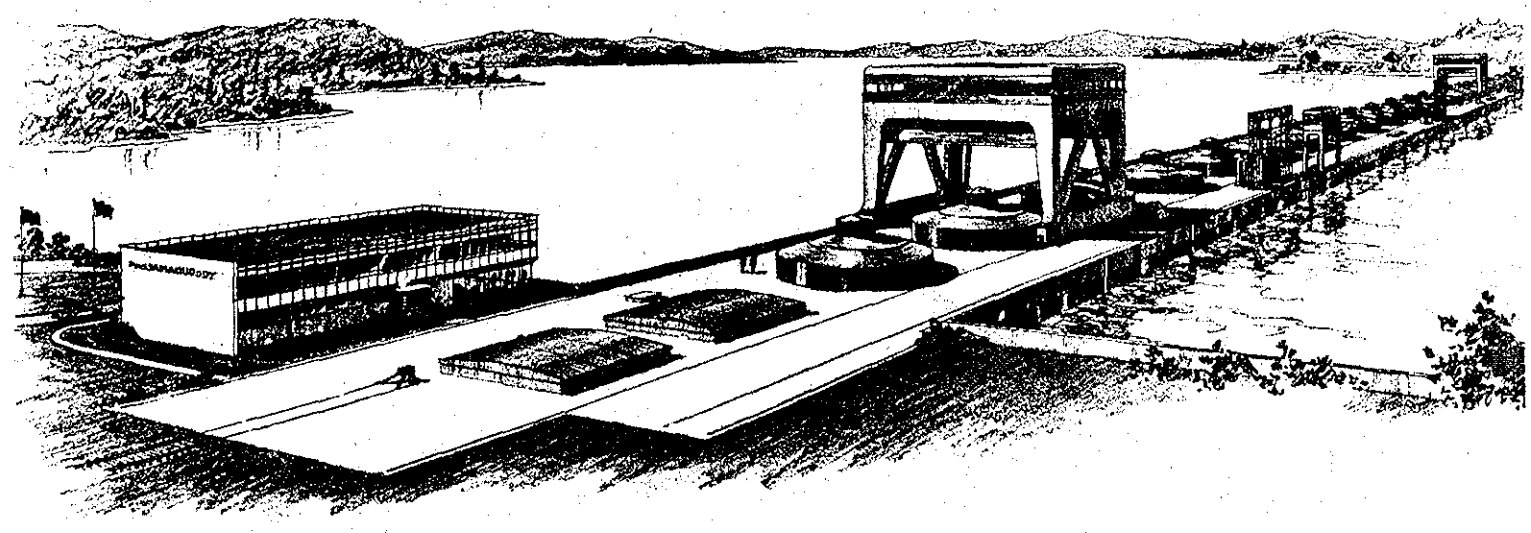
INVESTIGATION OF THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT



APPENDICES

11. Auxiliary Pumped-Storage Developments

12. Auxiliary River Hydro Developments

REPORT TO THE INTERNATIONAL JOINT COMMISSION BY THE INTERNATIONAL PASSAMAQUODDY ENGINEERING BOARD

October 1959

INTERNATIONAL PASSAMAQUODDY
ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT

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REPORT TO

INTERNATIONAL JOINT COMMISSION

ON

INVESTIGATION OF INTERNATIONAL

PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 11

AUXILIARY PUMPED-STORAGE DEVELOPMENTS

BY

INTERNATIONAL PASSAMAQUODDY

ENGINEERING BOARD

OTTAWA, ONTARIO
WASHINGTON, D.C.

OCTOBER 1959

INTERNATIONAL PASSAMAQUODDY
ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 11

AUXILIARY PUMPED-STORAGE DEVELOPMENTS

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cycle would supplement the tidal plant output when it is deficient. Appropriate application, of the pumped-storage function as an auxiliary to the tidal power project, is demonstrated by the plot of tidal plant output and typical load pattern of the area as shown on plate 11-2. The load follows the solar cycle while the tidal plant output follows the lunar cycle, so that one pattern is constantly shifting with respect to the other. The shift in time is equal to the 50-minute greater length of the lunar day compared to the solar day. At times, therefore, peak tidal plant output coincides with periods of minimum demand. In addition, the tidal plant output would vary with the tide range which changes from spring to neap twice a month. A pumped-storage plant would operate to maintain a more uniform output by storing a portion of spring tide energy to supplement the neap tide tidal plant output.

11-04 PRIOR AUXILIARY POWER STUDIES

a. Cooper's Pumped-storage Studies. It was recognized by Dexter P. Cooper in 1928 and by the U.S. Corps of Engineers in 1935 that the varying output of the tidal power plant would not be well suited for use by the normal power market and that some auxiliary power source would be very desirable to modify the tidal plant output. A pumped-storage plant at Haycock Harbor, Maine, south of Gobscook Bay and southwest of Lubec, was considered during the Cooper studies. This site, indicated on plate 11-1, would have a usable storage capacity of about 11 million kw.-hr. for maximum pool level at el. 120 feet mean sea level. The records also indicate, although not specifically stated, that a constant output of 250,000 kw. was considered by Mr. Cooper as the combined production of a 44-unit international tidal power project and the Haycock Harbor pumped-storage plant.

b. U.S. Corps of Engineers 1935 Studies. The Corps of Engineers, in their 1935 studies of the United States single-pool tidal project, also considered a pumped-storage plant located at either Haycock Harbor or near Calais. For Haycock Harbor, a maximum pool at el. 120 was planned with estimated usable storage capacity of 16 million kw.-hr. The generating capacity would have been 60,000 kw. and, with the tidal plant, the load factor would have been 50 percent. For the Calais site, also indicated on plate 11-1, the estimated usable storage capacity at maximum pool el. 198 was 16 million kw.-hr; the generating capacity would have been 60,000 kw.; and the load factor, with the tidal plant, would also have been 50 percent. Comparative cost estimates based on 1935 price levels, without engineering, overhead and contingencies, indicated that the Haycock Harbor development would have cost $21.8 million, while the Calais development would have cost $18 million. Although field data was somewhat less complete for the Calais site, it was concluded that this site offered, in addition to a less costly development, better foundation conditions than at Haycock Harbor.

c. International Passamaquoddy Engineering Board 1950 Studies. The former International Passamaquoddy Engineering Board in their "Report to the International Joint Commission on Scope and Cost of an Investigation of Passamaquoddy Tidal Power Project," dated March 1950, indicated that a site on the Digdeguash River had considerable merit for a pumped-storage plant. The drainage area of the river is in southern New Brunswick and the river enters the northerly part of Passamaquoddy Bay. General location of the Digdeguash site is shown on plate 11-1.

11-05 SELECTION OF SITES FOR DETAILED STUDIES

a. General. Primary consideration for selection of sites for detailed studies is the location of prospective reservoir areas of sufficient size and with sufficient head to develop economical energy and capacity to supplement the tidal power project. For the tidal plant now under consideration, the minimum requirements of the auxiliary pumped-storage plant are considered to be 30 million kw.-hr. of potential energy storage and 228,000 kw. of generating capacity. This is developed in appendix 13, "Project Power." Additional storage would be useful, if obtainable without significant increase in cost. Other considerations indicate the need for a reservoir from which leakage of the salt water would be small and incapable of damaging adjacent properties. Pumped-storage sites investigated by the U.S. Corps of Engineers in 1935 have been reviewed and studies have been made of the Digdeguash site in New Brunswick.

b. Haycock Harbor Site. Review of prior studies indicates that the Haycock Harbor site is one of the two locations in Maine most likely for auxiliary pumped-storage power development. Development of the Haycock Harbor site is possible, but more costly than development of the Calais site. The Haycock Harbor site has poorer foundation conditions, limited sources of embankment materials, and greater possibilities for detrimental leakage of salt water than the Calais site. Because of the lower head, the cost per kilowatt of pump-generator equipment would be greater for the Haycock site which, for the relatively large installation now being considered, would further increase the advantage of the Calais site. For these reasons, Haycock Harbor has not been considered for detailed study during the present survey.

c. Calais Site. In 1935, the Calais site, in Maine, was planned for storage of 16 million kw.-hr. This development was comparable to Haycock Harbor and was adequate for firming up the tidal power output for the single pool scheme then being considered. Additional storage possibilities were recognized but not proposed for the initial development. Since the international tidal power project would require greater storage, further study of the site was undertaken. These indicated that a reservoir with the maximum pool

at el. 201 and a drawdown of 34 feet would provide the required potential energy storage of 30 million kw.-hr. Numerous saddle dams would be required, but no spillway would be needed and care of water during construction would not be a problem. At el. 201, the pool would cover about 6,400 acres of which about 2,500 acres are now in fresh water lakes, and the remainder is in forests and marshes. A few camps and unimproved roads constitute the land improvements in the area.

d. Digdeguash River Basin Site. The most favorable site on the Canadian side of the project is the Digdeguash River site referred to by the International Passamaquoddy Engineering Board in their 1950 report. The site would provide the required energy storage capacity, and an economical site for a dam and the power plant. The reservoir area, dam, and plant site were surveyed by the Aero Service Corporation and plotted to a scale of 1 inch to 400 feet with a 10-foot contour interval. Seven drill holes were put down, in the fall of 1957, to explore dam and power plant foundation conditions. An appraisal of the results of this field work confirmed the early evaluation of the site as a favorable one. About 32.6 million kw.-hr. potential energy could be stored at a maximum pool level of el. 180 with a 40-foot drawdown. The pool area at el. 180 would be 6,600 acres, and the pool would inundate mostly forest lands and some farm land. The town of Elmsville would be inundated, as would about 19 miles of gravel roads. About 40 families and two small cemeteries would require relocation. The town of Rolling Dam near the upstream end of the reservoir would not be affected. These preliminary studies also indicated no significant difference in project cost or desirability when compared with the Calais site.

e. Summary. The preliminary studies of the three sites considered for the auxiliary pumped-storage plant indicated that only the Haycock Harbor site was definitely unsuitable. Accordingly, more detailed studies were undertaken to permit selection between the remaining Calais and Digdeguash sites. These studies are described in the following parts of this report.

11-06 INITIAL STUDIES, DIGDEGUASH SITE

a. Hydrology. Pertinent basic data for the Digdeguash River basin as developed in appendix 4, "Basic Hydrologic Data," is summarized for convenient reference as follows:

(1) The Digdeguash River basin is long and narrow and is surrounded by rolling hills. Most of the area is undeveloped timberland with scattered farms and pasture lands. A map of the area together with a profile of the river is shown on plate 11-3. At McAdam, New Brunswick, near the upstream end of the drainage area, the average annual precipitation is about 42 inches. The

monthly average precipitation ranges from about 3 to 4 inches with the maximum occurring during the late summer or fall months. Extreme temperatures range from about 28° F. below zero in winter to around 90° F. in summer. The river has not been gaged and therefore stream flow has been estimated by the method of drainage area proportions from the records of the Machias River basin at Whitneyville, Maine, with a drainage area of 457 square miles. This basin is located about 40 miles southwest of the Digdeguash River basin and has available flow records for the period 1906-21 and 1930-54.

(2) Drainage area, 176 square miles.

(3) Average annual flow, 364 c.f.s. or 265,000 acre-feet.

(4) Minimum annual flow, 218 c.f.s., or 159,000 acre-feet.

(5) Maximum annual flow, 524 c.f.s., or 382,000 acre-feet.

(6) The flood of September 1954 which was used for evaluating the flood risk during construction (estimated to have a 10 percent chance of occurring during any construction season) has a peak flow rate of 2,920 c.f.s. and a 20-day volume of 38,160 acre-feet.

(7) The three maximum floods of record which occurred during the spring breakup periods of 1920, 1936, and 1954 had estimated peak daily flow rates of 3,890, 3,880, and 4,740 c.f.s. respectively at the dam site. These floods are for the spring breakup periods, and the peak flow rates were increased by 10 percent to account for the smaller size of the Digdeguash basin.

(8) Area and storage capacity at the dam site would be as follows:

El. Ft., m.s.l.	Area in acres	Storage in thousands of acre-feet	Potential energy in millions of kw.-hr. above el. 5 ft., m.s.l.
100	701	8.51	0.60
120	2591	41.43	4.40
140	3715	104.49	12.20
160	5061	192.25	25.60
180	6569	308.54	44.80
200	8840	462.63	75.20

b. Project Layout. The maximum operating level of the Digdeguash reservoir was selected as el. 180 on the basis that the towns of Rolling Dam and Rolling Dam Station at the upstream end of the reservoir would not be affected. At the former, a 180 water level would be slightly above bankfull river stage, and at the latter, it would be about bankfull. Plate 11-4 is a reservoir map of the project. The layout and sections, shown on plates 11-5 and 11-6, were evolved from preliminary studies of a number of sites on the Digdeguash River. These studies indicated that the adopted site, upstream from the falls at the mouth of the Digdeguash River, is best suited for the pumped-storage project. The studies also showed it to be economical to excavate headrace and tailrace channels, as shown on plate 11-5, rather than provide the longer penstocks with surge tanks which would be needed with the greater penstock length. The required rock excavations would be sufficient for a rock-shell, impervious-core dam; this would provide the least costly closure. A spillway would care for floods originating from the drainage area and would be provided with gates for economy. The spillway would be a concrete gravity section founded on rock, and it would discharge into a natural draw which would convey these discharges to the tidewater portion of Digdeguash River.

c. Low Level Channel. As shown on plate 11-4, the tidewater portion of the existing Digdeguash River channel would be used to provide the necessary connecting channel between the dam and its appurtenances and Passamaquoddy Bay which would form the upper pool of the proposed international tidal power project. This channel would convey spillway and turbine discharges from the reservoir to Passamaquoddy Bay and the inflow for the pumping cycle in the opposite direction. The powerhouse would be connected to the existing tidewater channel by means of an excavated channel 272 feet wide on a 10 percent grade, as shown on plates 11-5 and 11-6. Stages at the low-water side of the powerhouse would fluctuate depending on the stage in the upper pool of the tidal power project, turbine releases, and spillway discharge, or the rates at which water would be pumped into the reservoir. The water levels, taken from data developed in appendix 4, "Basic Hydrologic Data," for the tidal pool at el. 6 feet would be as follows:

Normal turbine release 7,840 c.f.s.	el. 6.8
Maximum turbine release 24,400 c.f.s.	el. 9.7
Spillway design discharge 75,000 c.f.s.	el. 21.9
Normal pumping 5,580 c.f.s.	el. 5.6
Maximum pumping 16,300 c.f.s.	el. 1.0

Excavation of the existing channel would reduce the head-losses indicated in the above table and the attendant energy losses in both the pumping and generating cycles. However, a study of the costs involved indicated that this procedure would not be justified.

d. Care of Water During Construction. A relatively small quantity of materials (about 1.2 million cu. yd.) would be required in the main embankment across the Digdeguash River, shown on plate 11-5. The impervious core of the embankment section must be placed in the dry, therefore, facilities must be provided to bypass river flows during the closure period. Maximum river flows normally occur during the snowmelt period in this area with relatively small flow rates prevailing during the remainder of the year, except for occasional rainfall floods which occur during the summer and fall seasons. The closure could be easily accomplished in one construction season, and therefore it is planned that the operation be started after the spring flood and completed before the end of the construction season. A low level diversion tunnel is planned to pass the river flows during the period of construction. A construction season flood, as determined in appendix 4, "Basic Hydrologic Data," with a probability of occurrence of once in 10 years (the September 1954 flood) was used to determine the size of the tunnel. A 12- by 14-foot unlined diversion tunnel with upstream invert at el. 40 was selected on the basis that the upstream rockfill portion of the embankment could be raised to a sufficient level (el. 88) in a reasonable period (28 days) to pass the design flow of 2,920 c.f.s. Time would be available during the remaining construction period, in which the impervious core could be constructed without danger from overtopping. After completion of the embankment, the tunnel intake would be closed with a bulkhead which would permit plugging the tunnel with concrete. Construction would be scheduled so that the spillway would be available for flood flows at the time that the diversion tunnel is closed. No provision is planned for a low level outlet because of the low level (el. 95) of the power intakes and because the fresh water inflow rate is small (average 364 c.f.s.) when compared to the reservoir capacity and to the discharge capacity of the power units.

e. Geology.

(1) General. Investigations of geology, foundation conditions, and construction materials, presented in detail in appendix 2, are summarized herein and in subsequent paragraphs for convenient reference.

(2) Digdeguash River Basin. The Digdeguash River basin includes an area of about 176 square miles in the extreme southwest corner of New Brunswick Province, north of Passamaquoddy Bay. The basin is underlain principally by intrusive igneous rocks and pre-Silurian metamorphosed sediments, with a small segment in the southerly and easterly portions of the area underlain by rhyolite and basalt volcanic flows. The basin is generally mantled by a relatively thin deposit of glacial till. Numerous small lakes and

marshy areas dot the basin, and the drainage pattern is irregular and sluggish.

(3) Reservoir Site. The proposed reservoir area, comprising that portion of the river basin below el. 180, lies within an elongated valley composed of igneous flow and granitic intrusive rocks. A thin mantle of compact, impervious glacial till overlies much of the bedrock, forming the bottom and sides of the reservoir. The existence of numerous ponds and marshes indicates lack of subdrainage and for this reason no appreciable reservoir leakage is anticipated. Three saddle divides occur along the reservoir rim which would require closure to contain the proposed reservoir. Foundation conditions appear satisfactory, and adequate materials are available locally for construction of earth dams at the saddle locations.

(4) Dam Site. The dam site is located in a narrow section of the stream valley, a short distance above the falls where the Digdeguash River empties into the tidal basin. Bedrock on the axis of the dam is basalt. Immediately downstream from the axis there is some rhyolite. Both types of rock are sound and structurally adequate for site development. The bedrock in the vicinity of the dam site is partially mantled by a shallow blanket of glacial till. Subsurface exploration consisting of five drill holes (obtaining 2 1/8-inch-diameter rock cores) was carried out in 1957 at the site. Foundation conditions were found to be favorable for either concrete or earth dam construction. Some minor grouting would be required to seal off the relatively tight fractures and joints existing in the bedrock. The limited exploration which has been accomplished indicates that excavations for structures and channels immediately downstream from the proposed dam would encounter basalt rock underlain by the rhyolite, with some minor inactive faulting.

f. Construction Materials.

(1) Impervious Fill. Sufficient impervious material in the form of glacial till would be available for the impervious core of the main dam and for the saddle dams along the sides of the reservoir basin. The relatively thin mantle of till is found on the valley bottom and on the sides of the valley walls within the reservoir basin.

(2) Random Fill. The structure and channel excavation, in the dam site area and in the saddle dam areas, would supply a mixture of till and rock suitable for the random fill requirements.

(3) Pervious Fill. Pervious material could be obtained from the extensive gravel and sand terrace located along New Brunswick Highway No. 1, about 2 miles east of the Digdeguash River bridge.

(4) Rock for Shell and Riprap. Rock for the shell of dams and for riprap could be obtained from rock excavation at the dam site and from sources close to the saddle dams.

(5) Concrete Aggregates. Basalt and rhyolite rocks from excavations for structures and channels at the dam site are of suitable quality for processing into concrete aggregate. Unlimited quantity of sound rock occurs in the project vicinity which could be used for manufacturing concrete aggregates. Natural fine aggregate could be processed from the terrace deposit cited above.

g. Embankment.

(1) Top Level. The top level of the main dam and the saddle dams, located as shown on plate 11-4, were computed on the basis of a 60 m.p.h. wind from the direction of maximum fetch and assumed to occur when the pool is at the spillway design flood level, el. 184.5, as developed later in paragraph h. The fetches are generally short enough that the maximum wave heights will be reached with winds of about ½-hour duration. Runup would extend 1.5 times the wave height above still pool level on the 1 on 2 side slopes selected for the dams. Setup would not be significant because of the relatively great depth of the reservoir. The following table indicates the computation for the selected top levels of the various embankments:

	Wave ht., feet	Run-up, feet	Max. el. of wave action	Add. free-board, feet	Top level el.
Main dam	2.7	4.0	188.5	1.5	190
West saddle dam 1	3.4	5.1	189.6	1.4	191
East saddle dam 2	2.1	3.2	187.7	5.3	193
East saddle dam 3	3.2	4.8	189.3	5.7	195

Dams 2 and 3 were given a greater freeboard to prevent salt water from the pumped-storage reservoir from contaminating Digdeguash Lake on the other side of the divide.

(2) Cross Section. Impervious-core, rock-shell dams would be used for all closures as shown on plate 11-6. This selection was based on studies which included estimates for a concrete gravity dam at the main closure. The proposed sections would make maximum use of materials available from construction excavation and borrow sources. The exterior slopes of the dam are

designed for stability during construction and at all stages of reservoir level. Design of the transitions between zones of different materials, details of surface protection, and control of seepage would follow standard practice.

h. Spillway.

(1) General. A spillway would be provided for the pumped-storage reservoir to assure safety of the dam and its appurtenances even in the event of the maximum possible flood. A gated spillway as shown on plates 11-5 and 11-6 was selected for maximum economy. The spillway would be located at the right end of the embankment where the rock is of sufficient height to afford a suitable foundation. The spillway could consist of a gated ogee section and a paved chute, as shown on the previously cited plates.

(2) Spillway Design Flood. The maximum possible rainfall over the Digdeguash River drainage area was determined from Hydrometeorological Report No. 33 "Generalized Estimate of Maximum Possible Precipitation over New England and New York," prepared by the U.S. Weather Bureau, Washington, D.C., April 1956. The maximum possible rainfall over the area was applied to the synthetic unit hydrograph, which was developed in appendix 4, "Basic Hydrologic Data," to determine the maximum flow under natural conditions. The spillway design flood was determined by peaking the maximum ordinate of the flood hydrograph 25 percent higher to represent the inflow to a full reservoir. The hydrograph, as shown on plate 11-7, was then reshaped to the new peak ordinate, 108,000 c.f.s., retaining the original runoff volume.

(3) Overflow Dam and Gates. The crest gates for the spillway would be of the tainter type, 25 feet high and 40 feet wide. The top of the gates would be set at el. 180, the maximum normal operating pool level. The spillway crest would thus be at el. 155. Three gates were selected on the basis of the information on plate 11-8, which shows the surcharge which would occur with varying numbers of spillway gates if the spillway design flood would occur with the reservoir full to el. 180. The surcharge for 3 gates would be 4.5 feet, and the spillway design flood pool level el. 184.5. The ogee crest would be shaped for the maximum head, 29.5 feet, for the spillway design flood of 75,000 c.f.s. The spillway was laid out as a gravity structure conforming generally to previous designs. The resulting section was analysed for stability under the most adverse conditions. The piers would be 8 feet thick, making the gross spillway width 136 feet. The gates would be operated by individual hoists driven by electric motors. Stoplog slots would be provided upstream from the tainter gates to permit maintenance of the gates without drawing down the reservoir. Natural ground level upstream from the crest is at

el. 140 or lower. Because this is half the crest design depth or more, no significant reduction in the spillway capacity would result. Accordingly, no approach excavation was planned.

(4) Chute. The toe of the gravity overflow section would be joined to a paved chute by means of a 30-foot radius vertical curve. The paved chute would extend downstream from the toe of the spillway, on an 18 percent slope, for a distance of 150 feet. The flow on this chute would be faster than critical, having a velocity of about 74 feet per second and a depth of about 8.0 feet at the toe for the spillway design flood conditions. This flow would accelerate on the paved chute toward the normal velocity of nearly 89 feet per second and a depth of about 6.2 feet. Computations indicate no significant air entrainment would occur in the paved chute, and wall heights were established as 18 feet (8-foot water depth plus 10-foot freeboard). The above layout of a paved chute with supercritical flow and the unlined outlet channels, also for supercritical flow, and described in the following subparagraph, was selected as the least costly method of providing for the infrequent but high energy spillway releases. The 150-foot paved chute would assure that these velocities and the erosion they might inflict on the following unlined channels would not endanger the gravity overflow section and the pumped-storage project itself.

(5) Discharge Channel. The flow from the paved chute would enter a channel 136 feet wide and approximately 100 feet long excavated in the bedrock of the area. This excavated channel would end in an existing ravine which leads to the tidewater portion of the Digdeguash River channel. Spillway releases, of any substantial quantity, would maintain their supercritical velocities, in both the excavated channel and in the connecting ravine, and would remove the existing mantle of glacial till in the ravine. To avoid the possibility that this glacial till when washed out would obstruct the outlet from the powerhouse to Passamaquoddy Bay, the area downstream from the spillway shown on plate 11-5 would be stripped to rock.

i. Power.

(1) General. Detailed power studies covering operation of the tidal project and the required characteristics of the auxiliary pumped-storage plant are covered in detail in appendix 13, "Project Power." The values given in following subparagraphs are from that appendix and are repeated here for ready reference and as an aid in developing the design of the auxiliary power project.

(2) Energy from Fresh Water Inflow. The average flow of 364 c.f.s. from the 176 square mile drainage area of the Digdeguash River would generate 30 million kw.-hr. a year, on the average, through the proposed pumped-storage plant.

(3) Capacity. The dependable generating capacity which would be provided at the pumped-storage plant to firm the tidal project output to about a 60 percent load factor is 228,000 kw. The excess of tidal plant output over the same load curve is also about 228,000 kw. This would be the power available for use during the pumping cycle. However, it was found necessary to rate the electrical equipment at 260,000 kw. to be able to drive the water wheels as pumps.

(4) Drawdown. The limit of drawdown in Digdeguash pumped-storage reservoir was selected as el. 140 to provide slightly more storage than the minimum requirement of 30 million kw.-hr. of potential energy and a reasonable head range for the pump-turbine operation. The potential energy storage in the reservoir between els. 140 and 180 would be 32 million kw.-hr. (par. 11-06a).

(5) Operating Heads. The operating heads for the Digdeguash pump-turbines were established on the basis of the restrictive effect of the tidewater portion of Digdeguash River, and a duration curve of water levels in Passamaquoddy Bay with the tidal power plant in operation. The following table shows approximate controlling heads for the pump turbine units at Digdeguash Site:

	Operated as pump	Operated as turbine
Max. normal operating level, el.	180	180
Mean pool el.	163	163
Limit of drawdown, el.	140	140
Min. reservoir el. for required capacity	153	153
Max. tailwater (pump forebay), el.	11	9
Mean tailwater, el.	8	5
Min. tailwater (pump forebay), el.	5	2
Max. tailwater (pump forebay), el. for required capacity	10	8
Mean net heads	161	153
Max. net head in feet for operation	176	176
Min. net head in feet for operation	132	128
Min. net head in feet for capacity	152	139

j. Power Intakes. Cost studies of various types of intake systems for the pumped-storage project indicated the concrete lined tunnel, shown on plates 11-5 and 11-6, would provide the least costly means of connecting the power intakes themselves and the exposed penstocks. The approach channel (bottom el. 87) and intake structures were therefore designed to provide minimum cover over the lined tunnel. The intake

would also serve as an outlet during pumping operations, and consequently was laid out as a symmetrically flaring section (plate 11-6) to minimize losses during both pumping and generating cycles. Each of the four power intakes would consist of a concrete structure resting on rock and would be equipped with two 7- by 24-foot wheeled emergency slide gates operated by remote control from the powerhouse. The gates would be designed to close against unbalanced pressures. The trash racks would consist of two 14-foot-wide by 32-foot-high units and would afford a maximum flow velocity of 4 f.p.s. Air vents would be provided to prevent negative pressures in the penstocks in the event that the intake gate were closed in an emergency to stop flow through the units. The major flow area through the trash racks would be more than 20 feet below the level of minimum reservoir drawdown, therefore, no operating troubles are expected from reservoir ice. The principal structural members of the intake were analysed to determine their major dimensions, and the entire structure was analysed for stability. The intake would be serviced by a bridge connecting its east end with high ground, as shown on plate 11-5.

k. Power Tunnels and Penstocks. On the recommendation of the pump-turbine manufacturers, a 20-foot diameter for the tunnels and the penstocks was selected. With this diameter, maximum velocities would be about 18 feet per second. Circular, reinforced-concrete power tunnels through solid rock, about 320 feet long, would connect the power intake to the exposed steel penstocks, as shown on plates 11-5 and 11-6. The average diameter of the tunnel bore was taken as 25 feet, leaving 30 inches for the reinforced concrete lining. The minimum rock cover above the tunnel was laid out to be 1.5 times the tunnel bore diameter. Twenty-foot diameter steel penstocks, about 230 feet long and on about a 60 percent grade, would connect the nearly level power tunnels with the powerhouse. The relatively short length of penstock would make the 400-foot-long tailrace from the powerhouse to the existing channel of the Digdeguash River necessary (plate 11-5). This arrangement was the least costly of many study layouts, because it afforded the shortest practicable penstocks and because material excavated from the tailrace could be used in the main dam. The penstock would vary in thickness from 11/16 inch at the upper end to 15/16 inch at the lower end to provide adequate strength for the maximum surge under maximum head conditions. Massive concrete embedment would be provided at the upper and lower ends of the penstock to offset the hydraulic reaction of the change in flow direction which would occur at these locations. The steel penstocks would be protected to prevent salt water corrosion. No special provisions are planned to reduce freezing except possibly to drain the penstocks when not in use. The flow velocity and length of pipeline to the reservoir are such that adequate speed regulation would result with normal governor speeds and with the normal WR^2 of the generating units. The speed rise in percent of normal speed for full load

thrown off to zero, including the effects of waterhammer, would be 43.7 percent for a governor time of 4 seconds and 46.3 percent for a governor time of 5 seconds. Surge tanks are not planned. Shell thickness of the steel penstock was computed using normal design standards and including the effect of waterhammer.

1. Powerhouse.

(1) General. The powerhouse would be located at the toe of the dam on the left bank of the Digdeguash River as shown on plate 11-5. The powerhouse design for the initial study was carried only to the degree of refinement necessary to make a selection between the Digdeguash and Calais sites as the auxiliary pumped-storage plant. More detailed design of the powerhouse, a study requiring considerable work, was then performed for the selected site as described later in this appendix.

(2) Unit Size. The unit size for the Digdeguash site was determined primarily by the requirement for developing a dependable capacity of 228,000 kw. at a minimum net head of 139 feet. Shipping and manufacturing limitations indicated the maximum practical diameter for the pump-turbine runners is 16 feet. A 4-unit plant was selected on this basis, which would require 15-foot 5-inch-diameter runners. Output characteristics, settings, and dimensions for such units were obtained from a turbine manufacturer. The same speed, 150 r.p.m., would be used for both the pumping and generating cycles. The unit as a turbine would be rated 88,500 hp. at full gate and rated head of 152 feet. The unit operating as a pump at best gate and rated head of 168 feet would require a shaft input of 95,300 hp. Plant and per unit capabilities for pumping and generating cycles at the various heads are listed below:

Pumping cycle (best gate)

Net head	Pump hp. unit input	Motor kw. unit input	Percent of motor nom. rating	Total kw. demand	Total Q
155 ft.	93,600	72,000	112	288,000	19,300 c.f.s.
168 ft.	95,300	73,400	114	294,000	18,200 c.f.s.
178 ft.	96,400	74,200	115	297,000	17,150 c.f.s.

Generating cycle

Net head	Turbine hp. output-full gate	Gen. kw. output full gate	Percent of gen. nom. rating	Total kw. gen. 4 units	Total Q
139 ft.	78,800	57,000	88.4	228,000	22,800 c.f.s.
152 ft.	88,500	64,200	101.0	256,800	23,400 c.f.s.
168 ft.	101,000	73,100	113.0	292,400	23,900 c.f.s.

The unit should be operated as a pump only at best gate, and accordingly the electrical equipment was sized to permit this type of operation at nearly the maximum head which would prevail at the project. The 178-foot head for the pumping cycle in the above table was selected on this basis. The corresponding 74,200 kw. motor input in the above table would be met by a 68,000 kv.-a. unit operating at 15 percent overload and 95 percent power factor. Generating voltage would be 13.8 kv.

(3) Structure.

(a) General. The powerhouse, shown on plates 11-5 and 11-9, would be of the indoor type, with unit spacings of 68 feet and assembly area length of 75 feet. Plant access and assembly area would be at the east end of the plant at el. 20. Tailrace deck level, el. 20, would provide 6 feet of freeboard above the highest tailwater which would result from power generation. Spillway design flood tailwater level would be el. 22. Temporary stoplogs would be installed at structural openings to make the powerhouse watertight to about el. 30. The main power transformers would be located on the tailrace deck.

(b) Water Passages. Pump-turbine settings and water passage dimensions were based on information furnished by turbine manufacturers. Draft tube would be provided with a splitter pier and would have a thin floor slab. Uplift pressure would be relieved by weep holes.

(c) Main Floor. The main floor at el. -2 would provide 5 feet minimum concrete coverage over the steel scroll cases. Generators would be located on concrete barrels at el. 12. Governors and switchboards for main units would be on the main floor between units. The powerhouse walls would be of concrete, 5 feet thick and 63 feet apart, with crane rails at el. 51. This arrangement would provide adequate clearance for erection of generators and transformers. Rotor-handling clearance determined the wall height.

(d) Galleries. The 13.8 kv. switchgear, mechanical equipment, cables, and piping would be located in three longitudinal galleries under the tailrace deck at els. -2, -20 and -38. Draft tube access gallery would be at el. -38.

(e) Tailrace Deck. Power transformers and stoplog gantry crane would be located on the tailrace deck at el. 20. Track rails installed in deck would permit the moving of transformers into assembly bay area. Caster wheels would be provided on the transformers in lieu of a transfer car.

(f) Roof. The roof would be of multiple ply roofing paper on "Q" decking supported by rigid steel bents.

(g) Assembly and Station Service Area. This area would be 75 feet long and located inside the powerhouse walls at east end of plant. The area would have four floor levels, i.e., an assembly and access area at el. 20, office and control room space at el. -2, shop equipment rooms at el. -20, and oil facilities and unwatering system at el. -38.

(4) Pump-turbines and Governors.

(a) Pump-turbines. Units would be of the Francis-type, vertical-shaft, steel spiral case, 150-r.p.m. The turbine rating would be 88,500 hp. with a 152-foot head and at full gate. With the pump rating 95,300 hp. shaft input at 168-foot head. Bore of generator and generator barrel would be sized to permit passage of turbine head cover.

(b) Governors. The governors would be of the 300-p.s.i. oil-pressure, relay-valve, speed-responsive actuator type. Rate of gate movement would be adjustable to any value between 4 and 15 seconds. Governors, pumps, and tanks would be located between units on main floor, el. -2.

(5) Motor-generators. Each of the four units would be rated 68,000-kv.-a., 95 percent power factor, 60° C. temperature rise, class "B" insulation, 13.8 kv., 3-phase, 60-cycle, 150-r.p.m. with direct-connected, shaft-driven exciter and would be capable of continuous operation at 15 percent overload. Units would have normal WR^2, runaway speed, reactances and thrust bearing loading available in standard machines and would be provided with steel housings, air-to-water heat exchangers, carbon dioxide fire protection, magnetic-amplifier or similar type voltage regulators, surge protective equipment, and other normal features. Units would be designated for reduced voltage starting and for reverse rotation when operating as a motor.

(6) Motor-generator to Transformer Connection. Two motor-generator units would be connected by isolated phase bus to each of two main power transformers through generator air circuit breakers. Motor-operated selector switches in the bus runs would provide phase reversal required for motor-pump operation. An isolated phase bus connection for motor starting at reduced voltage would be provided from the midtap of power transformer to generator leads through an air circuit breaker and motor operated selector switch. Above mentioned and associated equipment would be located in switchgear gallery, el. -2, directly under the tailrace deck.

(7) Transformers. Each of the two main power transformers would be 3-phase, 156,400-kv.-a., 13.8/6.9-138-kv., delta-star connected, type FOA and sized to accommodate 115 percent rating of two motors. The 6.9-kv. midtap winding would be for reduced voltage starting of the motors. Transformers and lightning arresters would be located on tailrace deck and connected to switchyard by aerial lines.

(8) Plant Operation. Normal control would be from main control room with provisions for emergency operation at the units. A high degree of automation would be used to reduce operating personnel requirement. Turbine-generator operation would be of conventional nature. Motors would be started at 50 percent rated voltage and brought up to 95 percent synchronous speed, at which time the starting circuit would open and the unit would be connected to the system by the running breaker. Accelerating time would be approximately two minutes. Water would be depressed in draft tube during starting.

(9) Auxiliary Equipment and Systems. The station service electrical supply would be provided by two 1,000-kv.-a. transformers, each connected to a main unit bus through a reactor and circuit breaker. The power plant would be equipped with the conventional auxiliary equipment and systems normally used in a plant of this type. Detail station design for these auxiliary units was not made in this initial comparative study. An estimated value of their cost is, however, included in the cost study comparing the Digdeguash and Calais sites.

m. Switchyard.

(1) General. A 138-kv. switchyard with six outgoing lines would be located downstream from the powerhouse on the west bank of the tailrace channel. Two of these lines would connect to the tidal power plant, two to the pumped-storage plant and the remaining two to the Canadian distribution system. Switchyard operation would be remote-controlled from the powerhouse. A duct bank would be provided between switchyard and powerhouse for all electrical cables, except the high-voltage lines which would be aerial.

(2) Arrangement. Of the 2-breaker, 1½-breaker, and transfer-bus layout considered for the switchyard, the transfer-bus layout was selected as the most favorable. The layout would provide a main bus, transfer bus, bus-tie breaker bay, and a bay for each incoming and outgoing line. Each bay would be provided with an oil circuit breaker and a motor-operated disconnect switch. Manually operated bus sectionalizing switches would be located midway in both the main and the transfer bus to permit plant operation at two voltage levels. Lightning arresters would be provided for each transformer and transmission line.

n. Relocations.

(1) Roads. The reservoir for the Digdeguash pumped-storage plant would inundate a bridge a short distance upstream from the proposed dam, the bridge at Elmsville, the bridge at Rolling Dam, the settlement of Elmsville, and about 19 miles of road, as shown on plate 11-4. The principal road in the vicinity of the pumped-storage plant runs generally parallel to the Digdeguash River from Route 1 near Passamaquoddy Bay and crosses the reservoir area at Elmsville. The relocations would provide a similar road, on each side of the reservoir, which would be gravel surfaced and comparable to the existing road, except that modern standards of grade and alignment would be used where new right-of-way is needed. On the northeast side of the Digdeguash reservoir there would be about 10.2 miles of road relocation and of this length 0.8 mile would be on new right-of-way. On the southwest side of the reservoir approximately 3.7 miles of road relocation would be required, of which 3.3 miles would be on new right-of-way. These road relocations are shown on plate 11-4.

(2) Cemeteries. Two cemeteries, one in the town of Elmsville and the other on the east ridge near the east saddle dams, with a total of 200 graves, would be inundated by the reservoir. The remains in these cemeteries would be moved to a location above the reservoir area, as would the existing monuments. Standard new markers would be provided at the new graves for those bodies without monuments whose identity can be established.

(3) Other. No other relocations would be required.

o. Lands and Damages. Land to el. 180, the maximum normal operating pool level, and as required for the dam and its appurtenances, would be purchased in fee. Included would be 6,560 acres of land, mostly wooded, 41 residences, 51 barns, and 2 churches.

p. Clearing. It is planned that the portion of the reservoir area in the drawdown range, between el. 140 and 180, would be cleared. This would include about 2,840 acres.

q. Access and Service Roads. A heavy duty road about 6,200 feet long would be constructed from Highway 1 to the powerhouse. The road would be used during construction for materials

and equipment and would consist of a 24-foot-wide paved surface and 10-foot unpaved shoulders. Gravel-surfaced roads would be provided to connect the powerhouse to the tailrace area, switchyard, intake, spillway, and the crest of the dam as shown on plate 11-5.

r. Permanent Operating Equipment, Buildings, and Utilities. Permanent operating equipment for the Digdeguash pumped-storage plant would include a work boat, small power launch for the reservoir, three trucks of various sizes, and a sedan. Heavy or infrequently used equipment such as crawler cranes, additional trucks, graders, air compressors, welders, etc., would be transported from the tidal power project when needed. Buildings would include permanent quarters and garaging for personal vehicles for 12 familes of operating personnel, and a combined building for housing equipment, performing limited maintenance, and warehousing. Utilities for these buildings would include streets, sanitary sewers, water, drainage, and electricity.

s. Construction Schedule. A tentative construction schedule for the Digdeguash pumped-storage project is shown on plate 11-10 and is based on the following general considerations.

(1) The project would be completed at the same time as the tidal power project. Thus, with the tidal project construction schedule for a 6-year period, work on the pumped-storage project would be started in the third year of the tidal project construction period.

(2) Excavation for the various phases of the project, as well as the construction of the diversion tunnel, would be commenced in the third season.

(3) The diversion tunnel would be completed by the spring of the fourth year, allowing the stream closure and completion of the dam embankment during that year.

(4) The spillway would be finished during the fourth year to be available to care for the spring runoff of the fifth year.

(5) The first unit of the power plant would be completed at the end of the fifth year and the remaining three units by the fall of the sixth year, at which time the tidal plant would be ready for operation.

t. Estimate of Cost. The following cost estimate was prepared for the sole purpose of selecting between the Digdeguash and Calais sites. The final estimate for the auxiliary pumped-storage plant is contained in appendix 17, "Estimates of Cost." The estimate is based on prices prevailing in January 1958. Costs for the separate items of relocation and construction have been increased by 15 percent to cover contingencies. The total project first cost includes an allowance of about 9 percent of the direct costs for engineering, design, supervision, and administration. Not included is the allowance for interest during construction.

