
(2) Steel	715,000	Pound	$0.40	286,000
Total, anchors and supports				1,079,000
e. Station service conduits			Lump sum	142,000
f. Fill over penstocks	65,000	Cubic yard	$1	65,000
Total, penstocks				3,624,000

TABLE 20.—*Estimate of cost, Dickey project, 190 megawatts*—Continued

Item	Quantity	Unit	Unit price	Amount
6. Powerplant:				
a. Powerhouse			Lump sum	$11,300,000
b. Turbine, generators, etc			do	8,636,000
c. Accessory electrical equipment			do	870,000
d. Miscellaneous powerplant equipment			do	870,000
e. Power transformers			do	1,100,000
f. Tailrace:				
(1) Excavation:				
(*a*) Earth	1,430,000	Cubic yard	$0.50	715,000
(*b*) Rock	2,800,000	do	$1.80	5,040,000
Total, tailrace				5,755,000
Total, powerplant				28,531,000
7. Switchyard:				
a. Circuit breakers			Lump sum	478,000
b. Disconnecting switches			do	148,000
c. Grading, structures, bus, etc			do	957,000
Total, switchyard				1,583,000
8. Access roads:				
a. Access roads to dam and recreation area			Lump sum	270,000
b. Rebuild highway from St. Francis to Lincoln School.			do	240,000
c. Ferry ramps and access roads			do	50,000
Total, access roads				560,000
9. Buildings, grounds, and facilities:				
a. Housing			Lump sum	187,000
b. Service buildings			do	122,000
c. Operating equipment			do	89,000
d. Marine plant			do	122,000
e. Logway			do	208,000
Total, buildings, grounds, and facilities.				728,000
Subtotal, Dickey project				115,777,000
Contingencies				16,935,000
Subtotal				132,712,000
Engineering, design, supervision, and administration.				14,954,000
Total, project 1st cost (190 megawatts)				147,666,000

TABLE 21.—*Estimate of cost, Dickey project, 380 megawatts*

Lands and damages	$4,469,000
Relocations	1,363,000
Reservoir clearing	2,000,000
Dams	72,919,000
Penstocks	7,249,000
Powerplant:	
Powerhouse	12,200,000
Turbines and generators	17,150,000
Accessory electrical equipment	1,420,000
Miscellaneous powerplant equipment	990,000
Power transformers	1,578,000
Tailrace	5,755,000
Total, powerplant	39,093,000
Switchyard	1,940,000
Access roads and bridge	560,000
Buildings, grounds, and facilities	728,000
Subtotal	130,321,000

TABLE 21.—*Estimate of cost, Dickey project, 380 megawatts*—Continued

Contingencies	$18,691,000
Subtotal	149,012,000
Engineering, design, supervision, and administration	16,559,000
Total project, 1st cost (380 megawatts)	165,571,000

TABLE 22.—*Estimate of cost, Dickey project, 475 megawatts*

Lands and damages	$4,469,000
Relocations	1,363,000
Reservoir clearing	2,000,000
Dams	72,919,000
Penstocks	9,062,000
Powerplant:	
Powerhouse	12,600,000
Turbines and generators	21,440,000
Accessory electrical equipment	1,695,000
Miscellaneous powerplant equipment	1,045,000
Power transformers	2,056,000
Tailrace	5,755,000
Total, powerplant	44,591,000
Switchyard	2,787,000
Access roads and bridges	560,000
Buildings, grounds, and facilities	728,000
Subtotal	138,479,000
Contingencies	19,700,000
Subtotal	158,179,000
Engineering, design, supervision and administration	17,476,000
Total project, 1st cost (475 megawatts)	175,655,000

TABLE 23.—*Estimate of cost, Dickey project, 760 megawatts*

Lands and damages	$4,469,000
Relocations	1,363,000
Reservoir clearing	2,000,000
Dams	72,919,000
Penstocks	14,503,000
Powerplant:	
Powerhouse	13,900,000
Turbines and generators	34,300,000
Accessory electrical equipment	2,520,000
Miscellaneous powerplant equipment	1,220,000
Power transformers	2,534,000
Tailrace	5,755,000
Total powerplant	60,229,000
Switchyard	3,466,000
Access roads and bridges	560,000
Buildings, grounds, and facilities	728,000
Subtotal	160,237,000
Contingencies	22,321,000
Subtotal	182,558,000
Engineering, design, supervision, and administration	19,880,000
Total project, 1st cost (760 megawatts)	202,438,000

TABLE 24.—*Estimate of cost, Lincoln School project*

Item	Quantity	Unit	Unit price	Amount
1. Lands and damages:				
a. Lands	2,150	Acre	Lump sum	$190,000
b. Improvements (60 buildings)			do	180,000
c. Resettlements			do	30,000
Total, lands and damages				400,000
2. Relocations:				
a. Roads and bridges			Lump sum	1,200,000
b. Power and telephone lines			do	38,000
Total, relocations				1,238,000
3. Reservoir clearing			Lump sum	40,000
4. Dams:				
a. Steam control and diversion			do	100,000
b. Embankment:				
(1) Preparation of site			do	10,000
(2) Excavation:				
(*a*) Stripping	200,000	Cubic yard	$0.50	100,000
(*b*) Cutoff trench	50,000	do	$0.60	30,000
(3) Fill:				
(*a*) Impervious fill	485,000	do	$0.35	170,000
(*b*) Random fill	680,000	do	$0.35	238,000
(*c*) Rock fill	97,000	do	$0.40	39,000
(4) Gravel bedding	28,000	do	$1.50	42,000
(5) Rock slope protection:				
(*a*) From excavation	64,000	do	$0.40	26,000
(*b*) From borrow	19,000	do	$4.50	86,000
(6) Roadway across dam			Lump sum	24,000
Total, embankment	1,373,000			765,000
c. Spillway:				
(1) Preparation of site			Lump sum	10,000
(2) Excavation:				
(*a*) Earth	954,000	Cubic yard	$0.50	477,000
(*b*) Rock	282,000	do	$1.80	508,000
(3) Concrete	42,500	do	$45	1,913,000
(4) Taintor gates (4-40 feet by 30 feet), guides and hoists.			Lump sum	400,000
(5) Miscellaneous items			do	150,000
Total, spillway				3,458,000
Total, dams				4,323,000
5. Powerplant:				
a. Powerhouse			Lump sum	1,650,000
b. Turbines, generators, etc			do	3,273,000
c. Accessory electrical equipment			do	522,000
d. Miscellaneous powerplant equipment			do	261,000
e. Transformers			do	126,000
f. Forebay and tailrace excavation:				
(1) Earth	348,000	Cubic yard	$0.50	174,000
(2) Rock	158,000	do	$1.80	284,000
Total, powerplant				6,290,000
6. Switchyard:				
a. Circuit breakers			Lump sum	104,000
b. Disconnect switches			do	43,000
c. Grading, structures, bus, etc			do	240,000
Total, switchyard				387,000
7. Buildings, grounds, and facilities			Lump sum	208,000
8. Access roads			do	50,000
Subtotal				12,936,000
Contingencies				1,776,000
Subtotal				14,712,000
Engineering, design, supervision, and administration				1,553,000
Total project 1st cost				16,265,000

Senator MUSKIE. Mr. Secretary, welcome, and we are ready to receive your testimony.

STATEMENT OF HON. STEWART L. UDALL, SECRETARY OF THE INTERIOR; ACCOMPANIED BY KENNETH HOLUM, ASSISTANT SECRETARY OF THE INTERIOR FOR WATER AND POWER DEVELOPMENT; MORGAN D. DUBROW, SPECIAL ASSISTANT TO THE ASSISTANT SECRETARY; AND JOSEPH E. GUIDRY, SPECIAL ASSISTANT TO THE ASSISTANT SECRETARY

Secretary UDALL. Thank you very much, Senator. I have my associates who have been primarily connected with this study with me. I have a prepared statement. I would like to have it appear in the record, and I will read part of it and add some other comments. Then, if we could, because this is an essential part of my presentation, have a slides presentation shown. I think probably it would be better to have questions after the slides because part of the factual matter that is inherent in my presentation is in the slides.

Senator MUSKIE. Fine. That is perfectly agreeable.

Secretary UDALL. I understand Secretary Ailes will be along in a moment.

First off, in a general way, Mr. Chairman, I would like to say that the interesting thing about the Quoddy project to those of us who have been working on it in the last 3 years is that the more we study it, the more the experts look at it, the more its economic feasibility improves as you will see here today. In this latest updating of our report of a year ago, you will see some significant, very interesting differences. The more we study it, the more some of the objections that have been raised fall by the wayside which are enumerated. The more we study it, the more economically we find that it can be built. And, interestingly enough, the more we study the problem, the more we see ways that technology itself enhances the project and makes it more feasible, makes it a more flexible instrument for production of power. There is no question at all in my mind, seeing what is happening in the country generally in the electric power industry, that the developments we see forthcoming in technology are going to more and more enhance the value of the worth of this project. I just wanted to comment as sort of an aside on the fact that there is every appearance that this week in the Congress will see the culmination of a project that has been talked about almost as long as Quoddy, a project of interconnecting two whole regions of this country with heavy electric power transmission lines.

This Pacific Northwest-Southwest intertie project—which embraces an 11-State area and for which money is being appropriated for this week—is going to go forward. It is probably the most exciting thing in electric power business that has happened in many, many years. We are going to build two direct current long-distance lines, one of them all the way from the Columbia River to Los Angeles, the other from the Columbia to Hoover Dam. These will be the Nation's first and the world's longest direct current lines. We are going to build a series of four lines connecting the Pacific Northwest and Pacific Southwest, ultimately with interconnections and benefits to 11 Western States in one project. There appeared to be political ob-

stacles. There appeared to be 3 years ago when we first began studying the technical obstacles some people said that it was not feasible, that we could not do it, and yet we are going forward with it. It was not so wild a dream after all.

And, this leads me to believe on the basis of our experience with the Quoddy project that the value and attractiveness of this as a public works project, as a resource development project is—the more closely you scrutinize it, the more you work on it, the more we find that its value emerges.

I should like to comment again, too, as I have in the past, and I think this is a paramount fact. I am sure your colleagues such as Senator Metcalf, with whom I worker for many years in the Congress on western resources development projects, will be one of the first to say amen to this. The people of New England pay the same taxes as people anywhere else and yet New England is the one region which has been left out of the whole resource development picture.

We have had big dams and electric power projects on the St. Lawrence Seaway, for example, in the Great Lakes region, in the South and West, but New England as a region, when you look back over the history of the last 30 or 40 years, has been largely left out in terms of major Federal natural resource investment. The one big project that should be accomplished, the one big resource that is there to develop is the water of the St. John River and the tides of Passamaquoddy Bay. I hope that we can get this in a shape to make the final presentation and get the final clearances next year and get moving on it. My experts—and we have enjoyed working closely with the Corps of Engineers and the Secretary of the Army on this—we have established a very fine working relationship, a team interest, and we all believe in this project. That is the reason we are here today.

In evaluating the potential of Passamaquoddy, it is essential to recognize that the tide is a perpetual resource, fully predictable and dependable.