Lands and damages		$ 1,500,000
Relocations		
Roads	$ 269,700	
Cemeteries	57,500	327,200
Dams		
Diversion tunnel	188,400	
Embankment	1,472,700	
Spillway	2,981,700	
Intake	1,425,300	
Tunnels and penstocks	3,298,200	9,366,300
Power plant		
Powerhouse	6,338,000	
Turbines and generators	13,760,100	
Switchyard	2,194,200	
Accessory equipment	3,687,500	
Tailrace	1,262,900	27,242,700
Roads		373,500
Buildings, grounds, and utilities		361,100
Permanent operating equipment		41,700
Total direct cost		39,212,500
Engineering, design, supervision and administration		3,487,500
Total project first cost		42,700,000

The above sum is comparative to that given later in this report for the proposed Calais pumped-storage plant. It does, however, contain costs for residences for permanent operating personnel who would reimburse the project for the use of these quarters. The cost of these quarters, for this reason, should not be included in the cost of power from the tidal plant and pumped-storage combination.

11-07 INITIAL STUDIES, CALAIS SITE

a. Hydrology. As for the Digdeguash site, basic hydrologic data for the Calais site was developed in detail in appendix 4, "Basic Hydrologic Data." Pertinent data is summarized below for ready reference.

(1) The Calais reservoir would drain a small oval shaped area surrounded by hills and ridges. The area is about twice as large as the area which would be occupied by the reservoir itself. The portion of the drainage area not occupied by the reservoir is undeveloped timberland. Temperatures in the area range from about 23° F. below zero in the winter to around 95° F. in the summer. The average monthly precipitation is from 2.5 to 4.5 inches and the total annual average is about 43 inches. Since streams in the area had not been gaged, stream flows were estimated from gaging data available for other basins and from rainfall records. The U.S. Weather Bureau station at Woodland, Maine, located about 9 miles northwest of the drainage area with 39 years of record, was selected for determination of the rainfall volumes. Water losses from land areas were determined from the study of the Machias River basin (30 miles southwest of the Calais reservoir area) from which the hydrologic characteristics of the Digdeguash River were also estimated.

(2) Drainage area, 19.3 square miles.

(3) Average annual flow, 38.2 c.f.s.

(4) Minimum annual flow, 23.9 c.f.s.

(5) Maximum annual flow, 56.9 c.f.s.

(6) Area and storage capacity at the site would be as follows:

El., ft. m.s.l.	Area in acres	Storage in thousands of acre-feet	Potential energy in millions of kw.-hr. above el. 5 ft., m.s.l.
170	3,100	21.0	3.50
180	4,360	58.0	10.10
190	5,425	107.0	19.40
200	6,300	164.5	31.00

b. Project Layout. The general project layout, shown on plate 11-11, is similar to that developed in 1935-36 by the Corps of Engineers, U.S. Army, except that an additional area would be enclosed by the system of dams, and the maximum normal operating level would be raised to el. 201 to secure the minimum energy storage requirement of 30 million kw.-hr. Additional storage does not appear practicable because it would cause a sharp increase in the costs of dams which would range from 10 to 100 feet in height for the currently considered development. The powerhouse and reservoir intake locations are also approximately the same as determined during the earlier Corps of Engineers' study. An examination of topographic maps of the area confirmed the 1935 site selection for these facilities, in that any other powerhouse location would increase the cost of connecting the reservoir with the reservoir intake. Even with the selected layout shown on plate 11-11, a channel flanked by dams on both sides would be required to connect the reservoir with the reservoir intake. A short tailrace would connect the powerhouse with tidewater portion of St. Croix River. This river channel has such a large cross section that the stages at the powerhouse tailrace would be approximately equal to those of the upper pool, Passamaquoddy Bay, of the proposed international tidal power project.

c. Care of Water During Construction. Except for dams 13-A and 14 (plate 11-11), the structures for the Calais project would be located in areas where no conflict with existing waterways would arise during construction. Dam 13-A would cross the outlet from Nashs Lake, which has a very large water surface area compared to its drainage area. Dam 14 would cross the outlet from Howard Lake, which also has a relatively large water surface. A cofferdam could be constructed across these lake outlets in the early summer after snowmelt runoff has receded, and the remaining runoff could be allowed to accumulate in the reservoir. This would permit Dams 13-A and 14 to be constructed in the dry. After they have attained sufficient heights, the cofferdams could be removed, and the dams used to retain the water. The available

storage capacity of the reservoir amounts to about 160 inches of runoff from the total drainage area and would require about 6 years to fill at the average annual runoff rate of about 26.8 inches. Consequently, the possibility that any of the works would be overtopped during the construction period is considered remote. Because the natural runoff is relatively small, and because of the relatively large discharge capacity of pump-turbine plant, no separate low level outlets are planned.

d. Spillway. The need for a spillway for the Calais pumped-storage reservoir was examined by assuming the maximum possible rainfall to occur over the area with the reservoir full to its maximum operating level of el. 201. The maximum probable rainfall over the area was determined from Hydrometeorological Report No. 33, "Generalized Estimate of Maximum Probable Precipitation over New England and New York," prepared by the U.S. Weather Bureau, Washington, D.C., April 1956. An infiltration rate of 0.05 inch per hour for the duration of the storm was adopted in accordance with procedure established for reservoirs in this area. The effect of the maximum probable rainfall on a full reservoir, with zero outflow, is shown in the table below:

Time (hours)	Accumulated rainfall (inches)	Accumulated losses (inches)	Accumulated new inflow (inches)	Reservoir stage (ft., m.s.l.)
0	-	-	-	201.0
6	10.6	0.30	19.3	204.0
12	22.1	0.60	21.5	204.3
24	23.0	1.20	21.8	204.4
48	25.0	2.40	22.6	204.6

Because the surcharge would be only 3.6 feet, no spillway is planned for the reservoir.

e. Geology. Principal dam sites surrounding the proposed reservoir area were investigated by over 50 drill holes in 1935 and 1936. The locations of these explorations and the logs are shown in appendix 2, "Geology, Foundations, and Materials." These sites all appear to be satisfactory for the structures being considered. Overburden consists of glacial deposits which range from a few feet to over 60 feet in thickness. The overburden is either of a sandy or clayey nature and is underlain by granite bedrock. A small amount of settlement might occur in localized areas where the dams would be founded on clay,

and a small amount of blanketing may be necessary in the sandy areas. Leakage from the reservoir would not be a problem in either overburden or bedrock.

f. Construction Materials. Suitable pervious and impervious materials for the proposed dams are available in several local areas which were investigated in 1935. Rock for the outer shell of the dams and for riprap could be obtained from rock excavation for proposed structures or from sources reasonably close to embankment sites. Numerous outcrops of granite within the immediate project vicinity are excellent sources of material for concrete aggregates. Deposits of sands suitable for processing into fine aggregate are located in the general project area but somewhat farther from structure locations than the granite sources.

g. Embankment.

(1) Top Level. The top of the embankment was set at el. 210 to provide 9 feet of freeboard over the maximum normal pool level. Wave heights due to a wind of 60 miles per hour, with a duration long enough to generate the maximum wave, would be 4 feet at the embankment exposed to the longest fetch of 2.5 miles. These waves would ride 6 feet up the 1 on 2 side slope selected for the embankment. If the maximum wave heights were to occur at the time of the spillway design storm, some of the wave action would reach the top of the dam. Wind setup would be negligible.

(2) Cross Section. Earth embankments were selected for the Calais pumped-storage reservoir, because they afforded the least costly methods of accomplishing the several closures involved. Ample quantities of suitable construction materials are available at or near the embankment locations. The cross section for embankments, as shown on Plate 11-12, is predicated on economical use of structure excavation and adjacent borrow materials consisting of glacial till and deposits of sand and gravel. Exterior slopes of embankments are designed for stability during construction and all stages of reservoir level. Design of transitions between zones of different materials, details for surface protection, and control of seepage follow conventional practice.

h. Power.

(1) Energy from Fresh Water Inflow. No additional energy would be available from fresh water inflow to the reservoir since the drainage area is small, the reservoir covers about one-half of the drainage area, and evaporation from the reservoir would nearly equal precipitation.

(2) Capacity. Pumping and generating capacities for a pumped-storage auxiliary to the tidal power project are independent of pumped-storage plant location. Therefore, pumping and generating capacities at the Calais site would be equal (228,000 kw.) to those necessary for the Digdeguash site as outlined in par. 11-06i.

(3) Operating Heads. The operating heads for the Calais pump-turbines were established in part by routings of tidal plant energy in and out of the pumped-storage reservoir as required so that the combined output of the tidal and pumped-storage plants would be similar to the normal load pattern of the area. These data, combined with estimated stages in Passamaquoddy Bay for the various conditions, are summarized in the following table of pump-turbine operating conditions:

	Operated as pump	Operated as turbine
Max. normal operating el.	201	201
Limit of drawdown el.	167	167
Min. reservoir el. for dependable capacity	180	180
Mean reservoir el.	187	187
Max. tailwater (pump forebay) el.	13	12
Min. tailwater (pump forebay) el.	2	2
Max. tailwater (pump forebay) el. for dependable capacity	12	6
Mean tailwater el.	8	6
Mean net head, feet	183	177
Max. net head, feet	202	194
Min. net head, feet	159	151
Min. net head, feet, for dependable capacity	172	170

i. Power Intakes and Penstocks. The power intake would be located at the end of a channel flanked by dams as shown on plate 11-11, and at the edge of the plateau which would be occupied by the reservoir. The intakes which would also serve as the pump discharges are shown on plate 11-12 and would be similar to those planned for the Digdeguash project. Penstocks would be 19 feet 2 inches in diameter, and on a $1\frac{1}{2}$ on 1 slope. Since their length, about 300 feet, would be even shorter than at Digdeguash, surge tanks would not be provided.

j. Powerhouse and Switchyard.

(1) Location. The powerhouse would be located on the right bank of the tidewater portion of St. Croix River as shown on plate 11-11, and at the base of the slope excavated for the

penstocks as shown on plate 11-12. An excavated tailrace about 320 feet long would connect the powerhouse with St. Croix River. It would make possible an economical layout by shortening the penstocks as much as possible.

(2) Unit Size. The plant dependable capacity of 228,000 kw. would be required at the previously described minimum head of 170 feet. This capacity requirement, at full gate opening, and the number of units determined the unit size as for the Digdeguash project. Unit selection and plant and per unit capabilities for pumping and generating were made on the basis previously described for the Digdeguash project and are not described in detail. The considerations lead to a 4-unit plant of the cross section shown on plate 11-12.

(3) Structure and Equipment. The powerhouse structural layout, equipment, and systems would be similar to those previously described for the Digdeguash project, consequently, a further description will not be given.

(4) Switchyard. The most favorable location for the switchyard would be at the south end of the powerhouse, plate 11-12, which precludes the use of aerial connecting lines. "Oil-o-static" type cable, installed in gallery and tunnel, would connect the transformers to the switchyard. Other features are similar to the Digdeguash switchyard.

k. Relocations.

(1) Roads. U.S. Highway No. 1 generally parallels the shore of the St. Croix River in the vicinity of the proposed Calais reservoir and would be cut by the high-level forebay of the pumped-storage plant as indicated on plate 11-11. The relocation would consist of a bridge over the forebay and connecting ramps. No other roads are located in the proposed reservoir area.

(2) Other. The proposed reservoir area does not contain any other public facilities which would require relocation.

l. Lands and Damages. The pool area for the Calais reservoir at the maximum normal operating pool level, el. 201, would be about 6,300 acres. Of this area, 2,500 acres is now covered by lakes, leaving a net area of about 3,800 acres which would be acquired in fee for the project. The land area is wooded or marsh land with very few farm or camp improvements.

m. Clearing. The reservoir would be cleared in the operating range between els. 201 and 167. Involved would be 3,600 acres of land.

n. Access and Service Roads. Access to the pumped-storage plant would be over U.S. Highway No. 1 from Calais, Maine, which is served by a railroad. About ½ mile of heavy duty road would be required to connect the north side of the powerhouse site to the existing highway. Service roads totaling 17 miles would be required to encircle the proposed reservoir and to provide access to the various dams. Of this length, 5 miles would be on the dam crests and the remaining 12 miles would be connecting roads.

o. Permanent Operating Equipment, Buildings, and Utilities. Permanent operating equipment would be held to a minimum, because of the nearness to the tidal power project from where heavy or infrequently used equipment could be borrowed. This assumption was also made for the Digdeguash project. On this basis, permanent operating equipment would consist of a work boat and a small power boat for the reservoir and four vehicles of various sizes. A building would be provided for housing the vehicles, performing routine maintenance on them, and for minor warehousing. Twelve units would be provided for housing the pumped-storage plant operating personnel. Utilities would include streets, sanitary sewers, water, drainage, and electricity. A site for this development has not been developed.

p. Construction Schedule. The construction schedule, shown on plate 11-13, would be tied to that for the proposed tidal power plant, as was the case for the Digdeguash plant, and the pumped-storage plant would be available for operation when tidal plant energy production would begin.

q. Estimate of Cost. The following estimate, as was the preceding estimate for the Digdeguash site, was prepared solely for the purpose of selecting between the two sites under consideration. The final estimate for the auxiliary pumped-storage project is contained in appendix 17, "Estimates of Cost." The following estimate is based on prices prevailing in January 1958. Costs for the separate items of relocation and construction have been increased by 15 percent to cover contingencies. The total project first cost includes an allowance of about 9 percent of the direct costs for engineering, design, supervision, and administration. Not included is the allowance for interest during construction.

Lands and damages		$ 350,000
Relocations		
Roads	$ 120,800	
Bridge	272,600	
		393,400
Dams		
Embankment	8,952,400	
Intake	2,323,200	
Penstocks	1,804,800	
		13,080,400
Power plant		
Powerhouse	5,581,200	
Turbines and generators	11,534,700	
Switchyard	2,237,000	
Accessory equipment	3,213,100	
Tailrace	503,500	
		23,069,500
Roads		492,900
Buildings, grounds, and utilities		361,100
Permanent operating equipment		41,700
Total direct cost		37,789,000
Engineering, design, supervision, and administration		3,411,000
Total project first cost		41,200,000

Included in the above estimate are the costs of the operators' residences. Since these would be self-liquidating, they should not be included in the computation of the cost of power from the proposed tidal power project and its auxiliary.

11-08 SELECTION OF SITE FOR FINAL STUDY

a. Summary of Digdeguash Studies. The Digdeguash site could be developed as an auxiliary pumped-storage plant for the proposed international tidal power plant to develop the required 228,000 kw. of dependable capacity at a cost of $42.7 million. The reservoir storage capacity would be 32.6 million kw.-hr. of potential energy. This would amount to a margin of 2.6 million kw.-hr. more than the minimum requirement of 30 million kw.-hr. The runoff from the 176-square mile drainage area of Digdeguash River would permit generation of 30 million kw.-hr. of energy.

b. Summary of Calais Studies. The Calais site could also be developed as an auxiliary pumped-storage plant to develop the required 228,000 kw. of dependable capacity. The cost would be $41.2 million. The level of development studied has no significant amount of energy storage in excess of the minimum requirement of 30 million kw.-hr. The 2.6 million kw. excess possible at the Digdeguash site might be also developed at the Calais site by raising the dams about 1.5 feet. This would decrease or possibly even offset the slight cost advantage of the Calais site. Because of the very small tributary drainage area, fresh water inflow to the reservoir would not be of sufficient magnitude to permit generation of any significant amount of energy from this source.

c. Selection of Site. The 30 million kw.-hr. of energy which would be available at the Digdeguash site because of the fresh water inflow from the drainage area would have a first-cost value of about $5 million computed roughly on the basis of the first cost per annual tidal plant kilowatt-hour of energy. This value more than offsets any slight cost advantage which the Calais site may have over the Digdeguash site. For this reason, the Digdeguash site was selected for the pumped-storage auxiliary to the proposed international Passamaquoddy tidal power project. Pertinent data for the two sites is given in the following table.

PERTINENT DATA USED FOR SELECTION

OF PUMPED-STORAGE AUXILIARY TO TIDAL PROJECT

	DIGDEGUASH	CALAIS
Reservoir		
Drainage area, sq. mi.	176	19
Average annual runoff, 1,000 ac.-ft.	265	Negligible
Max. reservoir operating el.	180	201
Min. reservoir operating el.	140	167
Usable storage, 1,000 ac.-ft.	204	158
Bus bar energy from storage, million kw.-hr.	28	25.8
Annual energy from fresh water inflow, million kw.-hr.	30	None
Powerhouse		
Number of pump-turbines	4	4
Mean pumping head, ft.	161	183
Mean generating head, ft.	153	177
Dependable capacity, 1,000 kw.	228	228
Annual energy input, million kw.-hr.	400	400
Annual energy output, million kw.-hr. (including energy from fresh water inflow)	316	286
Spillway		
Length, ft.	136	None
No. of tainter gates and size	3 @ 25 ft. x 40 ft.	None
Crest el.	155	None
Spillway design discharge, c.f.s.	75,000	0
Embankments		
Total length, ft.	5,500	23,800
Max. height, ft.	190	100
Project cost	$42,700,000	$41,200,000

11-09 ADDITIONAL STUDIES FOR THE DIGDEGUASH SITE

a. General. Having selected the Digdeguash site as the most suitable for development of a pumped-storage auxiliary to the Passamaquoddy tidal power project, additional detailed studies were undertaken to refine the Digdeguash designs. The estimates of quantity and cost would be of the same accuracy as those for the various other components of the tidal power project. The additional studies were primarily concerned with the detailed design of the powerhouse and included a change in the type of pump-turbine runner; refinements in operating conditions and related equipment characteristics, and consideration of salt water corrosion on project equipment; and a more detailed study of relocations, lands, and damages. Appendix 10, "Service Facilities and Operating Staff," further developed the design of supporting facilities such as buildings, land and marine plant, utilities, and fresh water supply. No change was made in the required dependable capacity for the pumped-storage plant as outlined in paragraph 11-06i(3). Other elements of the project, such as embankment, intake structures, spillway, channel excavation, and control works were adequately developed in the initial studies. It is emphasized that the estimates presented in the previous paragraphs were made solely for the purpose of selecting a site and are not the same as the estimate used for the analyses of economic feasibility of the tidal power project, which are developed in appendix 17, "Estimates of Cost."

b. Pump-turbine Data. The previously described initial studies of the Digdeguash powerhouse were based upon use of a conventional Francis pump-turbine runner, a type which has been used successfully in a number of similar pumped-storage installations. Subsequent to the initial studies, performance curves for a newly developed feathering-blade type of pump-turbine runner were received from a turbine manufacturer. The new runner consists of a number of movable blades, supported within the runner hub somewhat in the manner of a Kaplan turbine, but with the blades sloping downward at about 45 degrees. The scroll case is set well above the runner to give a converging flow path, diagonal with respect to the axis of rotation, but axial with respect to the blades. The flow pattern is similar to that for a mixed-flow pump. The blades may be fully feathered, so as to virtually close the discharge throat, and with minor modifications the closure can be made sufficiently tight to permit elimination of the wicket gates. The overlap necessary for this closure prevents further feathering, which would permit the changeover from generating to pumping or vice versa, without reversing the direction of unit rotation. For this reason, the changeover requires reversing the rotation just as with the conventional pump-turbine runner.

The manufacturer furnished performance data for units both with and without wicket gates. These curves indicated that either type would operate efficiently over a greater range of heads than the more conventional Francis units. Efficiencies for the units varied slightly for different heads and functions, i.e., pumping or generating, but the conventional Francis-type, pump-turbine runner showed a slightly better overall efficiency at best gate and mean head. In addition the feathering-blade units operate at 100 r.p.m. rather than the 150 r.p.m. of the conventional unit, which in turn requires a large diameter, more expensive, motor-generator unit. The feathering feature would permit starting the unit on the pumping cycle without the need for evacuating the water from the draft tube, thereby eliminating an expensive compressor or blower system. It was concluded after consideration of all the various factors that the conventional Francis-type, pump-turbine runner and the feathering-blade, pump-turbine runner without associated wicket gates were about equal on a cost basis. The greater flexibility of operation of the latter unit justified making the final study on the basis of the feathering-blade unit.

c. Powerhouse Structure.

(1) General. The powerhouse, shown on plates 11-14 through 11-18, would be a standard indoor type plant of massive concrete construction. The powerhouse would be 379 feet long by 107 feet wide including the tailrace deck, and would be approximately 59 feet high above this deck. The main superstructure, which would measure approximately 379 feet long by 69 feet wide outside, would be divided into four main unit bays, 74 feet long by 59 feet wide inside, and one station service bay, 83 feet long, at the eastern end of the plant. Access to the powerhouse would be provided by a service road which would lead to the tailrace deck and the station service-bay erection area at el. 19. A single 365-ton, double-trolley, bridge crane would serve the main unit bays and erection area. The tailrace deck, adjacent to the main powerhouse downstream wall, would be utilized for a structure approximately 288 feet long by 22 feet wide and 20 feet high which would incorporate the two main transformer vaults and various shop and office spaces. The remaining 16 feet of tailrace deck, downstream from the deckhouse structure, would provide operating space for the 18-ton, draft-tube gantry crane. The gantry tracks, which would have an 8-foot gage, would also provide for transfer of the main power transformers into the erection area for overhaul.

(2) Substructure. The substructure of the main part of the powerhouse, plates 11-14 through 11-18, would consist of four individual blocks, separated by straight-through contraction joints. The blocks would rest on excavated rock and would extend

up to the level of the main deck at el. 14, inside the powerhouse, and el. 19 on the tailrace deck. The following criteria was used in determining the principal dimensions and elevations for the substructure.

Maximum normal operating tailwater, el.	14
Spillway design flood tailwater, el.	22.4
Minimum concrete coverage over scroll case, ft.	5
Generator housing diameter, ft.	42.6
Turbine discharge diameter, ft.	15.5
Scroll case inlet diameter, ft.	20.0
Maximum scroll case width, ft.	55.0
Turbine runner centerline, el.	-20.0
Draft tube, lowest point, el.	-50.5
Draft tube, exit width (minimum) ft.	54.0
Draft tube, exit height (minimum) ft.	16.0
Draft tube, center pier thickness, ft.	6.0
Draft tube, side pier thickness, ft.	7.0
Draft tube, pitch	1:6
Draft tube, length (minimum) ft.	61.5

The principal dimensions for the pump-turbine and scroll case were furnished by the manufacturer of the feathering-blade pump-turbine. Although the elevation of the runner centerline is unchanged from the setting for a conventional Francis-type runner, the lower speed permits a shallower draft tube. At the same time the diagonal flow arrangement of the unit causes the centerline of the scroll case to be considerably higher. As a result, the vertical dimensions of the powerhouse substructure would be about the same for either type of pump-turbine, but the entire substructure would be set about 10 feet higher for the feathering-blade unit, reducing excavation. The bottom of the draft tube would be at el. -50.5. The main generator deck would be at el. 14 to provide the specified minimum cover over the scroll case, but the draft-tube deck would be at el. 19 feet to provide 5 feet of freeboard above maximum normal operating tailwater.

The main-unit bay length would be 74 feet, with the unit centerline offset 3 feet from the block centerline. The draft tube downstream of the elbow would be oriented so its centerline at the exit would coincide with the centerline of the monolith. The selected length of the bay would provide a minimum of 8 feet outside of the scroll case, which would provide sufficient space between first pour concrete and the scroll case for erection work.

The service-bay substructure, plates 11-14 through 11-18, would be somewhat greater in area than a main-unit bay, but it would also be shallower. The service bay would be 83 feet long by 95 feet wide, extending down to el. -26 for most of the floor area. The drainage and unwatering sump block would extend further downward to el. -57 but would be only about 32 feet by 22 feet in area. The top of the service-bay substructure would be at el. 19 in the erection area. This elevation would be flush with the tailrace deck and road, for ease of access.

The draft tube deck width of 38 feet 4 inches would provide space for transformer vaults and deckhouse structure as well as for the draft tube gantry. It would not be necessary to increase the deck width to meet the requirements for minimum length of draft tube.

Longitudinal galleries would be provided under the draft tube deck at els. -2.5, -14, and -26. These galleries would extend the full length of the powerhouse and would serve for equipment housing and access.

(3) Superstructure. The powerhouse superstructure, plate 11-14, would be of concrete construction and would extend over the four main unit bays and the station service bay. The inside width of the bay would be 59 feet in order to provide required clearances for the generator air housing. The generator dimensions were taken from the dimensions of the units in the Chief Joseph powerhouse on the Columbia River which are very nearly the same as the units proposed for Digdeguash. The unit centerline would be 30 feet from the downstream wall in order to secure the required clearances between the first stage concrete and scroll case installations. The upstream wall would be 29 feet from the unit centerline which would permit a 7 3/4-foot passage at the most restricted location.

The longitudinal superstructure walls would be 5 feet thick to the level of the crane rail corbel, at el. 57 feet, with rigid frame steel bents and concrete nonload bearing walls above. The end walls would be concrete 3 feet thick carried to roof height. The roof would be a 5-ply tar and gravel covering on a rigid insulating plank and would be supported on tubular-steel

truss joists. The crane rails would be 43 feet above the generator room deck; the height was determined by clearance requirements as shown on plate 11-14.

(4) Generator Room. The generator room, plates 11-14 and 11-15, would comprise the four main unit bays with the floor at el. 14 feet. In addition to the motor-generators the room would contain governors, unit control boards, power distribution boards, and the generator protection carbon dioxide equipment. The generators, 42 feet 6 inches in diameter, would be set at floor height, with the top of the housing at el. 25 and top of exciter at el. 37. Access to the top of the housing would be by means of a short, steel stairway from generator-room floor level. Access to the turbine pit would also be provided at each unit, as well as a stairwell to the breaker gallery at el. -2.5 between units 2 and 3 as shown on plate 11-16. The area between unit 4 and the higher level erection area (plate 11-15) would serve as a transformer untanking area. Two short stairways, one adjacent to both the upstream and the downstream walls, would serve for access from the generator floor at el. 14 to the erection area at el. 19 as shown on plate 11-15. Similar stairways would be provided along the downstream wall for access to the various control and service rooms located in the deckhouse structure at el. 19. The entire area of the generator room would be accessible to the overhead cranes.

(5) Erection and Service Areas. Service areas would be located on four levels of the station service bay, with some additional space provided on the tailrace deck of the deckhouse structure. The topmost level, el. 19, of the station service bay, plate 11-15, would serve for rotor erection and similar work. The area would be contiguous to the generator room, but at a slightly higher level. Access to the erection area, from the exterior, would be through an 18-foot-wide rollup door, high enough to admit a fully assembled, main-power transformer. A set of 8-foot-gage rails, set flush in the floor, would permit bringing the transformer under the bridge crane. A 12½- by 15-foot hatchway would permit transfer of equipment to lower levels using the bridge crane auxiliary hook. An additional equipment access would be provided to the lower levels by a 4- by 29-foot hatchway on the draft tube deck located so equipment may be hoisted by the draft-tube gantry crane. This space would also serve as storage for stoplogs.

At the -2.5-foot level, as shown on plate 11-16, the portion directly below the erection area would contain a 2,800 square foot maintenance shop and tool room; a shower and locker room with facilities for 12 persons, the normal day shift complement; a small first aid room; and a 564-square foot room for the carbon dioxide protection system for the oil storage rooms. The portion

of this level downstream of the powerhouse wall line and beneath the draft tube deck would be separated by a 5-foot concrete wall and would be essentially an extension of the switchgear and cable gallery. A 40-foot space, at the end of this gallery, would be walled off to form an enclosed battery room with approximately 920 square feet of area. Space adjacent to the battery room would be provided for the two motor-generator, battery-charger sets, an auxiliary power board, and a battery switchboard.

The -17-foot level, as shown on plate 11-17, would contain a 40- by 58-foot oil-storage room, with a depressed floor at el. -20.5 to contain spillage; a 21- by 40-foot room for oil-purification equipment; a room 18 by 80 feet forming the main access area and hallway, one end of which would provide space for the four unwatering and drainage pump motors and controls. Downstream of this area, under the draft-tube deck, the service area would form an extension of the el. -14 pump and piping gallery, but at el. -17. Approximately 800 square feet would be reserved for the water treatment room and 950 square feet for the compressor area. Access to the water treatment room would be from the general area, and to the compressor area from either the general area or the piping gallery. The lowest level of the service bay, el. -26 and -31, would be greatly reduced in area, as shown on plate 11-18. Approximately 960 square feet at el. -26, would serve as equipment handling area for the heat-exchanger gallery, to permit hoisting through the 4- by 29-foot tailrace hatchway. The remainder of the area, approximately 400 square feet, would provide access to the top of the unwatering and drainage sump and space for the sewage pumps. Access would be solely from the galleries by means of the stairway in unit bay number 4. At the three uppermost levels, additional access would be provided by a stairwell at the extreme end of the plant, near the downstream powerhouse wall.

Additional space for service areas would be provided in the deckhouse structure on the tailrace deck, plate 11-15. Approximately 97 feet on the easterly end would be reserved for office space and ventilation equipment. The ventilation room would be 21 feet wide by 62 feet long and 16 feet high. Space would be provided for three offices, storage space, and a washroom. The exterior walls of the deckhouse would be of concrete, 12 inches thick, with a similar partition 8 inches thick, between the ventilation room and the office area. Access would be through the powerhouse.

(6) Galleries. The main equipment galleries, plate 11-14, would be located on the downstream side of the powerhouse beneath the tailrace deck, at el. -2.5, -14, and -26, extending the full length of the four main unit bays and the station service bay. The drainage gallery, at el. -29, would be located

just downstream of the draft tubes and would be shorter than the other galleries by half a bay length on the No. 1 unit bay end. Access between the various main gallery levels would be by means of stairwells at unit bays 2 and 4. Passages would be provided at each bay for access to the drainage gallery from the gallery at el. -26.

The main gallery at el. -2.5, as shown on plate 11-16, would provide space for the main unit switchgear, protective equipment and cable trays. As shown on plate 11-17, the next lower gallery, el. -14, would provide space for pumps, piping, and access to the scroll case. The lowest main gallery, at el. -26, would provide space for the generator cooling system heat exchangers and related piping as shown on plate 11-18.

(7) Control Room. The control room, plate 11-15, would be located near the center of the deckhouse structure on the tailrace deck downstream of the generator room, between units 2 and 3. The room would be approximately 69 feet long, 21 feet wide and 12 feet high to the suspended ceiling. The roof would be 4 feet above the suspended ceiling, at el. 35, but the exterior parapet would be carried to el. 39, to match the top line of the adjacent transformer vaults. The major portion of the control room area would be assigned to control equipment, but about 12 feet of the westerly end would be assigned as office and washroom space. The exterior walls would be of concrete, 12 inches thick, with no external openings. Access to the room would be through a door into the generator room.

(8) Transformer Vaults. The space in the deckhouse structure not occupied by the control room, office space or ventilating equipment room, would be occupied by the main power transformers and station service transformers as shown on plates 11-14 and 11-15. The two main power transformers would each occupy an open front vault approximately 39 feet 6 inches wide by 21 feet deep and 20 feet high. One main transformer vault would be located about midway between the main units 1 and 2 and the other would be similarly located between main units 3 and 4. Adjacent to each main transformer vault would be a smaller enclosed vault, about 19 feet by 21 feet, which would serve to house the station service transformers and switchgear.

(9) Trashracks and Stoplogs. As shown on plate 11-14, the draft tubes for the pump-turbines would be provided with guides for stoplogs in the manner conventionally used with turbines. As with conventional turbines, stoplogs would be inserted in these guides to permit unwatering the units for repair and maintenance. Two sets of stoplogs, of welded steel construction, would be provided as permanent operating equipment. Two additional temporary sets of stoplogs, which could be of reinforced concrete, would be provided for the construction period to permit inundating the

tailrace without filling the draft tube. During normal operation of the pump-turbines, trashracks would be inserted in these slots to protect the units from trash which might enter during the pumping cycle. The use of one set of guides for both stoplogs and trashracks follows the practice adopted for the Hiwassee pumped-storage unit of the Tennessee Valley Authority, United States.

(10) Structural and Architectural Considerations. The layout of the powerhouse was made using as guides existing designs of powerhouses of approximately the same proportions and the powerhouse designs prepared for the Rankin Rapids auxiliary to the proposed international tidal power project. No structural analyses were considered necessary to establish the cost of the powerhouse within the required limits of accuracy. As was the case for the Rankin Rapids powerhouse, utility would be the primary consideration in determining the interior treatment for the Digdeguash plant. Accordingly, the treatment for the pumped-storage plant would be the same as indicated in appendix 12, "Auxiliary River Hydro Developments."

d. Selection of Main Generating Units. The basic criteria that the pumped-storage plant be able to furnish 228,000 kw. of dependable generating capacity at 139-foot minimum net head remained unchanged from the initial studies. On this basis, it would also be possible to use essentially the same electrical rating for the motor-generator as had been selected in the initial studies. While such a rating would not permit utilization of all of the pumping units' capabilities at the highest heads, the total energy loss because of this would be very small. On the other hand, such a selection would keep the power demand upon the system, as well as the size of associated equipment, within reasonable limits and was retained. The plant and unit capabilities for both pumping and generating cycles would then be as follows:

Pumping cycle (best blade setting except as noted)

Net head	Pump hp. unit input	Motor kw. unit input	Percent of motor nominal rating	Total kw. demand
133 ft.	80,000	61,500	95	246,000
161 ft.	95,000	73,100	113	292,400
180 ft.	97,000*	74,600*	115	298,400

* Less than best blade setting: limited by motor overload rating

Motor unit rating: 100 r.p.m.

Nominal (nameplate), 60°C. rise, 84,300 hp., 13.8 kv., 0.95 P.F.
115 percent nominal rating, 80°C. rise, 97,000 hp., 13.8 kv., 0.95 P.F.

Generating cycle (Maximum power setting, except as noted)

Net head	Turbine hp. unit output	Generator kw. unit output	Percent generator nominal rating	Total kw. output
139	78,800	57,000	89	228,000
153	91,000	65,800	102	263,200
174	110,000	79,600*	123*	318,400*
174	100,000	72,400**	111.5**	289,600**

* Beyond generator overload rating.

** At best blade setting.

Generator unit rating: 100 r.p.m.

Nominal (nameplate) rating, 60°C. rise, 68,300 kv.-a., 13.8 kv., 0.95 P.F.

115 percent nominal rating, 80°C. rise, 78,500 kv.-a., 13.8 kv., 0.95 P.F.

When the unit is operated as a turbine, operation would be at the best blade setting whenever possible in order to obtain maximum water economy. It would be necessary, however, to operate at full blade angle to secure the specified dependable capacity at minimum net head. Similarly, when the unit is operated as a pump, it would be operated at the best blade angle as much as practicable. At maximum net head, however, this would result in loading the motor beyond its specified 115 percent overload rating, so it would be necessary to use a blade setting requiring less power. Discharge and efficiency would be less than at the blade angle of best efficiency. It might be found possible to avoid this type of operation, in part, if it develops that the motor would be able to tolerate short time overloads in excess of 115 percent of the rated load.

e. Pump-turbines and Governors. The pump-turbines would be vertical-shaft, single-runner, feathering-blade type, as described in paragraph 11-09b, with a plate steel spiral casing and elbow-type draft tubes. Viewed from above, rotation would be clockwise for generating and counterclockwise for pumping. The spiral case would be embedded in the concrete substructure of the main unit bay. The units would be constructed to permit removal of runner, shaft, bearings, head covers, and miscellaneous operating equipment from above through the motor-generator stator opening. Governors would be oil-pressure, relay-valve, actuator type and would be equipped with electrically driven, speed-responsive

elements to control speed of the unit during generation by controlling the runner blade setting. During the pumping cycle, when the electrical portion of the unit would be operating as a synchronous motor, control of the blade setting would be through a load-responsive control. The controls would be designed to permit the pumped-storage plant to operate in conjunction with the tidal power plant and utilize the pumped-storage plant to follow the load requirements by either pumping or generating as required with respect to the tidal plant output. The speed responsive elements would be driven by an alternating-current motor powered by a permanent-magnet generator which would be directly connected to the exciter shaft of the unit being governed. Each governor unit would consist of an actuator, restoring mechanisms, pumping units, pressure tanks, sump tanks, and necessary controls and appurtenances. The governors would operate at a pressure between 270 p.s.i. and 300 p.s.i. The complete assembly, including pressure tanks, would be grouped in pairs and located between successive pairs of main units on the generator floor, at el. 14. The connecting piping between governors and units would be carried overhead.

f. Speed Regulation. The rotating elements of the generators and pump-turbines would have sufficient normal flywheel effect so that neither additional WR^2 nor surge tanks would be required to obtain satisfactory speed regulation without resorting to an exceedingly short governor time. The combined WR^2 for the proposed motor-generator and pump-turbine unit would be 80 million lb.-ft.^{2} The speed rise, in percent of normal speed, for full load of 78,800 hp. thrown off to zero at a head of 139 feet and including the effects of water hammer was computed according to the method outlined in Engineering Monograph No. 20, "Selecting Hydraulic Reaction Turbines," United States Bureau of Reclamation, June 1954. The speed rise for several governor times is tabulated below.

Rated governor time, seconds	3	4	5
Speed rise, percent of normal speed	39.3	44.6	48.0

The U.S. Army Corps of Engineers Manual states that the speed rise should be limited to 30-40 percent of normal speed but may be increased to 50 percent with fixed propeller or adjustable type turbines. The above cited U.S. Bureau of Reclamation publication states that a speed rise not to exceed 60 percent can be permitted. With the close connection between the pumped-storage plant and the tidal plant, the speed rise is not considered excessive.

g. Motor-Generators.

(1) Rating. On the basis presented previously, the unit would have a motor rating of 84,300 hp., 13.8-kv., 3-phase, 60-cycles, and 95 percent power factor at 100 r.p.m. and 60°C. rise. The corresponding rating as a generator would be 68,300 kv.-a., 13.8-kv., 3-phase, 60-cycles, and 95 percent power factor at 100 r.p.m. and 60°C. rise. The units would be provided with Class "B" insulation and would be capable of continuous operation at 115 percent of the 60°C. rating stated above without exceeding the allowable temperature rise of 80°C.

(2) Description. The motor-generator units would be modified from the conventional designed generator to permit operating in the reverse direction as a motor. The reactances, WR^2, runaway speed, and thrust bearing loading would not exceed normal values available in standard design machines. The units would have direct-connected, shaft-driven main exciters and would be provided with a thrust-bearing, pressure-lubricating system for use during startup and shutdown operations. The motor-generators would be enclosed in steel air housings, cooled by air-to-water coolers located inside the housing, and equipped with air brakes, carbon dioxide fire protection system, magnetic-amplifier or similar type voltage regulator, excitation cubicle, amortisseur winding, electric heaters to prevent condensation, and other devices normally provided with equipment of this type. The stator windings would be divided into two equal groups per phase and brought out separately to terminals, thus making possible the use of a split-winding type differential protection.

(3) Surge Protection and Grounding. The surge protection equipment would be located in the bus gallery in a metal-enclosed housing. The arresters would be of the thyrite type rated 15 kv. maximum line-to-ground voltage. The capacitors would be single-phase, rated 13.8-kv. and 0.25-microfarads. One arrestor and one capacitor would be used for each phase. Generator grounding would be by distribution transformer - resistor type and would limit ground current to approximately 10 amperes. This type of grounding offers the best protection for the generators and other equipment without introducing disproportionate hazards and costs.

h. Motor Starting. The following two methods for starting of the motors were considered:

1. Full voltage start at normal frequency.

2. Reduced voltage start at normal frequency by connecting the motor to a 6.9-kv. tap on the 13.8-kv. winding of the main transformer.

The first method was discarded because about 160,000 kv.-a. would be imposed on the 138-kv. transmission line which could result in system instability.

The second method, shown on the main one-line diagram plate 11-19, was adopted since studies indicate the motor would accelerate in about 2 minutes at a starting load of 35,000 kv.-a. with the turbine blades in the fully closed position. The switching arrangement selected would permit the starting of any motor from one unit, operating as a generator, and as such would require little or no contribution from the transmission system. Starting of the fourth motor would require something less than 35,000 kv.-a. from the transmission system since the rotating WR^2 of the three running motors would cushion the requirement. The starting of a motor would be initiated by the closing of the starting breaker. The motor would accelerate to approximately 95 percent synchronous speed at which time a polarized field frequency relay would close the field breaker at the optimum rotor slip position. After a short time delay, the start breaker would trip and the run breaker would be closed by a synchronous check relay.

i. 13.8-kv. Switchgear.

(1) Switching Arrangement. As shown on the main one-line diagram plate 11-19, two motor-generator units would be connected by isolated phase bus to each of two main power transformers through air circuit breakers. Motor-operated selector switches in the bus runs would provide phase reversal required for motor-pump operation. An isolated phase bus connection, for motor starting at reduced voltage, would be provided from the midtap of power transformer to the motor-generator leads through an air circuit breaker and motor operated selector switch. The switchgear would be located in the longitudinal galleries under the tailrace deck as shown on plates 11-14, 11-16, and 11-17.

(2) Air Circuit Breakers. The motor-generator run and start circuit breakers would be of the compressed air, 13.8-kv., station-cubicle type, having a 4,000-ampere rating and a 1,500-mv.-a. interruping capacity. Each breaker would be equipped with an air storage tank of sufficient size to operate the breaker through two complete open-close cycles without requiring recharge. Air for these storage tanks would be provided by the station high-pressure air system. Each breaker would have a manual-operated disconnect switch on the line side for isolation of the breaker from the transformer. The breakers, disconnect switches, and cubicle housing doors would be mechanically interlocked to insure safe and proper operation.

(3) Motor Operated Disconnect Switches. Each motor-generator run disconnect switch would be of the metal-enclosed, motor-operated, no-load break, phase-reversal type, rated at 13.8-kv. and 4,000-amperes. The switch would be operated by a 440-volt motor through a gearbox drive. Each motor-start disconnect switch would be similar to the above described switch and would be used as a selector switch to connect one of the two motors to the starting circuit. All breakers and disconnect switches would be mechanically and electrically interlocked to insure the proper sequence of operation.

(4) Isolated Phase Bus. Connections between the motor-generators and the transformers for both the run and start circuits would be made by 13.8-kv. isolated-phase bus. The run bus would be rated 3,500-amperes except for the tap connection to the transformer which would have a current rating of 7,000-amperes. The motor-start bus would be rated at 3,500-amperes. These ratings provide an adequate margin of safety for 115 percent of motor-generator current ratings.

j. Transformers.