This is another thing we should not lose sight of. Any big dam in this country, no matter where it is built, has a life of a certain number of years. This depends upon the silting conditions and the value of every river hydroelectric project in this country to varying degrees, of course, will be reduced by silting in time, but a tidal power project is perpetual. It is not a 50-year project. It will last as long as you can keep your equipment there and keep it operating, and I think one should not lose sight of this because after all, we must recognize that this 50-year requirement for payout of projects, assuming a 50-year life of a project, is an arbitrary thing.

It may make sense to be conservative in terms of the planning of public works projects, and this is the traditional way of doing it, but we must recognize the fact that if this tidal project is as sound as we believe it is and once it is established that you have a resource as long as nature continues to follow its ordained course. The tides will rise and fall at Passamaquoddy and there is no silt to reduce the life of this project.

Senator MUSKIE. There are two other ways, aren't there, Mr. Secretary, at least two other ways, in which this differs from the conventional hydroelectric river project. One, there is no land condemnation in-

volved nor destruction of land values, no flooding of land values. And second, the tides, the volume of water, volume of energy is almost absolutely predictable for the indefinite future.

Secretary UDALL. Yes. You do not have the low and high water years that you have in all parts of this country. In fact, this is a unique project, and I think everyone who has studied it and looked at it knows it is a unique project. Some of its advantages far outweigh the various points that can be raised as objections to it. Now, Senator on the Quoddy portion of the project, the amount of land to be condemned and the amount of flooding is relatively insignificant. However, in the case of Dickey Dam and Reservoir, the flooding would be substantial encompassing a total of some 88,000 acres. This is not unusual in similar water resource development throughout the Nation.

The greatest rise and fall of the tides in the world occurs at the head of the Bay of Fundy on the Nova Scotia coast where tides as high as 40 to 50 feet are observed. The tides at Eastport, Maine, also in the Bay of Fundy and at Passamaquoddy, have a maximum rise and fall of about 26 feet with an average of 18.1 feet.

The plan adopted by the International Passamaquoddy Engineering Board for harnessing the tides of Passamaquoddy Bay and used in our investigations, consists of two pools, one of which is open to the sea through filling gates and the other open to the sea through emptying gates, with a powerplant between the pools. The gates to Passamaquoddy Bay, the high pool, open when the tide rises in the Bay of Fundy and close when the pool fills. Power is generated by releasing water from the high pool to the low pool through the powerhouse. The gates to Cobscook Bay, the low pool, open at low tide when the sea is below the level of the pool, allowing it to empty.

Passamaquoddy Bay has an area of 100 square miles—nearly 1½ times the size of the District of Columbia. It fills and empties with the tides in the Bay of Fundy. Twice in each tidal day of 24 hours and 50 minutes, the water level in this reservoir varies through a long-term average depth of 18.1 feet with a maximum of 25.7 feet and a minimum of 11.7 feet.

From a water supply standpoint, the tidal potential is unlimited and it becomes simply a problem of tidal range to fill Passamaquoddy Bay.

In the case of the river plants, full control of generation is available over long periods of time but the rivers are subject to drought, whereas the tides are not. One basic difference, however, does exist in the tides in that they must be utilized when they occur or else are lost forever. By the plan adopted, the primary operation of the tidal plant would be for peaking power, but substantial power would also be generated at most other times. This offpeak power generation will be integrated with the proposed Dickey-Lincoln School developments on the upper St. John River.

The electric power which can be generated utilizing the two-pool system is highly flexible and can be controlled to meet utility load patterns, or for very short "peaking" periods.

In the International Joint Commission's plan, the proposed operation was to meet the electric utility load patterns in the local area. Our studies show that Passamaquoddy should be a peaking operation to meet a daily peak of 2 hours.

The proposed operation of Passamaquoddy for peaking power is ideally suited for coordination of the tidal cycle and our 24-hour solar day.

The electric utility systems in the New England-New Brunswick area—and this would be an international project as I am sure you all realize—have characteristically experienced a predominant peak power demand daily and generally from 5 to 6 o'clock in the evening. Since each day two tides occur which are predictable in both time and magnitude, it is possible to select the proper tide so that a full high pool and an empty low pool will be available to permit generation to meet this peak power demand.

The load and resources study prepared by this Department for the marketing area embracing the New England States, eastern New York State and the Maritime Provinces of Canada, demonstrated the need for economical peaking power sources to meet future power requirements as loads increase and larger baseload units are added to utility systems.

Our studies of available power resources and predictions on future load growth concluded that Passamaquoddy could ultimately be developed as a peaking powerplant in the magnitude of 1 million kilowatts. Quoddy would also produce large amounts of offpeak power. Its operation should be coordinated with the Dickey storage reservoir and powerplant on the upper St. John River in Maine to maximize the power output of both features of the project.

This concept is predicated on (1) the use of low-cost axial-flow turbines capable of operation at the low heads available from the tide, and (2) extensive computer studies demonstrating the workability and determining the precise quantities of dependable power which could be obtained and delivered to utility systems in the region.

The substantive investigations and studies accomplished to date in collaboration with the Corps of Engineers, U.S. Army, clearly demonstrate the engineering and economic feasibility of the project.

This report contains the recommendations and conclusions reached by the Passamaquoddy Study Committee and its collaborative studies with the Corps of Engineers, U.S. Army.

As required by the procedures set forth in Senate Document No. 97, the report is being submitted to the interested Federal agencies, to the Governors of the affected States for review and comment. Such comments as are received will be embodied in my final report to President Johnson. Copies are also being sent to appropriate offices in the Canadian Government for any comments they wish to make.

For historical background, I would appreciate your permission to submit the following documents for the record:

1. "Summary of the Report of the International Joint Commission," dated April 1961.
2. "Load and Resources Study," dated December 1961.
3. My July 1963 review report on the project.
4. The supplemental report issued yesterday.
5. Department of the Interior news releases associated with these documents.

We are firmly convinced that these collective studies and investigations clearly demonstrate the engineering and economic feasibility of the Passamaquoddy-Dickey project.

This project will provide essential power required for the ever-expanding demand of the New England area by putting to beneficial use a wasting resource of the tides in the flow of the St. John River.

It will provide substantial area redevelopment benefits and national economic benefits consisting of 15,000 man-years of on-site employment for skilled and semiskilled workers, many thousands of additional man-years of employment in the manufacturing and transportation of materials and equipment, and sustained economic benefit derived from the availability of abundant relatively low-cost power, as well as an unparalleled international recreaton attraction.

The Department's Passamaquoddy-St. John River Study Committee recommends:

(1) Early authorization of the international Passamaquoddy tidal power project, the Upper St. John River developments, and the transmission system, for construction by the United States.

(2) Early construction of the project to develop low cost firm power for Maine and peaking power for the remainder of the New England States, combat poverty, develop recreation resources, and utilize the now wasted water resources of Maine.

The race for the moon has many scientific ramifications, but none so challenging in terms of immediate benefit to man than the harnessing of the ever-wasting tides—with the help of the moon, incidentally—to generate electricity. This endeavor and the utilization of nuclear energy to desalt the ocean's waters will be important tests of our ability to create a great scientific society.

I would like now as part of my testimony to have slide presentation if we could. I think this will give the members of the committee, Mr. Chairman, a very clear and concise, quick picture of the main elements of this plan.

Senator MUSKIE. Thank you, Mr. Secretary.

(The following is a transcription of the sound track of the slide presentation given by the Department of the Interior describing the Passamaquoddy project. The slides are on file in the office of the Committee on Public Works.)

Slide. Quoddy title.

Slide 1. In 1961, following a request of the late President John F. Kennedy, the Department of the Interior initiated a study of:

Slide 2. Changing patterns in electric generation and transmission technology, fuel costs, and electric demand which might make the long proposed Passamaquoddy tidal power project economically feasible.

Slide 3. Two years later, the Department reported that four basic changes now made Quoddy engineeringly and economically sound.

1. The load growth of the New England-New Brunswick market area;
2. Extra high voltage transmission;
3. Peaking capacity required with large, modern thermal units; and
4. The advent of horizontal flow turbines.

Slide 4. The Passamaquoddy area is located in northeastern Maine on the Bay of Fundy, where tides as high as 40 to 50 feet have been measured.

Slide 5. At Eastport, Maine, the maximum tidal range reaches 26 feet with an average of 18.1 feet. This is the tidal range that makes the development of the Passamaquoddy tidal power project possible and desirable.

Slide 6. Here is a stylized projection of the Quoddy area, after completion.

Slide 7. Starting from the top right and moving left, we see Passamaquoddy Bay. This is the high pool where incoming tides will be trapped, as water rushes through filling gates at Letite Passage and Deer Island. At center left is the first powerhouse and the site of the potential second powerhouse. Below them is Cobscook Bay—the low pool that will receive the water as it pours through turbines. The water then passes out through the emptying gates with the tide at low ebb.

Slide 8. Here is a closer view of the powerhouses.

Slide 9. To simplify the operation, this slide visualizes both the high and low pools as if they were empty.

Slide 10. As the filling gates are opened at high tide, the high pool fills.

Slide 11. When peaking power is required, the water is released through turbines into the low pool and then into the ocean through the emptying gates, when the tide is at low ebb.

Slide 12. This slide shows the projected load growth of the New England-New Brunswick market area. In 1950, 7.2 million kilowatts, including 800,000 kilowatts of peaking power, was required. In 1960, 11.7 million peaking demand. By 1970, 22 million kilowatts and a 2 million peaking ability will be needed. And, by 1980, 36 million kilowatts with a peaking demand of 4 million.

Slide 13. What causes peaking demand? During the daylight hours, a fairly constant load is caused by normal and industrial demand. But, from about 4 to 6 p.m., the turning on of lights, television, radios, ranges, and many other electrical appliances causes a sudden need for more power. As you know, this peak demand must be met, or a danger of a blackout and a loss of power will result throughout the entire area.

Slide 14. For example here you can see the vast daily changes in New England power loads for 1 week in December of 1980—as estimated by the Federal Power Commission.

Slide 15. This slide illustrates the ability of combined powerplants to meet New England baseload requirements in 1980. At the bottom in gray are baseload thermal plants. In blue, all of the older thermal and hydroelectric plants. And, in red, the additional needed peaking power including Quoddy. As large, efficient baseload thermal plants—fossil fuel or nuclear—are constructed, the need for efficient hydroelectric peaking projects—such as Quoddy—will increase in New England.

Slide 16. The final, and the most important advance, that makes Quoddy feasible is the advent of the horizontal reversible flow turbine. Notice that while the propeller is under water, the shaft runs at an angle to the generator which is high and dry in its own concrete housing out of the water. Four of these units can take the place of three conventional Kaplan units with lower installation costs.

Slide 17. Power generated at Quoddy and the auxiliary Dickey Dam on the St. John River will be transmitted to Bangor. Power will then move to the Boston area through two 345,000-volt lines. Other lines will feed New Brunswick with its share of power. And, power can also be fed in either direction—north to south, or vice versa.

Slide 18. In order to achieve the maximum benefit from water resource development, Dickey Dam should be constructed as an auxiliary hydroelectric plant on the St. John River immediately above the confluence with the Allagash River as shown on this slide.