(1) Rating. Two 3-phase, 157,000-kv.-a., 6.9/13.8-138-kv., delta-star connected, type FOA transformers would be provided. The 6.9-kv. circuit would be obtained by bringing out midtaps of the 13.8-kv. winding and would be used for reduced voltage starting of the motors. Each transformer would be connected to two motor-generators and sized to operate continuously at a capacity equivalent to 115 percent of the nominal rating of the two motor-generators. Type FOW transformers were considered but were discarded because fresh water would be at a premium at the powerhouse. The high voltage bushing would be rated 650-kv., BIL, and the neutral bushing and neutral end of the high voltage winding would be rated 110-kv., BIL. The low voltage bushings would be housed in a metal enclosure adapted for connection of isolated-phase bus. Each transformer would be provided with a manual operated, no-load, tap changer providing four $2\frac{1}{2}$ percent taps above and four $2\frac{1}{2}$ percent taps below normal on the high voltage winding. These taps would provide the necessary range of voltages and turns-ratio to accommodate both the pumping and generating cycles.

(2) Transfer Facilities. Each transformer would have flanged caster-type wheels for use in moving the transformer from the operating position on the draft-tube deck to assembly area in the powerhouse. One set of embedded rails in the tailrace deck would be used for moving both the transformer and the draft-tube gantry crane. The doorway into the assembly bay area would be large enough to permit passage of the assembled transformer with its high-voltage bushing in place when rotated 90 degrees on the turntable provided.

(3) Fire Protection. Firewalls would be provided on each side of the transformer. Spreading of burning oil would be further restricted by a removable barrier placed between the firewalls in front of the transformer. Drains inside this enclosure would empty into the tailrace below minimum water level. A waterfog fire-protection system would be provided for each transformer. Further discussion of the fire-protection and oil systems for the transformers is made later in this appendix.

(4) Lightning Protection. The high voltage side of each transformer would be protected from lightning by 121-kv., thyrite, single-pole, station-type, outdoor arresters. The arresters would be of the self-supporting type and mounted on a knee-brace, structural-steel frame supported on the powerhouse wall above the transformers, as shown on plate 11-14. The switchyard aerial lines would leave the powerhouse wall above the lightning arresters.

k. Powerhouse to Switchyard Connection. Two aerial lines over the tailrace channel, consisting of 795 M c.m. ACSR conductors and $\frac{1}{2}$ inch galvanized steel static wires, would connect the main transformers on the powerhouse draft-tube deck to the switchyard. Line takeoffs would be from the downstream powerhouse wall above each transformer at an angle of about 45 degrees with the powerhouse wall, as indicated on plate 11-15.

l. Powerhouse Control System.

(1) General. The control system would include all devices and circuits provided for starting, switching, synchronizing, loading, and shutdown, of the motor-generators. The functional relation of the various control elements is shown on the main one-line diagram, plate 11-19. It is expected that an abnormally high frequency of starting, switching, and shutdowns would be necessary at Digdeguash, because it would operate as an auxiliary to the proposed international tidal power project. To facilitate this type of operation, all normal operation would be conducted from the centrally located main control room. Remote control of unit auxiliaries, automatic starting, automatic synchronizing, and automatic loading would be used.

(2) Switchboard Equipment. Control switchboards would be of the vertical-duplex type having a depth of 72 inches and height of 90 inches. Panels and end doors would be of approximately 1/8-inch steel and finished in light grey lacquer. Instruments, relays, meters, and similar equipment would be supplied in cases for flush or semiflush mounting and would be provided with a dull black finish on exposed areas. Relays and watt-hour meters would be of the drawout type. Test blocks would be furnished for testing and maintenance of indicating and graphic instruments.

(3) Control Cables. Control cables would be rubber-insulated, multiconductor, neoprene-type or similarly jacketed, with conductor size not less than No. 19/22 AWG. Cables would be carried on expanded aluminum trays in the switchyard and connecting tunnel to the powerhouse and between the main units and control room.

(4) Main Control Room. The control room would be located on the tailrace deck, at el. 19, midway between the main transformers, as shown on plate 11-15, and would contain the main control switchboard, graphic instrument and load-control switchboard, 480-volt main switchboard, and the operator's desk.

(5) Main Control Switchboard. The selected arrangement of mimic bus, control switches, and instruments for the main control switchboards is shown on plate 11-20. Switching and synchronizing controls for the four 138-kv. lines would be located on the central 36-inch front panel. Standard 24-inch width panels at either side would contain the necessary indicating instruments and switches for remote starting, synchronizing, control of excitation, and loading of each motor-generator. Rear panels would contain the line relays, automatic synchronizer, unit-load controllers, and the "in" and "out" watt-hour meters for each unit.

(6) Graphic Instrument and Load Control Switchboard. The selected arrangement of the megawatt recorders and load controllers is shown on plate 11-20. The front panels would contain recorders for unit, line, and system megawatts; frequency; and water level. Carrier current and master load-control equipment would be mounted on the rear panels.

(7) Operator's Desk. The operator's desk would be located centrally in the room with a full front view of both control boards. Station telephone and carrier-current switchboard equipment would be mounted in the desk.

(8) 480-volt Main Switchboard. The main-station switchboard would be located in the main control room at the rear of the main control switchboard and is described in a subsequent paragraph.

(9) Unit Control Switchboard. Although normal operation would be from the main control room, provisions would be made for local operation of the units from the unit control switchboards during emergency and testing conditions. The unit control boards, as shown on plate 11-21, would be located near the units on the main floor and would be grouped in pairs in a right- and left-hand arrangement opposite the corresponding transformer banks. Each pair of unit control boards would

provide control; metering annunciation; temperature recording; and hydraulic devices for the respective generators, voltage regulators, transformer, generator breakers, turbines, and governors. Protective and control relaying for the main unit equipment would be mounted on the rear panels.

m. Powerhouse Metering System.

(1) General. All unit and line wattmeters, varmeters, and excitation meters would be of the center-zero type. Provision would be made for polarity reversal of the megawatt recorders when changing from generating to pumping.

(2) Motor-generators. The unit-control switchboard would contain a wattmeter, varmeter, ammeter with switch, voltmeter with switch, field voltmeter, field ammeter, and voltage-regulator balance indicator as shown on plate 11-21. The main-control switchboard unit front panel would contain a wattmeter, varmeter, ammeter, voltmeter, and voltage regulator balance indicator. The corresponding rear panel would provide two watt-hour meters with negative detents for "in" and "out" energy, respectively. The graphic switchboard would provide a megawatt recorder for each unit.

(3) 138-kv. Switchyard and Lines. An ammeter, voltmeter, wattmeter, and varmeter would be provided for each outgoing line on the center panel of the main-control switchboard as shown on plate 11-20. An additional voltmeter would be provided for each section of the 138-kv. bus. Line potential for the meters would be fed from capacitor coupling devices used for carrier current coupling and synchronizing. Current would be obtained from bushing type current transformers in the 138-kv. oil circuit breakers. Revenue metering would be accomplished only at the load ends of each outgoing 138-kv. line and not at the pumped-storage plant. Continuous carrier-current telemetering would be provided from these loadmeters to the megawatt recorders on the Digdeguash graphic switchboard shown on plate 11-20, for load-control purposes.

(4) Station Service System. An ammeter with switch, voltmeter with switch, wattmeter, remote tap-position indicator, and watt-hour meter would be provided on the 480-volt main switchboard for each station-service transformer.

n. Powerhouse Protective Relaying.

(1) General. The selected major relay protective system is shown on the one-line diagram, plate 11-19. The system would be conventional except that some relay circuits would be automatically switched when changing from generating to pumping. All shutdown or lockout relays would have contacts for trip-out of the load-control system.

(2) Motor-generators. Each unit would be provided with split-stator type differential, time-delay voltage-restrained overcurrent, ground, loss of field, under-power, out-of-step, and incomplete-sequence relay protection. An additional synchronism check relay would be used for motor starting, and a time-delay relay would be used to block too frequent starting for protection of the damper windings. Conventional bearing and winding temperature thermal relays would be used.

The principle protective relays would operate to trip spring-loaded, hand-reset type auxiliary or "shutdown" relays. The complete shutdown (86GC on plate 11-21) relay would be energized by the generator differential relay which would also cause release of carbon dioxide into the unit housing. The complete shutdown relay would trip the main 13.8-kv. breaker, the exciter-field breaker, governor shutdown solenoid, and annunciator. The 86GC relay may also be energized by manual emergency switches in the main control board and governor cabinets and also by release of carbon dioxide, mechanical tripping of the governor shutdown solenoid, and by tripping of the generator ground time-delay, auxiliary relay. Carbon dioxide would be released directly by operation of thermal relays near the motor-generator windings or from a break-glass station outside the unit barrel. The partial shutdown relay (86GP) would be tripped by the generator ground, overcurrent, and overspeed relays to energize the governor speed-no-load solenoid and open the main breaker. The time-delay, shutdown relay (86GT) would be energized by high bearing temperature or very low governor oil pressure to immediately operate the governor shutdown solenoid. Tripping of the main breaker would be delayed until the blades are closed to the speed-no-load position. An overvoltage relay (59 on plate 11-19) would be used for energizing the quick-lower contactor (39) to protect the generator winding against high voltage resulting from malfunction of the regulator, excess excitation, or load rejection while under manual control. The motor-generator, ground relay would be of the simple overvoltage type connected across the neutral ground resistor. Time delay auxiliary relays would be connected so that the odd-numbered unit partial shutdown relay in the ground-relay circuit would be tripped immediately by closure of the ground-relay contacts followed, after a short time delay by complete shutdown of whichever unit has the sustained ground. The 138-kv. breaker would be tripped also in case of a sustained ground on the even-numbered unit.

(3) Transformer. The main power transformer would be protected by winding temperature, differential and ground relay action to trip the transformer lockout relay (86T). A low oil-flow relay would also trip 86T after a suitable time delay. Both motor-generator breakers and the associated 138-kv. breaker would be tripped by 86T. Fog release would be initiated only by the transformer differential relays.

(4) Transmission Line. Impedance type relays (with carrier restraint, if required) would be provided on the rear panel of the main control board for 138-kv. line protection as indicated on plate 11-20. Operation of these relays would trip only the associated line breaker or transfer breaker through contacts on the line lockout relay (86L) located on the same panel.

(5) Station-service Transformers. Simple induction overcurrent relays would be provided for protection of each 1,000-kv.-a., station-service transformer. Settings and time delay would be coordinated with secondary breaker trip settings. Winding temperature relays would give an alarm at a moderately high temperature and trip the feeder breaker at a very high temperature.

(6) Control Transfer - Switchyard Auxiliary Bus. The basic switching scheme selected, shown on the main one-line diagram plate 11-19, would consist of two main and two transfer buses with two spare breakers. The transfer bus would be primarily for maintenance or emergency use only. Two spare breakers would be provided for flexibility of switching, to handle most abnormal situations. Key interlocks would be used to prevent closure of more than one motor-operated disconnect switch onto the transfer bus. Electrical interlocks would be provided to prevent closure of the disconnects if either spare breaker is closed. A transfer switch would be mechanically linked to the disconnect operating mechanism or control to shift the transformer differential relay circuit, synchronizing potential, and trip circuit to the selected spare breaker. Transfer switches would be provided to supply the proper synchronizing potential from the selected main bus potential device. All manually operated isolating disconnect switches would be key interlocked to prevent movement of the disconnect if the corresponding breaker were closed.

o. Load Control and Telemetering System.

(1) Generating. Normal operating procedure would consist of a load request from a system dispatcher, located at Quoddy or elsewhere to the Digdeguash operator by carrier telephone or by prearranged schedule. The operator would check the load status of the system as indicated on the graphic instrument board and then preset the desired net interchange on the recorder-controller. The necessary units would then be started manually by remote control and automatically synchronized to the system after which the automatic load controller would be switched into operation. Load limit alarms would signal the operator when an additional unit must be added or a unit may be shut down.

A functional diagram of the selected automatic system is shown on the one-line diagram, plate 11-19, and the physical arrangement of equipment on the load control boards is shown on plate 11-20.

Two independent control systems would be provided so that the Maine and New Brunswick loads may be controlled separately under certain conditions, if desired. Line load recorders would receive metering information by variable frequency type carrier current telemetering from the remote metering locations and the Quoddy megawatt output would be received by impulse type carrier current telemetering from Quoddy power plant. The Digdeguash megawatt unit recorders would be fed directly from thermal converters in the motor-generator metering circuits. On the basis of the telemetered information received by the line-load recorder-controller, master controller, and unit controllers, these controllers would initiate and route raise or lower impulses to the Digdeguash unit governors to maintain a constant output on the outgoing lines regardless of the diminishing or increasing proportion of the load furnished by the Quoddy plant. The equipment supplied would be adaptable to a system of direct dispatcher control, should this prove desirable at a later date.

(2) Pumping. The same load control equipment would be used on the pumping cycle, and motor loading would be controlled by the blade angle. The necessary reversal of recorder input polarity and interchange of raise-lower functions would be performed automatically through the reversing disconnect auxiliary switch.

p. Powerhouse Annunciator System. The annunciator system, shown on plate 11-22, would provide visual and audible signals in the control room and at the unit control boards in the event of trouble or abnormal conditions. Audible signals in the control room would be by soft-tone gong, whereas in the generator room they would be by two horns equally spaced and located 12 feet above floor level on the powerhouse wall. A horn having a different tone would also be provided in the generator room for annunciation of station service trouble. Visual signals would consist of groups of annunciator windows on the above mentioned boards. Closure of a trouble contact on any unit would give visual signal on its respective board and in the main control room and would also illuminate the unit-in-trouble lights located high enough on the powerhouse wall to be seen the full length of the powerhouse. The system would be provided with switches for testing and resetting the visual alarms and also for silencing the audible alarms. Design of the annunciator system assumes operators in the control room and only roving operators on the generator floor but available for duty at the unit control boards, station service boards, or elsewhere in the plant as needed. Annunciation of switchyard trouble would also be provided in a similar manner as described above. The annunciator system would be powered by the station 125-volt d.c. system.

q. Station Service System.

(1) Power Supply. Power for the station service system, shown on plate 11-23, would be supplied by two station service transformers connected individually to a main-unit bus through a current-limiting reactor and air circuit breaker. Each transformer would be sized to carry 100 percent of the station service demand load and would be 3-phase, type OA rated 1,000-kv.-a., 13,800/480-volts, with automatic load tapchanger. The transformer impedance would be such as to limit the short circuit duty on the 480-volt main distribution switchboard to 25,000 amperes. The reactor would be of the dry-type, provided with an isolating disconnecting switch, and rated to limit the interrupting duty of the circuit breakers to 500,000 kv.-a. The air circuit breakers would be of metal-clad construction, draw-out type, solenoid-operated, and rated 13.8-kv., 1,200 amperes, and 500,000 kv.-a. interrupting capacity. The reactors would be connected to the main-unit bus by isolated-phase bus and to the circuit breakers by 15-kv. rubber-insulated cable, routed in conduit. The transformers would be connected to the 13.8-kv. breakers by the above-mentioned type cable and to the main distribution switchboard by 480-volt bus duct.

(2) 480-volt Main Switchboard. This switchboard would serve as the switching center for supplying power to the various load centers in the powerhouse and exterior areas. The switchboard, shown on plate 11-24, would be located in the main control room and close-connected by bus duct to the transformers located in the adjacent room. The switchboard would be of the metal-enclosed type and provided with two sections of main bus, supply breakers, bus-tie breaker, and feeder breakers. The supply and bus-tie breakers would be of the draw-out electrically-operated type having a 1,600-ampere frame size and a 50,000-ampere interrupting rating. The breakers would be interlocked to prevent paralleling of the power sources. Feeder breakers would be of the draw-out, manual-operated type having a 600-ampere frame and an interrupting rating of 25,000 amperes.

(3) Distribution System. Studies comparing 480-volt and 2,400-volt distribution systems indicated the former to be adequate for the loads and the distances involved and was less costly, particularly with respect to switchgear. The 480-volt system was accordingly adopted for the station service distribution system in the plant and the switchyard. Feeders to the dam and to the project housing area would be stepped up to 4,160 volts and transmitted by aerial lines from the powerhouse. Duplicate feeders from the 480-volt main switchboard, one from each section of the dual bus, would be provided to all of the important load centers. The switching arrangements at the load ends of duplicate feeders would be mechanically interlocked to prevent paralleling at the load. Rubber-insulated conductors, routed in conduits and cable trays, would be used for all 480-volt distribution circuits.

(4) Motor Control Centers. The 480-volt one-line diagram, plate 11-23, shows the various power panels and load centers located throughout the plant and also their connected loads. The selected physical layout of the principal motor control centers and auxiliary power boards is shown on plate 11-24. The unit power panels would be grouped in pairs to conform to the two-generators-per-transformer arrangement. The standard industrial load center, NEMA Type B, with front access to the bus would be used for floor mounting against the wall. Each motor controller would include a molded case type breaker with instantaneous and thermal overload trip and a contactor with suitable thermal overload trip device. All breakers and contactors would have an interrupting capacity of at least 15,000 amperes. Series reactors would be used in the supply feeders to the motor control centers, as required, to limit the short-circuited current to 15,000 amperes.

r. Powerhouse Lighting. The station lighting system, the riser diagram for which is shown on plate 11-25, would be supplied from the lighting panelboards fed from adjacent dry-type, 3-phase, 480/120-208-volt transformers except that the generator room high-bay lighting would be supplied directly at 480 volts. Generator room high-bay fixtures would be of the mercury vapor, color-corrected type and would provide an intensity of 18 foot-candles at main floor level. Supplemental lighting of unit control switchboard would be supplied by incandescent luminaires, mounted on the powerhouse wall in front of the switchboard, and would provide an intensity of 20 foot-candles on the vertical surfaces of the control boards. Main control room lighting would be provided by a luminous ceiling type system using slim-line fluorescent lamps. Illumination on the vertical surfaces of these boards would be approximately 30 foot-candles. Office and shop areas would be lighted by fluorescent type fixtures. Incandescent type fixtures would be used to illuminate all other areas. Intensity level of illumination would be that which is consistent with the function of the area.

An emergency lighting system would be provided in the control room, stairways, galleries, turbine pits, and unit control boards. The emergency lighting system would be supplied from emergency panelboards which would be connected through automatic transfer switches to either the normal a.c. system or to the 125-volt d.c. system. Loss of a.c. power would automatically connect the emergency lighting load to the d.c. system. Resumption of power would automatically return it to the normal a.c. source.

s. Powerhouse Grounding. The station grounding system, shown on plate 11-26, would consist of an interconnected network of copper conductors throughout the powerhouse and connected to the station ground mat by two 500 M c.m. copper cables. The ground mat would consist of bare copper cables forming an interconnected grid. Ground rods, 3/4 inch by 10 feet, would be driven and connected to the cables as required to obtain a 0.5 ohm resistance mat. The exact location and design of the mat would be determined by ground resistance tests which would be made at the site when the project advances to the design stage. The noncurrent carrying parts of all electrical equipment would be grounded as would all major nonelectrical equipment such as turbines, penstocks, structural steel, handrails, etc. The grounding of generator and transformer neutrals and of lightning arresters would be to the main ground buses through separate conductors for each. Ground test stations would be provided to permit testing by removal of bolted type connections at the proper locations.

t. Powerhouse Telephone and Code Call System. Local communication and signaling facilities would be provided by a private 60 station, automatic exchange (PAX) system, complete with a code call system as an integral part. The PAX would provide for interconnecting all telephones in the powerhouse, switchyard, intake, dam, and spillway. Two trunk lines from a private utility telephone company would be provided for calls outside the station area. The switchboard would be mounted on the operator's desk in the main control room.

u. Powerhouse Direct Current System. The 125-volt d.c. system shown on plate 11-27 would include a 125-volt battery, two battery-charging motor-generator sets, battery board, d.c. distribution panels, and distribution circuits. Normal loads on the battery would be annunciation, control, and indication circuits. Other loads would include close and trip circuits for the metal clad switchgear, emergency lights, and emergency preferred a.c. inverter set for certain communication circuits. The switchyard and generator circuit breakers would be operated by compressed air and would require only a small current for d.c. control. A 60-cell battery would be used as source of power for the 125-volt d.c. system. Each battery charger would be rated 5 kw. and would be considered as a spare but could be operated concurrently with the other if required.

v. Powerhouse Utilities Systems.

(1) Water Supply and Distribution. The powerhouse water treatment facilities, located on the -17 foot deck of the station service bay would be designed to treat all the fresh water required for powerhouse operation. Also included has been the domestic water requirements for the nine operators' residences which would be located nearby. It is estimated that the following quantities of fresh water would be required:

Generator cooling and plant heating system.

Initial filling 4 units @ 2,300 gal.	9,200 gal.
Makeup @ 5 percent per week (estimated)	460 gal.
Air compressor cooling	20 g.p.m.
Hose bibbs	5 g.p.m.
Powerhouse domestic	8 g.p.m.
Residential area	25 g.p.m.
Transformer fog system	430 g.p.m.

All of the above water would be fully treated, except that for transformer fire protection which would be only strained. The required fresh water would be secured from Lily Lake, which is located about 2.5 miles southeast of the Digdeguash dam site as shown on plate 11-3. An 8-inch gravity main would lead from Lily Lake to a small pond on the knoll southeast of the powerhouse. This pond would be used as an open, elevated reservoir, and the water level in it would be maintained at a predetermined level by a float-controlled outlet valve in the incoming line, which would have a capacity of about 500 g.p.m. A 6-inch gravity line, having a capacity of 1,000 g.p.m., would connect the elevated storage pond to the powerhouse. In the powerhouse, the distribution system would be as shown schematically on plate 11-28. The line would enter the powerhouse at the southeast corner, at about el. 10, and drop down to the water treatment room and through a fine mesh duplex basket strainer. A 6-inch header would supply water, without further treatment, to the transformer fog system and to the various hose bibbs. Pressure reducing valves would be provided on the branches serving the hose bibbs to reduce the supply pressure from 115 p.s.i. to about 30 p.s.i. Beyond the firemain takeoff a 4-inch line would lead into the water treatment room, which would be equipped with a soda-ash and alum pretreatment, two 6-foot-diameter pressure sand filters, a hypochlorinating unit, and a 750-gal. surge and detention tank. The sand filters would each be rated at 57 g.p.m. normal capacity, and 85 g.p.m. maximum capacity. On this basis a single filter at normal capacity would be capable of handling the estimated 58 g.p.m. of powerhouse and residential domestic demand, but two would be provided to permit backwashing of the units with the least trouble. After filtration the water would be chlorinated and held in the detention tank for a 30-minute detention period. The tank would also serve as a surge tank and would be equipped with the necessary automatic controls to maintain the proper water levels in the tank. From the tank, the treated water would be reduced to 30 p.s.i. and distributed to

the air compressor cooling jackets, the generator cooling system makeup and the sanitary fixtures. A 2½-inch line would convey treated water at 115 p.s.i. to the residence area for domestic use.

Hot water would be supplied to all lavatories, showers, and the two service sinks on the -2.5 level from two electric hot water heaters. A 40-gal., 12-kw. unit in the service closet of the -2.5 level would supply all hot water requirements, except for the control room lavatory which would be equipped with a 5-gal., 1-kw. unit for hot water supply.

(2) Sanitary Facilities. Sanitary facilities would be provided for the operating personnel. Most of the operating and maintenance personnel would be served by a locker and shower room on the -2.5 level of the station-service bay shown on plate 11-16. This room would be equipped with four water closets, three urinals, four lavatories, two stall showers, and a drinking fountain. Office personnel would be served by a small toilet room located in the center of the office area at el. 19, plate 11-15, which would be equipped with one water closet, one urinal, and one lavatory. A drinking fountain would also be provided nearby. Control room personnel would be served by a similar toilet room adjacent to the control room, with the drinking fountain located in the control room proper. Additional drinking fountains would be provided near the center of the generator room, at el. 14, and in the maintenance shop, at el. -2.5. Toilet facilities would not be provided for visitors or female personnel, as the plant would be manned only by male personnel. Service sinks would be provided in the service closet, at el. -2.5, adjacent to the locker room; in the battery room, at el. -2.5; and in both the oil purification room and the water treatment room, at el. -17. The first aid room, adjacent to the locker room at el. -2.5, would be only equipped with a lavatory, as it is close to the main toilet facilities.

Sewage would be treated by a two-chamber septic tank located in the station-service bay beneath the oil storage room, at el. -20.5, as shown on plate 11-18. The sludge tank would have a 1,300 gal. capacity which would provide a 24-hour detention period. The effluent tank would be equipped with a chlorinating unit to treat the effluent before discharging it into the tailrace. The septic tank would be located below all units served so that flow would be by gravity throughout. Float controlled, duplex, 50-g.p.m. pumps would be installed in the pump room, at el. -31, to discharge effluent to the tailrace through a 4-inch pipe leading into the 18-inch unwatering and drainage discharge header. The pumps would be valved for use in pumping sludge from the settling tank. Access to the septic tank would be provided by a sealed manhole located in the oil storage room at el. -20.5. A schematic diagram of the sanitary waste system is shown on plate 11-29.

(3) Unwatering and Drainage. The unwatering system, shown schematically on plate 11-29, would be a closed type installation capable of unwatering the penstock, scroll case, and draft tube of each main unit. Each main unit draft tube would be provided with a 14-inch mud valve with screened inlet located in the splitter pier and connected directly to a 20-inch header beneath the draft tubes, as shown on plate 11-14. The mud valves would be manually operated from gear operated floor stands in the gallery, at el. -29. The unwatering header would be continuous under all draft tubes, at el. -54, and would terminate in a valved manifold in the unwatering sump, located beneath the -31 level of the station-service bay. As the scroll case would be designed for diagonal flow conditions there would be free drainage of all water from the scroll case to the draft-tube mud-valve inlet. Unwatering of all water passages, down to tailwater level, would be accomplished by gravity. The unwatering system would be capable of evacuating all water passages from el. 14, maximum normal tailwater level, in 1 hour and 40 minutes. Refilling would be accomplished by cross-filling the draft tube and scroll case from an adjacent unit through the mud valves and removing the stoplogs under balanced head. The head gates would then be "cracked" to fill the penstock.

The station drainage would flow to a sump, adjacent to the unwatering sump, through a number of headers located at different elevations, as shown schematically on plate 11-29. An 8-inch header beneath the drainage gallery, sloping from el. -31 to -42, would collect all powerhouse floor and equipment drainage; a 6-inch header beneath the penstocks, sloping from el. -13 to -18, would collect all of the upstream powerhouse roof drainage and the surface drainage from the penstock area immediately upstream of the powerhouse; and several 4- and 6-inch lines would collect the drainage from the floor and equipment drains on the various levels of the station-service bay.

All of the drainage and unwatering pumps would be installed in the unwatering sump, because of space and access limitations in the pump room, at el. -17. The two unwatering pumps would be 4,000-g.p.m., vertical-shaft, mixed-flow, propeller pumps powered by 75-hp. electric motors. The pump suctions would be coupled, in parallel, directly to the 20-inch unwatering header. Each pump suction would be equipped with a shutoff valve operated from floor stands on the -31 level. A 12-inch valve, similarly operated, would permit draining the unwatering header to the sump, so that incidental leakage would be handled by the 20-hp., 1,000-g.p.m., vertical-turbine, unwatering sump pump. The drainage sump pump would be similar to the unwatering sump pump in capacity and rating. It would also be installed within the unwatering sump and would be connected to the drainage sump by an 8-inch suction line, equipped with a shutoff valve. A 10-inch bypass, at el. -41, would

permit the drainage sump to overflow to the unwatering sump, if necessary to permit the unwatering sump pump to serve as a standby drainage pump during abnormal drainage requirements. Both sumps would be sealed at the -31 floor level and vented to a point above maximum tailwater. Interior drainage headers would be extended with a vertical drop to el. -53, within the drainage sump, to form a water seal against internal venting.

The unwatering pumps could be operated either singly or in parallel. The pumps would be controled by hand start and automatic shutdown, for normal unwatering operation. The unwatering sump pump would be float-controlled to handle normal leakage from one unwatered main unit. If excessive leakage should occur, the 4,000-g.p.m. unwatering pumps, also on automatic standby during the unwatered period, would supplement the sump pump. The drainage sump pump would be similarly float-controlled to maintain prescribed water levels within the sump, with the unwatering sump pump as automatic standby.

All pumps would be vertical-column, oil-lubricated, with below-grade discharge heads, and they would be driven by vertical, hollow-shaft, squirrel-cage induction motors. The pump motors would be located at el. -17 with the discharge header hung from overhead in the pump room below, at el. -20. The discharge from all pumps would be brought into a common 18-inch header which would terminate in a flap gated outlet into the tailrace at el. 14. Each pump discharge connection to the header would consist of a check valve, gate, valve, and flexible connector. All piping for the unwatering system would be steel. Area, floor, and equipment drainage lines in 4- and 6-inch size would be cast iron; all other sizes would be steel.

(4) Compressed Air. Two compressed air systems, shown schematically on plate 11-30, would be provided for the powerhouse. The low pressure station-service air system, at 115 p.s.i., would supply all the compressed air requirements for pneumatic tool outlets and for the motor-generator brake system. The high-pressure air system, at 350 p.s.i. would supply the compressed air requirements for the air circuit breakers and the governor charging system. All compressor equipment and controls would be located in the compressor area, at el. -17, of the station-service bay. Compressors would be installed in duplicate for each system, one for normal supply and the second as standby. The systems would be automatically controlled for start and stop through pressure actuated relays arranged for sequential operation, periodically alternated. Compressed air requirements and system components sizes have been selected on the basis of similar powerhouse installations. Sufficient capacity would be available for construction phase use by utilization of all units. The low-

pressure system compressors would each be rated at 115 p.s.i. and 150 c.f.m. They would be double-acting, two-stage, water-cooled horizontal units equipped with aftercoolers and moisture separators and would be powered by 30-hp. electric motors. Two 57-cu. ft. receivers, 3 feet in diameter by 8 feet high would be provided for the low-pressure system. The high-pressure system compressors would each be rated at 350 p.s.i. and 40 c.f.m. They would be single-acting, two-stage, water-cooled, vertical units equipped with aftercoolers and moisture separators and would be powered by 20-hp. electric motors. Two 34-cu. ft. receivers, 2½ feet in diameter by 7 feet high would be provided for the high-pressure system.

Compressed air would be distributed throughout the plant through galvanized steel, standard weight, threaded pipe. Drip legs with drain cocks would be provided at base of all vertical risers and at blind ends of long headers. Low points would be equipped with automatic float operated drains to eliminate condensed moisture. The low-pressure air would be distributed through three separate headers: (a) one 1½-inch header would be suspended from the overhead of the piping gallery, at about el. -5, and would run the length of the four main unit bays to supply air for the main unit brake system at 115 p.s.i.; (b) an adjacent 2-inch header would supply all the unit bay-service outlets and would be equipped with a 3/8-inch orifice plate to limit service-air outlet flow to 234 c.f.m. at 100 p.s.i.; and (c) a 2½-inch header would supply air for all the service outlets in the equipment and maintenance areas and would also be equipped with an orifice plate to limit air flow to 234 c.f.m. at 100 p.s.i. This line would also supply air for "blowing out" of the unwatering drains through the unwatering header. High-pressure air distribution would be through two separate 1½-inch headers running the entire length of the powerhouse, at el. -5 in the piping gallery. One header, with a pressure reduction station set for 310 p.s.i., would supply air for charging the governor pressure tanks. This header would be equipped with a pressure relief valve, set at 320 p.s.i., and a pressure control valve, which would close off the line if pressure in the supply tanks should drop below 250 p.s.i. to prevent accidental depletion of circuit-breaker pressure. The other header, with a pressure reduction station set for 250 p.s.i., would supply air for recharging the air circuit breaker tanks. A relief valve would be provided, set at 260 p.s.i. All compressors would be equipped with electronic controls for automatic lead-and-lag unloaded starting and stopping, load-and-unload continuous running, low oil pressure cutout, high temperature air discharge cutout, low cooling water pressure cutout, and thermostatically controlled cooling water flow.

(5) Oil Storage and Distribution. Complete and separate systems, shown on plate 11-31, would be provided in (a) the powerhouse to receive, store, process, and transfer the light insulating type oil used in the power transformers and oil circuit breakers and (b) for the viscous lubricating type oil used in the motor-generator brakes and thrust bearings, in the pump-turbine guide bearing, and in the governors. The seven storage tanks would be installed in the oil storage room, at el. -20.5 of the station-service bay as shown on plate 11-17. All tanks would be horizontal, cylindrical, and of steel construction. Three tanks would be 8 feet in diameter and 12 feet 6 inches long with a capacity of 4,700 gal., and four tanks would be 10 feet in diameter and 14 feet long with a capacity of 8,200 gal. Two of the smaller tanks would be used with the lubricating oil system, one for dirty oil and one for clean oil. The remaining small tank would be used to store clean insulating oil for the switchyard circuit breakers. The four larger, 8,200-gal. tanks would be used for the transformer insulating oil system; two would be used for dirty oil and two for clean oil. The tanks have been sized on the basis of the best information available on estimated oil requirements for the various items of equipment. One 4,700-gal. tank would be sufficient to hold all the lubricating oil drained from the generator bearings (2,500 gal.), turbine bearings (125 gal.), and governor system (1,500 gal.) of one main unit. A similar size tank would hold all the oil from one complete oil circuit breaker in the switchyard. Two of the 8,200-gal. tanks would provide sufficient capacity to hold the oil drained from one main power transformer (15,500 gal.) plus drainage from the headers.

All piping and transfer pumping would be arranged to prevent accidential mixing of clean and dirty oil. To achieve this, each separate pumping unit would be installed in the clean and dirty oil circuits of each oil system. The transfer pumps would be of the rotary type, driven by electric motors, and would be installed in the oil storage room. The piping would be arranged so that essentially all of the equipment drainage to the dirty-oil tanks would be by gravity flow. The dirty-oil pumps would be utilized only to pump rejected oil to the tank car discharge coupling on the tailrace deck. The clean-oil pumps would transfer oil, from the clean-oil tanks to the equipment or flush the supply and return headers. These pumps would be equipped with a pressure actuated cut-off switch, in the pressure relief bypass line, to protect against extended operation with a closed discharge line. Circulation of oil from the system headers, or storage tanks, through the filters for purification would be accomplished by the filtration unit pump. The pumps, for the lubricating oil system, would each be rated at 30 g.p.m., and 100 p.s.i. and would be driven by 3-hp. motors; the pumps for the transformer insulating oil system

would be rated at 60 g.p.m. and 53 p.s.i. and would be driven by 3-hp. motors; the single pump for the circuit breaker insulating oil would be rated at 60 g.p.m. and 125 p.s.i. and would be driven by a 5-hp. motor. The oil purification unit would consist of 7½-hp. circulating pump, filter press, centrifuge unit driven by a 3-hp. motor, a 72-kw. heating unit, and a totalizing flow meter. The filtration unit would be installed in the oil purification room, adjacent to the oil storage room, and would have a capacity of 20 g.p.m. of light insulating oil, or 10 g.p.m. of viscous lubricating oil. A 1,250-watt drying oven, for filter paper, and a dielectric tester, for checking insulating oil, would complete the oil purification installation.

All piping would be pitched for gravity drainage from the equipment to the dirty-oil tanks. Dirty oil which could not be reclaimed would be pumped to a tank car or truck through the discharge connection on the deck at el. 19, using the system dirty-oil pump. Fresh oil would be delivered by gravity from the same level to the clean-oil storage tank. Oil in the dirty-oil tanks which is to be reused would be passed through the purifier, using the purifier circulating pumps. The processed oil could then be delivered directly to the equipment, or returned to the clean-oil storage tank. Oil from the clean-oil tanks could be delivered to the equipment by the clean-oil pump, or passed through the purifier before delivery to the units. All clean-oil and circulating-oil lines would be type K copper tubing with solder fittings, and all dirty-oil lines would be black steel pipe. All piping would run exposed in the galleries and equipment spaces. Insulating gaskets and bolt sleeves would be used at joints between ferrous and nonferrous piping.

(6) Fire Protection. Two types of fire protection systems, shown on plate 11-32, would be installed in the powerhouse; i.e., fixed carbon dioxide systems for protection of the main motor-generators and of the oil storage and handling systems, and a waterfog spray system for the main power transformers. Two separate carbon dioxide banks each consisting of thirty-one 75-lb. carbon dioxide cylinders would be provided to protect the four motor-generator units. The banks would be located between alternate pairs of units and would consist of 17 initial discharge cylinders and 14 delayed discharge cylinders capable of maintaining a 25 percent concentration of carbon dioxide within the unit air housing for 30 minutes. The two banks would be linked by a 2-inch tie header, for manual transfer during retanking. The station-service transformer room would be protected by a bank of six carbon dioxide cylinders, located in the breaker gallery at el. -2.5 directly below the transformer. The cylinders would be arranged for simultaneous discharge. The oil storage room would be protected by a bank of twenty-eight 75-lb. initial discharge cylinders and the

oil purification room by ten initial discharge cylinders, all located in the carbon dioxide room at the -2.5 level above the rooms to be protected. The two oil room protection systems would be separate, and neither would have a delayed discharge bank, nor would an installed reserve be provided. A stock of 31 full cylinders would be maintained in the carbon dioxide room to permit replacement of the largest single bank of cylinders in the plant. All carbon dioxide systems would be automatically controlled by rate-of-rise thermostats, within the enclosure to be protected, which would activate the system upon either a sharp rise of temperature, or at a temperature of 180°F. Manual, remote, break-glass stations would also be provided, located near the hazard area, and in the case of the motor-generator units the carbon dioxide discharge would also be initiated by a differential relay. Automatic control valves at the cylinder banks would route the carbon dioxide to the proper motor-generator unit. In the case of the oil rooms an audible alarm would sound for 30 seconds before the carbon dioxide is discharged. Electrical equipment would be simultaneously de-energized and all ventilation openings within the rooms would be closed. Provision would be made to de-energize the individual unit carbon dioxide system when it is necessary for personnel to enter the motor-generator air housing.

The waterfog fire protection system for the main power transformers would consist of 24 fog nozzles, with a capacity of 18 g.p.m. each, at a pressure of 65 p.s.i., which would supply 0.3 g.p.m. per square foot of protected area. The water would be used as previously described. From the main header at the water treatment room, a 6-inch header would run virtually the full length of the piping gallery, suspended from the overhead at el. -5. A 4-inch vertical riser equipped with a 4-inch solenoid valve would be provided beneath each of the two main power transformer vaults. The vertical portion of the header and all branches above the solenoid valve would be dry-pipe and would be equipped with a spring-loaded valve for automatic drainage in case of leakage through the solenoid valve. The solenoid valve would be actuated by a transformer differential relay or by remote, manual, break-glass stations. Booster pumps would not be provided as the system static head would be sufficient to maintain a residual pressure of 65 p.s.i. at the nozzles when delivering 430 g.p.m. A minimum of 40 p.s.i. would be sufficient for adequate atomization of the waterfog. Each nozzle would be equipped with an integral strainer to supplement the basket strainer on the main powerhouse water supply line.

(7) Generator Cooling System. Generator temperatures would be controlled by the cooling system shown schematically on plate 11-33. Fresh water would be used in most of the system to avoid the corrosive effects of sea water. Because of the relative scarcity of fresh water, a closed circuit would be used for the fresh water permit its reuse. In the last stage of the system, the heat

would be transferred from the fresh water to the salt water in heat exchangers to which salt water would be fed by lines from the scroll case for each unit. The waste salt water would be discharged into the tailrace.

Each generator would be provided with air-to-fresh-water heat exchangers in the air housing having a total rating of 5,050,000 B.t.u. per hour and a thrust bearing oil cooler rated at 300,000 B.t.u. per hour. These coolers would be fed from a 10-inch high-pressure fresh water tie header and discharge into a 10-inch low-pressure tie header. Five sets of two fresh-to-salt-water heat exchangers, each set having a combined rating of 5,350,000 B.t.u. per hour at a temperature difference of 15°F. would be connected to two 10-inch headers. Fresh water would be circulated through each set by means of a 1,400 g.p.m. pump driven by a 30-hp. electric motor. Also connected to the two 10-inch headers would be a fresh-water-to-air heat exchanger rated at 3,385,000 B.t.u. per hour, which would be a part of the heating system of the plant as described later.

Each set of the fresh-to-salt water heat exchangers would have a sufficient capacity to absorb the waste heat from one main unit operating at maximum load with a temperature drop of 8°F. in the fresh water circuit. The fifth set would be provided for use during emergencies, and while one of the other units is down for maintenance.

Sea water for the water-to-water heat exchanger would be provided by means of a 10-inch connection to each main unit penstock, drawing water at pool head pressure. The sea water heat exchangers would be located in the heat exchanger gallery at el. -26. The heat exchangers would be divided into two groups, each with an independent sea water circuit. One group of two exchanger banks would be located between main units 1 and 2, and the second group consisting of three heat exchanger banks would be located between main units 3 and 4. The sea water supply to all of the exchangers within a group would be connected through a 10-inch tie-header, and the discharge would be similarly linked to a single 12-inch line discharging to tailwater at el. 14.

Temperature control of the system would be automatically maintained by modulating the flow of sea water through the water-to-water exchangers. The system has been designed to maintain a maximum air temperature of 40°C. within the unit air housing. Fresh water would be supplied to the generator air coolers at a constant rate and would absorb heat for ultimate rejection to the sea water. A thermostatic element, within the air housing, would modulate the flow of sea water through the exchangers to maintain the air housing temperature between 35° and 40°C. With

(9) Cranes. Two cranes would be provided for the powerhouse; a 365-ton indoor bridge crane, and an 18-ton outdoor gantry crane. The powerhouse bridge crane would be a double-trolley,

a maximum sea water temperature of 67°F., it is expected that proper unit cooling would be maintained with a fresh water flow of 1,400 g.p.m. and a water temperature of 91°F. leaving the coolers and 83°F. returning.