Slide 19. The main dam across the St. John River would be of the earth filled type;

Slide 20. With a center of compacted impervious fill—that is to say fill that would repel water seepage;

Slide 21. Compacted pervious fill or compacted earth would make up the bulk of the dam;

Slide 22. To prevent erosion, 2 feet of gravel would face the pervious fill; and to prevent the washing away of gravel, a 4-foot—

Slide 23. Covering of rock would surface the water side of the dam all structural features would be located on the right bank and in general founded on rock.

Slide 24. The dam height would be 925 feet above sea level with ground level at 583 feet above sea level.

Slide 25. The maximum reservoir elevations, indicated above sea level, would be 910 feet.

Slide 26. The minimum elevation, above sea level, 870 feet. This would provide a 40-foot drawdown and still leave the dam operable.

Slide 27. At maximum elevation of 910 feet, the reservoir area would be 88,600 acres and its capacity 8,008,000 acre-feet. At drawdown level of 870 feet, the reservoir area would be 58,500 acres and its capacity 5,180,000 acre-feet. The current engineering study takes into consideration the 3-year drought of 1955 through 1958 and the greatest flood, that of May 1960.

Slide 28. This is a simplified top view of Dickey Dam. The powerhouse is located in the center.

Slide 29. Here we see the flow of water, in red, when water is released for power, or when the overflow chute is used.

Slide 30. Because of the tremendous volume of water when it is released, it will be necessary to relocate the Allagash River Channel by eliminating the loop shown here and allowing the water to glide back into the St. John River. The loop will encompass about 3,000 yards of the Allagash but the straight channel will prevent flooding of the Allagash.

Slide 31. The Dickey site was chosen over the Rankin Rapids site so that the Allagash would be preserved.

Slide 32. This famed canoe waterway should remain as one of the great scenic wilderness routes for all time while Dickey serves the economy of Maine and New England.

Slide 33. The Dickey site is located in Aroostook County.

Slide 34. The Passamaquoddy international tidal powerplant will be constructed in Washington County. Washington County's population declined from 1950 to 1960, while Aroostook County's population increased at a much slower rate in contrast to the national average.

Slide 35. *Economic opportunity has been denied to the youth of both counties—*

Slide 36. With subsequent migration to other cities and States, breaking down the traditional family solidarity characteristic of New England.

Slide 37. Industry has moved to other areas, causing many retail and service establishments to close. High electric costs have been a significant factor in the industrial decline of the area.

Slide 38. Fish canneries have gone out of business.

Slide 39. *Agriculture is uncertain, and the lumber industry fluctuates widely.*

Slide 40. A national sampling conducted by the Federal Government in 1959 shows that a typical family of four needs an annual income of $6,000 a year to maintain a modest but adequate standard of living.

Slide 41. Yet, in Washington County, 34 percent of the families have incomes of less than $3,000.

Slide 42. And, in Aroostook County, over 30 percent of the families earn less than $3,000.

Slide 43. In Washington County, nearly 17 percent of the family units receive public assistance.

Slide 44. On Aroostook County, about 12 percent of the families receive public assistance.

Slide 45. Using this yardstick, one-third of the people of the area live in poverty, as contrasted to a national poverty level of one-fifth.

Slide 46. In 60 years of water resource development the Department of the Interior has learned conclusively that each dollar of Federal water resource investment means that—

Slide 47. *An additional $2 of private business is stimulated. Through on-site* employment, through jobs generated in the manufacturing and transportation of materials and equipment, and through the sustained economic benefit of abundant, relatively low cost power—

Slide 48. Factories reopen and local business thrives.

Slide 49. New employment opportunity is created, a new ray of hope is instilled in people who live now with a mounting sense of despair, and this exit *from poverty gives new opportunity for self-reliant people to advance themselves* to the limits of their capabilities.

Slide 50. What would the Quoddy-Dickey project cost, and what are its power benefits?

Slide 51. Quoddy, $582 million; Dickey Dam, $210.4 million; Lincoln School reregulating dam, $16.6 million; the transmission system, $87 million; a total of $896 million, and, using—

Slide 52. *Reversible axial flow turbines, 50 generators at Quoddy combined* with generation at Dickey can produce the same peaking power benefits that 100 generators could have produced only a year ago—another example of skillful, efficient, and imaginative engineering.

Slide 53. Annual benefits in dollars are as follows: Power, $42.4 million; recreation, $2.3 million; area redevelopment, $2.2 million; total, $46.9 million, as contrasted with annual costs of $31.9 million. How will the project pay for itself?

Slide 54. Power revenues of $19.75 per kilowatt-year for capacity and 3 mills per kilowatt-hour for energy will repay the entire cost of Quoddy and *Dickey, including interest, within 50 years after each power unit becomes* revenue producing—a normal requirement for all Federal water resource development. Equivalent private costs would be:

Slide 55. Fossil fuel, $27.70 for capacity and 3 mills for energy; nuclear fuel, $30.89 for capacity and 188 mills for energy; pumped storage, $25.32 for capacity and 6 mills for energy. Careful and rigorous analysis of all possible alternatives to Quoddy were studied. The conclusions:

Slide 56. Economic analysis alone precludes all privately financed fossil fuel, nuclear or pumped storage projects as an alternative to Quoddy in New England. Realistic private alternatives cannot produce equivalent power at lower costs, ignoring all other resource values of Quoddy. Now—considering only power costs, and other economic alternatives:

Slide 57. Basic legislative authority to construct Federal steamplants does not exist for the U.S. Army Corps of Engineers or the Department of the Interior, although they would be cheaper. But, they could not provide maximum regional benefits as required in Senate Document No. 97—which specifies conditions to be met in all water resource development. Another less expensive alternative is a Federal atomic plant, but—

Slide 58. Legislative history indicates conclusively that Congress does not envision federally financed and federally operated nuclear power projects. Also, a Federal nuclear plant—as well as Federal fossil fuel plant—would have to be operated inefficiently to produce the equivalent, efficient peaking power of Quoddy. A third cheaper alternative would be Federal pumped storage plants in New England. But—

Slide 59. This type of development does not offer—as does Quoddy and Dickey—equivalent benefits in water resource development, in flood control, in outdoor recreation, and in the war against poverty. Pumped storage units—unless they contain a builtin source of abundant, low-cost power, such as Quoddy—use more energy than they create. Finally:

Slide 60. There is no alternative to Passamaquoddy to conserve the ever-wasting energy of the tides and to put this tremendous source of energy to work for man.

Slide 61. In the years ahead, conventional pumped storage and hydroelectric power—and particularly privately owned fossil fuel and nuclear plants—will be absolutely essential.

Slide 62 (projection of Quoddy). But, Quoddy is a first and necessary step toward vitally needed economic rejuvenation in New England [pause] you have seen the Quoddy-Dickey story.

Now—what will it accomplish?

Slide 63 (Allagash shot). It will preserve the Allagash River—whose destruction or flooding would be a national fatality.

Slide 64 (open factory). Its area redevelopment benefits are enormous, and the value of its exodus from poverty immeasurable. Its low-cost power could mark the beginning of a second industrial revolution in New England—the cradle of this Nation's first advance toward economic progress.

Slide 65. Its construction would forge a new link of cooperation between the United States and Canada—creating the possibility of an international electric intertie, like that endorsed recently by President Johnson as "launching a new era of cooperation between private power and public power * * *."

Slide 66 (unlabeled Quoddy). Trillions of tons of water have passed the pilings of Eastport since the day Dexter Cooper, the father of Quoddy, shared a vision with his neighbor, Franklin Delano Roosevelt. France and Russia are moving ahead. And, the waters of Passamaquoddy Bay are still waiting to be put to beneficial use for man.

Silde 67 (no substitute slide). This is a different moon race. One that has more immediate benefit for mankind. One which adds to the sum total of human technology.

The race for the moon has many scientific ramifications, but none so challenging in terms of immediate benefit to man than the harnessing of the everwasting tides. This endeavor will be an important test of our Nation's ability to create a great scientific society.

Slide 68 (growth from intertie). Growth is a never-ending process which ultimately depends upon the use we make of our natural resources, and—

Slide 69 (man from intertie). One measure of the greatest of a society is the energy it holds in its hand. Conservation is the highest form of national thrift. Only by new and imaginative decisions can our Nation prosper.

Slide 70 (powerhouse). The Department of the Interior, a major conservation agency of the Federal Government, is devoted to the principle that expendable resources should be conserved, that renewable resources should be

managed to produce maximum benefits, and that all resources should contribute their full measure to enrich the lives of all Americans—now and in the future.

Slide (Department seal).

Senator MUSKIE. Thank you, Mr. Secretary, and I would like to express my appreciation not only to you but your technicians who produced that excellent presentation. I think it is as good a brief presentation as could be devised for the purpose of indicating in broad brush strokes exactly what it is that we are talking about here and what it is that we are trying to do.

I think it might be useful for the members of the committee—some of whom have had some exposure to this project in years past but most of whom perhaps know it only as a name—to sketch in some of the history of this project since it was first conceived by Dexter Cooper, and as I sketch this out with you, Mr. Secretary, of course, you have Joe Guidry and Morgan Dubrow, and Ken Holum to add to the record.

As I recall, Dexter Cooper first conceived this idea about 1919. Am I correct there? And it was in the 1930's that President Roosevelt undertook to start the project using WPA funds in the early 1930's. At that time, because it was not possible to develop Canadian agreement for use of the international waters, it was decided to proceed with the so-called one-pool plan, built around Cobscook Bay and located entirely within the boundaries of the State of Maine. It was necessary for the President to go to Congress ultimately for authorization of the project in order to proceed beyond the preliminary phases which he found it possible to undertake with WPA funds. Congress never approved it. The feasibility of the project at that time was not established to the satisfaction of the Congress. And so the project apparently died at that time.

It was resurrected for practical purposes by the survey, economic survey, which was authorized in the mid-1950's under legislation introduced by the members of the Maine delegation to which Congressman McIntire has already made reference.

That study was undertaken by the International Joint Commission, and the IJC's report was filed with the President in April of 1961.

Now, this project was based on the two-pool plan which has been described here this morning. The IJC report in 1961 found that the project would not be economically feasible for reasons that are indicated in that report, and that report will be made a part of the record.

(NOTE.—The summary of the "Report of the International Joint Commission," dated April 1961, is published in a separate volume to this hearing record, entitled "Appendix I." The IJC report in its entirety is on file in the office of the Committee on Public Works.)

Senator MUSKIE. That report left open certain posibilities for the project in the future and to study those possibilities, President Kennedy directed the Department of the Interior to undertake the efforts which culminated a year ago in the favorable report.

The favorable report of a year ago was not a final report because there were certain aspects of the project which still had to be studied, particularly the engineering aspects of the project on the upper St. John at Dickey and the powerhouse locations at Passamaquoddy Bay.

So this report today is to fill out those gaps of information and to nail them down.

Now, is that roughly an accurate summary of the history of this project?

Secretary UDALL. I think that this is accurate in every respect so far as we are concerned, Senator. This is a very good thumbnail sketch.

Senator MUSKIE. Now, questions, of course, have been raised about this project over the past year, ever since the favorable report of the Department, and I think it would be useful for the record, Mr. Secretary, if you could give us some indication of the competence of the people who have worked on the report of a year ago and this report.