(8) Heating and Ventilation. The powerhouse heating system is designed to maintain an interior temperature of 60°F. in the powerhouse when the outside temperature is -10°F. Certain office and personnel areas would be maintained at 70° or 75°F. The principal heat supply for the powerhouse would be the waste heat from the main unit motor-generators which would be used to heat the air in the forced circulation ventilating system, supplemented by electric resistance heating units for spot heating.

The powerhouse would require 3,460,000 B.t.u. per hour to maintain the desired temperature under the design conditions. One main unit, operating at a generator output of 69,800 kv.-a., or a

combined would be capable of hoisting a load of 365 tons consisting of a main unit motor-generator rotor (358 tons) and a lifting beam (7 tons) or a load consisting of a main power transformer without oil (182 tons) and a lifting beam (7 tons). A single main crane hook would have sufficient capacity to handle a main unit pump-turbine runner plus lifting device, a pump-turbine shaft plus lifting device, or a main power transformer core.

The motors for hoists and for bridge and trolley travel would be wound-rotor type, operating on 480-volt, 3-phase, 60-cycle current supplied through a three conductor feed-rail mounted on the corbel below the crane rails. Each hoist would be equipped with an automatic, electric load-brake, and each hoist or travel motor would be provided with a spring-set, electrically-released, shoe-type brake. The bridge travel motors would also be equipped with hydraulic service brakes. All control equipment would be located in the bridge-mounted operator's cab, and the controllers would be master-control, full-magnetic, variable-speed, reversing, definite time limit, or other approved type of acceleration control. The cab would be located beneath the downstream end of the crane girders for best visibility.

The 18-ton outdoor gantry crane would be a double-hook, fixed-trolley, traveling-gantry type, with a span between rails of 8 feet, and would travel the full length of the powerhouse tailrace deck. The total capacity of the twin hooks would be 18 tons with a maximum hook travel of 49 feet at a speed of 20 feet per minute. The capacity of the crane was based upon the estimated weight of the draft tube bulkhead sections, each one of which would be approximately 9 feet high, 29 feet long, and would weigh about 36,000 lb. The crane would also be used to hoist items of equipment from the equipment galleries through the 4- by 29-foot hatchway at the eastern end of the tailrace deck. The gantry crane would operate on 480-volt, 3-phase, 60-cycle current supplied through a flexible, portable power cable from plug-in power receptacles along the tailrace deck. The outlets would be located approximately 100 feet apart, and

(10) Maintenance Facilities. A combined electrical and machine shop would be provided at el. -2.5 of the service bay. The shop would be directly below the rotor erection area with access to it by stairway and through an equipment hatchway. The shop, including tool room space, would have an area of about 2,700 sq. ft. and would provide space and equipment for minor repairs and overhauling of equipment for the powerhouse. Equipment space allocation has not been made, but a tentative list of equipment for a shop of this nature would include:

Bench lathe	10 inches by 48 inches
Shaper	24 inches
Radial drill	36 inches
Power hacksaw	9 inches by 9 inches
Drill press (floor)	21 inches
Drill press (bench)	14 inches
Pedestal grinder	10 inches
Bench grinder (2)	7 inches
Arbor press	75-ton
Portable pipe threader	$\frac{1}{4}$ inch to 3 inches
Portable pipe threader	3 inches to 8 inches
Welding machine	300 amperes

Benches, power outlets, service air and water, electrical test panels, and other items would be provided at convenient locations. Equipment handling within the shop area would be done with an electric battery-powered forklift truck, as the size of the installation does not warrant bridge cranes or monorail hoists.

w. Switchyard.

(1) General. The switchyard, shown on plate 11-35, would be located on the right bank of the tailrace in a cut area, developed during earth borrowing activities for the earth-filled dam. The layout would be of the extended ground type construction and would provide separate bays for each of two bus tie breakers, two feeders from the powerhouse and four transmission lines. The switchyard would be designed for 138 kv. and for "heavy-loading" climatic conditions. The yard would be

graded level to el. 60, covered with 6 inches of gravel, and enclosed by a chain-link fence. A 5- by 7-foot utility tunnel would be provided from the powerhouse and would extend the full length of the switchyard. The tunnel would be of reinforced concrete and would be used for routing of oil piping and electrical circuits.

(2) Switching Arrangement. The transfer-bus type layout, shown on the main one-line diagram plate 11-19, was selected as the optimum switching arrangement, based on cost and required flexibility. As indicated on this plate, a main and a transfer bus would be provided for the full length of the switchyard. Each transmission and powerhouse line would connect to the main bus through an oil-circuit breaker and to the transfer bus through a motor-operated disconnect switch. Two bus-tie breaker bays would be provided to facilitate maintenance activities and for certain operational switching requirements. Each bus would be sectionalized by motor-operated disconnect switch located midway of the switchyard.

(3) Structural Steel. Overhead structures would be of fabricated structural steel and would consist principally of towers for terminating transmission lines, transformer lines, overhead ground wires, and for supporting rigid type buses. Bus conductors would be supported by individual columns, and switches would be mounted on raised lattice-work steel frames. Concrete footings would be used.

(4) Buses. The buses would be of 2-inch tubular aluminum rigidly supported on pedestal type insulators, mounted atop steel columns. The conductor sag under heavy-loading conditions would not exceed one diameter of the conductor. Bolted clamp-type connectors would be used to join the conductors and connect to equipment. Expansion joints would be used in the bus as required to prevent excessive stresses on insulators.

(5) Oil Circuit Breakers. Oil circuit breakers would be of the pneumatic-operated type, rated 1,200 amperes continuous, 3-cycle operating speed, 20-cycle reclosure speed, and 5,000-mv.-a. interrupting capacity. Each breaker would be equipped with self-contained air compressor and receiver. The compressor would be driven by a 440-volt motor and automatically controlled to maintain the proper operating air pressure. Breakers would have bushing type current transformers as required for metering and for relay protection. The breaker would be mounted and bolted to a concrete pad. Breaker control would be by d.c. circuits from the powerhouse main control room.

(6) Disconnecting Switches. Disconnecting switches would be gang-operated, 3-pole, nonload break, rated at 1,200 amperes continuous, and mounted on a lattice type steel frame. Switches connected to the transfer bus would be motor-operated and controlled from the powerhouse main control room. The remaining disconnect switches would be manually operated from ground level. Ground switch blades would be provided on those disconnect switches connected to the powerhouse and transmission lines. All switches and breakers would be interlocked both electrically and mechanically (key) to insure proper sequence of operation.

(7) Lightning Arresters. Lightning arresters would be provided on each phase of the transmission lines. They would be of the self-supporting, thyrite, single-pole, outdoor station type, and rated at 121 kv.

(8) Potential Devices. A line-to-ground coupling capacitor with potential device would be connected to each transmission line conductor. The potential from these devices would be used for synchronizing, metering, and relaying. These same coupling capacitors, in conjunction with wave traps, would serve to connect the carrier-current circuits to the lines. Similar line-to-ground coupling capacitors with potential devices would be connected to the same phase conductor of the main bus and the transfer bus. The single phase potential from these devices would be used for synchronizing to the buses.

(9) Underground Grounding. The switchyard grounding system, shown on plate 11-26, would consist of an interconnected network of buried copper conductors throughout the switchyard and connected to the station ground mat by two 500 M c.m. copper cables. Connections would also be made to the overhead grounding wires and to the powerhouse ground buses. Structural steel would be grounded to the mat at each separate footing. Circuit breakers, potential devices, lightning arresters, fences, and all such equipment will be grounded to the switchyard mat by direct copper connections.

(10) Overhead Grounding. An overhead ground network of galvanized steel cables would be installed over the switchyard proper as a protection against direct strokes of lightning. This network would be supported by steel towers, as shown on plate 11-35. A copper cable connected to the network at each tower would extend down and connect to the underground ground mat.

(11) Utilities. Two 480-volt, duplicate feeder, power circuits, would be run from the powerhouse to a power distribution panel located in the switchyard tunnel. Power receptacles (480-volt and 3-phase) would be installed in alternate bays near the circuit

breakers for convenience during maintenance activities. The switchyard lighting would be by substation type luminaires mounted on the switchyard structural steel and supplied by a 3-phase dry-type transformer located in the tunnel. Oil-piping, run in the tunnel, would connect the circuit breakers with the oil handling, storage, and purification equipment located in the powerhouse.

x. Material Selection and Corrosion Prevention.

(1) General. The conditions of exposure for plant and equipment at Digdeguash would be similar to those which would exist at the tidal power plant at Carryingplace Cove. In both instances, the plants would be situated upon a body of salt water, and would utilize this salt water for hydraulic power. As a consequence of the corrosive effects of salt water upon metals, it would be necessary that special attention be given to selection or protection of metals which would reduce the effects of corrosion. This problem of corrosion and corrosion prevention is discussed in detail in appendix 8, "Tidal Power Plant and Corrosion Prevention," but the major points are reiterated here for convenience. This section will be concerned only with metals either continuously, or intermittently submerged in sea water. Some attention will be paid to the problem of marine growth upon submerged parts, but this is expected to be of minor importance except where static or very low velocity flow conditions would be encountered. Materials other than metals, and marine atmospheric exposure are discussed elsewhere.

(2) Protective Methods.

(a) General. Corrosion of metals in sea water can be reduced or controlled by use of metals having an inherently high resistance to corrosion, use of protective coatings on the surface of nonresistive metals, use of cathodic protection systems to counterbalance the electrochemical forces causing corrosion, or a combination of any of the above methods. Generally, a combination of these methods is likely to result in the most economic installation.

(b) Corrosion Resistant Metals. All metals have some degree of resistance to corrosion in sea water. The most resistant metals are generally the nonferrous metals and alloys, or the highly alloyed stainless steels. In comparison with mild steel these metals are expensive, so that in addition to first cost, consideration must be given to actual rate of deterioration and life expectancy, cost and ease of maintenance, and not least of all to the physical strength of the metal. The most resistive metal, determined on the basis of least weight loss per unit of exposed area, is a stainless steel, classified as AISI type 316, containing

approximately 10-14 percent nickel, 16-18 percent chromium, and 2-3 percent molybdenum. However this metal is, in common with all the stainless steels, subject to relatively deep, localized pitting when the velocity of the water flow past the metal surface is less than about 5 feet per second. At velocities above 5 f.p.s., tests have shown that corrosion is virtually eliminated on exposed surfaces. Even with the high velocity flow care must be exercised to avoid sharp re-entrant angles, corners, and crevices where the water may stagnate and cause concentrated pitting or crevice corrosion. Another stainless steel belonging to the iron-chromium stainless steels, and containing about 12 percent chromium (known as AISI type 410) has less corrosion resistance than the 316 but is cheaper and stronger. However this steel, in the presence of cathodic protection currents, deteriorates badly due to the formation of hydrogen blisters on the surface. This phenomenon has been shown to occur at current densities less than those required for polarization or protection of the metal, and also to extend some distance into the metal. The 316 stainless does not exhibit this deterioration.

The group of nonferrous copper-bearing alloys classified as bronzes all exhibit relatively good corrosion resistance compared with carbon steel. These metals also have good inherent antifouling properties, due to their copper content. They are generally less expensive than the stainless steels. Among the most effective alloys are the aluminum and nickel-aluminum bronzes, which have the best resistance but are also the most expensive. These metals have greater loss and consequently shorter life expectancy than the stainless steels under the most suitable conditions for each. The actual life of some of the better alloys cannot be predicted with any accuracy as they are relatively new, and there has been insufficient experience upon which to base prediction. This is especially true of the nickel-aluminum bronze group. Another factor influencing life expectancy is that the bronzes show accelerated wear if exposed to high velocity flow a great proportion of the time. Evidence indicates that bronzes perform best in low velocity flows, or where high velocity flows are intermittent and infrequent.

(c) Cathodic Protection. Most authorities are now agreed that corrosion is essentially an electrochemical phenomenon, and upon this basis corrosion can be prevented or controlled by imposition of an external current to counteract the corroding current. This is the fundamental basis of cathodic protection. The current could be introduced from an external source through a suspended anode, which would be designated as "impressed voltage" protection, or by means of a suspended anode of less "noble" metal which would create a current through "galvanic couple" action. In the "galvanic couple" system the anode would be

sacrificially corroded to protect the cathodic metal of the protected structure. In the "impressed voltage" system, the external power source would supply the necessary ions. The anodes would still corrode, but at a much slower rate; the rate varying for different metals.

A galvanic couple is a corroding influence as well as a protective one. This occurs when different parts of a unit exposed to sea water are of dissimilar metals. The actual rate of corrosion would depend upon the relative masses of the metals and their relative positions in the electropotential series. For instance, a hydraulic turbine in which the runner is of stainless steel or bronze and the remaining parts of carbon steel would form a couple in which the more "noble" metal of the runner would be the cathode, and the carbon steel would be the anode. The latter would be corroded at an accelerated rate. Therefore when such a combination of metals is used, some additional measures must also be taken. Coating the mild steel with an impermeable coating would be satisfactory if the coating is strong enough to withstand impact without puncturing or breaking, as such a break would cause concentrated attack at the exposed point. Therefore if a combination of metals is to be used, a cathodic protection system sufficient to overcome or suppress the potential galvanic couple would be necessary.

Under certain circumstances of exposure and construction, carbon steel can be used with a cathodic protection system to achieve the most economical installation.

(d) Protective Coatings. Metals can be protected from the corrosive action of sea water by coating the exposed surfaces with a relatively impervious, inert, or passivating coating such as paint, plastic, rubber or rubber-like materials, or even thin coatings of more resistant metals. These coatings protect the base metal in various ways. Some are inert and impermeable and protect the metal surface by excluding the sea water. If these coatings are damaged they provide no further protection to the exposed areas. Other coatings contain constituents which act to form passivating films in the presence of water. These afford some degree of protection to the base metal even when broken through. Some coatings, such as a thin layer of stainless steel, would actually accelerate the deterioration of the base metal once the coating is pierced, so the coating layer must be both strong and impervious. Among the more successful protective coatings which have been used in sea water are hot-applied coal tar enamels, lead-in-oil paints, vinyl and phenolic inorganic resin lacquers, and rubber and rubber-like compounds.

Coal tar enamel has been used successfully for years in sea water exposure. It is an impervious, inert coating that is relatively inexpensive to prepare and apply, but requires properly trained personnel for proper application. It has little mechanical strength and is easily damaged. It has no passivating action that would provide residual protection. It is also difficult to patch adequately without excessive cost.

The lead-in-oil paints are somewhat permeable and contain passivating agents for protection. These paints have been used successfully for many years but are being replaced by the newer compounds which apparently perform better.

In the class of inorganic resin lacquers, the vinyl paints appear to furnish the best protection. They are relatively expensive and require thoroughly clean, sandblasted surfaces for proper adhesion, but can be applied by painters without special training. The vinyls have been used in both fresh and salt water service where exposed to relatively high velocities such as in penstocks and on hulls of fast naval vessels. On destroyers in salt water, life expectancy is from 18 to 36 months, but it is believed this relatively short life is the result of drydock practice which does not guarantee dry metal surfaces for application, and which refloat the vessel before the paint is dry. Experience has shown that both these practices drastically reduce the life of a vinyl coating. Vinyls are also relatively impervious, and when used in conjunction with proper cathodic protection systems have evidenced no tendency to blister due to formation of free hydrogen beneath the paint. Repair of vinyl coatings is simple and inexpensive.

Rubber and rubber-like coatings, called elastomers, are employed as protective coatings in many industries. They are equally suitable for this application, the materials being inert to sea water. The moisture permeability of the different compounds varies considerably which would affect their efficancy, especially in conjunction with cathodic protection systems. The materials may be applied either in sheet form or as dispersion solutions. Neoprene and Thiokol are types which have been used with some success in salt water applications where there is considerable velocity. The results have not been unqualifiedly successful, and the technique of application appears to be a critical factor. These coatings are also relatively expensive to apply.

(3) Recommended Measures.

(a) General. The recommendations for selection of materials contained herein were developed upon the basis of corrosion resistance or inertness, costs of application and

maintenance and expected life of the application. It should be pointed out that the materials chosen on the basis of available information and experience as of the date of this study may not be the best at the time construction would be undertaken. It is expected that development of some promising materials, especially in the organic resin lacquer and elastomer classes, will have advanced in the next few years to the point where reconsideration will be required. With this in mind, the following recommendations are made, with the understanding they are considered the most suitable at the present time.

(b) Pump-Turbines. The rotating parts of the pump-turbine, that is the blades, hub, and cone, would be made of type 316 stainless steel. The discharge ring, that is the section of throat at the end of the runner blades, would also be 316 stainless. The choice of either a full section cast stainless steel, or a facing surface of stainless steel on carbon steel would be made later on the basis of manufacturers recommendations. The top 4 feet of the draft tube liner, immediately below the discharge ring, would be 316 stainless clad plate. The internal facing surfaces between the runner and the inner head cover where sea water could penetrate and stagnate, would be faced with "K" monel for resistance to crevice corrosion. A sleeve of "K" monel would also be provided on the runner blade trunnions where they enter the runner hub. The trunnion hole would be bushed with "S" monel. A sleeve of "K" monel would also be provided on the pump-turbine shaft under the packing gland.

All remaining metal in the pump-turbine would be carbon steel, either cast, or rolled. All surfaces exposed to sea water, including the inner and outer head cover, stay and guide vanes would be painted with a 10 mil, 6-coat application of vinyl paint conforming to standard Corps of Engineers formulation for ferrous surfaces subject to immersion in sea water and fouling from marine organisms. The top two coats would be antifouling coats to control marine growth which might occur during the frequent periods of nonoperation. An impressed current cathodic protection system would also be provided to protect the carbon steel against corrosion in the event the vinyl coat should be breached. The system would consist of anodes located in the scroll case and in the draft tube. A monitoring system would be installed to prevent overprotection.

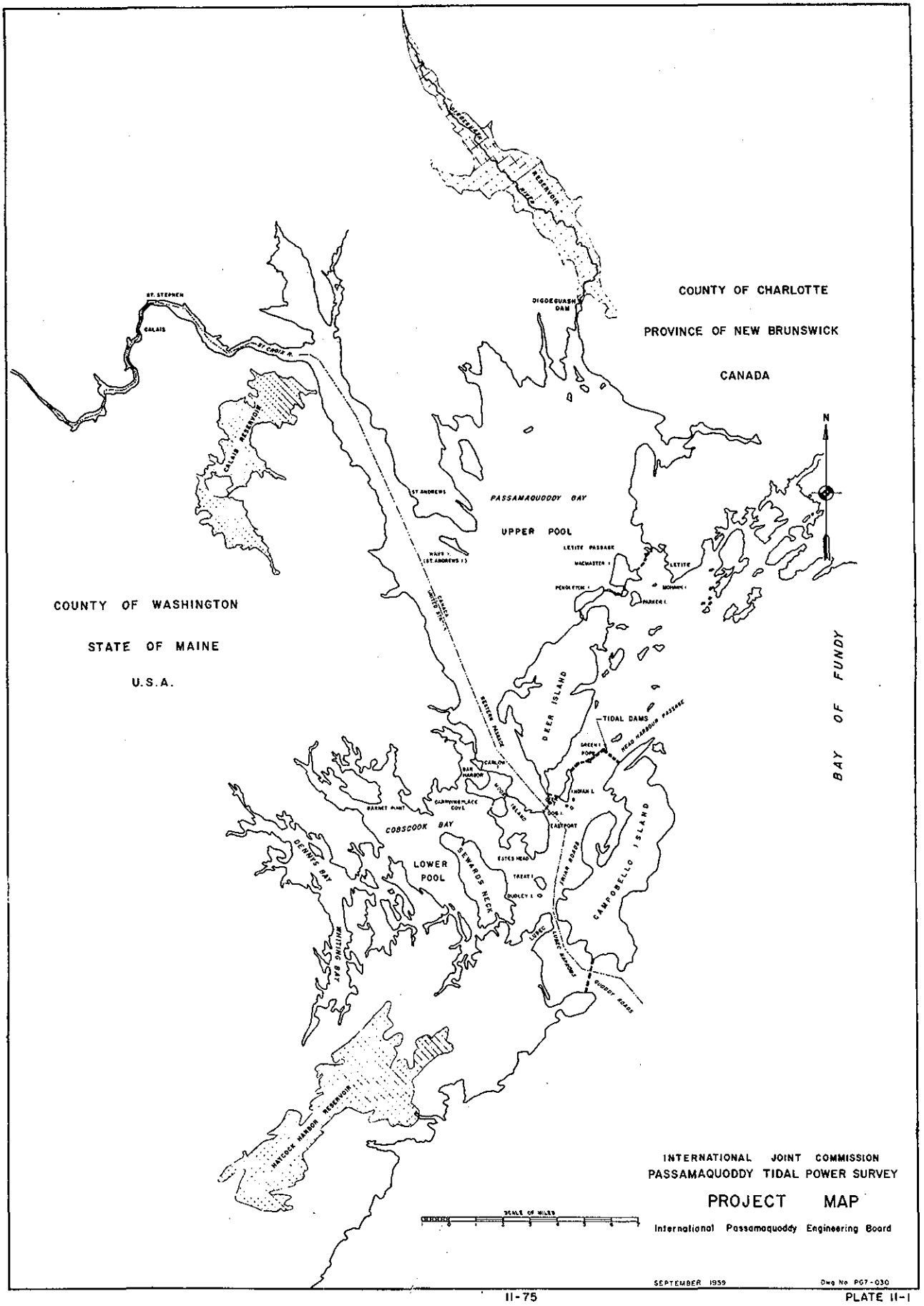
(c) Water Passages. The penstock, scroll case, and draft tube liner would be carbon steel plate, painted with the 6-coat antifouling vinyl system on all surfaces exposed to salt water. The exterior surface of the penstock would be painted with a 4-coat vinyl system conforming to the Corps of Engineers' standard formulation for exterior ferrous surfaces subject to fresh water immersion. This is in line with the Corps' recommendation for such marine atmospheric exposure.

The penstock, scroll case, and draft tube liner would be protected by an impressed current cathodic protection system, essentially an extension of the pump-turbine protection system.

(d) Gates and Trashracks. Powerhouse intake head gates, intake and draft tube trashracks, and spillway gates would all be fabricated of carbon steel plates and shapes, coated with a coal tar enamel primer coat. The draft tube, stoplogs, or bulkhead, being out of water most of the time would be carbon steel, painted with a 4-coat vinyl system, omitting the antifouling coats. Seal plates for the powerhouse intake and draft tube trashracks and gates would be fabricated of a highly corrosion-resistant alloy cast-iron of the Ni-Resist type as their relatively inaccessible locations would make maintenance, or replacement, a very expensive operation. The spillway gate seal plates and bulkhead guides, which would be accessible for periodic maintenance during the time when the storage pool would be near minimum operating levels, would be of carbon steel. All exposed metal would be given an initial covering of a 6-coat antifouling vinyl system, except the "Ni-Resist" which would receive only the 2 antifouling coats. In certain locations subject to abrasive or rolling contact, such as taintor gate seal plates and powerhouse intake head gates, the paint coating on the contact surfaces cannot be expected to last an appreciable number of operating cycles. Such operation is expected to be relatively infrequent and the paint coating would have significant effect before deterioration.

Cathodic protection would be provided for all locations mentioned above, by means of impressed voltage cathodic protection systems with replaceable anodes located near the particular installation to be protected.

y. Relocations, Lands, and Damages. After selection of the Digdeguash River site for detailed study for the auxiliary pumped-storage plant, a more accurate estimate was undertaken to determine real estate costs than was done for the initial studies. All lands below el. 180 and lands needed for severence reasons, access, relocations of utilities and cemeteries, and construction and borrow would be acquired in fee simple. The District Engineer, Public Works Department, Saint John, New Brunswick, arranged to have the area visited and the costs estimated by personnel who were experienced in real estate matters. It was determined that 1,326 acres of land would be acquired for severance reasons in addition to the 6,842 acres required for the reservoir, structures, and access. Right-of-way required for road relocations would amount to 0.8 mile on the east side of the reservoir and 3.7 miles on the west side. In addition, land would be required outside the reservoir area for the relocation of about 200 graves. The real estate costs determined from the above described survey are included in the project cost estimate presented in appendix 17, "Estimates of Cost."



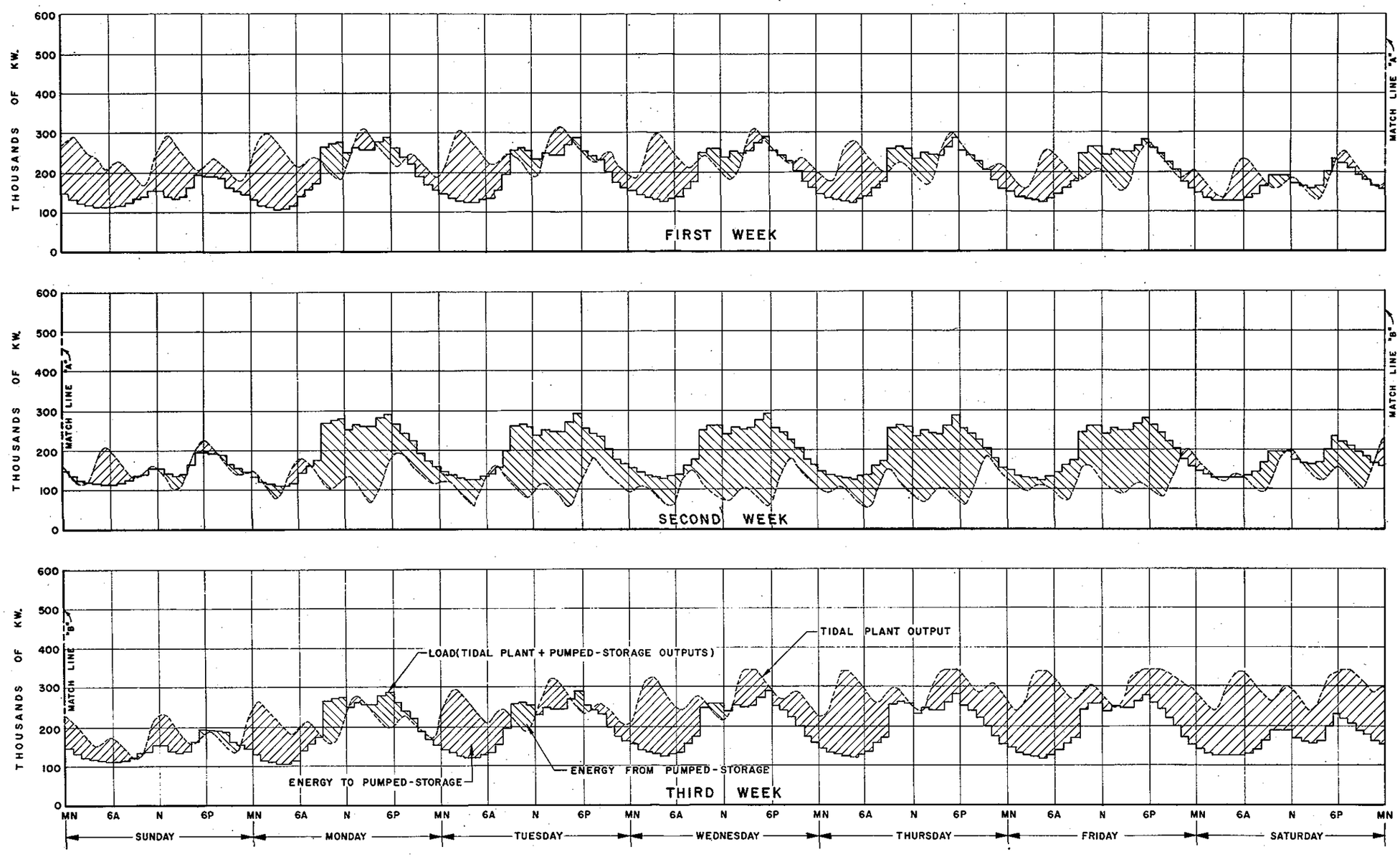
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

PROJECT MAP

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg No PG7-030

PLATE II-1



INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

PUMPED-STORAGE DEVELOPMENT

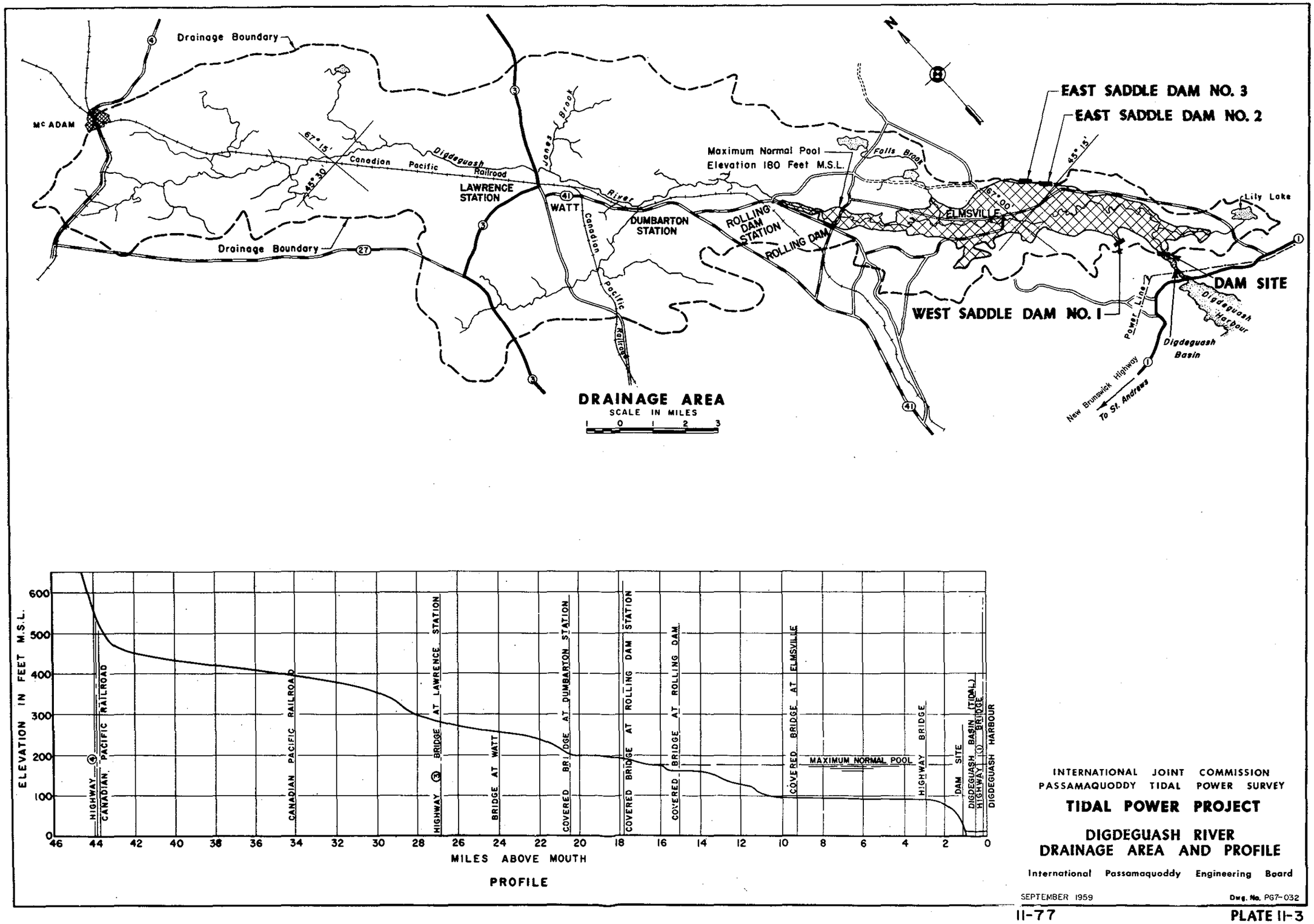
TIDAL PLANT OUTPUT

AND LOAD PATTERN

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. PG7-031

PLATE II-2



INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL POWER PROJECT

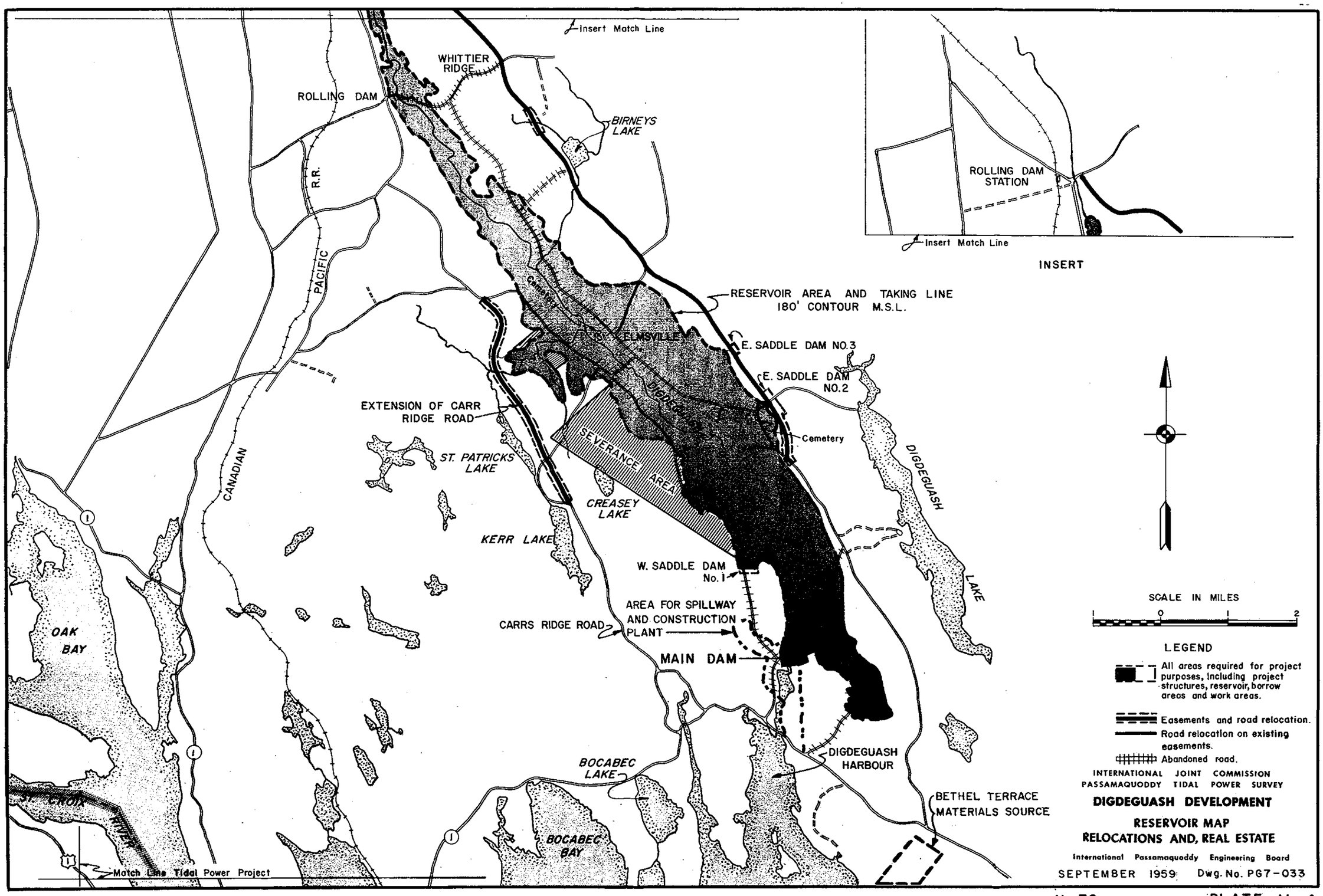
DIGDEGUASH RIVER
DRAINAGE AREA AND PROFILE

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. PG7-032

PLATE II-3


Insert Match Line
WHITTIER RIDGE
ROLLING DAM
BIRNEYS LAKE
R.R.
PACIFIC
CANADIAN
ROLLING DAM STATION
Insert Match Line
INSERT
RESERVOIR AREA AND TAKING LINE 180' CONTOUR M.S.L.
ELMSVILLE
E. SADDLE DAM NO.3
E. SADDLE DAM NO.2
DIGDEGUASH
Cemetery
EXTENSION OF CARR RIDGE ROAD
ST. PATRICKS LAKE
SEVERANCE AREA
CREASEY LAKE
KERR LAKE
DIGDEGUASH
LAKE
W. SADDLE DAM No. 1
AREA FOR SPILLWAY AND CONSTRUCTION PLANT
CARRS RIDGE ROAD
MAIN DAM
OAK BAY
DIGDEGUASH HARBOUR
BOCABEC LAKE
BETHEL TERRACE MATERIALS SOURCE
ST. CROIX RIVER
BOCABEC BAY
Match Line Tidal Power Project
SCALE IN MILES
0
1
2
LEGEND
All areas required for project purposes, including project structures, reservoir, borrow areas and work areas.
Easements and road relocation.
Road relocation on existing easements.
Abandoned road.
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
DIGDEGUASH DEVELOPMENT
RESERVOIR MAP
RELOCATIONS AND, REAL ESTATE
International Passamaquoddy Engineering Board
SEPTEMBER 1959 Dwg. No. PG7-033

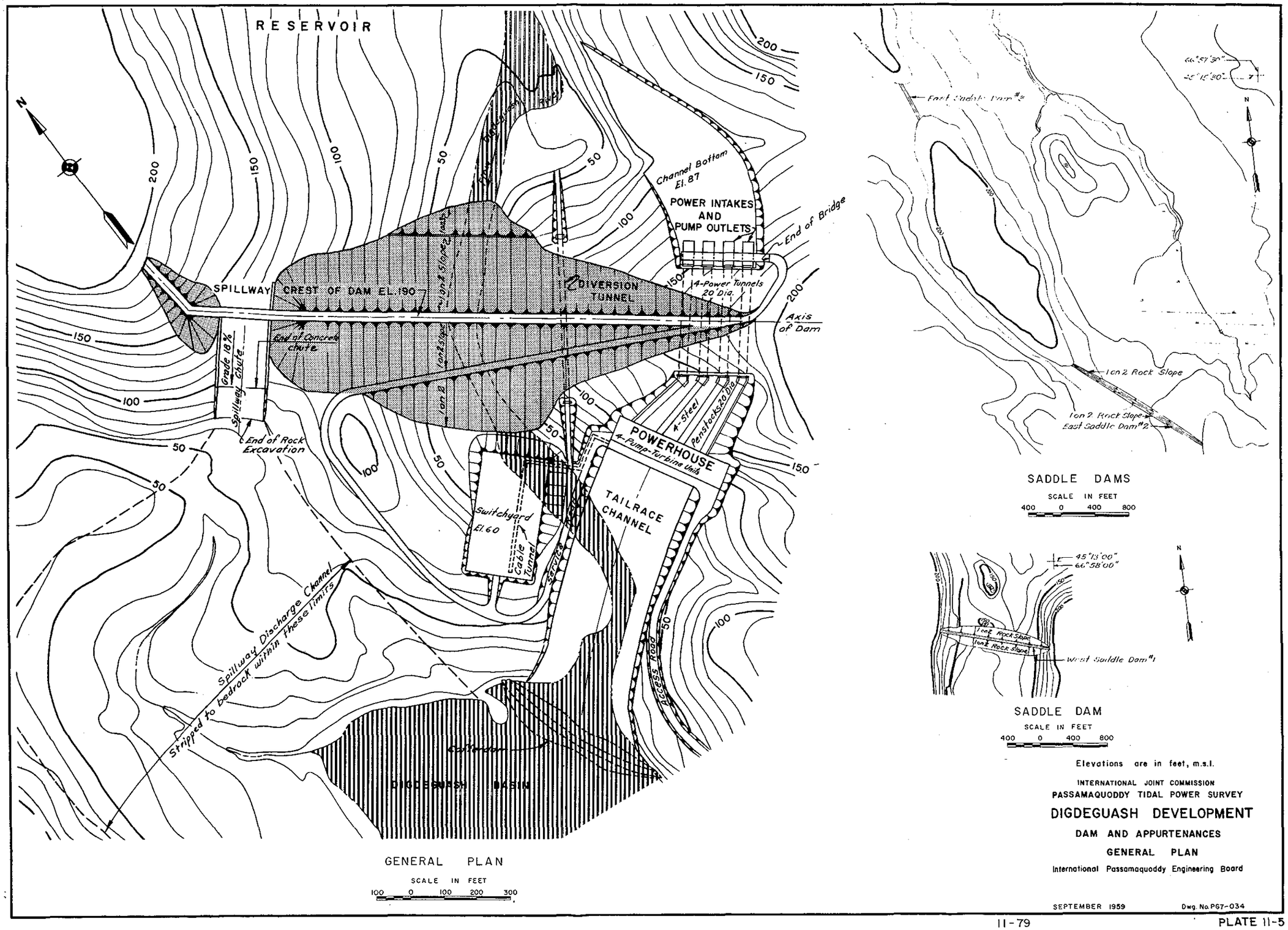
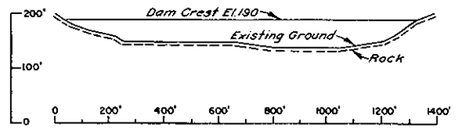
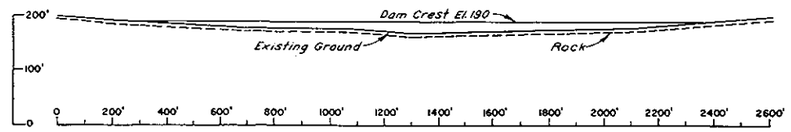

RESERVOIR
SPILLWAY
CREST OF DAM EL. 190
DIVERSION TUNNEL
Channel Bottom El. 87
POWER INTAKES AND PUMP OUTLETS
End of Bridge
4-Power Tunnels 20' Dia.
Axis of Dam
End of Concrete chute
Grade 18%
Spillway Chute
End of Rock Excavation
POWERHOUSE
4-Pump-Turbine Units
4-Steel Penstocks 20' Dia.
TAILRACE CHANNEL
Switchyard El. 60
Cable Tunnel
Service
Access Road
Spillway Discharge Channel
Stripped to bedrock within these limits
Cofferdam
DIGDEGUASH BASIN
GENERAL PLAN
SCALE IN FEET
100 0 100 200 300
East Saddle Dam #3
1 on 2 Rock Slope
1 on 2 Rock Slope
East Saddle Dam #2
SADDLE DAMS
SCALE IN FEET
400 0 400 800
45°13'00"
66°58'00"
West Saddle Dam #1
SADDLE DAM
SCALE IN FEET
400 0 400 800
Elevations are in feet, m.s.l.
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
DIGDEGUASH DEVELOPMENT
DAM AND APPURTENANCES
GENERAL PLAN
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. PG7-034

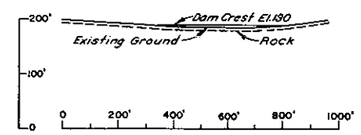
PLATE II-5



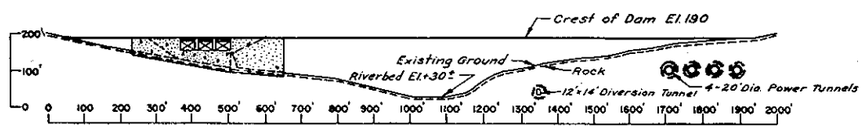
PROFILE-WEST SADDLE DAM NO.1



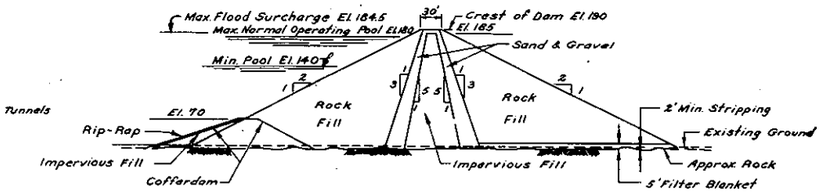
PROFILE - EAST SADDLE DAM NO.2



PROFILE - EAST SADDLE DAM NO.3

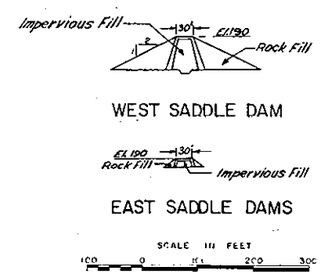


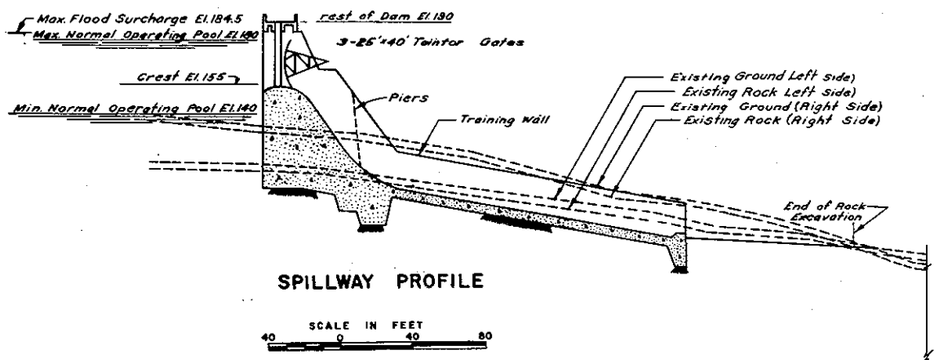
SECTION ON AXIS OF DAM



DAM SECTION

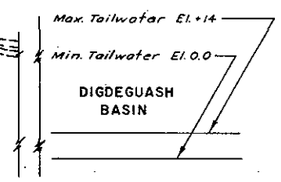
SCALE IN FEET
100 0 100 200

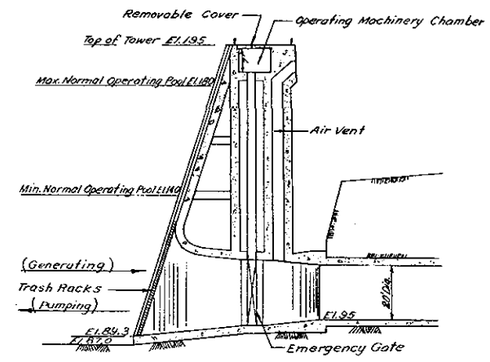




SPILLWAY PROFILE

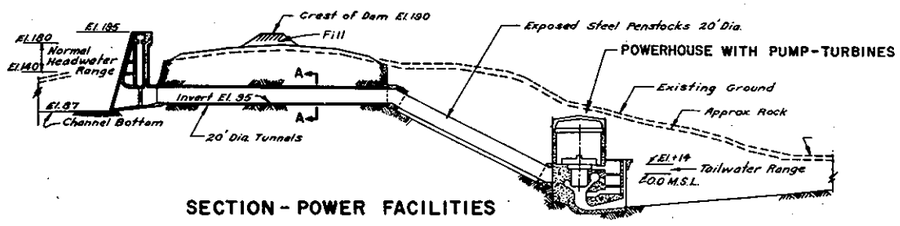
SCALE IN FEET
40 0 40 80





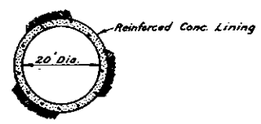
SECTION-INTAKE STRUCTURE

SCALE IN FEET
20 0 20 40

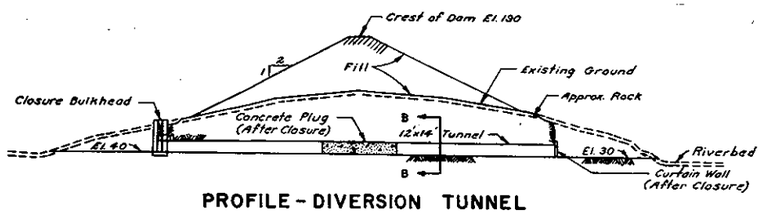


SECTION - POWER FACILITIES

SCALE IN FEET
100 0 100 200

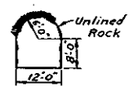


POWER TUNNEL
SECTION A-A



PROFILE - DIVERSION TUNNEL

SCALE IN FEET
100 0 100 200



DIVERSION TUNNEL
SECTION B-B

ELEVATIONS ARE IN FEET, M.S.L.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

DAM AND APPURTENANCES

ELEVATION AND SECTIONS

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. PG7-035

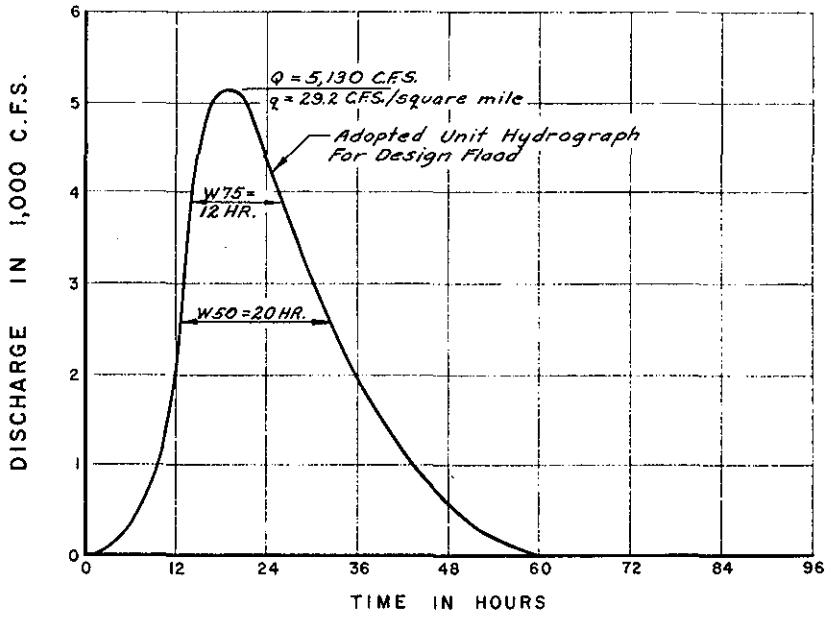


FIG. 1 – 6 HOUR UNIT HYDROGRAPH

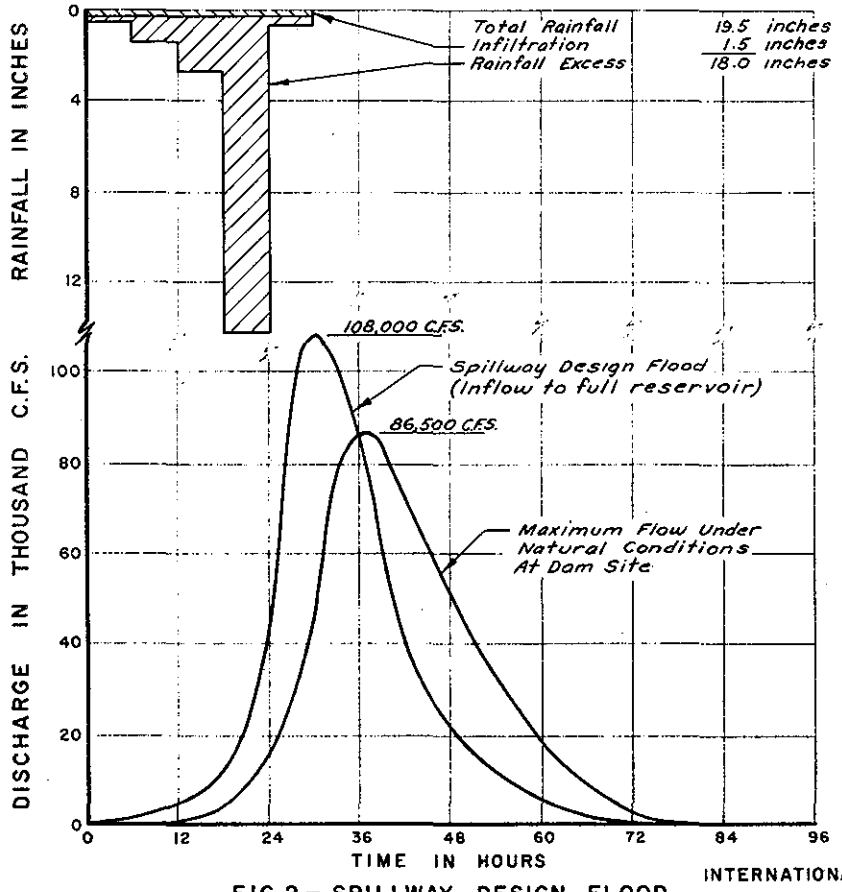
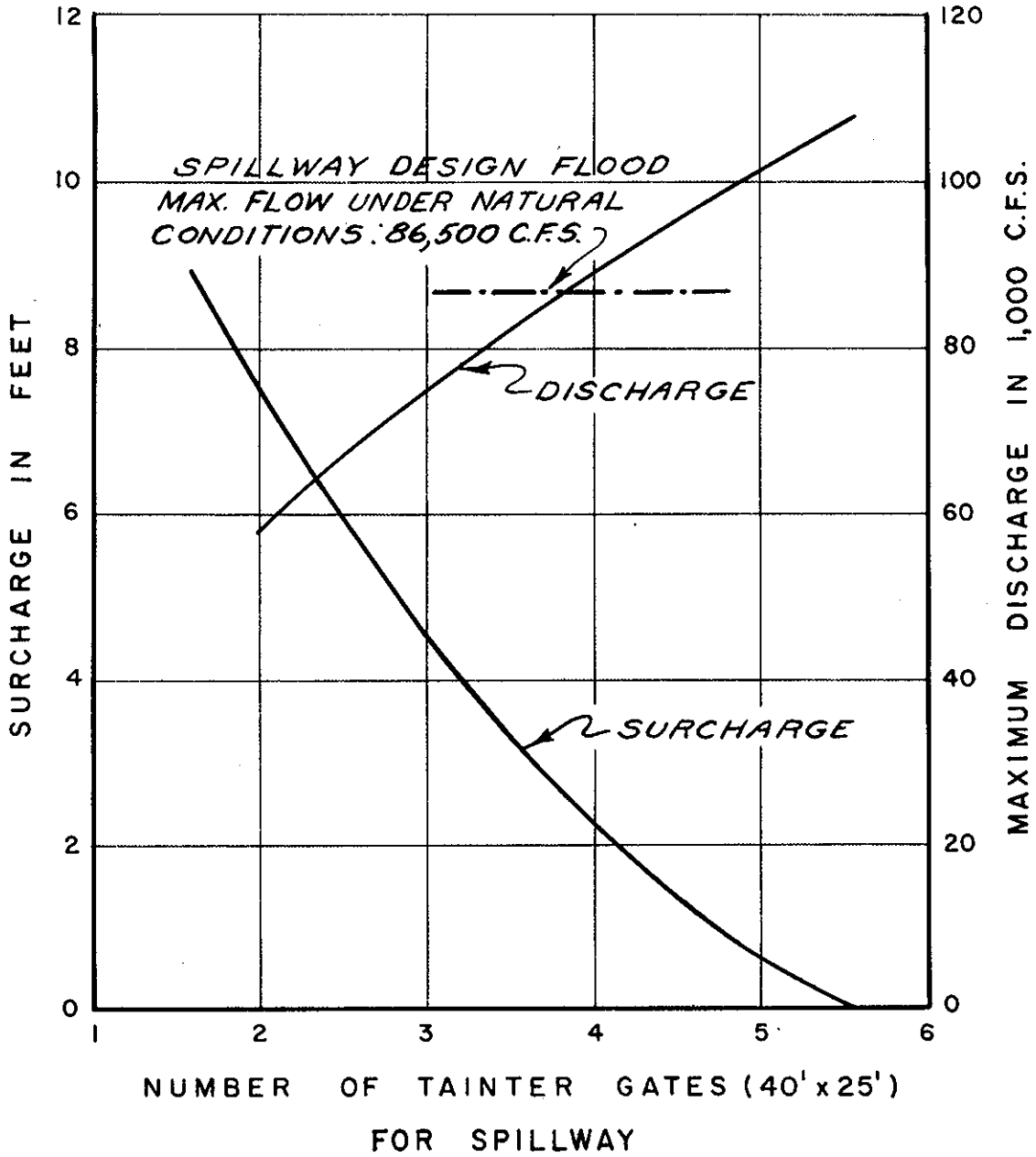


FIG. 2 – SPILLWAY DESIGN FLOOD

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
DIGDEGUASH DEVELOPMENT
SPILLWAY
DESIGN FLOOD HYDROGRAPHS
INT'L. PASSAMAQUODDY ENGR. BOARD
SEPTEMBER 1959 Dwg. No PG7-036



NOTE:

RESERVOIR WAS ASSUMED FULL TO TOP OF GATES, EL. 180, AT THE START OF SPILLWAY DESIGN FLOOD.

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

SPILLWAY

NO. OF GATES VS SURCHARGE

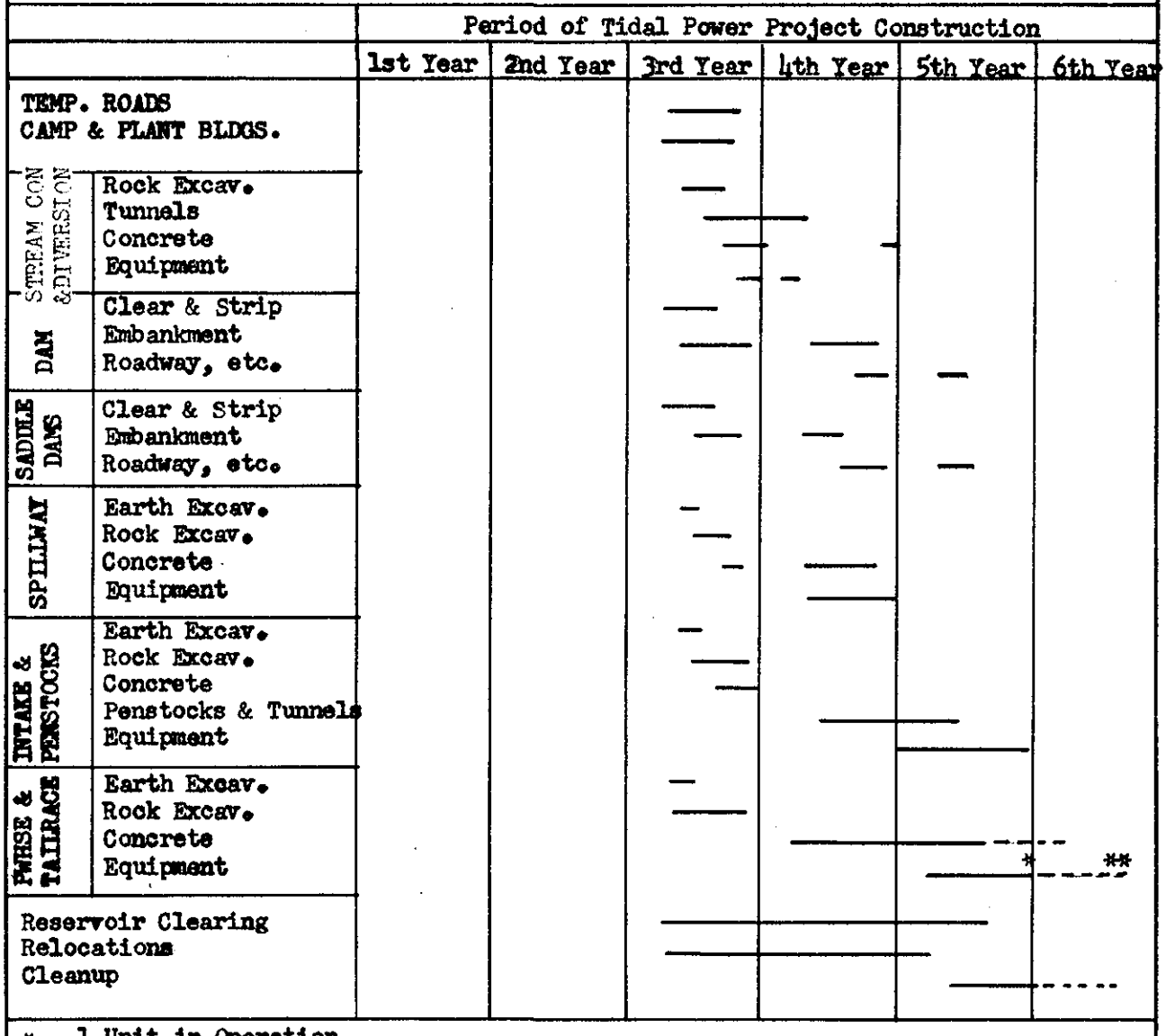
INT'L. PASSAMAQUODDY ENGR. BOARD

SEPTEMBER 1959 Dwg. No. PG7-037

SEPTEMBER 1959 Dwg. No. PG7-038

DIGDEGUASH PUMPED STORAGE

CONSTRUCTION SCHEDULE



* 1 Unit in Operation
** 4 Units in Operation

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

CONSTRUCTION SCHEDULE

INT'L. PASSAMAQUODDY ENGR. BOARD

SEPTEMBER 1959 Dwg. No. PG7-039

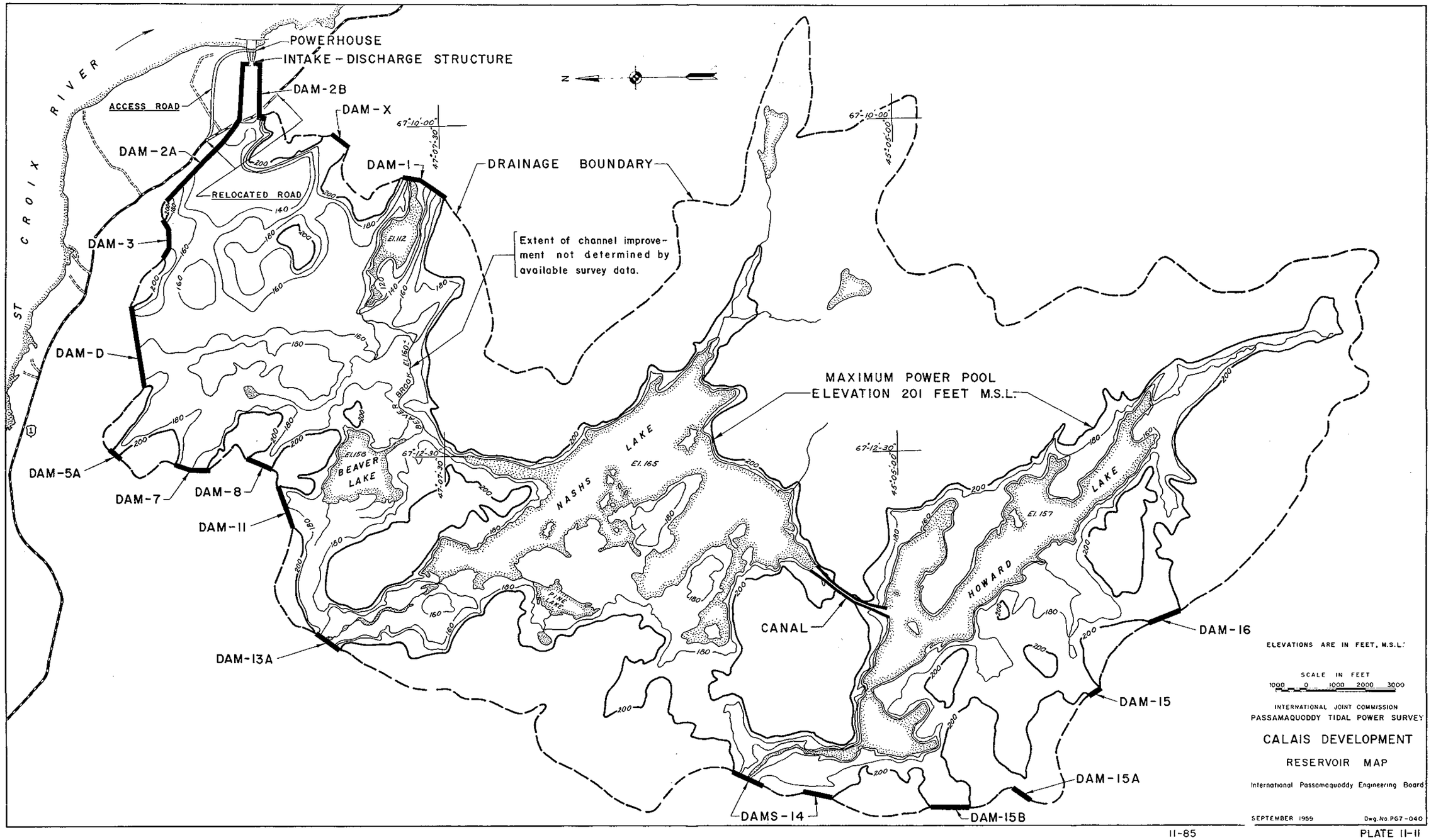
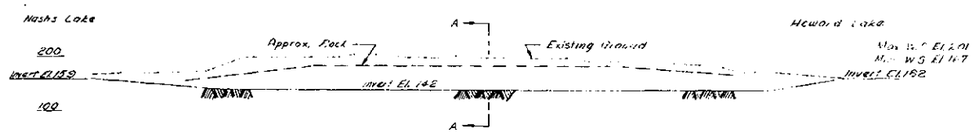
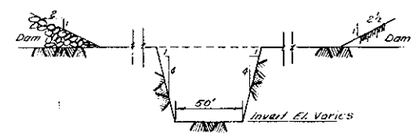

POWERHOUSE
INTAKE - DISCHARGE STRUCTURE
DAM-2B
DAM-X
ACCESS ROAD
DAM-2A
DAM-1
DRAINAGE BOUNDARY
RELOCATED ROAD
DAM-3
Extent of channel improvement not determined by available survey data.
DAM-D
MAXIMUM POWER POOL
ELEVATION 201 FEET M.S.L.
DAM-5A
DAM-7
DAM-8
DAM-11
DAM-13A
BEAVER LAKE
NASHS LAKE
PINE LAKE
HOWARD LAKE
CANAL
DAM-16
DAM-15
DAM-15A
DAMS-14
DAM-15B
ST CROIX RIVER
ELEVATIONS ARE IN FEET, M.S.L.
SCALE IN FEET
1000 0 1000 2000 3000
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
CALAIS DEVELOPMENT
RESERVOIR MAP
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. PG7-040

PLATE II-11



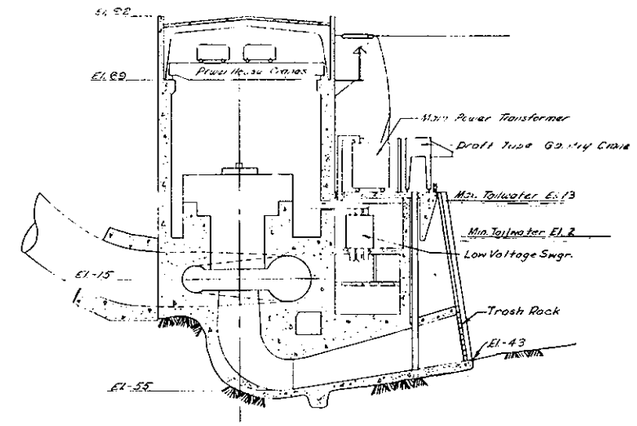
CANAL PROFILE - NASHS LAKE TO HOWARD LAKE
Scale: Horiz. 1"=200' Vert. 1"=10'

SCALE IN FEET
200 0 200 400



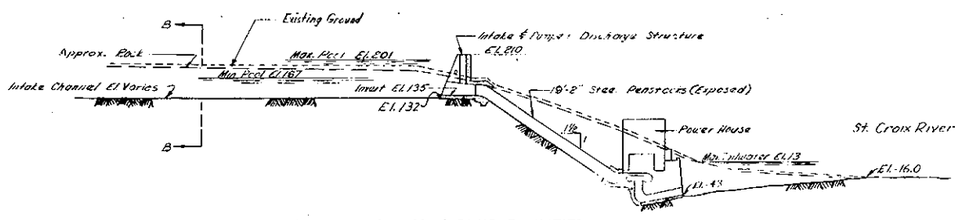
INTAKE APPROACH - CROSS SECTION B-B
Scale 1"=40'

SCALE IN FEET
40 0 40 80



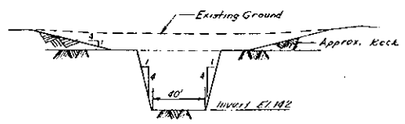
POWER HOUSE SECTION
Scale 1"=20'

SCALE IN FEET
20 0 20 40

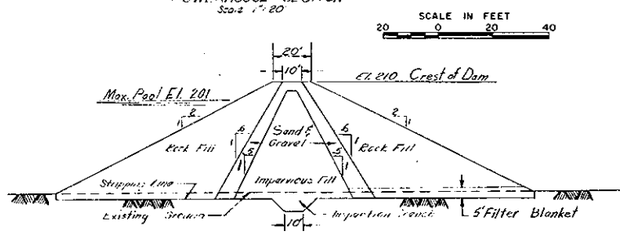


PROFILE - POWER & PUMP FACILITIES
Scale 1"=100'

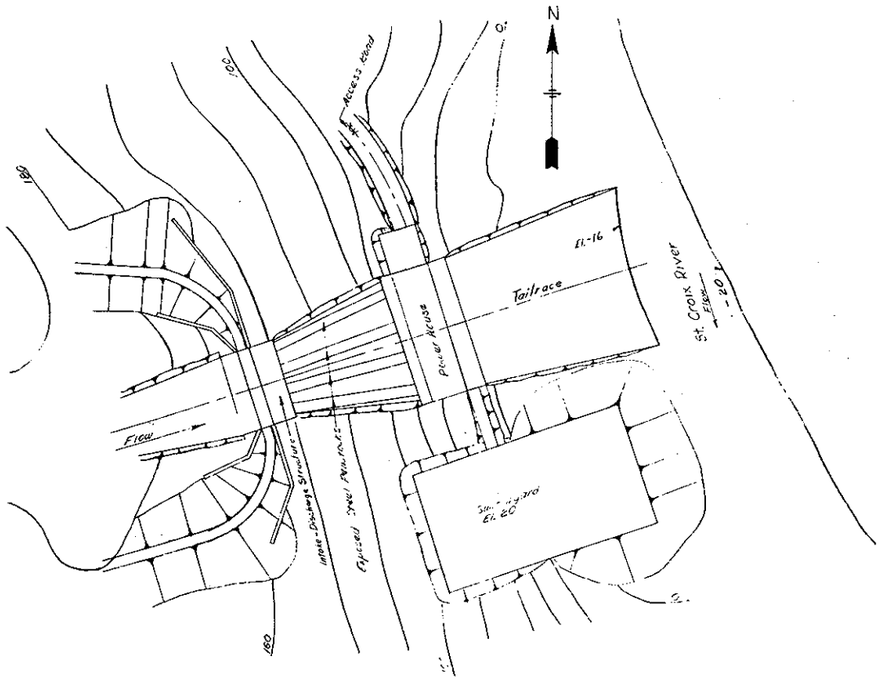
SCALE IN FEET
100 0 100 200



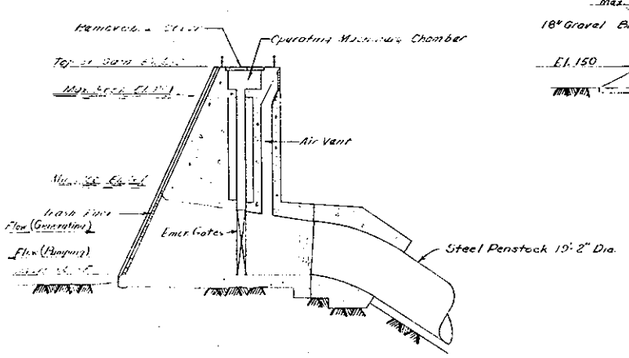
CANAL CROSS SECTION A-A
Scale 1"=40'



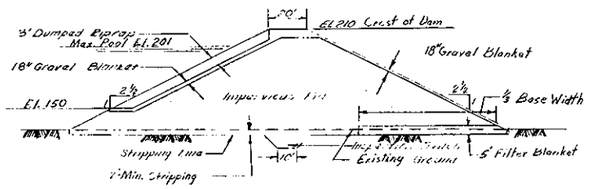
TYPICAL CROSS SECTION
(DAM NOS. 1, 14, 15, 15A, 15B, 16)
Scale: None



GENERAL PLAN AT POWERHOUSE
Scale 1"=100'



SECTION THRU POWER INTAKE & PUMPED DISCHARGE STRUCTURE
Scale 1"=20'



TYPICAL CROSS SECTION
(DAM NOS. X, 2A, 2B, 3, D, 5A, 7, 8, 11, 13A)
Scale: None

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

CALAIS DEVELOPMENT

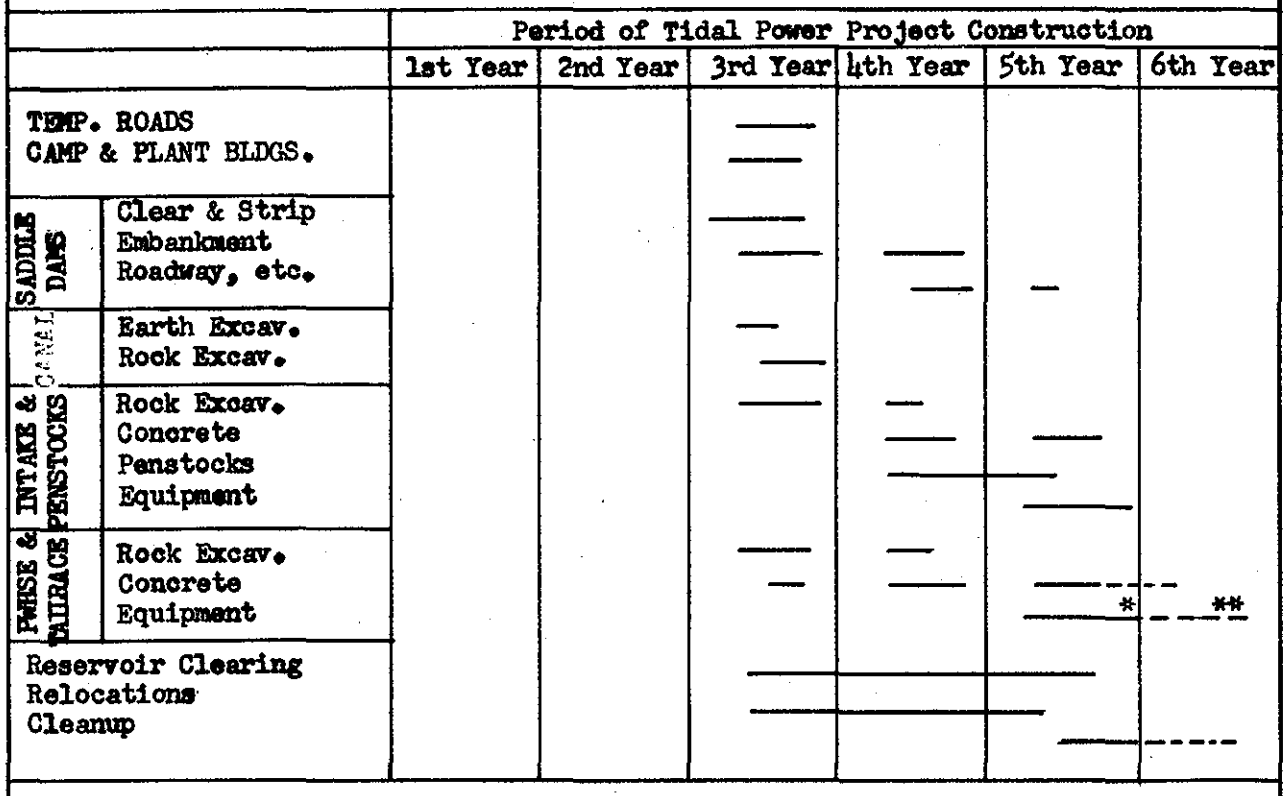
PLANS, PROFILES & SECTIONS

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. PG7-041

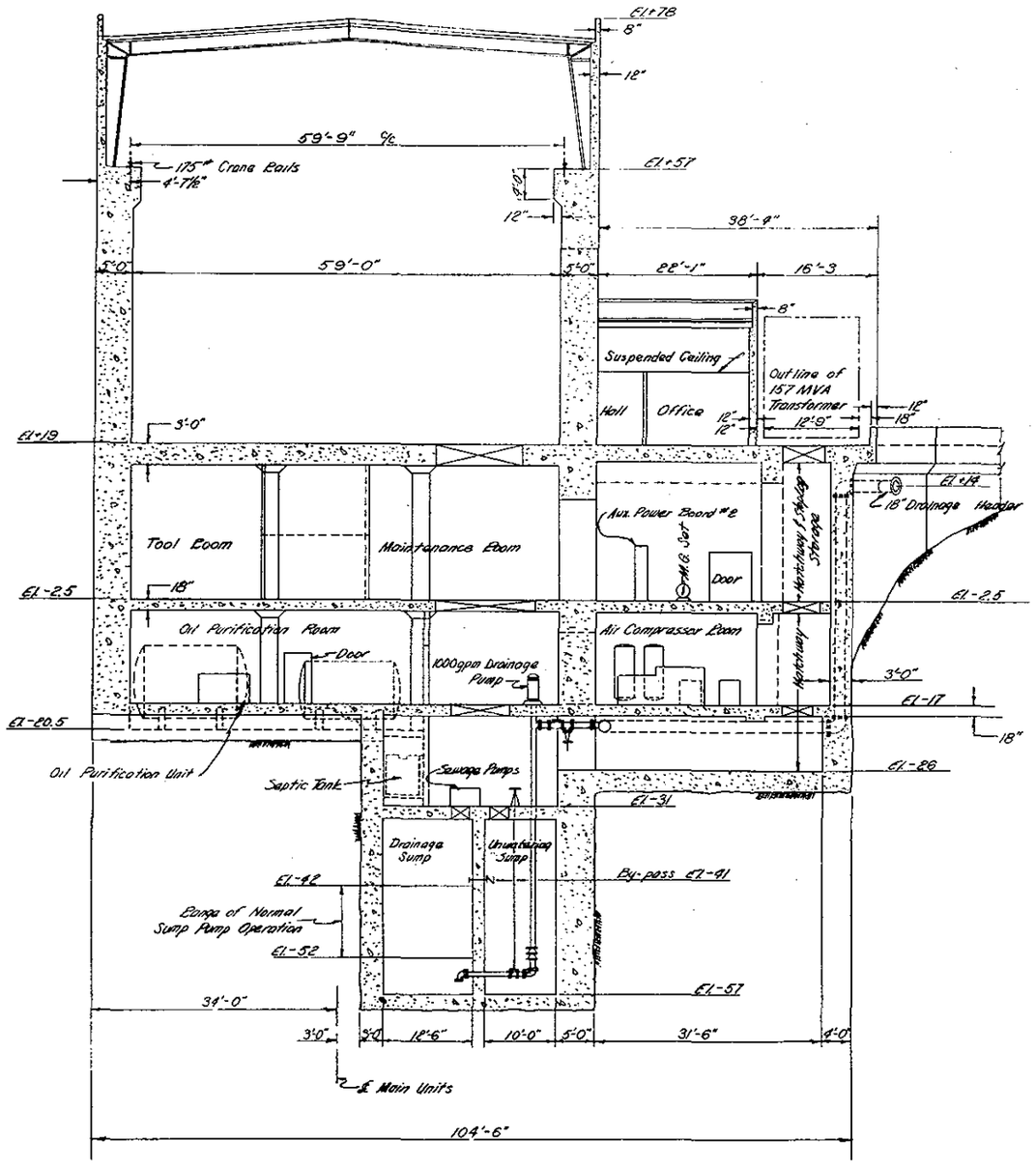
CALAIS PUMPED STORAGE

CONSTRUCTION SCHEDULE

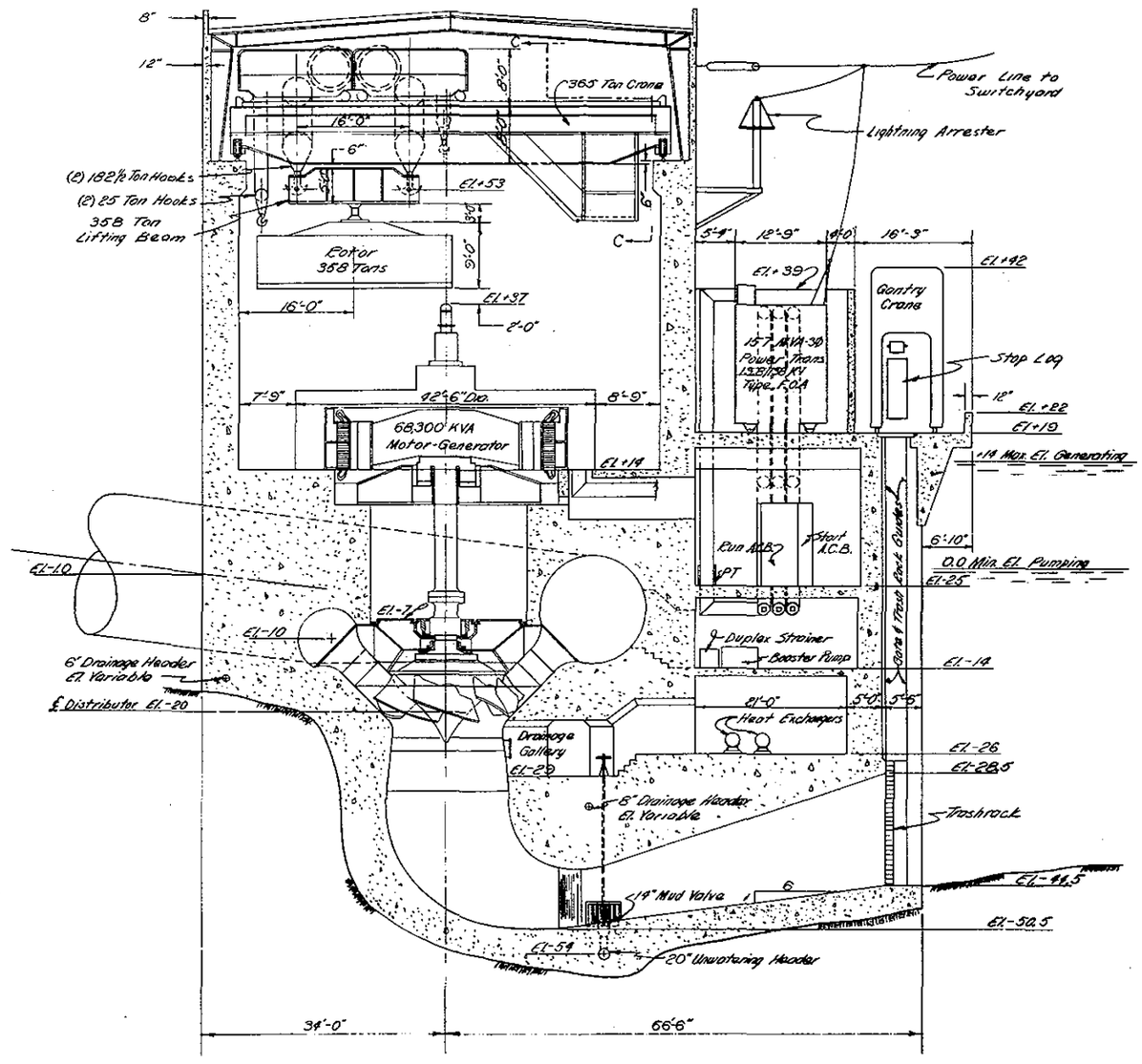


* 1 Unit in operation
** 4 Units in operation

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
CALAIS DEVELOPMENT
CONSTRUCTION SCHEDULE
INT'L. PASSAMAQUODDY ENGR. BOARD
SEPTEMBER 1959. Dwg. No. PG7-042