Secretary UDALL. Well, Senator, we were asked to study it because my Department markets and transmits through our various agencies nearly all of the power generated at Federal dams, most of them, of course, hydroelectric dams. Mr. Dubrow and Mr. Guidry are the top electrical experts in my Department, and I think they are among the top experts in the country. We had the most competent people in the Department work on it. The reason we were asked to get into the picture was that electric power marketing and electric power technology were the question marks that were left from the 1961 report. The truth of the matter is that—just as this Pacific Northwest-Southwest intertie which is now possible and which is moving forward, involving expenditures of nearly three-quarters of a billion dollars in both public and private funds—new developments in technology really have made this now economically feasible whereas the project when Franklin Roosevelt started it 30 years ago, considering the technology available at that time, seriously limited its feasibility.

And, so I think I can say to you that we have had top experts on this team that worked the past 3 years. We also have had experts from the Corps of Engineers, the Atomic Energy Commission, the Federal Power Commission, and other agencies participate in the final studies which further strengthened the economic and engineering feasibility of the project.

I think I can say to you that it has had some of the ablest minds in the Federal Government working on it.

Senator MUSKIE. What experience have the people who have worked on this report had in the building of dams and the operation of power systems, and so on?

Secretary UDALL. The Department's Bureau of Reclamation which for over 60 years has worked to develop the water resources of the western United States made vital contributions.

This agency has built 223 multipurpose dams, 136 diversion dams, 12,160 circuit miles of transmission lines, 50 powerplants with an installed capacity of nearly 7 million kilowatts which generate 29.3 billion kilowatt-hours annually, providing an annual income of $74.3 million.

The Bureau operates one of the Nation's largest engineering centers located in Denver, Colo. The highly trained staff performed the hydrologic studies and computer studies which proved the feasibility of the Passamaquoddy project. The Bureau of Reclamation's technical personnel has given assistance to almost every country in the free world. This Denver Engineering Center is so competent that

engineers from all countries of the free world come there to work for periods of up to a year to be trained in the latest technical developments related to water resource development.

I think I can say to you that these two reports will stand up under the closest scrutiny of any type of experts that the committee might want to consult with regard to their soundness.

Senator MUSKIE. In other words, there has been available during the development of this report, its conclusions, and its recommendations, the professional engineering skills which have been developed in the Department of the Interior, Bureau of Reclamation, and Army Engineers, over the period of their work for several decades, and indeed longer than that.

Secretary UDALL. Yes.

Senator MUSKIE. These are not amateurs who put this report together. These are professionals.

Secretary UDALL. I think as I said before, in our own Department we have put some of our ablest, most experienced people on this.

(Technical biographies of members of the Advisory Board are printed in appendix I. See pp. 149–156.)

Senator MUSKIE. I think at this point I would like to invite my colleagues on the committee to ask such questions as they may have. I know their time is pressing, and they may not be able to stay with us throughout the hearing this morning. The rest of us have been exposed to this project for so long we may not focus on questions that would occur to those who are only recently exposed to it.

Senator Randolph, I know you were a Member of the Congress in the thirties and you developed an interest in Passamaquoddy at that early time.

Senator RANDOLPH. Mr. Chairman, I was exposed to it earlier perhaps than some who sit at this table. It was in the Emergency Relief Appropriation Act of 1935 that the funds were initially appropriated for the carrying forward of at least one stage of this program. Only for the record, I asked to be supplied with the rollcall. That measure passed by—it was a joint resolution—by 329 to 78, and I was one of those that voted "aye," and so I can be identified perhaps with the project from that early period.

As I recall, there were various estimates of money and the way the project should proceed, but finally the Corps of Engineers went forward and some $7 million were spent—I believe my memory is correct on that point.

Now, this background is of no particular value except I use it for purposes of questioning. What was accomplished with that $7 million spent? What is now there from that expenditure which in any way has value as we think in terms of this larger and newer development?

Secretary UDALL. I would like Mr. Dubrow to answer that, Senator.

Mr. DUBROW. Senator, that $7 million which was expended back in the middle thirties was spent to build——

Senator RANDOLPH. That went on until 1936.

Mr. DUBROW. Yes, the Army Engineers went up there and built Quoddy Village. They set up a construction organization, and they actually built one of the dikes which will be a part of the project when it is completed. That dike is still in existence, and it demon-

strated in a small way that this project from an engineering point of view can be built and should be built. It also demonstrates that this dike has withstood the tides for nearly 30 years without any harmful effects.

Senator RANDOLPH. Then the work done then in degrees still has value as an installation which could be incorporated in the proposal now before the committee.

Mr. DUBROW. Yes, sir.

Senator RANDOLPH. Mr. Chairman, I think that would supply me with the one question that I felt was important today, to just evaluate the efforts which had been made and its possible use in the project pending.

Senator MUSKIE. Thank you, Senator Randolph.

Senator Gruening? Senator Gruening is an old "Maniac."

Senator GRUENING. As Senator Muskie knows, I have been interested in this project I think longer than anyone here present, approximately 35 years, and when I was a newspaper editor in Maine, and then subsequently not out of any desire on my part, I became involved in a political controversy on the Hill and proved to be a key witness in the controversy between the late Senator Owen Brewster and a representative of the White House, Mr. Thomas G. Cochran.

I think it is a wonderful project. I hope we proceed with it. I hope we can move just as rapidly as the Federal Government is able to complete its studies and bring it up to the Hill for authorization and appropriations. I look forward to supporting it.

Senator MUSKIE. I think it would be appropriate for the record to indicate that Senator Gruening and I, together with Senator Moss of Utah, spent 30 days together in the Soviet Union 5 years ago looking over their hydroelectric projects, and I think that visit and that exposure to what the Russians have done in advancing the technology of this science in their own country stimulated our interest in the development of hydroelectric projects in this country. I know of Senator Gruening's enthusiasm for Quoddy and welcome it.

Senator GRUENING. And then subsequently, Assistant Secretary Holum visited the Scandinavian countries and saw what magnificent use they made there of hydoelectric power.

Senator MUSKIE. Senator Jordan?

Senator JORDAN. I am sorry I am late; I have had one meeting and started another one 30 minutes ago which I am supposed to be presiding over. I know mighty little about this project. I have read something. I want to know more about it, and I will read this testimony with a great deal of interest because it is a fascinating project to me, and one I want to learn a lot more about. I am sorry I have got to go to this other meeting and leave you but I did want to show my interest by coming by and at least being seen and let you know I am for this project.

Senator MUSKIE. Thank you, Senator Jordan. I appreciate the attendance of all of my colleagues who have come this morning.

Senator Fong, I owe you an apology. I concentrated on this side of the aisle.

Senator FONG. I do not mind. I only know Quoddy by name, but after viewing the documentary and noting your technical studies I hope that you will at the next Congress expand the hearings. I hope

that this project will prove feasible. I hope that the cost-benefit ratio will prove such that we will be able to vote on it favorably.

I feel that this project challenges the imagination, and if it is feasible I will vote for it.

Senator MUSKIE. Thank you, Senator Fong.

I think it is particularly appropriate that we should give some exposure to this project to a Senator who has just embarked upon his senatorial career. At the very outset we want to be sure that this is high on his list of priorities for attention in the next session of the Congress.

Senator Salinger?

Senator SALINGER. Senator Muskie, as you will recall, my interest in this project goes back to a trip that we made along with President Kennedy in a helicopter when we went over the area of the project. I think it was in 1963. And of course, he was interested in the project, and my knowledge of his interest came from almost the time that I started to work for him in 1959, and that interest was so large it has become infectious to those who were around him.

So I have shared that interest and the challenge that is posed by this project and would count myself as a supporter of the project. And I am hopeful that these hearings will develop the information and the background which will enable the Congress to move ahead with this project. I might say to the Secretary also that I do agree very much that this concept, the use of the tides in hydroelectric power, in addition to the desalting of water by atomic methods are two of the most important areas that we are moving into the next 10 years.

So I am happy to have him state that in his statement this morning.

Senator MUSKIE. Thank you, Senator.

I have several more questions I would like to ask, but I think it would be appropriate now to give my colleagues on the Maine congressional delegation an opportunity to ask some questions. I do not know what the pressure on their time is. Congressman McIntire, would you like to ask any questions?

Mr. MCINTIRE. I have some questions, but I will let Congressman Tupper go first.

Mr. TUPPER. Mr. Chairman, I have no questions, but I want to thank you for inviting me to participate at this hearing and commend Secretary Udall for his very fine presentation. I think it is most helpful at this point.

Mr. MCINTIRE. On February 7, each of us of the Maine delegation introduced legislation. My own bill was H.R. 10179. I would draw, and I think appropriately draw, a conclusion that this hearing is related to a report on some technical aspects, and might I ask of the Secretary—this is not in lieu or will this replace or will there be a subsequent legislative report to the Congress in response to the requests which have been made of your Department and others for the usual legislative report?

Secretary UDALL. I think this is a very good question, Congressman, and I think I should review for the record what we consider the posture of this to be.

Our report of a year ago left several very important unanswered questions. For example, the Corps of Engineers embarked on a project to determine whether the Dickey site was a feasible site. They had to core drill it, et cetera. This had to be established.

There were also several other questions raised, that the report itself raised, with regard to the powerplants and the manner in which the projects would be integrated together. So we and the corps undertook parts of the study together. We put a team together to inquire into all of these problems that had been raised by the 1963 report so that we could answer all the major questions.

This new study which has taken us nearly a year to put together has come up with some very interesting changes, as you see. These improve the feasibility of the project. But we are dutybound, of course, to follow the usual procedure on any project, to submit this to the Federal agencies, to submit it to the States for comments. We also intend to submit it to the Canadian Government for information. And when those comments are in later in the fall, we should be able next year, the corps and my Department working together, to put together a final report. We would hope at that time to have the regular legislative report sometime next year available for the committee. But, we still have got to go through the regular process.

Mr. McINTIRE. And this has not constituted a part of the usual legislative report which you will be sending up in response to——

Secretary UDALL. That is correct. This is a regular hearing to bring the committee up to date on our studies at this point. May I add one other thing, because I do not think we should lose sight of this, that is the fact that this project as it is conceived is an international project. Part of the works will be built in Canada and although this is not true so much of the Saint John River phase of it, because almost the entire area is located within the United States, but when you get to the Quoddy project itself, we are going to have to have some kind of agreement reached with the Canadians with regard to this. And I think this new report takes us one step further down the road toward that government.

The only serious question that has been raised that I see in the picture, and I discussed this with some of my Canadian Cabinet counterparts in the spring in Ottawa, is the fact that some of the people in New Brunswick have raised the question as to whether this project would do damage to the fishery resources in the Passamaquoddy Bay region. We have had Don McKernan, the Director of the Bureau of Commercial Fisheries, with his Canadian counterpart, working on this problem.

The result of their investigations appear on page 31 of the report released yesterday. The 1961 IJC report found these would have very little effect on the important sardine fishery and only a minor effect on other fisheries. Although the new report has already been submitted for the record, I would like to quote its conclusions—

> that the previous predictions contained in the IJC report concerning the effect of the project on the fisheries of the area are generally valid.

I do not foresee any insurmountable obstacles to our reaching an understanding with the Canadian Government on this matter.