SECTION "B-B"



SECTION "A-A"

SCALE 1/8" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

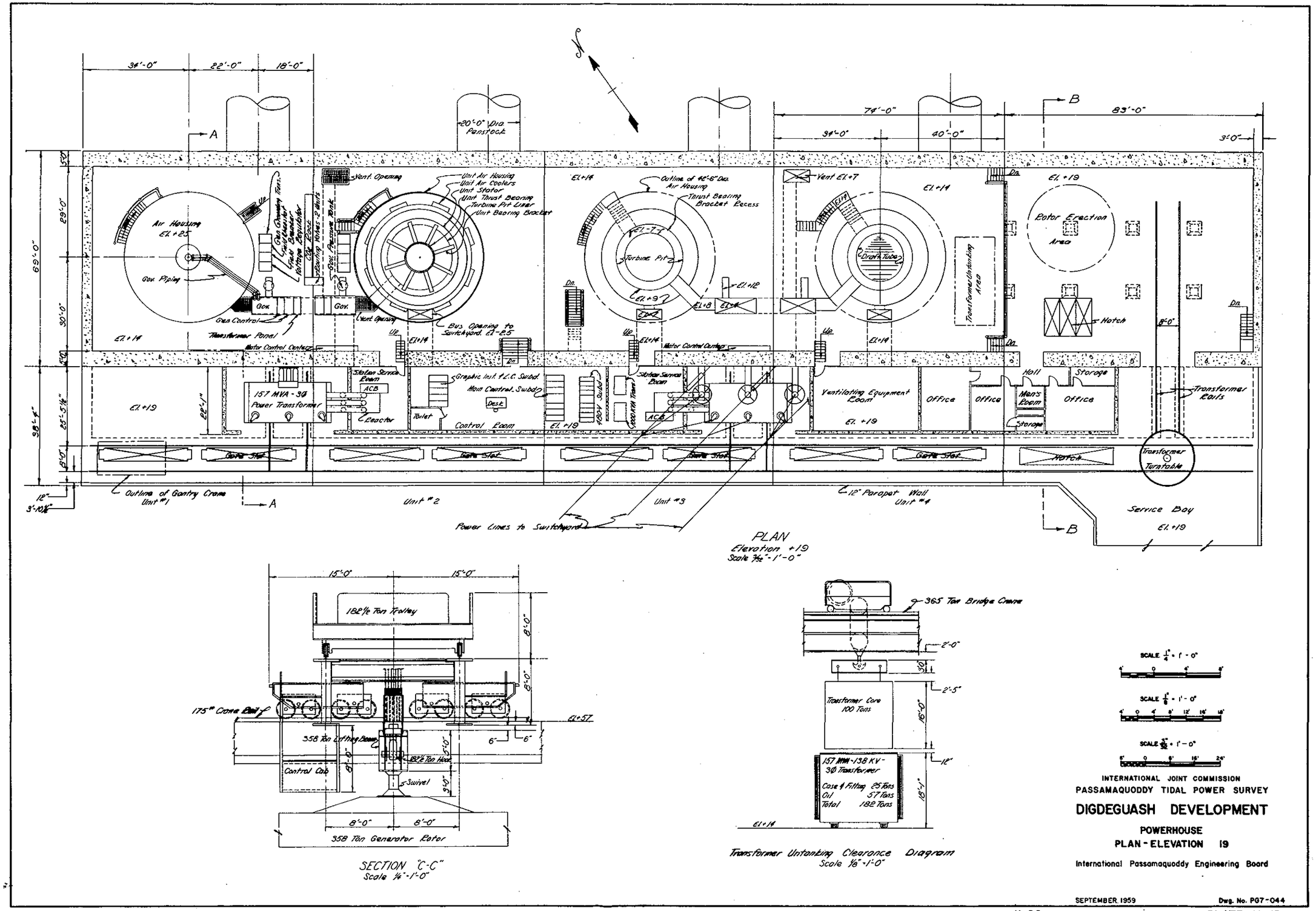
DIGDEGUASH DEVELOPMENT

POWERHOUSE SECTIONS

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. PG7-043



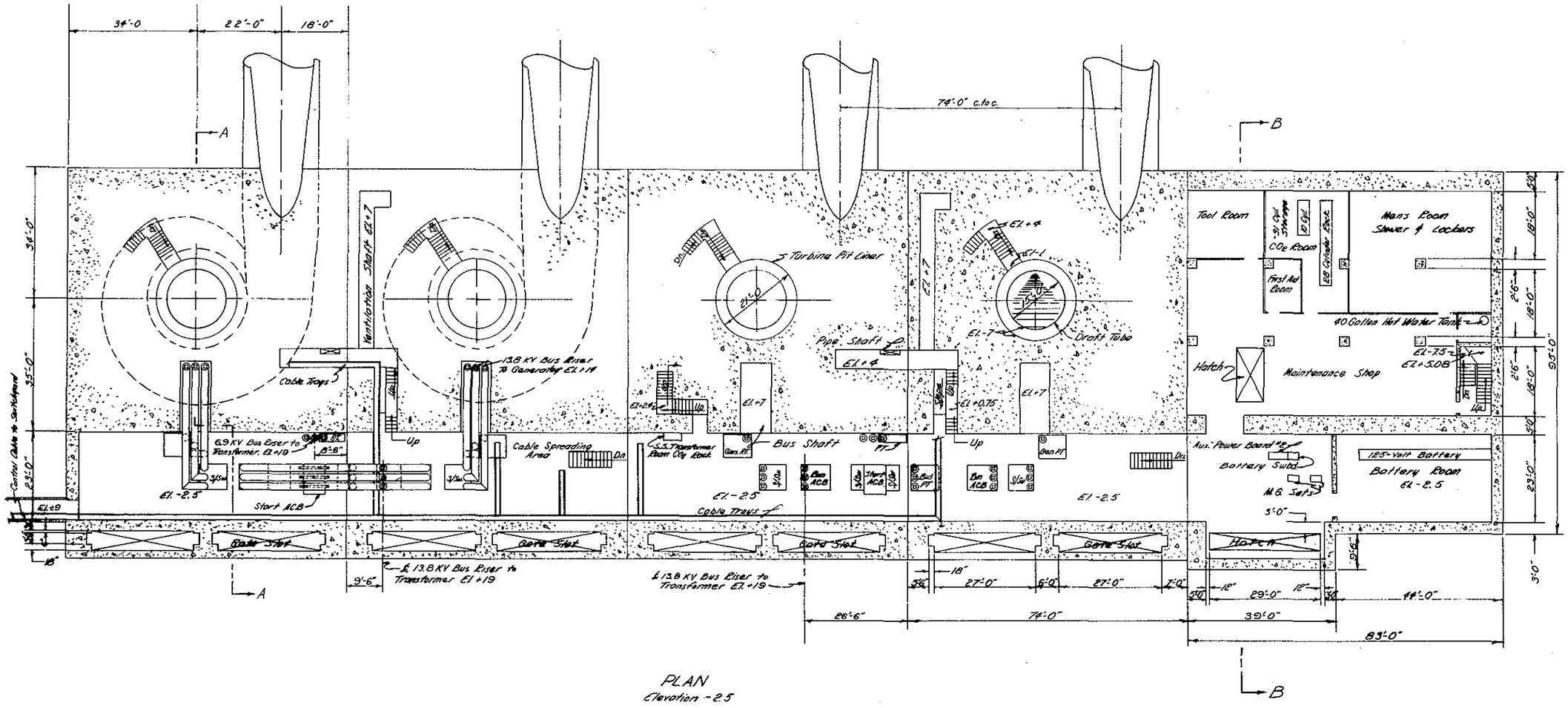
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

POWERHOUSE
PLAN - ELEVATION 19

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. PG7-044



PLAN
Elevation -2.5

SCALE 3/32" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

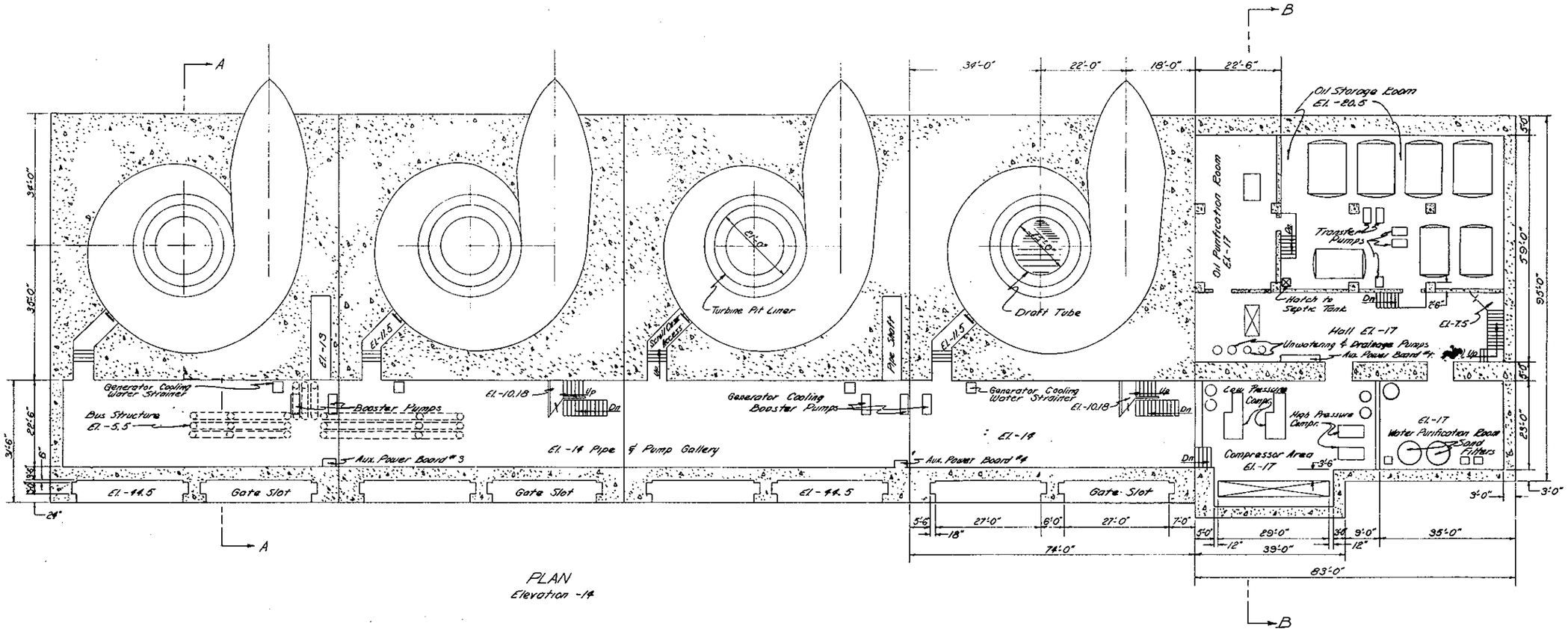
DIGDEGUASH DEVELOPMENT

POWERHOUSE

PLAN - ELEVATION - 2.5

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. PG7-045



PLAN
Elevation -14

SCALE 1/32" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

POWERHOUSE

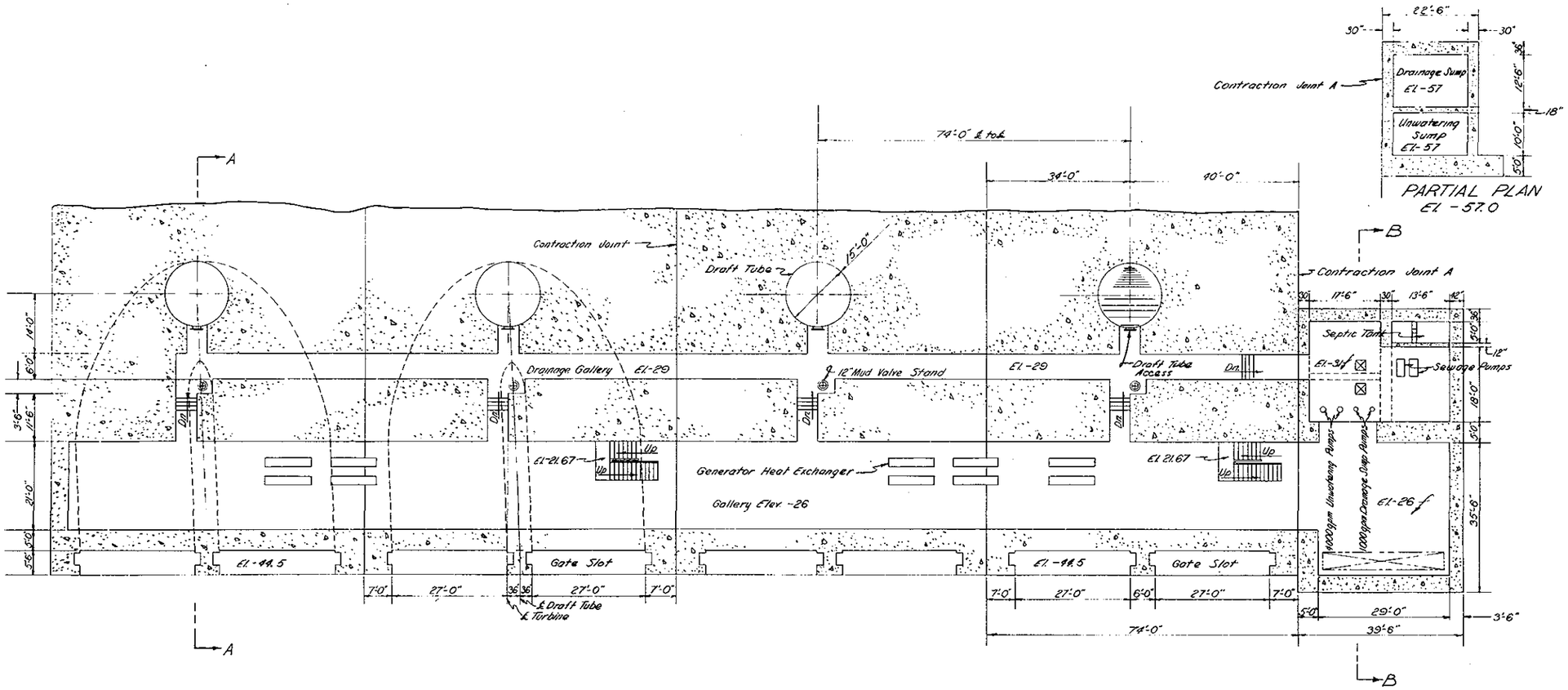
PLAN - ELEVATION - 14

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. PG7 - 046

PLATE II-17



SCALE $\frac{3}{32}$" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

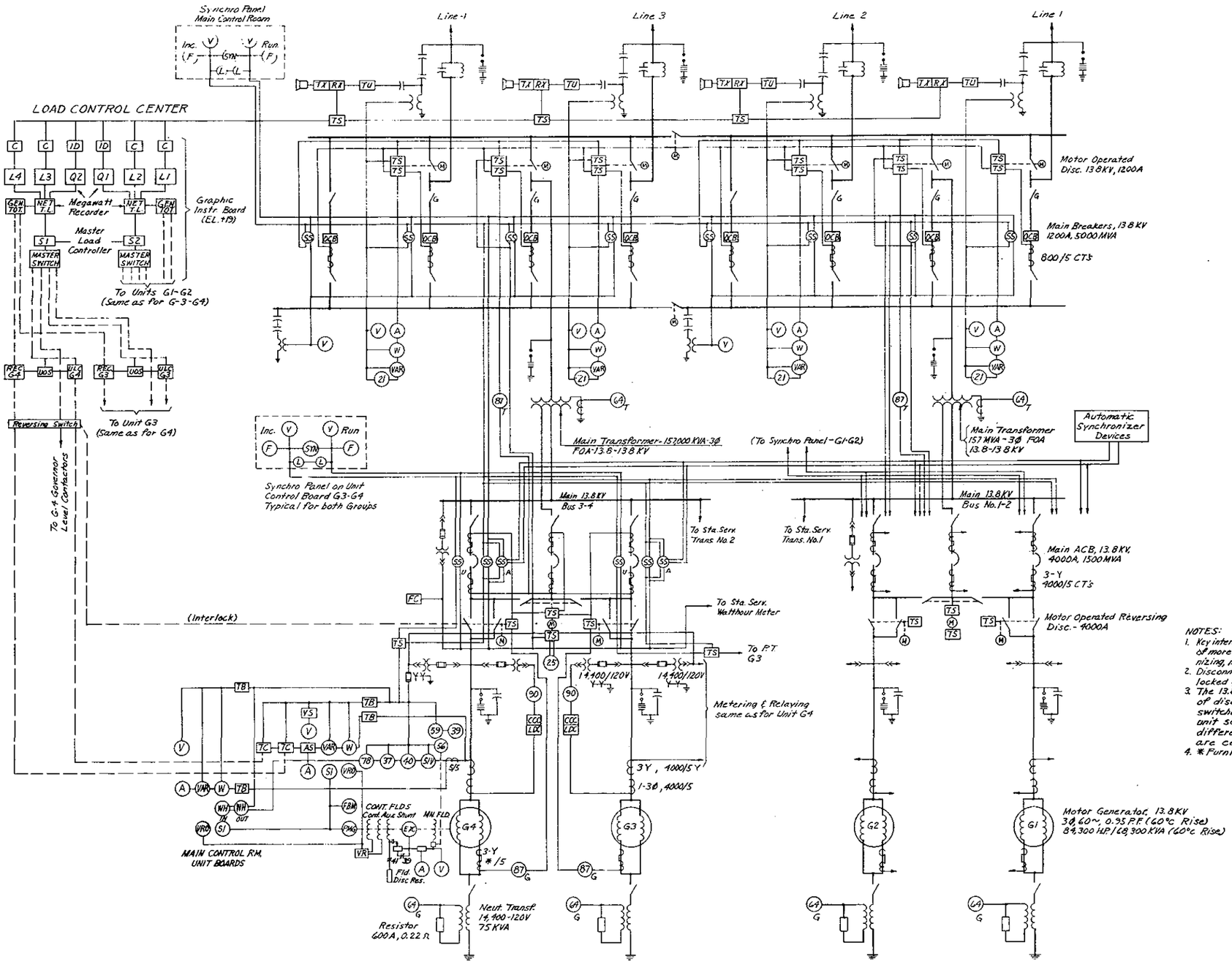
DIGDEGUASH DEVELOPMENT

POWERHOUSE

PLAN - ELEVATION -26

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. PG7-047



SYMBOLS:

- Varmeter
- Wattmeter
- Ammeter
- Voltmeter
- Impedance Relay
- Ground Relay-G=Generator; T=Transformer
- Differential Relay-G=Generator; T=Transformer
- Overvoltage Relay Contactor
- Voltage Regulator Output Indicator
- Speed Indicator
- Voltage Regulator
- Fly-Ball Motor
- Permanent Magnet Generator
- Exciter
- Synchroscope
- Synchroscope Lamp
- Motor Operated
- Synchronizing Switch {"A" Designates Auto-"U" Designates Unit Board
- Frequency Meter
- Generator Overvoltage Relay
- Megawatt Recorder
- Test Block
- Voltmeter Switch
- Ammeter Switch
- Voltage Regulator
- Cross Current Compensator
- Line Drop Compensator
- Transfer Switch
- Oil Circuit Breaker
- Frequency Converter
- Thermal Converter
- Unit Load Control
- Line Tuning Unit
- Variable Frequency Converter
- Impulse Decoder
- Frequency Recorder Controller
- Carrier Transmitter Receiver
- Synchronism Check Relay
- Underpower Relay
- Polarized Field Frequency Relay
- Out of Step Relay
- Field Failure Relay

NOTES:

1. Key interlocks & transfer switches are connected to prevent closure of more than one motor-operated disconnect & to transfer synchronizing, metering & relaying to the spare circuit breaker.
2. Disconnect Switches marked with a "G" is equipped with an interlocked grounding switch on the line or transformer side only.
3. The 13.8KV Switchgear is interlocked to prevent operation of disconnects unless associated breakers are open. Transfer switches are provided on reversing disconnects and on unit selector starting disconnects to maintain proper differential protection and synchronizing-indicating meters are center-zero type where necessary.
4. * Furnished by Mfr. (Approx. 2000/5).

NO SCALE

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

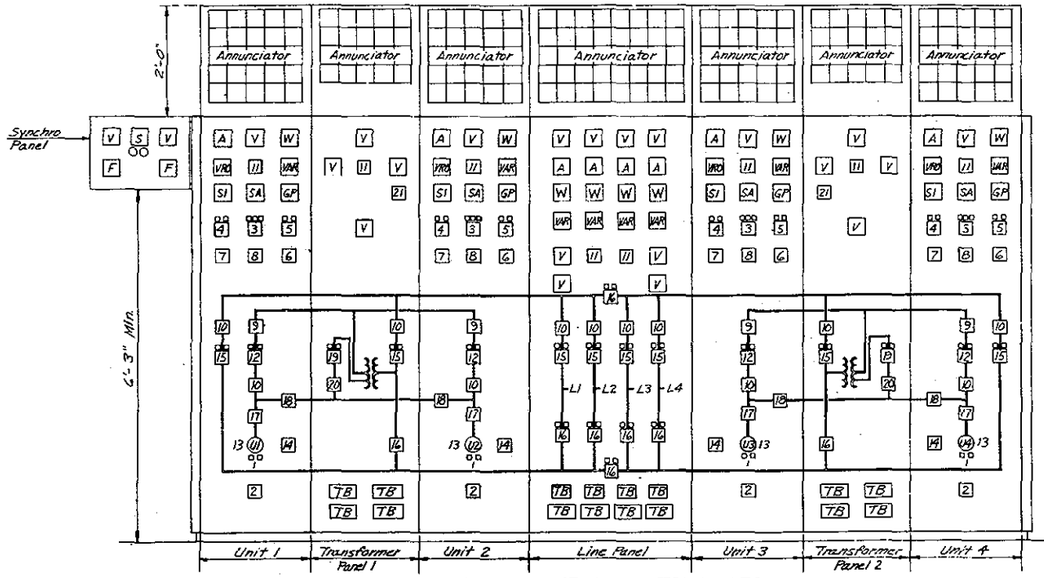
POWERHOUSE

MAIN ONE-LINE DIAGRAM

International Passamaquoddy Engineering Board

SEPTEMBER 1959

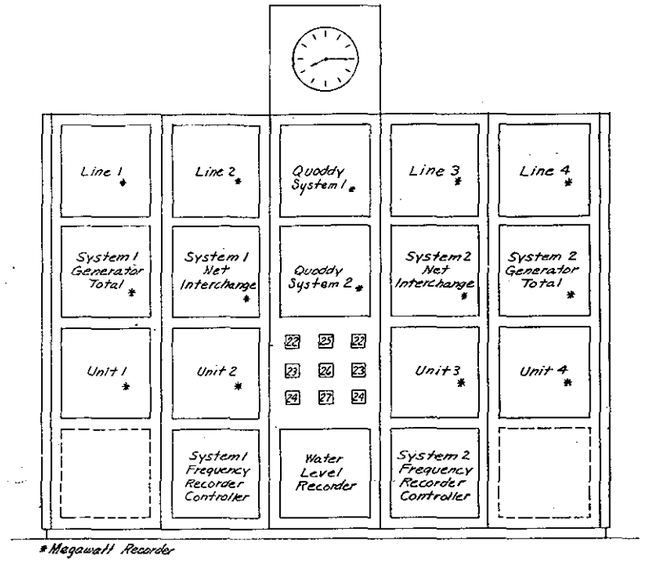
Dwg. No. PG7-048



MAIN CONTROL SWITCHBOARD
FRONT PANELS

NOMENCLATURE

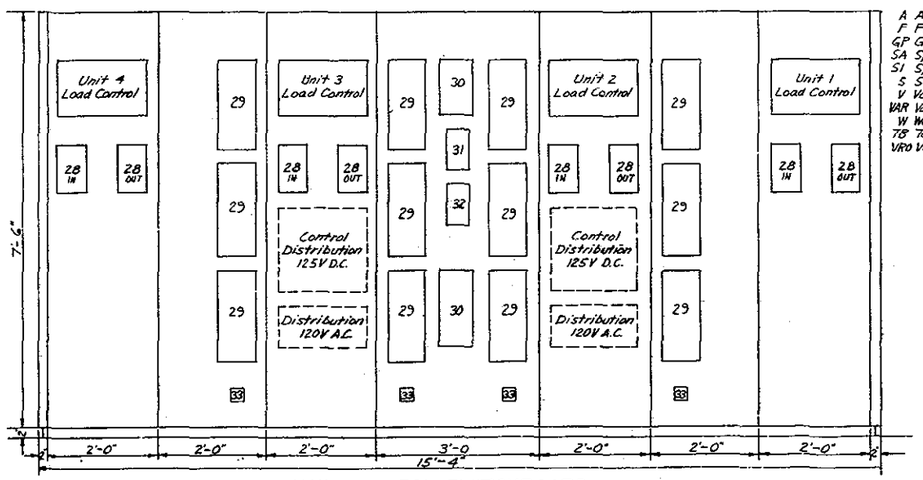
1. Local Remote Control Indicator Lights
2. Emergency Stop
3. Voltage Regulator Control Switch
4. Voltage Adjusting Rheostat Control
5. Field Raise-Lower (Manual)
6. Gate Limit Control
7. Speed Adjustment
8. Unit Operation Selector Switch
9. Automatic Synchro Selector Switch
10. Synchro Switch-(Manual)
11. Annunciator Control Switch
12. Circuit Breaker Control
13. Generator Symbol with Light
14. Governor Motor Response Rheostat
15. 138 KV Bkr. Control Switch
16. Motor Operated Disc. Switch
17. Reversing Disc. Switch
18. Selector Disc. Switch
19. Circuit Bkr. Control-Starting
20. Permissive Switch-Motor Starting
21. Voltmeter Switch
22. System Operation Selector Switch
23. Master Control Switch
24. Line Selector Switch
25. Clock Reset Switch
26. Standard Time Switch
27. Carrier Current Switch
28. Watthour Meter
29. Impedance Relay (21)
30. Automatic Synchro. Device
31. Voltage Relay Synchro Bus-Running
32. Voltage Relay Synchro Bus-Incoming
33. Line Lockout Relay (86L)



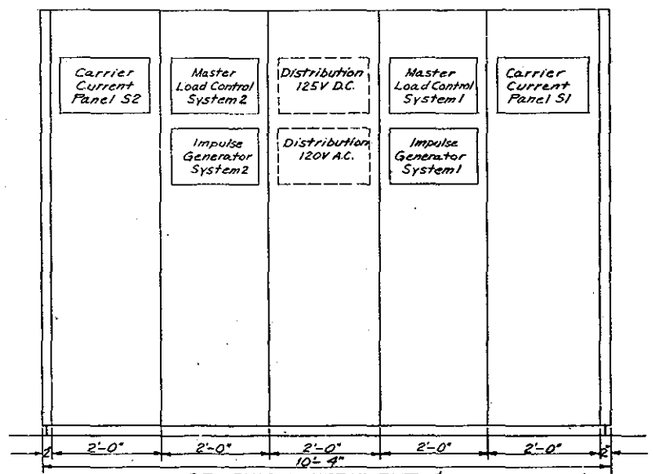
* Megawatt Recorder

GRAPHIC INSTRUMENT &
LOAD CONTROL SWITCHBOARD
FRONT PANELS

A Ammeter
F Frequency Meter
GP Gate Position Indicator
SA Speed Adjustment Indicator
SI Speed Indicator
S Synchroscope
V Voltmeter
VAR Varmeter
W Wattmeter
TB Test Block
VRO Voltage Regulator Output



MAIN CONTROL SWITCHBOARD
REAR PANELS



GRAPHIC INSTRUMENT &
LOAD CONTROL SWITCHBOARD
REAR PANELS

NOTE:
Depth of Panels shown = 6'-0"

SCALE 1" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

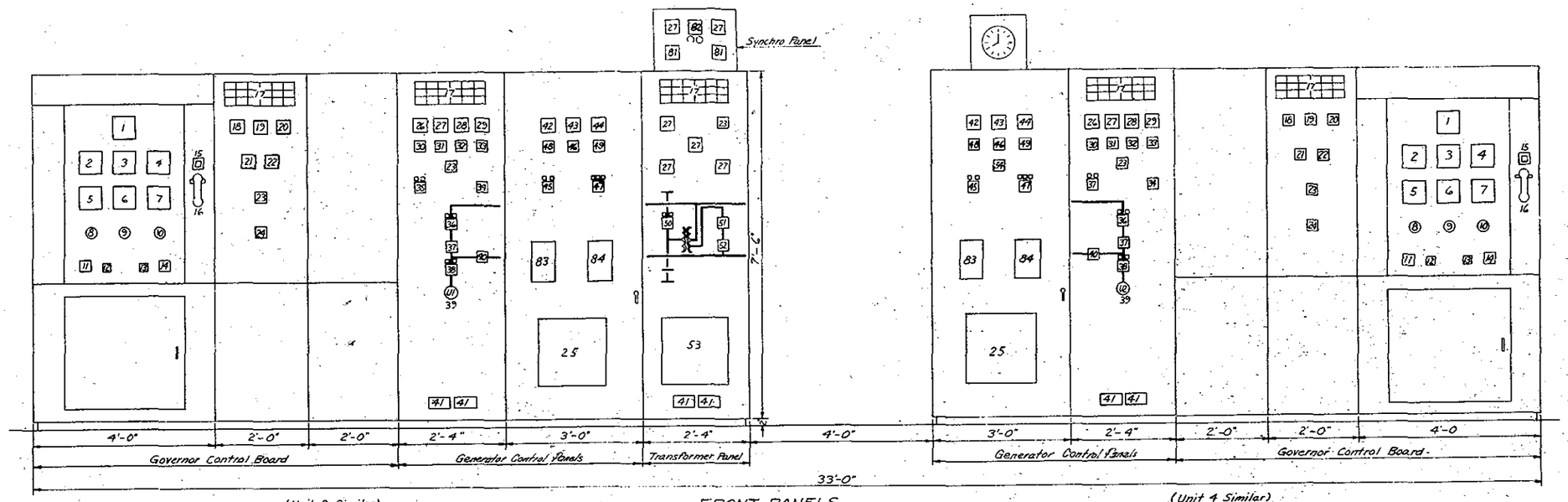
POWERHOUSE

MAIN CONTROL SWITCHBOARDS

International Passamaquoddy Engineering Board

SEPTEMBER 1959

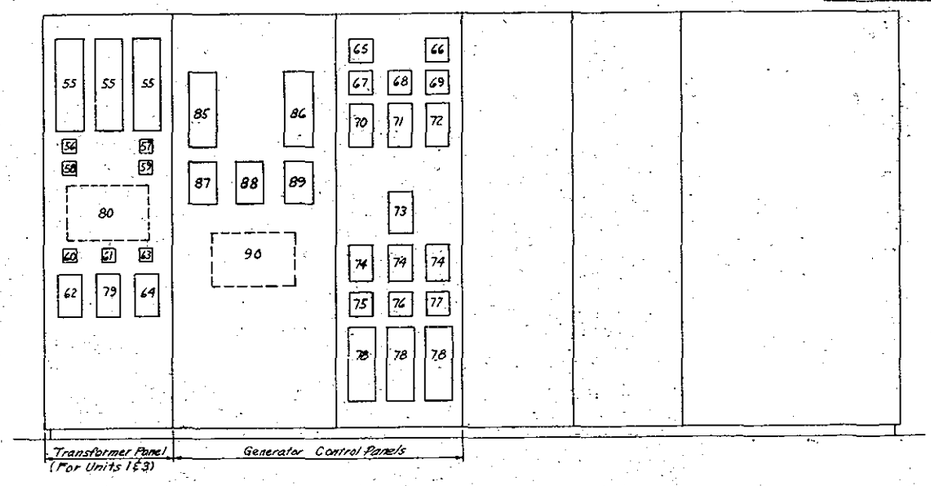
Dwg. No. PG7-049



(Unit 3 Similar)

FRONT PANELS
(Looking toward Generators)

(Unit 4 Similar)



REAR PANELS
(Typical for all Units)

NOMENCLATURE:

1. Speed Indicator
2. Duplex Air Pressure Gauge
3. Oil Pressure Gauge
4. Transfer Valve Position Indicator
5. Speed Droop Indicator
6. Blade Position Limit Indicator
7. Speed Adjustment Indicator
8. Speed Droop Control Knob
9. Blade Limit Control Knob
10. Speed Adjustment Control Knob
11. Cabinet Light Switch & Pilot Lights
12. Generator Air Break Control Knob
13. Transfer Valve Control Knob
14. Emergency Shutdown & Reset
15. Generator CO2 Break Glass Station
16. PAX Telephone
17. Annunciator
18. Generator Thrust Bearing Temperature Ind.
19. Generator Thrust Bearing Oil Temp. Ind.
20. Turbine Bearing Oil Temperature Indicator
21. Turbine Bearing Temperature Indicator
22. Turbine Scroll Case Pressure Gauge
23. Annunciator Test & Reset Control Switch
24. Head Gate Emergency Close
25. Bearing Temperature Recorder
26. Ammeter
27. Voltmeter
28. Wattmeter
29. Varmeter
30. Ammeter Switch - 3 Circuit
31. Voltmeter Switch - 3 Circuit
32. Lockout Relay - 86GC (Complete)
33. Lockout Relay - 86GP (Partial)
34. Lockout Relay - 86GT (Time)
35. Local Remote Control Selector Switch w/Key
36. Circuit Breaker Control Switch
37. Synchronizing Switch
38. Reversing Disconnect Switch
39. Generator Symbol w/Light
40. Selector Disconnect Switch (Start)
41. Test Block
42. Ammeter Generator Field
43. Main Excitation Voltmeter
44. Voltage Regulating Meter
45. Voltage Adjusting Rheostat Switch
46. Trip Relay Switch - Voltage Regulator
47. Manual Field Control Switch
48. Field Breaker Control Switch
49. Voltage Regulator Transfer Switch
50. Emergency Transformer Trip Switch
51. Circuit Breaker Control Starting
52. Permissive Switch Motor Starting
53. Transformer and Stator Temperature Recorder
54. Clock Reset
55. Transformer Differential Relay (87T)
56. Transformer Differential Auxiliary Relay
57. Transformer Lockout Relay (86T)
58. Transformer Differential Auxiliary Relay
59. Transformer Overheat Auxiliary Relay
60. Transformer Cooling Air Auxiliary Relay
61. Transformer Oil Flow Auxiliary Relay
62. Transformer Oil Flow Auxiliary Relay (Time Delay)
63. Transformer Undervoltage Auxiliary Relay
64. Transformer Undervoltage Relay
65. Generator Bearing Thermal Auxiliary Relay
66. Governor Oil Pressure Auxiliary Relay
67. Generator Overspeed Auxiliary Relay
68. Generator Ground Auxiliary Relay X
69. Generator Unit-Run Auxiliary Relay
70. Generator Ground Relay (64G)
71. Generator Ground Auxiliary Relay Y
72. Generator Ground Auxiliary Relay Z
73. Generator Overvoltage Relay (59)
74. Generator Differential Relay (87G)
75. Overcurrent Auxiliary Relay
76. Generator Differential Auxiliary Relay X
77. Generator Differential Auxiliary Relay Y
78. Overcurrent Relay w/Voltage Restraint (51V)
79. Transformer Ground Relay (64T)
80. 120V AC Supply
81. Frequency Meter
82. Synchroscope
83. Incomplete Start Relay (48)
84. Incomplete Start Delay Relay (48A)
85. Field Failure Relay (40)
86. Synchronism Check Relay (25)
87. Underpower Relay (37)
88. Polarized Field Freq. Relay (54)
89. Out of step Relay (78)
. 125V D.C. Supply

SCALE 1" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

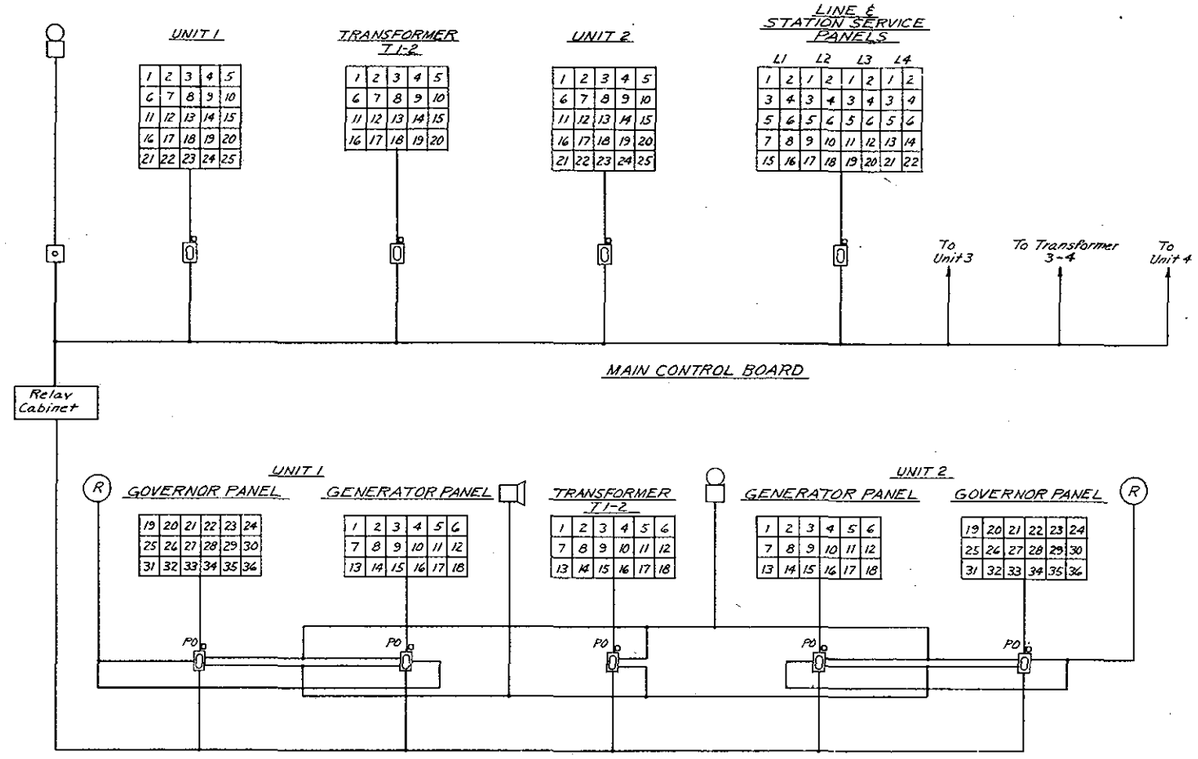
DIGDEGUASH DEVELOPMENT

POWERHOUSE
UNIT CONTROL SWITCHBOARDS

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. PG7-050



UNIT CONTROL BOARD - GROUP NO. 1-2
(Typical Group No. 3-4)

MAIN CONTROL BOARD					
MAIN UNIT		TRANSFORMER		LINE & STATION SERVICE	
1.	Differential Trip	1.	Differential Trip	1.	H.V. Ground Trip
2.	Ground Trip	2.	Transformer Ground	2.	Line Relay Trip
3.	Overcurrent Trip	3.	High Temp. Trip	3.	Line Pilot Trouble
4.	Emergency Shutdown	4.	High Oil Temp.	4.	H.V. OCB Low Air
5.	Hot Bearing Trip	5.	Low Oil Flow	5.	System No.1 Load Limit
6.	Overspeed	6.	Cooling Fan Failure	6.	Spare
7.	Overvoltage	7.	High or Low Oil Level	7.	Sta. Trans. No.1 Overload Trip
8.	CO2 Release	8.	High or Low Gas Pressure	8.	Sta. Trans. No.1 Overheat
9.	Governor Low Oil Pressure	9.	Diaphram Rupture	9.	480V Bus No.1 Ground
10.	Thrust High Temp.	10.	Fog Release	10.	480V Bus No.1 Undervoltage
11.	Turbine Bearing High Temp.	11.	O.C.B. Low Air	11.	Sta. Trans. No.2 Overload Trip
12.	Turbine Bearing Low Oil	12.	Spare	12.	Sta. Trans. No.2 Overheat
13.	Gen. Ground	13.	D.C. Supply Trip	13.	480V Bus No.2 Ground
14.	Stator High Temp	14.	480V Trouble	14.	480V Bus No.2 Undervoltage
15.	Generator Field Failure	15.	Oil Pump Trip	15.	125V D.C. Supply Trouble
16.	Cooling Water Low Flow	16.	Spare	16.	Sump High Water
17.	High Air Temp.	17.	15 KV Ground	17.	Standard Time Trouble
18.	480V Supply Trouble	18.	Spare	18.	Load Control Trip
19.	Incomplete Start	19.	Transformer Overheat	19.	Carrier Trouble
20.	Out of Step Trip	20.	Spare	20.	Tie Breaker No.1 Trip
21.	Start Delay			21.	Tie Breaker No.2 Trip
22.	Spare			22.	Oil Room-CO2 Release
23.	Spare				
24.	Spare				
25.	Spare				