Mr. McINTIRE. Mr. Chairman, could I make a further inquiry of the Secretary?

Senator MUSKIE. Yes.

Mr. McINTIRE. Have there been to date any formal conferences held with the appropriate Canadian and American officials related to the basis of agreement?

Secretary UDALL. Mr. Dubrow is chairman of the team designated to conduct formal negotiations with the Canadian Government. Conferences were held on a technical level in December of 1963. However, we have not had the type of negotiations that would lead to agreement because we did not feel that we had all the technical data pulled together, and I think this report, for example, on the fishery side of the problem is something we had to have before we could start. I think that the Canadian officials certainly should be encouraged by the additional data we have developed and conclusions developed in this new report.

Mr. MCINTIRE. So it has been a matter, Mr. Secretary, of sort of discussions of technical people with a mutual interest——

Secretary UDALL. Yes.

Mr. MCINTIRE. And there have been no formal discussions as between the two governments on the total aspects of the project.

Secretary UDALL. That is correct.

Mr. MCINTIRE. Mr. Secretary, on page 68 of the report in the discussion of marketing policy—I am not going to take time to go into it, but I think the paragraph, the last paragraph on the page, if you could prepare for us some further detailed memorandum as to what—how this is to be interpreted, I think it would be helpful, because I read this that—

downstream benefits provided by the projects and received in the United States from the Canadian authorities in the form of power and energy shall be received, transmitted and disposed of by the Secretary of the Interior.

There are presently some installations which perhaps would get downstream benefits, and I would be interested in a memorandum to elaborate on how this would relate to some of the existing installations on which there are already agreements between the New Brunswick Power Commission and some of the private utilities for the purchase of power and how this would affect that, at your convenience.

Secretary UDALL. I will be very glad to provide you and the committee with a memorandum on this point.

Mr. MCINTIRE. Thank you.

(The information requested is as follows:)

To date, no negotiations have been entered into between the Canadian Government and the United States regarding any phases of the Passamaquoddy-St. John River project. One technical briefing session was held on December 4 and 5, 1963. The language contained in the report is of a general nature and intended to indicate to whom payment of downstream benefits would be made. No detailed discussions have been held either with the New Brunswick Electric Power Commission or the private utilities in the United States and it is impossible for us at this time to speculate or indicate on how these might be effected by any formal agreement between our two countries.

Senator MUSKIE. Mr. Secretary, I would like to ask this question. What are the essential differences between the project as reported last year and this report?

Secretary UDALL. Well, I want to summarize these because I think this is very important.

The current report contains a number of significant improvements in the design and cost of the project which make for more effective use of the tidal river flow resources for the production of lower cost power. These are the things we have achieved in the last year with this more refined study. The principal changes are these. One, in-

creased dependable capacity output of the Quoddy powerplant by the addition of reversible turbines. This is a very important technological development, thus removing the limitation during extremely low tide by pumping in advance of such conditions.

Furthermore, these reversible pumps make it possible to operate Quoddy to meet peaks of 2 or more hours as needed. Under the earlier plan we were talking about just 1-hour peak. We can enlarge that, enlarge the performance of the plant.

Two, better utilization of the Upper St. John River by improved locations and designs of the Dickey and Lincoln School powerplants for optimum power generation.

Three, proven foundation data, design concepts, and cost data completely assuring the economic and engineering feasibility. These are matters that the corps, of course, has gone into.

Four, economic evaluation on required and exactng standards further testing financial feasibility. We used interest rates of 3 percent, the current cost, rather than the 2⅞ percent which was in the earlier report which was a point that some people raised.

Five, the power costs are lower. For example, capacity charges a year ago were $24 per kilowatt-year. Now they are $19.75. Energy charges a year ago were 4 mills per kilowatt-hour. Now they are 3. This includes the transmission to load centers, 410 miles away.

These charges will completely repay the power resource investment with interest within 50 years after each power unit becomes ready to produce.

So these are some of the more significant improvements.

Senator MUSKIE. I cannot resist asking your reaction to criticism which has been directed at the project within the last week or two by a group of Maine people who called it a boondoggle. I wonder how you would react to that description of it.

Secretary UDALL. Well, I do not think that that helps this committee or helps us form any conclusions on this. I think what we need are engineers, scientists, and economists, economic analysts expressing hard-headed opinions on this. Our reputation is on the line, the reputations of these experts here with me are on the line.

Some of the same people here with me today worked on putting together this Pacific Norhwest-Southwest big electric power intertie. This is the boldest, most ambitious plan for electric power transmission in the history of the country, involving an investment of nearly three-quarters of a billion dollars. There was a great deal of skepticism about this 3 years ago. Whether we should attempt it, whether direct current transmission was engineeringly feasible, et cetera. But, we have the General Electric Co. and other people that are ready to go, and if the Congress acts this week, you are going to see some very exciting things happen.

So trying to be conservative, Senator, I would say that we think that the report we have prepared will stand the closest kind of scrutiny, and we think it certainly will stand any idle charges that anyone wants to make.

Senator MUSKIE. I think it is accurate to say that in all of your public discussions of this project, all the discussions in which your people, including these distinguished gentlemen with you, have been involved, you are concentrating entirely upon the merits of the project.

You have willingly opened yourself to questions directed at the merits of the project. And if those who have questions about it would also concern themselves with the merits of the project rather than with undertaking to describe it with colorful labels, then maybe we could stay on the merits and prove or disprove the feasibility of this project on that basis.

I remember when I visited the Bonneville project for the first time, I think it was in 1958, that I was told then something of the history of that project and how it was described back in the 1930's as a boondoggle producing power that never conceivably could be used in that area. What is the history of the use of Bonneville power?

Secretary UDALL. Well, it was criticized in the 1930's because there were no visible possible users of power of the quantity or magnitude that would be produced from the great dams that were built on the Columbia, Bonneville, and Grand Coulee. I think someone made the famous statement in the Senate, "Who will use the power? Who will buy it, jackrabbits?" There are a lot of jackrabbits in that region. And, of course, what you find if you go there today is the Aluminum Corp. of America, the Boeing Co., and other large industries that are consumers. I cannot help, Senator, but contrast the Northwest region of the United States with the Northeast region of the United States I am not saying this is the only key to growth, but I am saying that low-cost electric power produced at a major Federal project, serving as a yardstick function also, has certainly enhanced the whole economic picture of the Pacific Northwest, and I think that the New England region would equally benefit if we could get a project of this magnitude up there.

Senator MUSKIE. At one place in this report, I noticed that you emphasized the importance of the fact that now with the use of reversible turbines in the pumping operation, it is going to be possible to use the full capacity of the generators at Quoddy during any period when it is required. Would you want to elaborate on that?

Secretary UDALL. I would like Morgan Dubrow, the top engineer on this, to explain the reversible turbine for the committee because Allis-Chalmers and some other companies, the French, and others are working on this. This reversible turbine has just been developed in the last 2 or 3 years, and it is a wonderfully flexible instrument and opens up a whole new potential in terms of electric power generation. You might describe it.

Mr. DUBROW. Well, Senator, this reversible turbine either acts as a generator and a motor. When the water is flowing from the upper pool to the lower pool, it generates electricity. But it is so designed that this same generator can be used as a motor when you feed power into it. You can pump water from the lower pool into the upper pool.

Now, what we would do, and what we intend to do, is to operate Quoddy during offpeak periods and hold water in Dickey Reservoir. This will enable us to have available at all times power from Dickey to operate the reversible turbines at Quoddy.

Now, on 1 or 2 days out of each month you have a real low tide called a neap tide. On this particular day, the generators would not put out 10,000 kilowatts each unless you had a little more head.

Now, during the offpeak period, we would take energy from the Dickey project, operate the reversible turbines at Quoddy as pumps, raise the upper pool just a matter of a foot. Then, when the peak

comes on that evening, as has been projected by the Federal Power Commission as far in the future as 1980, you would have available the maximum capability of every single turbine at Quoddy. You could put all of them on the line and get at least 10,000 kilowatts out of each installed generator, thereby providing 500,000 kilowatts from Quoddy and over a million kilowatts when combined with Dickey.

Senator MUSKIE. Now, do I understand that the net effect of that is, first, to increase the amount of power that is available during those periods? And, second, to lower the cost?

Mr. DUBROW. Well, you lower the cost because all of the capacity is dependable and therefore you can sell all of it instead of a part of it. As a result, you can sell it at a lower cost. That is correct.

Senator MUSKIE. And the effect would seem to be, and I am speaking now as a layman, to redistribute the power from one part of the system and one period of time to another part of the system and another period of time.

Mr. DUBROW. This is correct.

Senator MUSKIE. At minimum cost, indeed, at no net cost.

Mr. DUBROW. That is right. That is correct.

Senator FONG. Mr. Chairman, may I ask the Secretary a question?

Mr. Secretary, would you tell us what point of the study we are at now? How much more study do you have to give to this project? How much more money do you have to carry on what you are doing now so that we have an idea as to where we are on this project?

Secretary UDALL. Senator, I think this is a good question. I think we have reached the point where we are at really the final refining stage. As far as the Corps of Engineers is concerned, I think you will find that most of their studies are completed. I think this report which has just been completed ties most of the remaining loose ends. So I think we are well along. We do not have any big problems ahead of us, and we do have adequate funds to complete the final report.

Senator MUSKIE. There are one or two other questions I have on technical aspects.

I think in the slides of the presentation you discussed this and in the report you discussed it, but it is important enough, I think, to emphasize again.

I am speaking of the question of realistic alternatives. I know you studied that. It was part of your responsibilities to study that. And I would appreciate it, Mr. Dubrow, if you would give us your findings in that respect.

Mr. DUBROW. Well, Senator, as required by Senate Document No. 97, we considered all possible alternatives to Quoddy and Dickey. A Federal nuclear plant would be less expensive. Now, the Congress has made it quite clear that these will be private developments, and they are not in a true sense an alternative to Quoddy. We also considered pump storage, and we found that pump storage, privately financed, was more expensive than Quoddy. We found that thermal steamplants privately financed were more expensive than Quoddy and Dickey. A cheaper alternative would be Federal pumped storage plants in New England, but this type of development does not offer, as does Quoddy and Dickey, equivalent benefits in water resource development, in flood control, in outdoor recreation, and in the war against poverty. We found that an alternative—which would not really develop this resource—but which was cheaper would be a federally

financed steamplant. Certainly up to this point, the Congress has given no indication that they would have the Department of the Interior or U.S. Army Corps of Engineers build a Federal steamplant. So the real answer comes that if you want to develop ths resource, there is no alternative except to get on with the job.

Senator MUSKIE. Is there any substance, Mr. Dubrow, to the allegation that there would be a control problem for getting the generators at Quoddy on the line simultaneously?

Mr. DUBROW. Senator, in the Pacific Northwest, if I may use that as an example, we have a combined private, public, and Federal power system which encompasses some 12 to 15 million kilowatts of hydroelectric generation of which about 50 percent of it is controlled and operated by the U.S. Government. Now, these Government dams have anywhere from 14 to 20 generators in them and they are all integrated and synchronized electronically when they come on the line. They are controlled from one single center and they come on the line automatically. It certainly seems to me that in this age when we can put a satellite in orbit and control it with a computer, we can certainly put 50 or 100 generators at Quoddy on the line when they are needed to meet the loads.