UNIT CONTROL BOARD					
GOVERNOR PANEL		GENERATOR PANEL		TRANSFORMER PANEL	
19.	Emergency Shutdown	1.	Differential	1.	Differential Trip
20.	Low Governor Oil Trip	2.	Ground	2.	Transformer Ground
21.	Hot Bearing Trip	3.	Overcurrent	3.	High Temp. Trip
22.	Thrust High Temp.	4.	Overvoltage	4.	High Oil Temp.
23.	Turbine Bearing High Temp.	5.	CO2 Release	5.	Low Oil Flow
24.	Overspeed	6.	Stator High Temp.	6.	Cooling Fan Failure
25.	Spare	7.	Field High Temp.	7.	H. or L. Oil Level
26.	Turbine Brg. Low Oil Press.	8.	Cooling Water Flow	8.	H. or L. Gas Pressure
27.	Bearing Oil Level	9.	High Air Temp.	9.	Diaphram Rupture
28.	Spare	10.	Gov. Low Oil Pressure	10.	Fog Release
29.	Spare	11.	Field Failure	11.	O.C.B. Low Air
30.	Spare	12.	Spare	12.	Spare
31.	D.C. Control off	13.	CO2 off	13.	D.C. Supply Trip
32.	480V Trouble	14.	Voltage Regulator Trip	14.	480V Trouble
33.	D.C. Breaker Trip	15.	ACB Low Air	15.	Oil Pump Trip
34.	Brakes On	16.	Incomplete Start	16.	Line Relay Trip
35.	Grease Failure	17.	Out of Step Trip	17.	15KV Trip
36.		18.	Start Delay	18.	Transformer Overheat

NO SCALE

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

POWERHOUSE

ANNUNCIATOR SYSTEM

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. P97-051

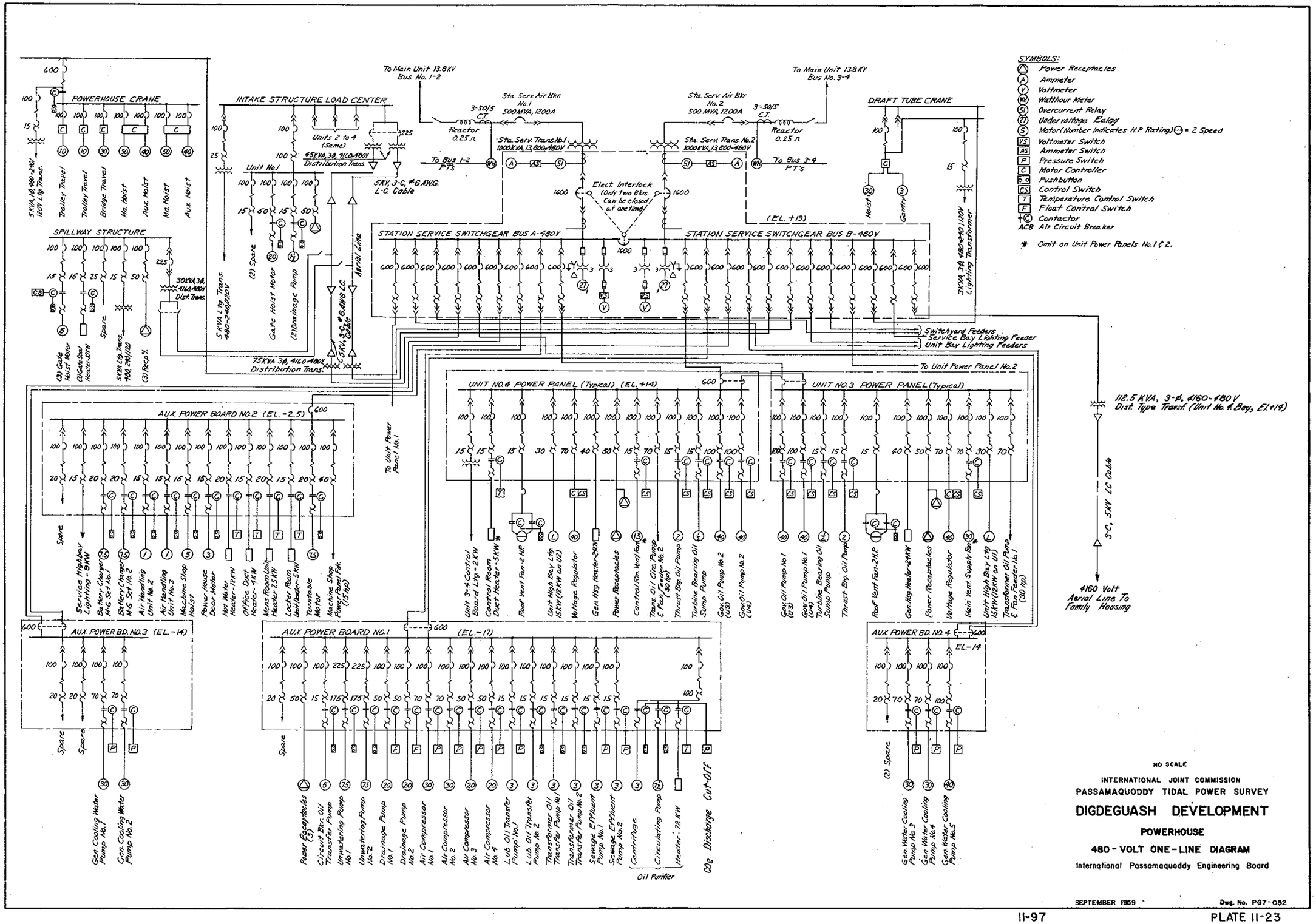
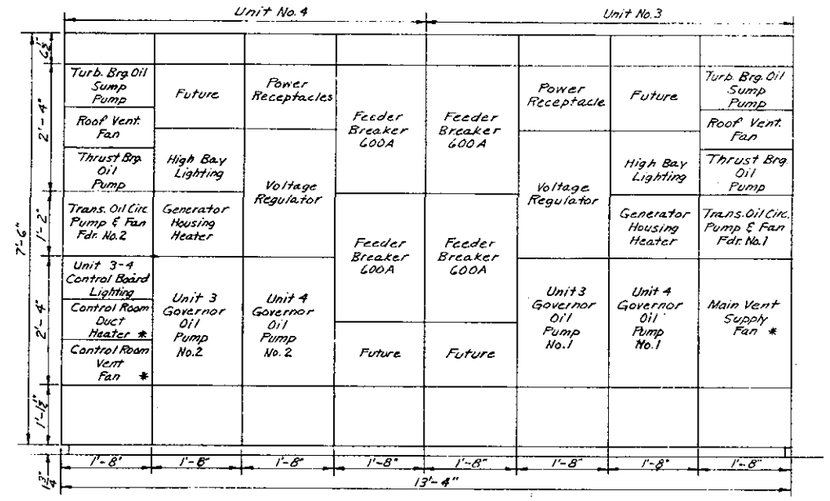

SYMBOLS:
Power Receptacles
Ammeter
Voltmeter
Watthour Meter
Overcurrent Relay
Undervoltage Relay
Motor (Number Indicates H.P. Rating) = 2 Speed
Voltmeter Switch
Ammeter Switch
Pressure Switch
Motor Controller
Pushbutton
Control Switch
Temperature Control Switch
Float Control Switch
Contactor
ACB Air Circuit Breaker
* Omit on Unit Power Panels No.1 & 2.
POWERHOUSE CRANE
INTAKE STRUCTURE LOAD CENTER
DRAFT TUBE CRANE
SPILLWAY STRUCTURE
To Main Unit 13.8KV Bus No. 1-2
To Main Unit 13.8KV Bus No. 3-4
Sta. Serv. Air Bkr. No.1 500MVA, 1200A
Sta. Serv. Air Bkr. No.2 500MVA, 1200A
Sta. Serv. Trans. No.1 1000KVA, 13,800-480V
Sta. Serv. Trans. No.2 1000KVA, 13,800-480V
Elect. Interlock (Only two Bkrs. can be closed at one time)
STATION SERVICE SWITCHGEAR BUS A-480V
STATION SERVICE SWITCHGEAR BUS B-480V
(EL. +19)
Switchyard Feeders
Service Bay Lighting Feeder
Unit Bay Lighting Feeders
To Unit Power Panel No.2
To Unit Power Panel No.1
UNIT NO.4 POWER PANEL (Typical) (EL. +14)
UNIT NO.3 POWER PANEL (Typical)
AUX. POWER BOARD NO.2 (EL. -2.5)
AUX. POWER BD. NO.3 (EL. -14)
AUX. POWER BOARD NO.1 (EL. -17)
AUX. POWER BD. NO.4 EL. -14
112.5 KVA, 3-Ø, 4160-480V Dist. Type Transf. (Unit No. 4 Bay, El. +19)
3-C, 5KV LC Cable
4160 Volt Aerial Line To Family Housing
Aerial Line
CO2 Discharge Cut-Off
Oil Purifier
NO SCALE
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
DIGDEGUASH DEVELOPMENT
POWERHOUSE
480 - VOLT ONE-LINE DIAGRAM
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. PG7-052

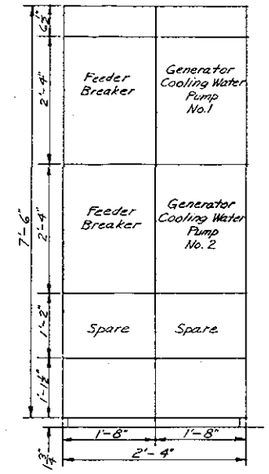
PLATE 11-23



MOTOR CONTROL CENTER - UNIT 3-4 (EL. +19)

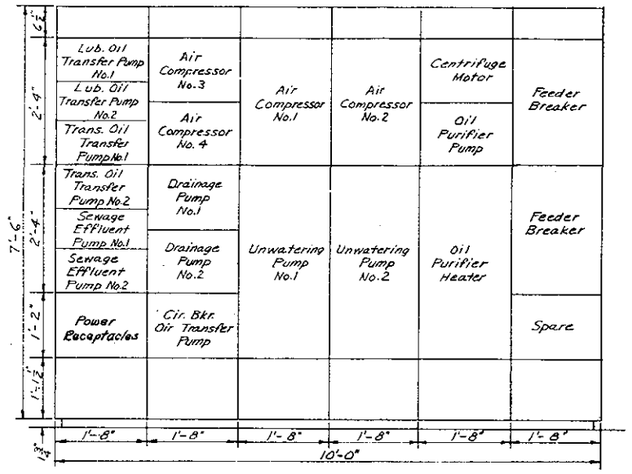
(Unit 1-2 Motor Control Center Same)

* Omit on Power Panels 1-2.



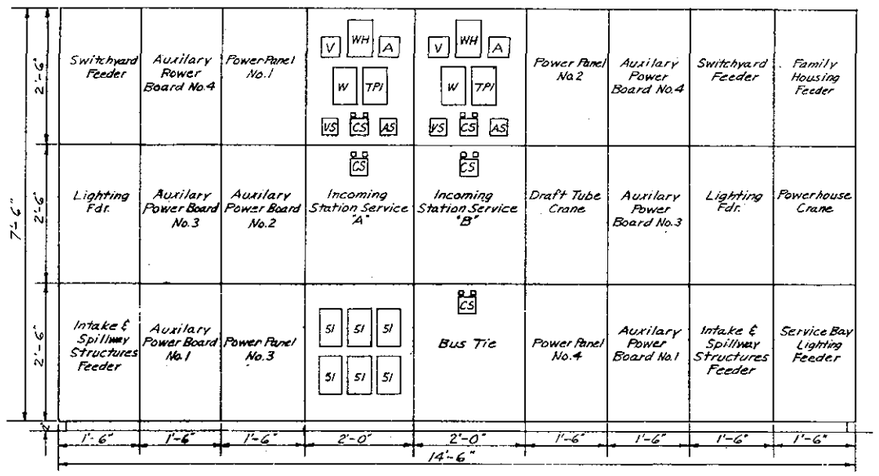
AUXILARY POWER BOARD NO. 3

(EL. -14)



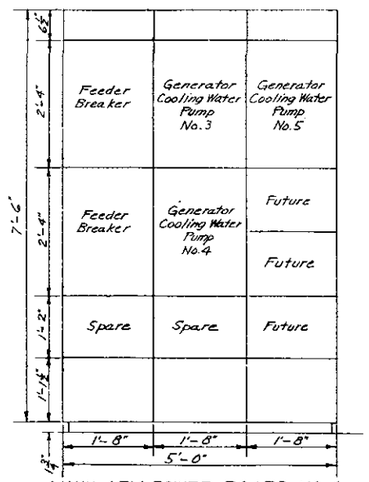
AUXILARY POWER BOARD NO. 1

(EL. -17)



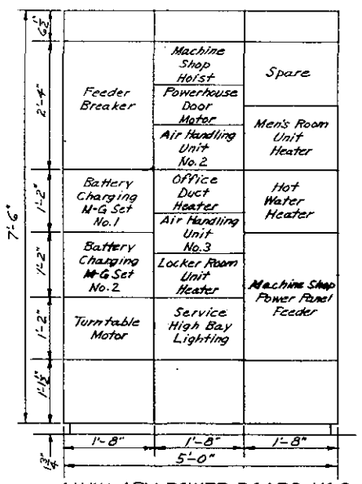
480V MAIN SWITCHBOARD

(EL. +19)



AUXILARY POWER BOARD NO. 4

(EL. -14)



AUXILARY POWER BOARD NO. 2

(EL. -25)

SYMBOLS:

- V Voltmeter
- A Ammeter
- VS Voltmeter Switch
- AS Ammeter Switch
- WH Watthour Meter
- R Overcurrent Relay
- W Wattmeter
- CS Control Switch
- TPI Tap Position Indicator

NOTES:

1. Depth of 480V Main Switchboard = 4'-6".
2. Depth of Motor Control & Auxilary Power Boards = 1'-8".

SCALE 1" = 1'-0"

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

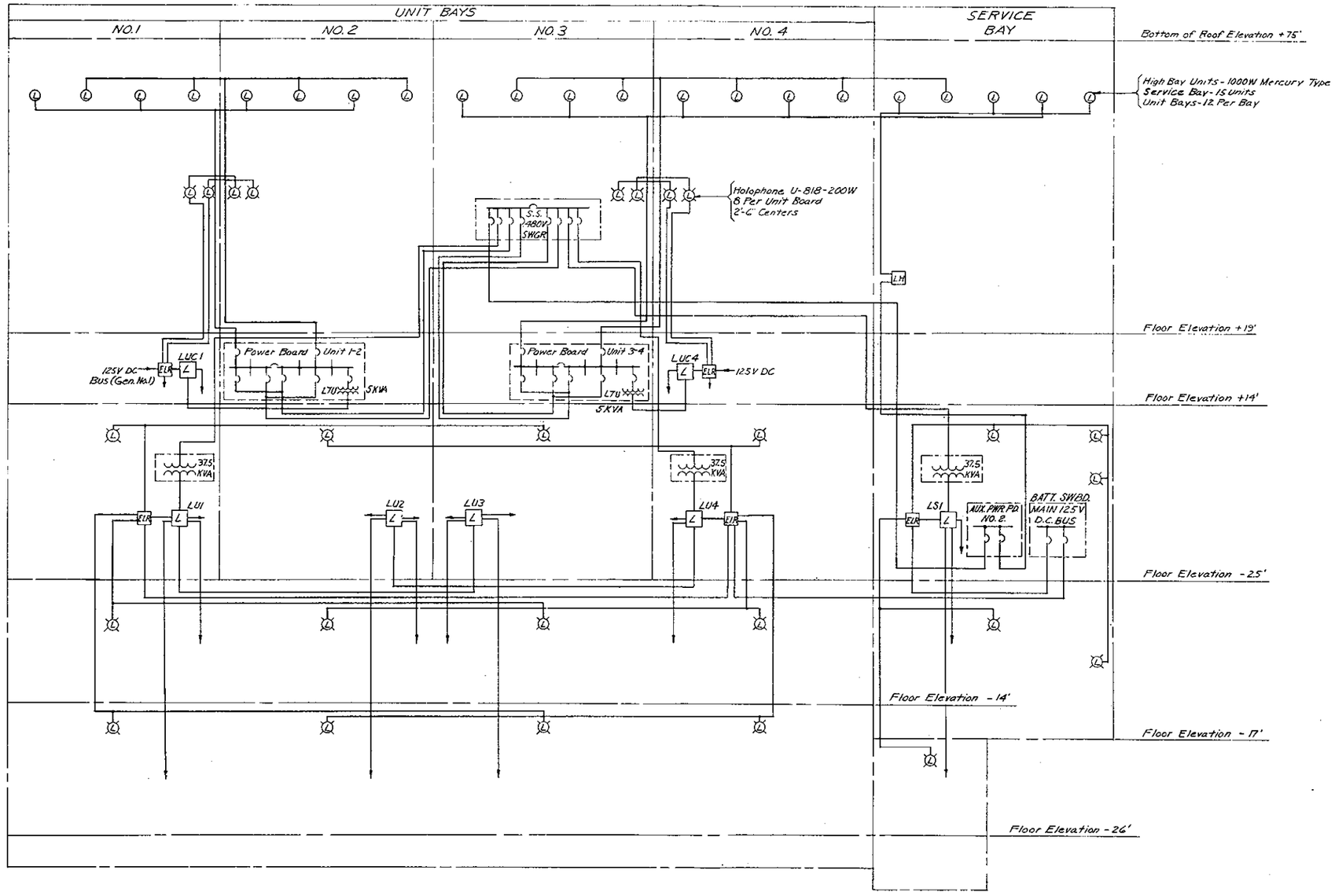
POWERHOUSE

480 - VOLT SWITCHBOARDS

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. PG7-053



LEGEND:
- Emergency D.C. Lights
- Lighting Dist. Panel
- C Control
- ELR Emergency Lighting Relay
- H Highbay Lighting
- L Lighting
- T Transformer
- U Unit Bay
- S Service Bay

NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

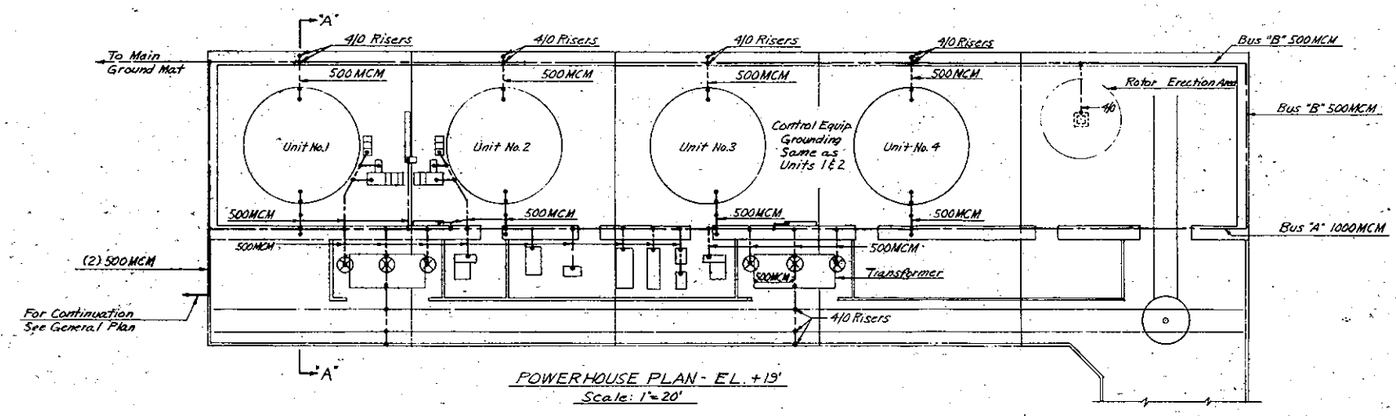
DIGDEGUASH DEVELOPMENT

POWERHOUSE
LIGHTING RISER DIAGRAM

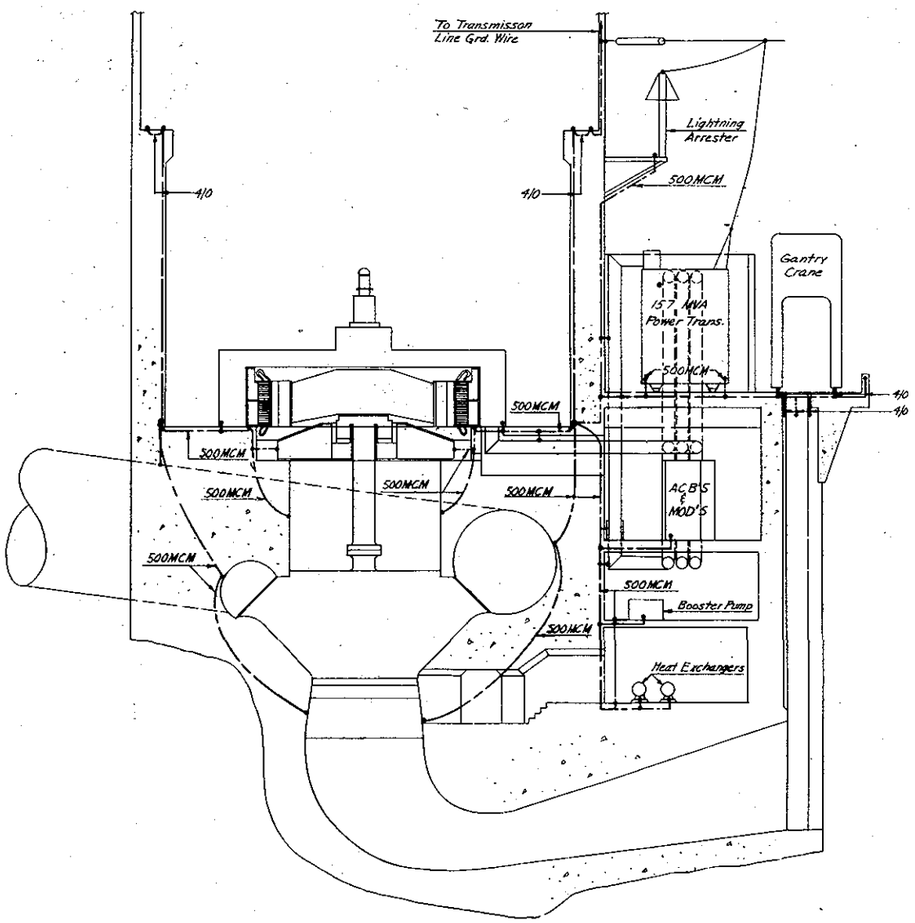
International Passamaquoddy Engineering Board

SEPTEMBER 1959

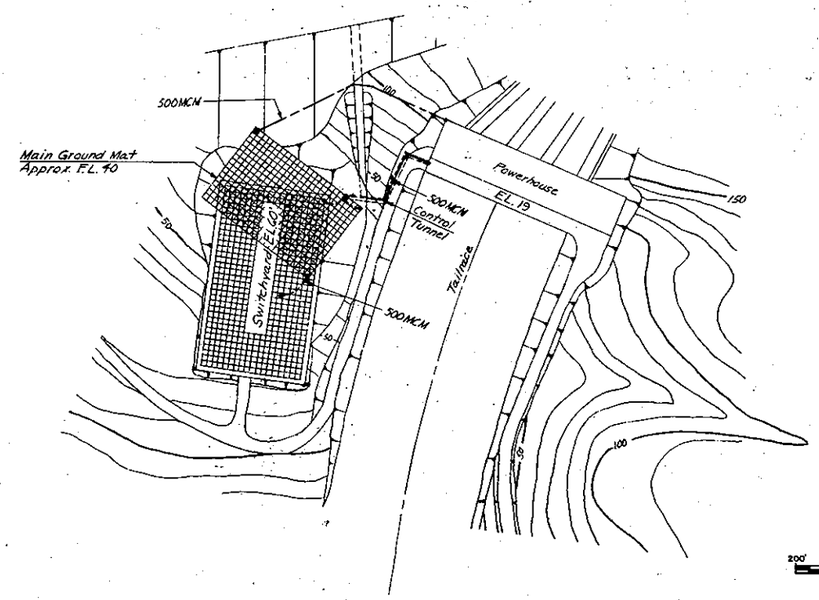
Dwg. No. PG7-054



POWERHOUSE PLAN - EL. +19'
Scale: 1"=20'



SECTION A-A
Scale: 1/8"=1'-0"



GENERAL GROUNDING PLAN
Scale: 1"=200'

SCALE 1" = 200'

SCALE 1" = 20'

SCALE 1/8" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

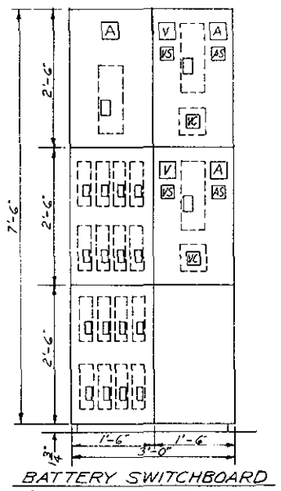
POWERHOUSE

STATION GROUNDING

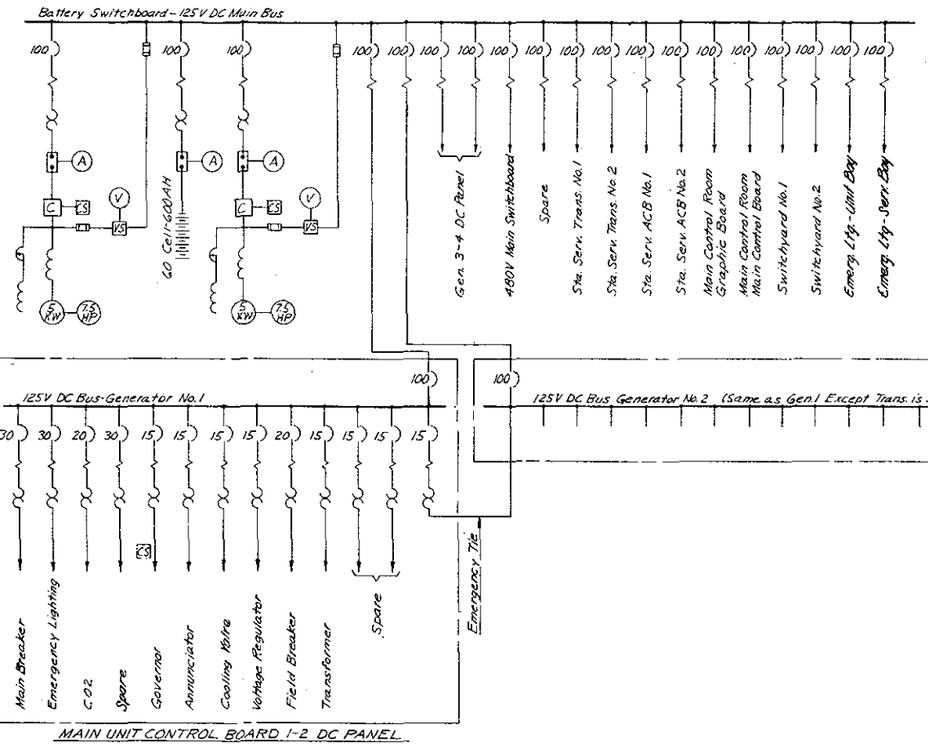
International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. PG7-055



BATTERY SWITCHBOARD
(Service Bay - El. -2.5)



NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

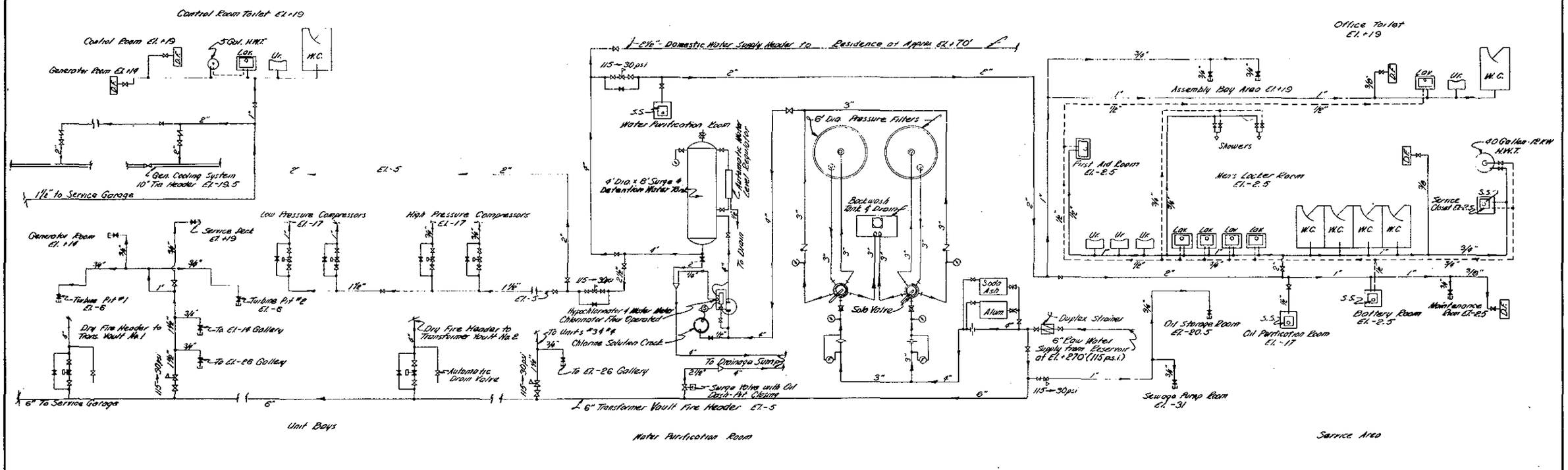
POWERHOUSE

DIRECT CURRENT SYSTEM

International Passamaquoddy Engineering Board

SEPTEMBER, 1959 Dwg. No. PG7-056

PLATE 11-27



SCHEMATIC
Domestic Water System

LEGEND

- Cold Water Piping
- Hot Water Piping
- Gate Valve
- Globe Valve
- Check Valve
- Pressure Relief Valve
- Needle Valve
- Orifice Plate
- Hose Coupling
- Pressure Reduction Valve
- Solenoid Valve
- Ur. Urinal
- W.C. Water Closet
- Lav. Lavatory
- S.S. Service Sink
- H.W.T. Hot Water Tank
- D.F. Drinking Fountain
- Pressure Gage
- Water Flow Indicator

NO SCALE

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

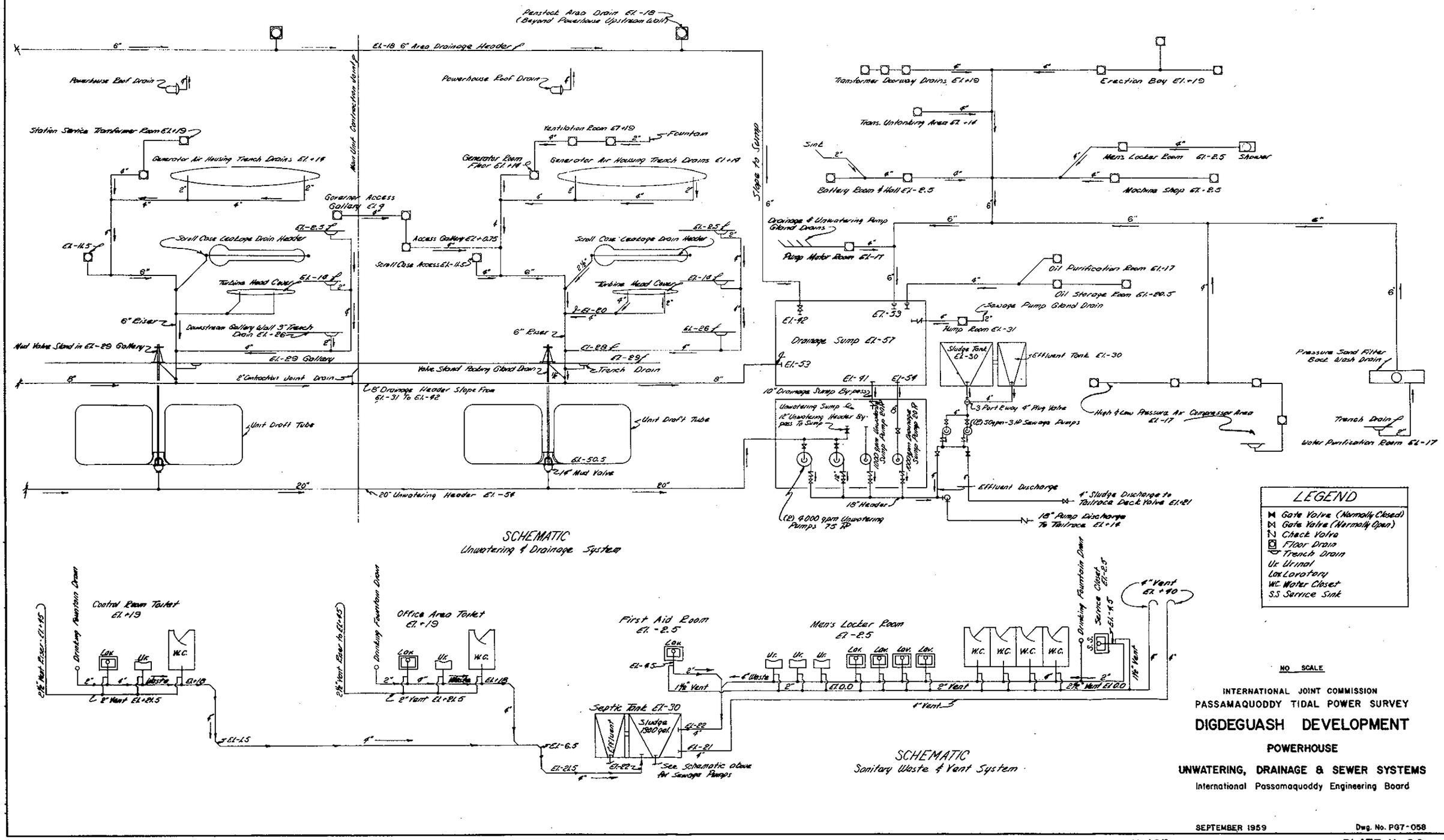
POWERHOUSE

FRESH WATER SYSTEM

International Passamaquoddy Engineering Board

SEPTEMBER 1959.

Dwg. No. PG7-057



NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

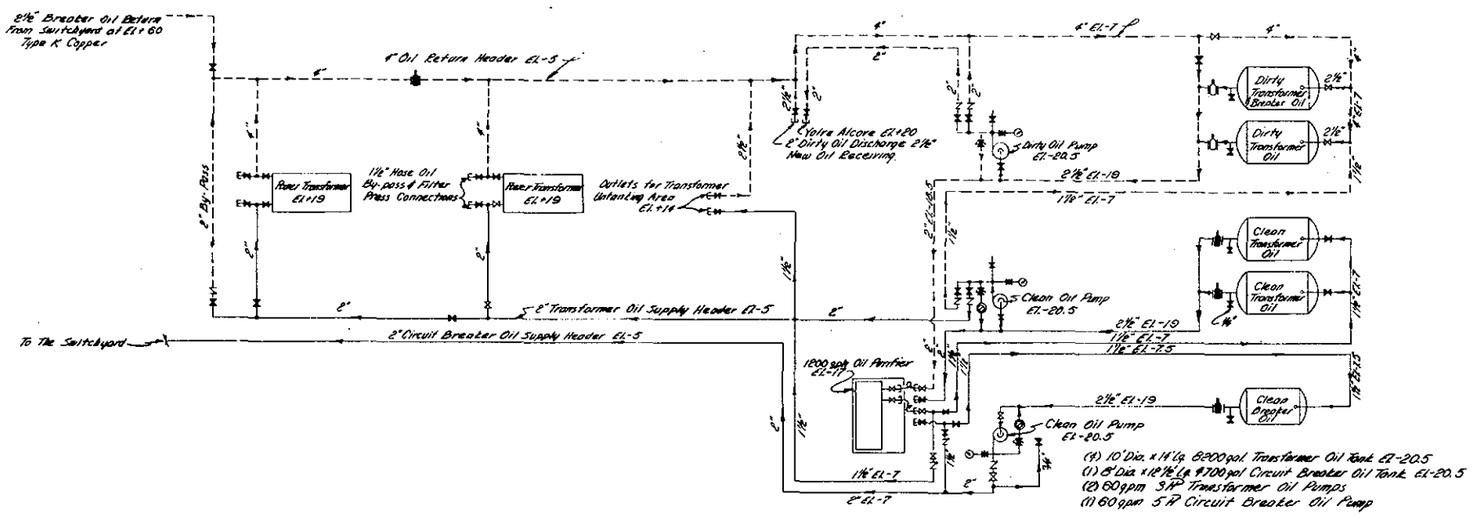
DIGDEGUASH DEVELOPMENT

POWERHOUSE

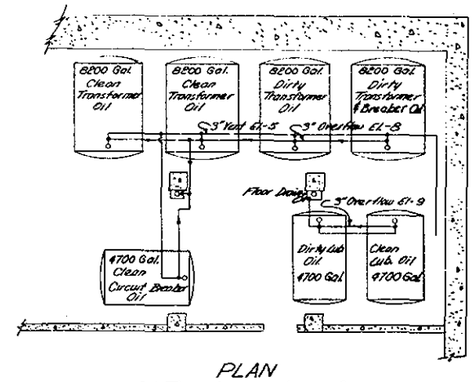
UNWATERING, DRAINAGE & SEWER SYSTEMS

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. PG7-058



SCHEMATIC
Insulating Oil System



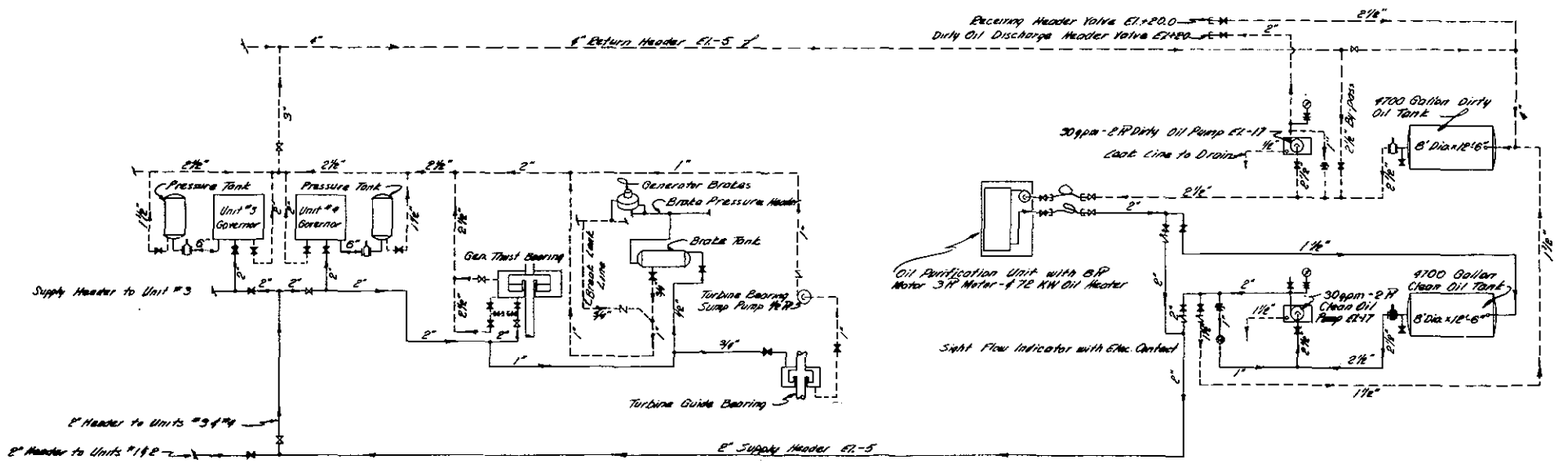
PLAN
Oil Tank Overflow & Vent Piping
Scale 1/8" = 1'-0"

LEGEND

- Gate Valve (Normally Open)
- Gate Valve (Normally Closed)
- Plug Valve (Normally Open)
- Needle Valve (Normally Closed)
- Plug Valve (Normally Closed)
- Relief Valve (Normally Closed)
- Check Valve
- Pressure Gage
- Sight Flow Indicator with Electrical Contact
- Hose Coupling
- ——— Clean Oil Piping
- - - - - Contaminated Oil Piping

NOTE

1. Lubricating oil valving arrangement shown for filling thrust bearing oil pot by filtering oil from the dirty oil tank.
2. Valve arrangement for transformer oil shown for filtering oil from dirty oil tank & filling No. 4 transformer.
3. Clean oil piping to be hard copper. Dirty oil piping to be black steel, schedule #10, except where noted.