Senator MUSKIE. I think it would also be useful, Mr. Dubrow, if you would discuss the approach to the financing, the general economics, and repayments of the project.

Mr. DUBROW. Well, Senator, in our economic analysis of this project, we use the procedures which are laid down in Senate Document No. 97.

Senator MUSKIE. Is that a part of the record, or is it available to us? We will make it part of the record if it is not too long.

(The procedures in S. Doc. 97 are published in app. I, on pp. 162–176.)

Mr. DUBROW. And this document summarizes the recommendations which were made and adopted by the Senate from the Department of the Interior, Department of Health, Education, and Welfare, Department of the Army, Department of Agriculture, and the Bureau of the Budget in which we established procedures for project formulation. It was determined that since these water reservoir projects will last for at least a hundred years a project would be formulated on a hundred year basis. In formulating Quoddy and Dickey, this procedure has been used, and it is on that basis that the benefit-to-cost ratio is determined. But at the same time, consistent with the long-established policy of the Government, of the executive branch of the Government, we have made certain that the revenues which will be produced from the power features of these projects would repay the Federal investment at 3 percent interest within 50 years after each unit becomes operable. This is consistent with the practice that we use in every project which we built throughout the country.

Senator MUSKIE. Do you expect to have—from the engineering point of view—any problems related to the corrosive effect of salt water?

Mr. DUBROW. Senator, this is one of the things that we gave serious attention to. The Allis-Chalmers Co. and other companies that we talked to, Baldwin-Lima-Hamilton, the Newport News, English Electric, they all assured us that the one-eighth stainless steel plating is specified for these turbines and this would protect them against any corrosive impact of sea water.

Senator MUSKIE. Now, Mr. Dubrow, you have spoken about the long life of this project. Secretary Udall has spoken of it. Now, in projecting your costs over the 100-year period, and 50-year period, have you taken into account the necessity to replace parts and replace equipment?

Mr. DUBROW. Yes, sir; we have, as we do in the case of every project which we present and which we build, allowed in our cost estimates money—based on many, many years of experience of the U.S. Army Corps of Engineers and the Bureau of Reclamation—for operation and maintenance and replacement of parts as becomes necessary.

Senator MUSKIE. And is this related to your estimates of the corrosive effects of the salt water?

Mr. DUBROW. Well, yes. It is related. We have allowed money actually to replace these turbines as it becomes necessary.

Senator MUSKIE. Now, in the discussion of this project that has taken place in various places over the past year, there has been a tendency to overlook the distinction between peaking power and load factor power as it relates to Quoddy and other alternatives. I think it would be useful for the record at this point if you would give us a little discussion of the use of fossil fuel or thermal or nuclear plants in production of peaking power.

Mr. DUBROW. Well, Senator, in this modern day, most utilities throughout the country are buying thermal or nuclear plants in sizes which start at 500,000 kilowatts. Now, these plants are wonderful if they operate at maximum efficiency. And, by that I mean they must operate about 90 to 95 percent of the time.

When they do, and this is what they are designed for, and this is what they are built for, and this is the way they are operated, they do produce low-cost power. For example, the Boston Edison Co.'s new Boston Street station produces power for around somewhere between 6 and 7 mills at 90- to 95-percent load factor. But if you were to operate that plant for 2 hours, the cost of this power from it, when you consider the capital cost, would be 50 or 60 mills, whereas the Quoddy-Dickey combination produces power at about 12 mills overall on the average. The real answer to the question is that as utility systems increase and as we indicated with our slide projection program, as this peak builds up, a project such as Quoddy becomes more and more valuable because peaking power is worth three to four times what load factor power is.

Senator MUSKIE. Is it accurate and fair to say that there is no real substitute for hydroelectric power for peaking purposes?

Mr. DUBROW. Certainly there is no cheaper substitute, Senator. You can use gas turbines. Some of the companies buy them. The cost per kilowatt for the unit is cheap. But it takes as much as 2 to 3 cents a kilowatt-hour for the power that comes out of it. So there is no cheaper substitute for hydroelectric power for peaking.

Senator MUSKIE. As a matter of fact, the development of the pump storage concept is a recognition of the fact that peaking power is needed.

Mr. DUBROW. Precisely. And, Consolidated Edison, as you know, of New York, is trying to install a 1,800,000-kilowatt pump storage plant on the Hudson which they need for peaking. Now, the advantage that Quoddy has over a pump storage is that Quoddy-Dickey

develops and generates 3 billion kilowatt-hours of energy annually whereas a pump storage plant, you have to put 3 kilowatt-hours into it to get 2 back.

Senator MUSKIE. By the very nature of the process it is expensive.

Mr. DUBROW. Yes.

Senator MUSKIE. What is needed to develop a pump storage facility?

Mr. DUBROW. You have to have a source of energy.

Senator MUSKIE. How about terrain?

Mr. DUBROW. Sir?

Senator MUSKIE. How about terrain?

Mr. DUBROW. And you have to have suitable terrain in which you have a substantial difference in elevation, at least 600 to 800 feet to get into anything that is economic.

Senator MUSKIE. In other words, you need a place to store the water that you are going to use to generate power subsequently.

Mr. DUBROW. Right.

Senator MUSKIE. And this is not necessarily available in locations which have use for it.

Mr. DUBROW. Precisely.

Senator MUSKIE. I am sure the report will suggest a great many more questions to a great many more people in the course of the days and weeks ahead, but I have about used up my questions.

Congressman McIntire has another question or two that he would like to ask.

Mr. MCINTIRE. Mr. Dubrow, would you comment on the use of jet engines in a stationary unit.

Mr. DUBROW. Sir?

Mr. MCINTIRE. Will you comment on the use of jet engines and stationary units for peaking power?

Mr. DUBROW. Secretary Holum and I attended a conference in Venice about 2 years ago, I believe, on peaking power, and we found that a great many European countries, particularly Great Britain, are using jet engines for peaking, and they are cheap, but the cost of operating them is prohibitive in time, and the maintenance cost on them is prohibitive in time. They are all right on a small power system where you have a little peak, but if you are going to have, as we will have in this country, a completely integrated power system, the jet engine is just not economic.

Mr. MCINTIRE. Are there any being operated in this country?

Mr. DUBROW. Oh, yes, indeed, but the fuel costs run from 2 to 3 cents a kilowatt-hour.

Mr. HOLUM. I think, Congressman, a very accurate summary of this international conference Mr. Dubrow and I attended on peakloads coverage went to this point, and they recognized that gas turbines were an available source of peakload of electrifying energy but everybody was looking for a cheaper and a better source, and I think we are very fortunate here in the United States, particularly in New England, to have this exciting opportunity available to us to provide peakload generation by using the renewable energy of the tides. There is no question but what there are alternatives, but this is much more desirable and cheaper.

Senator MUSKIE. Could you give us, any of you, an up-to-date report on the status of the LaRance River project in France?

Mr. DUBROW. Senator, when Secretary Holum and I went to this Peaking Power Conference, one of the principal reasons that we went was to go and have a look at this project. We talked to the engineer who had spent some 30 years of his life in making this a reality, and this project, although it is a little bit behind the construction schedule, it is scheduled to go on the line late in 1965. Isn't it, Joe?

Mr. GUIDRY. 1966.

Mr. DUBROW. Or early in 1966.

Mr. HOLUM. I think the visit to LaRance was very, very impressive. I am not a technical person, but obviously the French have found a way to get this energy and are going to get the job done. They have established for their own country and for the world that these techniques do work.

Senator MUSKIE. So the French now have under construction a tidal power project which will be completed in 1965 or beyond.

Mr. DUBROW. Or 1966, which will have an installed capacity of 240,000 kilowatts.

Senator MUSKIE. I think it is an interesting fact that the mixture of hydro and thermal plants in France is about 50–50 which I think would be one of the highest in the world outside of the Scandinavian countries. Would that be true, Mr. Dubrow?

Mr. DUBROW. Well, for a country; yes, sir. That is right. We have a rather unique situation in the Pacific Northwest where we now have 90 percent hydroelectric power, but throughout the United States I think the ratio is something like 80 percent thermal and 20 percent hydro.

Senator MUSKIE. And that ratio indicates the importance of developing our remaining hydro resources if we are to retain a proper mix.

Mr. DUBROW. Well, this is precisely right. As a matter of fact, Senator, Duke Power Co. built a plant down in North Carolina which will have a lower load factor than we are projecting for Quoddy. It has an installed capacity of about 300,000 kilowatts, and it will operate at a 5-percent-or-lower load factor, and this just shows you how important it is to have power available to meet peakloads.

Senator MUSKIE. Up to this point, in the history of the technology, the economics of energy, it has been considered important to have a mix of hydro and thermal plants, is that not so?

Mr. DUBROW. Yes, sir. Precisely.

Senator MUSKIE. There is nothing in the development of that technology to indicate that that would be outmoded.

Mr. DUBROW. No, sir. I think as time goes on, our hydro projects will become more and more valuable and they will become more and more peaking projects.

Senator MUSKIE. This is true for a number of reasons, I think most of which you have stated here this morning in the record, and one reason that appeals to me above all others is that in hydro we are using a renewable rather than a wasting resource.

Mr. DUBROW. That is right, and, of course, with a hydroplant we have complete flexibility and as power systems get bigger, this becomes more and more important.

Senator MUSKIE. Thank you very much, gentleman. You have been most helpful and also interesting.

Secretary UDALL. Thank you, Senator. Hope to see you again soon.
Senator MUSKIE. Thank you.
(Secretary Udall's prepared statement is as follows:)

PREPARED STATEMENT OF SECRETARY OF THE INTERIOR STEWART L. UDALL

It is a pleasure for me to be here today to present our appraisal of the proposed international Passamaquoddy tidal power project, United States and Canada, the proposed Dickey and Lincoln School hydroelectric power developments on the upper St. John River, and the essential backbone transmission system to interconnect these powerplants and to deliver power to the load centers within the marketing area.

Our intensive investigations on this project stem from 1961 when Senator Muskie requested the President to conduct a "careful and vigorous analysis" of the International Joint Commission's Report of April 1961 on the international Passamaquoddy tidal power project and of the upper St. John River project. As we have progressed in this review, the practicability and desirability of harnessing the tides in Passamaquoddy Bay for the generation of electric power to meet the future peak demands of the utility systems in the New England-New Brunswick area has become more and more evident. In addition, we recognize the inherently significant economic values in immediate and sustained recreational and employment opportunities from developing this most important resource which is constantly being wasted to the sea.

In evaluating the potential of Passamaquoddy, it is essential to recognize that *the tide is a perpetual resource, fully predictable and dependable. It is due to* forces which are astronomic in origin and dependent on the relative positions of the earth, the sun, and the moon.

The greatest rise and fall of the tides in the world occurs at the head of the Bay of Fundy on the Nova Scotia coast where tides as high as 40 to 50 feet are observed. The tides at Eastport, Maine, also in the Bay of Fundy and at Passamaquoddy, have a maximum rise and fall of about 26 feet with an average of 18.1 feet.

The plan adopted by the International Passamaquoddy Engineering Board for harnessing the tides of Passamaquoddy Bay and used in our investigations, consists of two pools, one of which is open to the sea through filling gates and the other open to the sea through emptying gates, with a powerplant between the pools. The gates to Passamaquoddy Bay, the high pool, open when the tide rises in the Bay of Fundy and close when the pool fills. Power is generated by releasing water from the high pool to the low pool through the powerhouse. The gates to Cobscook Bay, the low pool, open at low tide when the sea is below the level of the pool, allowing it to empty.

Passamaquoddy Bay has an area of 100 square miles—nearly 1½ times the size of the District of Columbia. It fills and empties with the tides in the Bay of Fundy. Twice in each tidal day of 24 hours and 50 minutes, the water level in this reservoir varies through a long-term average of depth of 18.1 feet with a maximum of 25.7 feet and a minimum of 11.7 feet. Approximately 1 million acre-feet of water, over 300 billion gallons, enter and are discharged from Passamaquoddy Bay during each average tidal rise and fall of 18.1 feet.

From a water supply standpoint, the tidal potential is unlimited and it becomes simply a problem of tidal range to fill Passamaquoddy Bay.

In the case of the river plants, full control of generation is available over long periods of time but the rivers are subject to drought, whereas the tides are not. One basic difference, however, does exist in the tides in that they must be utilized when they occur or else are lost forever. By the plan adopted, the primary operation of the tidal plant would be for peaking power, but substantial *power would also be generated at most other times. This offpeak power generation* will be integrated with the proposed Dickey-Lincoln School developments on the upper St. John River.

The electric power which can be generated utilizing the two-pool system is highly flexible and can be controlled to meet utility load patterns, or for very *short "peaking" periods.*

In the International Joint Commission's plan, the proposed operation was to meet the electric utility load patterns in the local area. Our studies show that Passamaquoddy should be a peaking operation to meet a daily peak of 2 hours.

The proposed operation of Passamaquoddy for peaking power is ideally suited for coordination of the tidal cycle and our 24-hour solar day.

The electric utility systems in the New England-New Brunswick area have characteristically experienced a predominant peak power demand daily and generally from 5 to 6 o'clock in the evening. Since each day two tides occur which are predictable in both time and magnitude, it is possible to select the proper tide so that a full high pool and an empty low pool will be available to permit generation to meet this peak power demand.

The load and resources study prepared by this Department for the marketing area embracing the New England States, eastern New York State, and the Maritime Provinces of Canada, demonstrated the need for economical peaking power sources to meet future power requirements as loads increase and larger baseload units are added to utility systems.

Our studies of available power resources and predictions on future load growth concluded that Passamaquoddy could ultimately be developed as a peaking powerplant in the magnitude of 1 million kilowatts. Quoddy would also produce large amounts of offpeak power. Its operation should be coordinated with the Dickey storage reservoir and powerplant on the upper St. John River in Maine to maximize the power output of both features of the project.

This concept is predicated on (1) the use of low-cost axial flow turbines capable of operation at the low heads available from the tide, and (2) extensive computer studies demonstrating the workability and determining the precise quantities of dependable power which could be obtained and delivered to utility systems in the region.

The substantive investigations and studies accomplished to date in collaboration with the Corps of Engineers, U.S. Army, clearly demonstrate the engineering and economic feasibility of the project.

This report contains the recommendations and conclusions reached by the Passamaquoddy Study Committee and its collaborative studies with the Corps of Engineers, U.S. Army.

As required by the procedures set forth in Senate Document No. 97, the report is being submitted to the interested Federal agencies, to the Governors of the affected States, as well as to the appropriate offices within the Canadian Government, for review and comment. Such comments as are received will be embodied in my final report to President Johnson.

For historical background, I would appreciate your permission to submit the following documents for the record:

1. Summary of the report of the International Joint Commission dated April 1961.
2. Load and resources study dated December 1961.
3. My July 1963 review report on the project.
4. The supplemental report issued yesterday.
5. Department of the Interior news releases associated with these documents.

We are firmly convinced that these collective studies and investigations clearly demonstrate the engineering and economic feasibility of the Passamaquoddy-Dickey project.

This project will provide essential power required for the ever-expanding demand of the New England area by putting to beneficial use a wasting resource of the tides in the flow of the St. John River.

It will provide substantial area redevelopment benefits and national economic benefits consisting of 15,000 man-years of onsite employment for skilled and semiskilled workers, many thousands of additional man-years of employment in the manufacturing and transportation of materials and equipment, and sustained economic benefit derived from the availability of abundant relatively low-cost power, as well as an unparalleled international recreation attraction.

The Department's Passamaquoddy-St. John River Study Committee recommends—

(1) Early authorization of the international Passamaquoddy tidal power project, the upper St. John River developments, and the transmission system, for construction by the United States; and

(2) Early construction of the project to develop low-cost firm power for Maine and peaking power for the remainder of the New England States, combat poverty, develop recreation resources, and utilize the now wasted water resources of Maine.

"The race for the moon has many scientific ramifications, but none so challenging in terms of immediate benefit to man than the harnessing of the ever-wasting tides to generate electricity. This endeavor and the utilization of nuclear energy to desalt the ocean's waters will be important tests of our ability to create a great scientific society."

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Senator MUSKIE. Our next witness, and I apologize for the delay in bringing him to the table, is Secretary StephenAiles of the Army. I understand you have with you the following: Mr. John W. Roche, Engineering Policy and Legislative Branch, Office of the Chief of Engineers; Mr. Wendell E. Johnson, Chief, Engineering Division, Office of the Chief of Engineers; Mr. Fred Thrall, Assistant Chief, Multiple-Use Coordination Branch, Planning Division, Office of the Chief of Engineers; and Mr. John Leslie, Office of the Division Engineer, New England Division, Corps of Engineers.

STATEMENT OF HON. STEPHEN AILES, SECRETARY OF THE ARMY; ACCOMPANIED BY WENDELL E. JOHNSON, CHIEF, ENGINEERING DIVISION, OFFICE OF THE CHIEF OF ENGINEERS; AND JOHN LESLIE, CHIEF, ENGINEERING DIVISION, U.S. ARMY ENGINEER DIVISION, NEW ENGLAND

Secretary AILES. Yes. I have Mr. Wendell Johnson with me this morning and Mr. John Leslie, who is the Chief of Engineering in the New England Division stationed in Boston.

Senator MUSKIE. I want to say that we have enjoyed a long and cooperative relationship with the Army Engineers, and we appreciate that and appreciate the longstanding interest that you have had in this project.

Mr. Secretary, you have a prepared statement, and you may handle it in any way you would like.

Secretary AILES. All right, sir. I might as well read it. It is quite brief.

Mr. Chairman and members of the committee, Secretary Udall has already outlined for you the background and current status of the proposed report on the Passamaquoddy-upper St. John River project. He also mentioned the additional studies that have been carried out cooperatively by the Department of the Interior and the Corps of Engineers since the submission of his original report to President Kennedy in July 1963.

At the time the report of the Secretary of the Interior was presented in July 1963, President Kennedy directed that, to insure full consideration of the proposals, the Interior Department and the Corps of Engineers were to accelerate their work on the remaining studies of the details. In compliance with this directive a work plan was developed jointly by the corps and Interior under which the studies were divided between the agencies on a logical basis that would permit the additional work to be completed in the shortest possible time. It was arranged for the Department of the Interior to make the additional studies necessary to determine the optimum development and its economic justification. The Corps of Engineers would immediately investigate the feasibility of constructing a dam at the Dickey site, and perform that part of the studies necessary to prove out the engineering practicabality of the proposed developments, and to obtain a reliable cost estimate thereof. A joint advisory board comprised of experienced engineers of the Department of the Interior and the Corps of Engineers was also established to guide and assist the two agencies in their studies. The Board, which was later expanded to include representatives of other agencies interested in the developments, has worked

closely with both Interior and the corps and coordinated their efforts throughout the preparation of the additional studies.

I would like to say that both of the gentlemen here with me this morning were members of that advisory board.

The basic layout of the structures for the Passamaquoddy project presented by the Department of Interior is essentially the same as that presented by the International Joint Commission in its report of April 1961, the only significant changes in the tidal project being in the power features and the proposed method of operation. The auxiliary hydropower project, as contemplated for the upper St. John River by the International Joint Commission has been moved, however, to a new site in order to preserve the unique recreation characteristics of the Allagash River.

The engineering studies made by the International Joint Commission were carefully prepared and of the highest quality. Where possible these studies have been used. Our current investigations were primarily concerned with those additional aspects which were not covered in the original report of the International Joint Commission, although cost data were also reviewed and brought up to date. The International Joint Commission report analyzed a tidal project with a total power installation of 300,000 kilowatts, while the report of the Interior Department contemplated larger installations for peaking power purposes with various size installations of up to as much as 1 million kilowatts. Present plans also contemplate the use of recently developed reversible axial-flow generating units instead of the conventional type considered in connection with the International Joint Commission report. Additional foundation explorations and other investigations have been made to determine the practicability of these modifications, the costs thereof, and to obtain the engineering data required to enable the Department of Interior to make economic analyses and determine the optimum installation of the tidal powerplant.

Under the direction of the Division Engineer of the Corps of Engineers' New England Division, soils and foundations, explorations of the proposed Dickey site were begun as soon as possible after the President directive for the supplemental studies. These investigations resulted in the location of a suitable damsite, and layouts and cost estimates of a dam that would preserve the Allagash were undertaken. These studies established that a dam immediately above the mouth of the Allagash is engineeringly feasible and that it can be built at a cost reasonably commensurate with the preliminary estimates made by the Department of Interior.

The engineering studies undertaken by the Department of the Army for this report are complete. They are contained in a supplemental report appended to the report of the Passamaquoddy-St. John River Study Committee which, I understand, you have before you. Everything after the blue page is the Corps of Engineers' report.

I have with me today, as we just said, two of our engineers who participated in developing these supplemental engineering studies. If they, or myself, can assist in explaining the details of our investigations we shall be pleased to do so.

Mr. Chairman, that completes my statement.

Senator MUSKIE. Thank you Mr. Secretary.

Now, may I ask you or the engineers with you whether you are thoroughly satisfied that this project, the Quoddy project, can be built from an engineer's standpoint?

Secretary AILES. I am sure that everyone will state that there is no question but what from the point of view of the engineering problem, this project can be built.

Senator MUSKIE. What are some of the unique engineering problems which you have had to consider, if there are such problems, and I assume there are.

Secretary AILES. I will let Mr. Leslie discuss the building of a dike across the channel with flowing tide where the channel is 300 feet deep. Some problems of that character.

Mr. Leslie, would you like to speak to that?

Mr. LESLIE. This is probably one of the most challenging problems, to build closure dikes across this depth which at one point would be about 330 feet in depth.

We have made extensive investigations to check the foundations underneath this area. We had drill rigs come from Houston, Tex., that are normally engaged in offshore drilling for oil wells, to check on the situation.

The problem of placing the fill is one of tremendous import, and studies were conducted at the University of Minnesota under the now deceased Dr. Lorenz G. Straub[1] who was an international expert on this sort of situation. We feel it can be accomplished as a result of the tests made there, real model tests of placing the fill. As I talked to the Secretary who was with me at Quoddy just recently looking at the site, it will be one that will probably even involve the use of computers because you must face the situation where you may have tides that at times will be as much as 26 feet. You will have velocities in the range of 10 to 12 feet at times, and when the material is dropped by bottom dump scows it will be carried by the flow of the tides. It will have a tendency to drift so that it will be necessary to take the scows and spot them in such locations that the fill will end up where you want it, some 300-odd feet below that.

The locations will be computed and spotted just where you will. It is practical to do this, and we feel it is engineeringly feasible to accomplish what we intend.

Senator MUSKIE. As a matter of fact, is it accurate to say that the judgment of engineers on this point has been pretty well satisfied for a number of years, even predating the International Joint Commission's report?

Mr. LESLIE. Well, I would say so. I think it is challenging, and I do not know of instances where this has been done, but we have talked about its feasibility with, as I say, private consultants, people of stature in the Government, engineers. We have talked to the Navy Department which is familiar with this sort of operation, and they all feel that it is practical and feasible to do.

Senator MUSKIE. With respect to the Dickey site on the upper St. John River, does that pose any unusual or unique or difficult problems?

Mr. LESLIE. No. I see no problems. It will be unusual for the New England area because it will probably be the largest dam ever

[1] The biography of Dr. Straub appears in app. I on p. 154.

built there, but they have been building them for many years in the Far West and Midwest.

Senator MUSKIE. So you have ample experience in dealing with that kind of a problem.

Mr. LESLIE. Yes, sir.

Senator MUSKIE. What is the function of the reregulating dam at Lincoln School which will be located below Dickey?

Mr. LESLIE. Well, the main purpose of it is to regulate releases from Dickey.

When Dickey is used for peaking you will have large discharges of water that if dumped down the stream helter-skelter would cause bank erosion and various things like that. Therefore, Lincoln School would have as one purpose, that we can regulate the stream and put down discharges that are compatible with the stream itself. Second, it has a considerable impact on the downstream plants in Canada. With Lincoln School we can regulate the discharges to be more compatible with the pattern of operation of the reservoirs in Canada. This amplifies and guarantees the amount of water that is in their reservoirs so that they can meet their load requirements as needed.

Senator MUSKIE. So that the reregulating dam has two purposes. One, to even out the flow of the river, and two, to produce supplemental power.

Mr. LESLIE. That is correct.

Mr. MCINTIRE. The first dam which you mentioned, Mr. Leslie, and the Secretary was mentioning, what would be your comment on the criticism that this dam cannot be made tight enough so that loss by flowing through the dam would be appreciable? Can it be made tight enough?

Secretary AILES. Mr. McIntire, are you referring to the dike?

Mr. MCINTIRE. That is right.

Secretary AILES. That 350-foot depth?

Mr. LESLIE. Well, we do not see that it is an insurmountable problem. First of all, this is building a dam similar to what we would build in dry land, except that we are putting it under water. There will be a clay core in the center which is impervious to the flow of water. It will have a clay core, and then pervious material adjacent to it and then a rock blanket to hold it in place, but the core itself will guarantee that it is watertight.

We feel that it can be done as I say; the studies that were done at the University of Minnesota indicate they can be made watertight, and we have also had Dr. Casagrande,[2] probably one of the foremost soil engineers in the world—he feels that it can be made tight.

Mr. JOHNSON. I might add this is a problem that we face almost every day. There is nothing unusual about it. We have many dams of this size and even larger, and in fact, I would say that the problems that now appear to us at the Dickey site are probably less, of a lesser degree than we have at other locations.

Mr. MCINTIRE. I am not referring to the Dickey site. I am interested in putting in a clay core in this dam, all under the water. Now, the normal construction of this type of dam is a dry dam, is it not? And you compact the clay core to make it impervious, but this dike that I was referring to is going to be built under water, and a com-

[2] The biography of Dr. Casagrande appears in app. I on p. 156.

ment that has been directed to me more than once has been, How do you build a dike under water and get it impervious enough to hold the water as you need to hold it in that area? This is my question. I am perfectly familiar with putting a core into a dam when it is a dry dam and you can compact this core and get it impervious, but you are not dealing with that kind of a situation in this dike. We are dealing with it under water all the time.

Mr. JOHNSON. Of course, we do have this problem elsewhere, Mr. Congressman. In the case of many of our cofferdam constructions, for example, where we have to wall off an area and then dump it out, we have to construct these cofferdams under water, and in some of our projects on the Missouri River, we have had to build up the foundation under water first before we proceeded with the construction of the dam. One of the current projects that has received a great deal of attention in the year is the Aswan Dam in Egypt where the dam, the lower part of the dam, and a very massive part of the dam, is being built in the existing Aswan Reservoir under water. So that this is not entirely unprecedented, but it will require some special provisions to insure that we do get a satisfactory project.

Secretary AILES. I think one fact of interest, Mr. Leslie, what did you tell me was the width of that dike at the base, 3,000 feet?

Mr. LESLIE. Yes, 3,000.

Secretary AILES. In other words, that is not a narow shell that is put in there. This is tremendously wide at the bottom which has some connection with the impervious nature of it.

Senator MUSKIE. 3,000 feet, you say, at the base?

Secretary AILES. Yes.

Senator MUSKIE. What is going to be the height of the Dickey dam?

Mr. LESLIE. Of Dickey Dam? It is 340 feet as I recall, Senator.

Senator MUSKIE. Now, with respect to the Quoddy project, there will be, I understand, 90 filling gates and something like 70 emptying gates.

Mr. LESLIE. That is correct.

Senator MUSKIE. Does the construction of these involve any particular difficulties?

Mr. LESLIE. No. Although we have talked about the 300 feet in depth, this is the most dramatic depth. The other areas are much less; we will be in the neighborhood of a hundred feet in some places and in others down to as low as 50 feet. Building in this amount of water is not too bad. We just cofferdam them, pump out the area, and then build them all in the dry. So in the building of the gates there will be no problem at all.

Senator MUSKIE. So your 300-odd-foot problem exists in only one location?

Mr. LESLIE. It occurs in only one place, very providentially a very short stretch of the 7 miles of dike.

Senator MUSKIE. The Almighty has already built part of this dam, in other words.

Mr. LESLIE. He has been on our side, I would say.

Senator MUSKIE. There are going to be some navigation locks in there?

Mr. LESLIE. Yes. There will be four navigation locks in each of the pools of different sizes. As I recall, two of them are about 400 feet long, 60 feet wide, and 21 feet deep for the deeper fishing type of vessel

or cargo boats that will be going through there. Then there will be two smaller locks that are about 95 feet long, 25 feet wide, and 12 feet in depth to take care of the sailing vessels and small pleasure craft that may be going through the area.

Senator MUSKIE. Does the construction of these offer any particular difficulties?

Mr. LESLIE. No. The corps has been building these on the Ohio River and other places for many years, and we have the benefit of this experience.

Senator MUSKIE. Will the construction in any way deal with the fisheries problem that some people fear?

Mr. LESLIE. The reports that we have from the joint fisheries study groups of Canada and the United States are that the effects on fishing will be of minor significance.

Secretary AILES. You do have fishways in some of these places, do you not?

Mr. LESLIE. Yes. There are fishways, incidentally, in the powerhouses so that fish can pass back and forth from the two pools. Of course, also, there are fish ladders provided on the dam at Dickey.

Senator MUSKIE. Now, there will be two powerhouses eventually. What will be the dimensions of these structures?

Mr. LESLIE. I will have to look that up, sir. I am sorry. I do not have it right at my fingertips.

Secretary AILES. They will have 500,000-kilowatt capacity each.

Senator MUSKIE. And each will have 50 turbines, as I understand it?

Secretary AILES. That is right.

Mr. LESLIE. They will be in the neighborhood of 3,500 feet in length.

Senator MUSKIE. Now, does the installation of the axial-flow turbines pose any problems that are more difficult or is it a less difficult problem than the installation of conventional turbines?

Mr. LESLIE. I do not see that they would be particularly difficult. There is a little more difficulty in the alinement of them but I am quite sure we can handle it.

Senator MUSKIE. Would this involve a smaller structure or in any way decrease the cost of the project, the use of the axial-flow turbines as against the conventional?

Mr. LESLIE. The indications are that they are less expensive. Of course, our experience is limited. I think as we have more opportunities to study them, we will find increased savings on them. But the indications are that they will be cheaper. We have found particularly that it does narrow the bay that is required for each of the turbines and generators compared to a standard vertical type. We have been able to shorten the powerhouses because of this.

Senator MUSKIE. Have you had any opportunities at all to study the LaRance River project, Mr. Leslie?

Mr. LESLIE. Well, I have personally visited the LaRance project. In 1960 I was there when they had put in the pilot installation. They had built it in one of the locks on the LaRance River. Similarly Mr. Dubrow visited M. Gibrat, who is the Chief Engineer of Electricity of France, and I have also followed his progress from time to time and communicated with him.

You might be interested to know with respect to one of your earlier questions, Senator, on corrosion, the French had used different types

of steel on one of the impellers to find out which is the best one for salt water corrosion, so we will have the benefit of this in our studies.

Senator MUSKIE. In all of the units they use they are using the axial-flow turbines also, aren't they?

Mr. LESLIE. They have a slightly different one. They have a completely enclosed unit on a straight horizontal axis where the turbine and generator are all enclosed in one unit. We feel the unit considered for Quoddy is a more practical one because we keep all the generators up out of the water, and by the inclination we get better flow patterns. We feel this is an improved version over the one installed at LaRance.

Senator MUSKIE. Are there likely to be any problems connected with the seal between the dry and the wet portions of the turbine?

Mr. LESLIE. I do not see that there should be any, Senator.

Senator MUSKIE. That is a rather conventional problem?

Mr. LESLIE. Yes, sir.

Senator MUSKIE. I think that exhausts our questions for the time being. I wish I knew more about your science so that I could be more informed. I think for our purposes, Mr. Secretary and gentlemen, we have benefited from your testimony this morning, and, Mr. Secretary, we do appreciate your taking the time out of a busy day to come here. And we are particularly grateful for the outstanding cooperation you have given us over the years and on this project in particular.

Secretary AILES. Thank you very much.

Senator MUSKIE. Thank you, sir. The hearing is adjourned.

(Whereupon, at 11 a.m., the committee was adjourned, to reconvene subject to the call of the Chair.)

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MATERIAL ON FILE WITH THE COMMITTEE

Investigation of the international Passamaquoddy tidal power project—Report in three sections: section A—Report of the International Joint Commission, dated April 1961; section B—Report of the Passamaquoddy Engineering Board, dated October 1959; section C—Report of the International Passamaquoddy Fisheries Board, dated October 1959. (Report is on file in the office of the Committee on Public Works, U.S. Senate.)

Investigation of the international Passamaquoddy tidal power project—Report to the International Joint Commission by the International Passamaquoddy Engineering Board, dated October 1959. Contains six volumes, appendixes 1–19 (on file in the office of the Committee on Public Works, U.S. Senate).

International Passamaquoddy Fisheries Board—Report to International Joint Commission, October 1959. Contains report and appendixes I–V (on file in the office of the Committee on Public Works, U.S. Senate).

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