SCHEMATIC
Lubricating Oil System

SCALE 1/8" = 1'-0"

4' 0' 4' 8' 12' 16' 20'

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

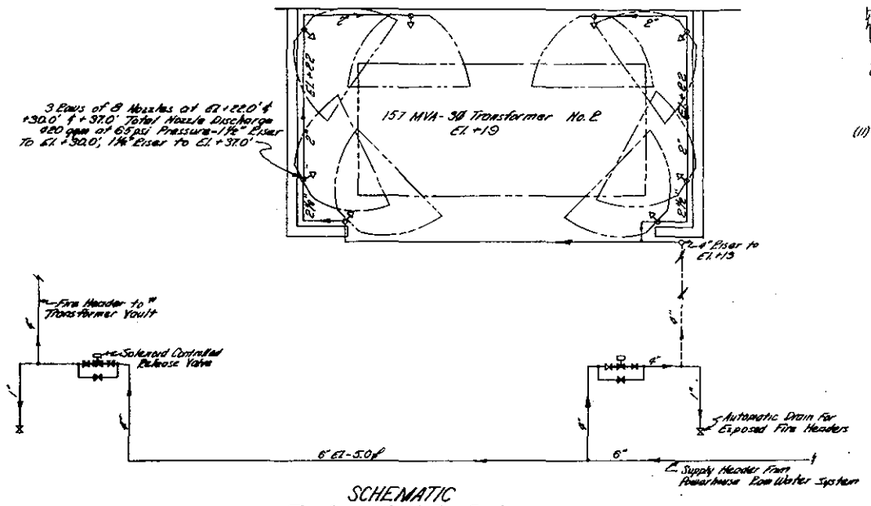
POWERHOUSE

OIL SYSTEMS

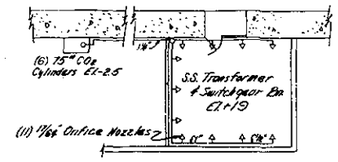
International Passamaquoddy Engineering Board

SEPTEMBER 1959

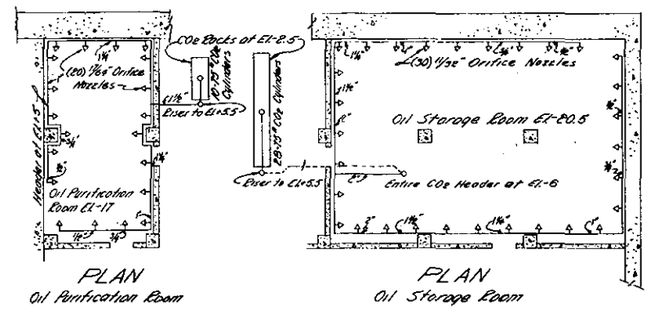
Dwg. No. PG7-060



SCHEMATIC
Transformer Vault Fog System

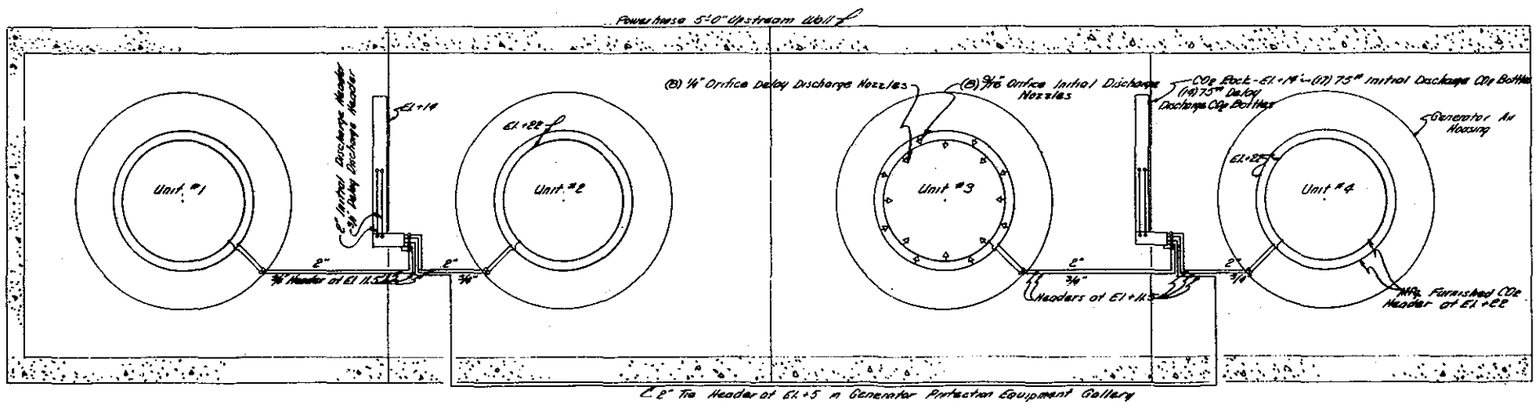


PLAN
Station Service Transformer Room



PLAN
Oil Purification Room

PLAN
Oil Storage Room



PLAN
Main Unit CO2 Systems

NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

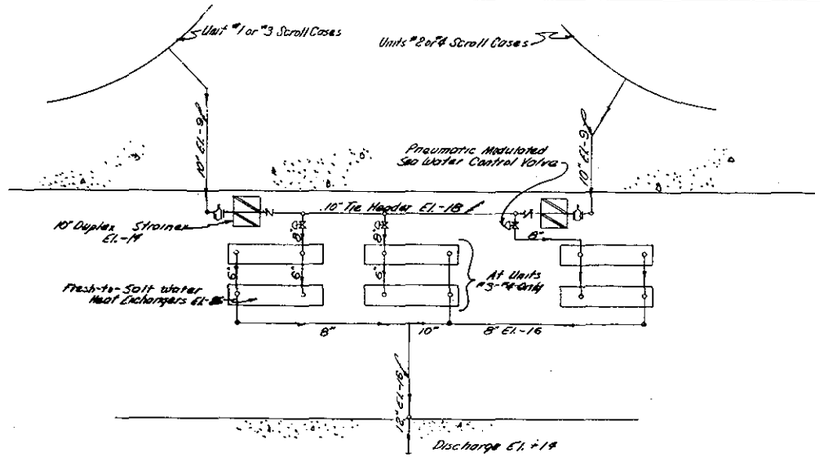
DIGDEGUASH DEVELOPMENT

POWERHOUSE

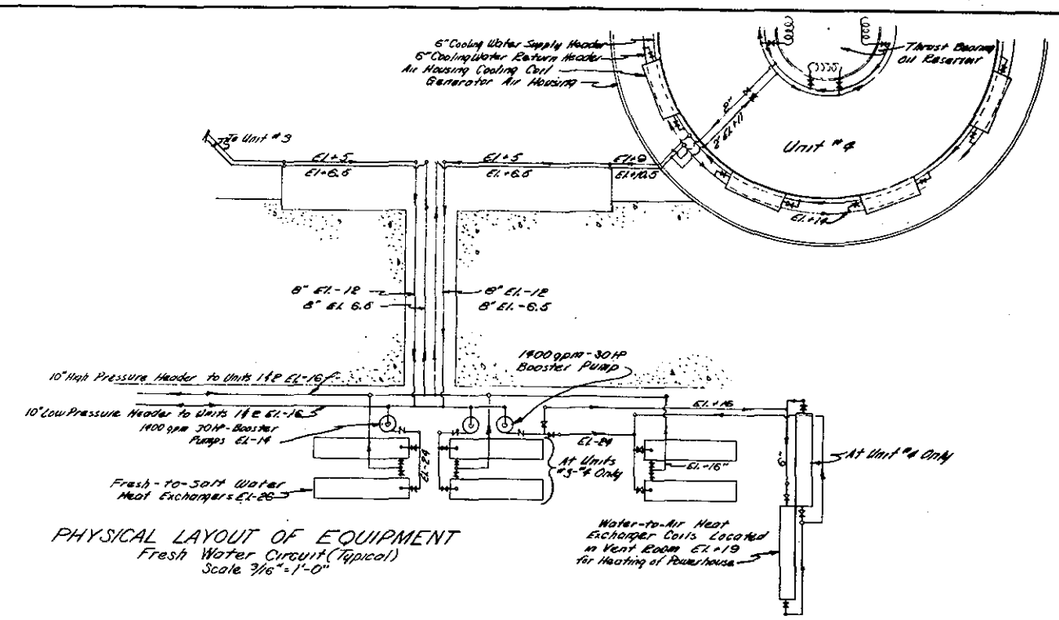
FIRE PROTECTION SYSTEMS

International Passamaquoddy Engineering Board

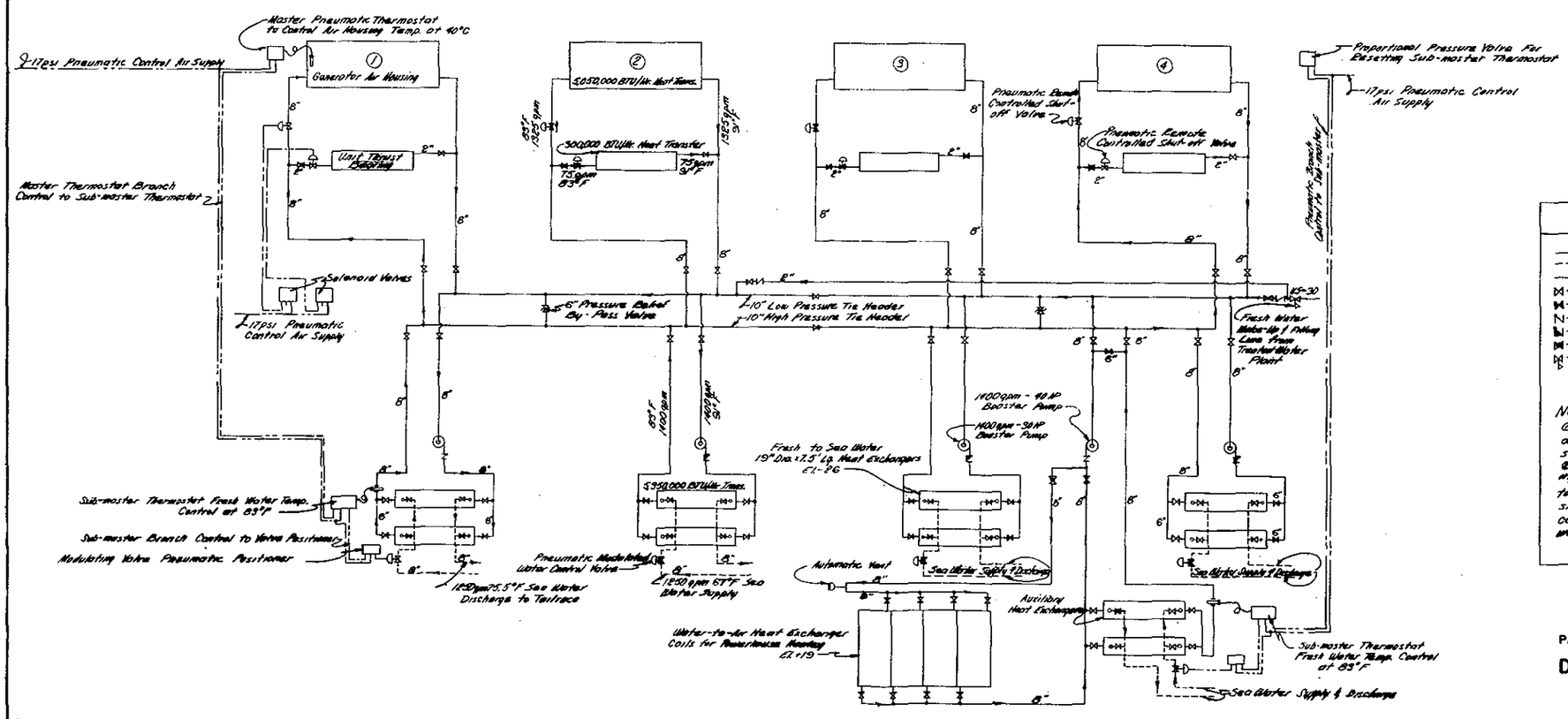
SEPTEMBER 1959 Dwg. No. PG7-061



PHYSICAL LAYOUT OF EQUIPMENT
Sea Water Circuit (Typical)
Scale 3/16" = 1'-0"



PHYSICAL LAYOUT OF EQUIPMENT
Fresh Water Circuit (Typical)
Scale 3/16" = 1'-0"



SCHEMATIC FLOW DIAGRAM

LEGEND

- Fresh Water
- Salt Water
- Control Air Line
- Gate Valve (Normally Open)
- Gate Valve (Normally Closed)
- Check Valve (Normally Open)
- Check Valve (Normally Closed)
- Globe Valve
- Pressure Reduction Valve

NOTE

① Typical pneumatic controls shown on unit #1 only. Capacities & Ratings shown on Unit #2.

② Schematic shows valving for unit #4 supplying warm water to water to air heat exchangers, units #2 & #3 shut down, unit #1 normal generator cooling through fresh water to sea water heat exchangers.

SCALE 3/16" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

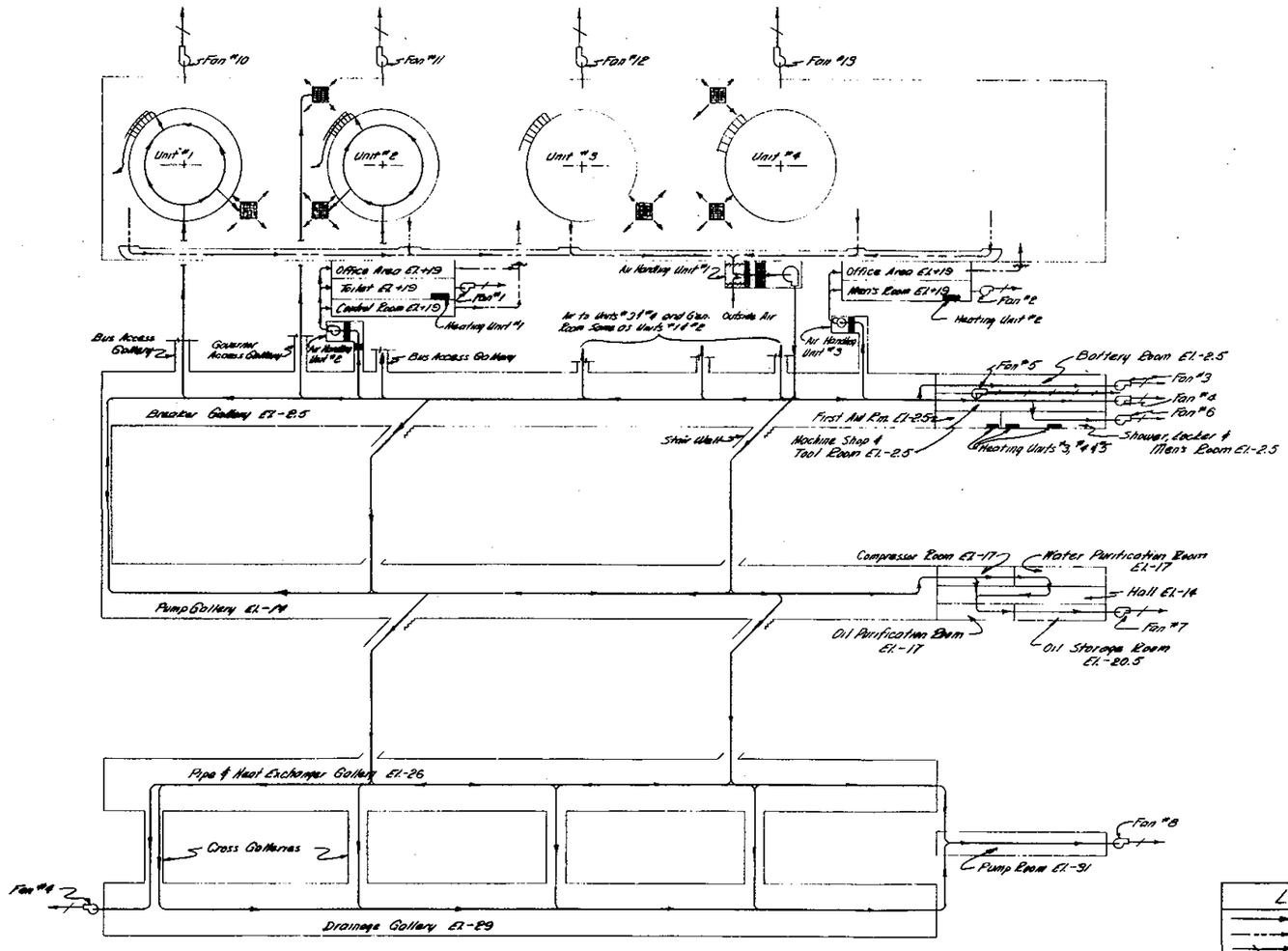
POWERHOUSE

GENERATOR COOLING SYSTEM

International Passamaquoddy Engineering Board

SEPTEMBER, 1959

Dwg. No. PG7-062



SCHEMATIC
Heating & Ventilating System

EQUIPMENT SCHEDULE

Item	Location	Area Served	Description
Air Handling Unit No. 1	Deckhouse El. 19	Powerhouse	
Hot Water Coil			3,385,500 BTU/hr.
Filter			Viscous Type, 10 hr.
Fresh Air Damper			Louvered, Motor Opr'd
Recirculated Air Damper			Louvered, Motor Opr'd
Fan			77,000 cfm, 1 3/4" S.P. 30 HP Motor
Air Handling Unit No. 2	Control Room	Deckhouse West	
Elec. Duct Heater			5 KW
Filter			1200 cfm
Fan			1200 cfm, 2" S.P. 1 HP Motor
Air Handling Unit No. 3	Storage Room	Deckhouse East	
Elec. Duct Heater			4 KW
Fan			1000 cfm, 2" S.P. 1 HP Motor
Exhaust Fans			
No. 1	Toilet, Deckhouse, El. 19		120 cfm, 1/8" S.P. 1/20 HP Motor
No. 2	Men's Room Deckhouse El. 19		100 cfm 1/8" S.P. 1/20 HP Motor
No. 3	Battery Room El.-2.5		3200 cfm 1/8" S.P. 1/3 HP Motor
No. 4	Machine Shop & Tool Room El.-2.5		2000 cfm 1/8" S.P. 1/6 HP Motor
No. 5	Machine Shop & Tool Room El.-2.5		2000 cfm 1/8" S.P. 1/6 HP Motor
No. 6	Shower, Locker & Men's Room El.-2.5		1800 cfm 1/8" S.P. 1/6 HP Motor
No. 7	Oil Storage Room El.-20.5		1300 cfm 1/8" S.P. 1/6 HP Motor
No. 8	Pump Room El.-31		1500 cfm 1/8" S.P. 1/6 HP Motor
No. 9	Drainage Gallery El.-29		1500 cfm 1/8" S.P. 1/6 HP Motor
No. 10 - 13	Generator Room Roof El. 78	Generator Room & Erection Bay	6000/12000 cfm 1/8" S.P. 2 HP Motor
Heating Units			
No. 1	Toilet, Deckhouse, El. 19		Elec. Wall Mtd. .2 KW
No. 2	Men's Room, Deckhouse El. 19		Elec. Wall Mtd. .2 KW
No. 3	First Aid Room El.-2.5		Elec. Wall Mtd. .5 KW
No. 4	Shower & Locker Room El.-2.5		Elec. Ceiling Mtd. 5 KW
No. 5	Men's Room El.-2.5		Elec. Ceiling Mtd. 7.5 KW

LEGEND

- Supply Air
- Return Air
- Exhaust Air
- Centrifugal Fan
- Air Filter
- Electric Heating Unit
- Hot Water Heating Coils
- Louvered Damper
- Floor Mounted Air Outlet Grill

NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

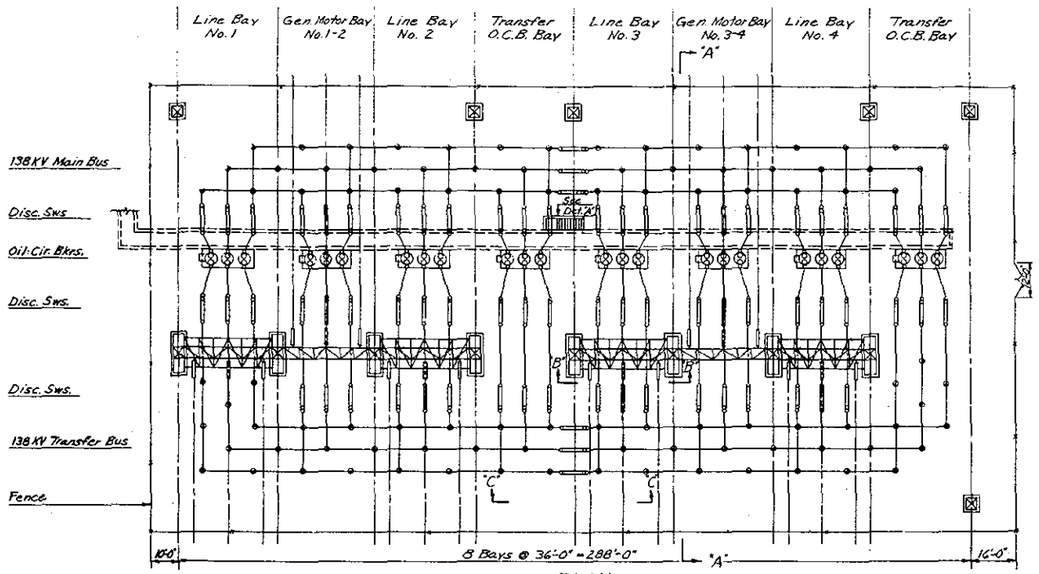
DIGDEGUASH DEVELOPMENT

POWERHOUSE

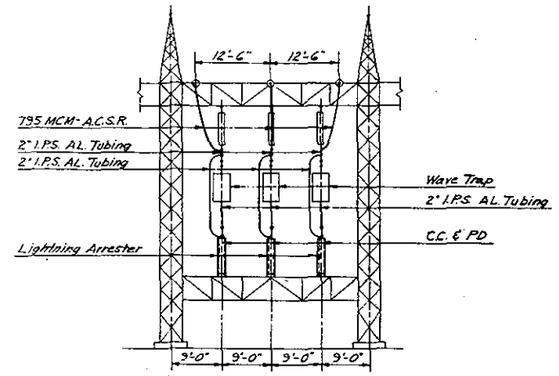
HEATING & VENTILATING SYSTEM

International Passamaquoddy Engineering Board

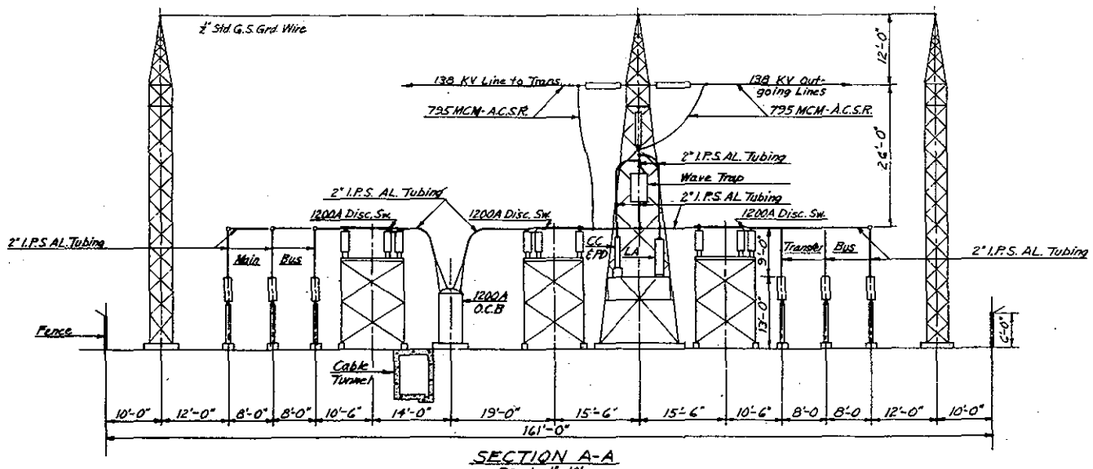
SEPTEMBER 1959 Dwg. No. P67-063



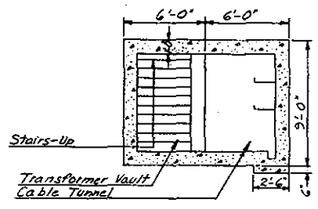
PLAN
Scale: 1" = 20'



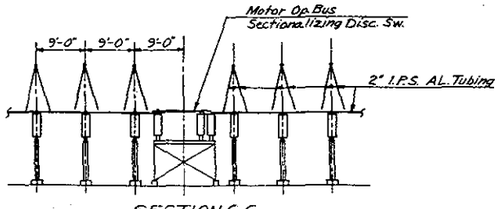
SECTION B-B
Scale: 1" = 10'



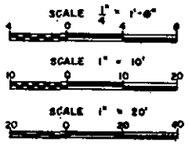
SECTION A-A
Scale: 1" = 10'



DETAIL "A"
Scale: 1/4" = 1'-0"



SECTION C-C
Scale: 1" = 10'



INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

SWITCHYARD

PLAN & SECTIONS

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. PG7-064

REPORT TO

INTERNATIONAL JOINT COMMISSION

ON

INVESTIGATION OF INTERNATIONAL

PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 12

AUXILIARY RIVER HYDRO DEVELOPMENTS

BY

INTERNATIONAL PASSAMAQUODDY

ENGINEERING BOARD

OTTAWA, ONTARIO
WASHINGTON, D. C.

OCTOBER 1959

INTERNATIONAL PASSAMAQUODDY
ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 12

AUXILIARY RIVER HYDRO DEVELOPMENTS

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PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 12

AUXILIARY RIVER HYDRO DEVELOPMENTS

12-01 PURPOSE

This appendix presents studies made for the determination of the site and design of the river hydro auxiliary for the proposed international Passamaquoddy tidal power project. The design serves as the basis for an estimate of cost which, with other information, is used to measure the feasibility of the proposed tidal power project.

12-02 SCOPE

An appraisal of available sites in Maine and New Brunswick narrowed the choice of potential river hydro auxiliaries to three on the upper Saint John River in Maine. The potential auxiliaries are called Rankin Rapids, Big Rapids, and the Big Rapids-Lincoln School combination. Careful comparison of the three led to selecting Rankin Rapids as the river-hydro auxiliary to the international Passamaquoddy tidal power project. Designs of the Rankin Rapids project were then refined to serve as the basis for a reliable estimate of cost. Quantities, unit costs, and the cost estimate of the Rankin Rapids auxiliary used in determining the economic justification of the tidal project are presented in appendix 17, "Estimates of Cost." Phases of the study not covered in this appendix include certain specialized investigations which are covered in appendix 2, "Geology, Foundations, and Materials"; appendix 4, "Basic Hydrologic Data"; appendix 13, "Project Power"; and appendix 14, "Power Markets and Transmission Lines."

12-03 FUNCTION OF AN AUXILIARY POWER PROJECT

As indicated in appendix 13, "Project Power," the output of the proposed 30-unit, two-pool tidal power project would vary continuously during each tide cycle as the upper pool is filled through the gates and drawn down through the powerhouse, and as the lower pool is emptied through the gates and filled through the powerhouse. The tidal plant output also wanes and increases as the tides pass through their 2-week cycle from spring tide to neap tide and back to spring tide. The length of the lunar day causes tides to occur 50

minutes later each day. The power requirements follow the solar day with more energy being used during the day than at night. The load has a characteristic pattern of hour-to-hour variation during the workdays of the week with a similar but lesser use of power during Saturdays and Sundays. The completely different patterns of the load and tidal project power output and the constantly changing nature of these differences are demonstrated in appendix 13. The differences between the load pattern and the tidal power pattern result in a low tidal plant capacity, 95,000 kw., compared with the average generation of 210,000 kw. and the rated installed capacity of 300,000 kw. A river hydro auxiliary would put more of the tidal energy under the load curve, and thus permit installing more capacity at the auxiliary to realize greater benefits. If the tidal output were transmitted to the load as generated, the remaining generating facilities serving the load would need to operate in a continually changing pattern to match the total output to the pattern of the load. The river hydro auxiliary power output combined with the power output of the tidal plant would vary in proportion to the load so that the load to be supplied by the remaining generating facilities would remain virtually unchanged from the generating pattern now followed. Details of these considerations are discussed in appendix 13.

12-04 PRIOR STUDIES OF AUXILIARY POWER PROJECTS

The difficulties of matching the normal pattern of tidal power generation to the normal pattern of the load was recognized in the several investigations made of potential tidal power projects in the Passamaquoddy-Cobscook Bay area. Dexter P. Cooper is known to have considered a pumped-storage plant at the Haycock Harbor site, southwest of Lubec, Maine, and the U.S. Army Corps of Engineers in their studies of 1935-37 considered auxiliary pumped-storage projects at Haycock Harbor and near Calais, Maine. Also considered was a diesel generating plant to firm the output of the single-pool project under construction at that time. The International Passamaquoddy Engineering Board report of March 1950 indicated that plans for auxiliary power projects should be considered for firming the varying tidal power output, and that these plans should consider pumped-storage projects and stream flow projects in Maine and New Brunswick. The March 1950 report contains the first known reference to a river hydro auxiliary to the proposed tidal power project.

12-05 POTENTIAL AUXILIARY POWER PROJECTS

a. General. Early during the current survey, an examination was made of available data on undeveloped hydroelectric power sites located in the major river basins of Maine and contiguous areas in New Hampshire and New Brunswick for the purpose of determining the

most suitable sites for further investigation as an auxiliary source of power for firming the variable output of the proposed tidal power project.

b. Undeveloped River Hydro Sites. The most up-to-date information on undeveloped water power in the area of the proposed tidal power project is contained in the report of the New England-New York Inter-Agency Committee entitled "The Resources of the New England-New York Region," completed in March 1955, and the "Interim Report on the Water Resources of the Saint John River Basin," dated April 6, 1953, submitted to the International Joint Commission by the International Saint John Engineering Board. Data obtained from these reports concerning undeveloped water power sites in the Saint John, Kennebec, Penobscot, and Androscoggin River basins are shown on table 12-1. Power possibilities on the St. Croix River were reviewed but no potential development was found of sufficient magnitude to act as an auxiliary to the tidal power project. Annual project costs and cost of average annual energy shown in the table, are based on private financing, except for projects in New Brunswick which are predicated on public financing of the estimated capital investment. The tabulated data shows that the Rankin Rapids project on the Saint John River in Maine provides the largest power and storage potential at the lowest at-site cost compared with any other single project or combination of projects. Other large potential sites which might be adequate for the purpose of firming Passamaquoddy output include Grand Falls storage combined with Pierce Pond on the Kennebec River; and Stratton Rips combined with the Bangor diversion in the Penobscot River basin. Costs associated with the latter are excessive and would not be justified by potential power benefits at this time.

c. Rankin Rapids Project Plans. As proposed in the NENYIAC and Saint John Survey Reports, plans for developing the Rankin Rapids site include an earthfill dam on the Saint John River about 3½ miles above the mouth of the St. Francis River at St. Francis, Maine. The drainage area at this site is 4,060 square miles. At full pool level, el. 810 feet, m.s.l. the reservoir would cover 47,000 acres and provide about 1,460,000 acre-feet of usable storage with a drawdown of 34 feet. Other preliminary studies of this project proposed 2,400,000 acre-feet of usable storage, a continuous power output of about 100,000 kw., an installed capacity of 230,000 kw., and an annual energy generation of about 900 million kw.-hr. under an average net head of about 235 feet. The estimated first cost of the project, based on 1949 price levels, was $65,490,000 with annual costs under private financing of $6,858,000. The at-site cost of the average annual generation was estimated as 7.6 mills per kw.-hr. With public financing excluding Federal, State and local taxes, the energy cost was estimated to be about 4 mills per kw.-hr.

d. Rankin Rapids Controversy. The Rankin Rapids site is located downstream from the junction of Allagash River and the main stem of the Saint John River as indicated on plate 12-1. Development of this site would flood a series of rapids in the lower reaches of the Allagash River. These rapids are esteemed by many for the trout fishing and the white water canoeing they afford. Those interested in the wildlife and natural recreational assets of the nation are actively opposed to the development of Rankin Rapids. An alternate to the Rankin Rapids project was suggested in the NENYIAC report in order to mitigate alleged losses to fish and wildlife and to prevent inundation of the white water of the lower Allagash River. The alternate would consist of a high-head dam at the Big Rapids site, upstream from the mouth of Allagash River, and a low-head project at the Lincoln School site, a short distance downstream from the Rankin Rapids site. The relative locations and their relation to the proposed tidal project are shown on plate 12-1.

e. Selection of Sites for Initial Study. The combinations selected for an initial study of the river hydro auxiliary for the proposed tidal power project consist of (a) Rankin Rapids, (b) Big Rapids, and (c) Big Rapids and Lincoln School, all of which are in Maine. The Lincoln School project would not develop a significant amount of storage which would be available for regulating river flows. Because of the low head and the lack of storage, a project at the Lincoln School site would be less attractive as an auxiliary than projects at either the Rankin or Big Rapids sites. For this reason, an auxiliary power project at the Lincoln School site alone was not considered. Initial studies were then undertaken to determine which of the combinations selected was best suited as an auxiliary so that final and more detailed examinations could be made on one auxiliary river hydro project.

12-06 OTHER ASPECTS OF A SAINT JOHN RIVER DEVELOPMENT

a. General. Construction and operation of a reservoir with large amounts of storage in the upstream reaches of the Saint John River would have many effects in the general project area in addition to developing power to supplement the varying output of the proposed tidal power project. The most important of these other effects are discussed briefly in the following subparagraphs.

b. Power at Downstream Projects. An auxiliary power project on the Saint John River with substantial amounts of storage would even out the seasonal variation of flows and benefit downstream power projects. This regulation effect is so important that providing upstream storage may make certain downstream projects feasible which otherwise might not be feasible. Indicated on plate 12-1 are the existing hydroplants at Grand Falls and Beechwood which would

benefit from an upstream development. Also indicated are sites for potential projects at Morrill and Crocks Point. All of these sites are in Canada while the upstream development would be in the United States. Plate 12-2 shows a profile of the Saint John River with the projects and sites under discussion. Maximum benefits would undoubtedly accrue if all hydropower projects on the Saint John River were operated in coordination. Completely detailed studies to develop the optimum system and its benefits are complex, expensive, and time-consuming, and consequently have not been undertaken for the current study of the proposed tidal power project. The results of the few preliminary evaluations which have been undertaken are discussed in appendix 13, "Project Power."

c. Flood Control. Damages from floods occur with some regularity along the Saint John River, and the damages would be reduced by an upstream storage project. The extent of these annual damages, as indicated in the first three items in the attached correspondence is a substantial loss to the area, but very small compared to the power benefits of the projects being considered. Flood control benefits which might accrue would have only a small effect on the benefit-cost ratio of the tidal project and its auxiliary, therefore, further study in this direction was not undertaken.

d. Fish and Wildlife. Changing portions of the Saint John or Allagash Rivers from fast-water streams to deep hydroelectric project reservoirs would change the type of fish and fishing which would prevail. Other wildlife habitat would also be affected. The United States Bureau of Sport Fisheries and Wildlife has examined the effects of auxiliary hydroelectric projects on the fish and wildlife resources of the area. To minimize the fish and wildlife losses in the event of project authorization, the Bureau recommends that the following measures be considered:

1. Establish a management framework for fish and wildlife resources at the project site.

2. Provide public access.

3. Purchase additional land for wildlife management purposes.

4. Modify land clearing plans to preserve insofar as possible deer yarding areas.

5. Construct barrier dams to prevent invasion of undesirable fish species.

6. Provide for minimum flows as required to benefit downstream fisheries.

7. Provide for a fish hatchery and rearing facilities.

8. Manage tributary streams.

9. Provide subimpoundments for waterfowl within reservoir maximum flow line.

10. Control reservoir pool elevations and provide for spawning beds.

11. Control temperature of water released to improve downstream conditions for fish.

A discussion of the fisheries in the downstream reaches of the Saint John River is given in the correspondence at the end of this appendix under the date May 1, 1958.

e. Log Driving. The upper Saint John River is used for log driving by both United States and Canadian nationals. This practice (on the part of Canadians) is based on the "Webster-Ashburton Treaty" of August 9, 1842 which is discussed in memos dated February 26, 1958 and March 14,1958 of the attached correspondence. The effect of one upstream reservoir on the practice of log driving is discussed briefly in the letter dated May 16, 1958 with the attached correspondence. Facilities for conveying logs over Rankin Rapids Dam have been incorporated in the detailed study of the project described later in this appendix.

f. Pollution. A storage project on the upper Saint John River would produce certain improvements in any stream pollution which might prevail downstream. The improvements would be partly offset, however, by other deleterious effects. These considerations are discussed in the letter dated April 28, 1958 with the attached correspondence. Further consideration is beyond the scope of the current survey and was not undertaken.

12-07 INITIAL STUDY; RANKIN RAPIDS

a. Location. The project would be at the site selected in both the NENYIAC and Saint John River reports, although the embankment alignment would vary slightly from that used in the prior reports. The site is in Maine about 8 miles downstream from the confluence of Allagash and Saint John Rivers, 3.6 miles upstream from the confluence of St. Francis and Saint John Rivers, and 3.5 miles upstream from the settlement of St.Francis, Maine. It is about 175 miles northwest from the site of the proposed tidal power project.

b. Prior Studies. Foundation explorations, topographic surveys of the site, layout studies, and cost estimates were prepared for the Saint John River and NENYIAC reports. The powerhouse considered in these reports had a capacity (230,000 kw.) substantially less than

needed as the river hydro auxiliary for the proposed tidal power project. It is now evident that both the carryover storage (1.46 million acre-feet) and the maximum normal operating level (el. 810), used in these earlier reports, might be increased to make greater use of the potential of the site and to achieve the most economical auxiliary to the tidal power plant. A layer of relatively weak material found in the river channel during the cited foundation explorations indicated that a higher dam would probably require a modified embankment section. For these reasons, the designs in the earlier reports were modified to develop a design for an auxiliary power plant.

c. Hydrology. Basic data pertinent to the Rankin Rapids site are discussed in appendix 4, "Basic Hydrologic Data," and are summarized for convenient reference as follows:

1. The upper Saint John River basin has a humid climate with short, cool summers and long, cold winters. Extreme temperatures range from 40° F. below zero in winter to over 100° F. in summer. The average annual precipitation for the upper basin is about 38 inches and ranges from less than 31 to over 42 inches. The average monthly precipitation ranges from 2 to 5 inches with the annual monthly maximum occurring during the summer months. Winter precipitation is practically all in the form of snow with an annual average fall of about 100 inches. The accumulation of snow may contain as much as 6 inches of equivalent water content and is an important source of runoff each spring.

2. Drainage area, 4,060 square miles.

3. Average annual flow, 6,780 c.f.s., or 4,908,000 acre-feet.

4. Minimum annual flow, 1948, 4,872 c.f.s., or 3,536,000 acre-feet.

5. Maximum annual flow, 1947, 9,023 c.f.s., or 6,532,000 acre-feet.

6. The normal annual pattern of flow consists of increasing flows accompanied by running ice and ice jams during the warming weather of the spring. Melting of the snow, accumulated during the previous winter, results in a concentrated runoff in a relatively short period. After the spring runoff the flow diminishes gradually and then usually remains quite uniform until the following winter, except for occasional rises due to rainfall. Then the diminishing trend is resumed until the cycle repeats.

7. The flood of 10-year frequency (used for evaluating the flood risk during the construction period) has a peak flow of 32,880 c.f.s. and a 30-day volume of 950,000 acre-feet.

8. A construction season flood of 10-year frequency has a peak of 31,500 c.f.s.

9. The floods of 1933, 1939, and 1947, the largest of record, had estimated peak flows of 90,400, 87,800, and 84,400 c.f.s. at the Rankin Rapids site.

10. Area and storage capacity at the Rankin Rapids site would be as follows:

El., ft.	Area, acres	Storage, million acre-feet
750	31,200	2.18
760	34,200	2.50
770	37,500	2.85
780	41,000	3.23
790	44,500	3.67
800	48,000	4.15
810	52,600	4.66
820	58,500	5.23
830	65,000	5.86
840	73,500	6.57
850	82,500	7.33
860	93,260	8.226

11. Tailwater elevations would fluctuate depending upon the turbine releases and spillway discharge. The elevations, rounded to the nearest foot, would be as follows:

For tailwater discharge of 2,000 c.f.s., el. 548
Maximum turbine release, 24,500 c.f.s., el. 553
Spillway design discharge, 167,000 c.f.s., el. 559

d. Geology, Foundations, and Materials.

(1) General. Investigations and analyses pertaining to geology, foundation conditions, and construction materials are presented in detail in appendix 2, and are summarized in the following subparagraphs for ready reference.

(2) Geology. Topography of the upper reaches of the Saint John River Valley consists of moderate to low glacial moraine-capped upland hills rising to elevations ranging generally from 1,000 to 1,500 feet above mean sea level. The Saint John River flows in a

valley which is 70 to 120 feet above the preglacial channel. Bedrock of Ordovician or Silurian Age is composed mainly of metamorphosed shales with some sandy layers. The dip of these rocks is nearly vertical and the strike is about N50°E in the dam site areas. These shales are relatively hard and dense, approaching slates in durability. Compact glacial till mantles the bedrock over most of the area, the greatest thickness occurring in the river valleys. This till originated mainly from the immediate area so that the sand, gravel, and boulders it contains are largely of the same origin as the bedrock of the area. As the glaciers retreated, some gravel, sand, and silt deposits were laid down as glacial outwash along the stream channels and banks of the rivers and as kame terraces along preglacial valley walls. The platy shale fragments which occur in large amounts would be difficult to remove by washing; as a result, the numerous sand and gravel deposits in the area are unsuitable for concrete aggregates. As the overburden in the reservoir area is mainly impervious glacial till and bedrock is relatively tight, leakage from a reservoir through the foundation would be inconsequential.

(3) Foundation Conditions. The Rankin Rapids dam site was investigated in 1951 and 1952, when nine test borings were drilled. The stream bed is covered with a shallow layer of gravel and boulders. The preglacial valley extends under the left bank of the stream, reaching a depth of about 80 feet below the present stream level. Bedrock is found from 20 to 40 feet below the surface on the right abutment, at more shallow depths on the left abutment, and crops out near the shore on the right bank of the stream. The overburden is a compact glacial till on both abutments except for a terrace deposit of stratified sand and gravel on the left bank. A fairly compact silt underlies the river and extends under the left abutment forming a pocket somewhat above the bottom of the preglacial stream valley. Plate 12-3 is the general plan of the proposed project on which are shown locations of exploratory drilling. Plate 12-4 shows the geologic profile and logs of drill holes.

(4) Construction Materials. Materials for the construction of an earth dam including rock for slope protection occur in ample quantity and suitable quality at or near the dam site. One of the conspicuous characteristics of the Saint John River valley in the general vicinity of Rankin Rapids is the lack of good quality materials for concrete aggregates. This condition arises from the fact that existing granular overburden deposits are derived largely from the local shale bedrock. The platy shale fragments which occur in large amounts are unsuitable for making durable concrete, and these particles would be difficult and expensive to separate and remove. The nearest known sources of commercially available aggregate are the limestone quarries near Presque Isle, Maine, about 80 miles by rail from St. Francis. The track of the Bangor and Aroostook Railroad ends at St. Francis about 3½ miles from the Rankin Rapids damsite. Reconnaissance

in the project vicinity has resulted in discovery of an undeveloped source of granite at Deboulie Mountain, about 16 road miles south of Rankin Rapids, which is accessible at present only via logging roads. Cost analyses indicate that this source is the most economical one for production of concrete aggregates for the Rankin Rapids project.

e. Site Development. The degree to which the Rankin Rapids site should be developed was studied shortly after the review of the previous work on the site. The previous work was based on a maximum pool level of el. 810, and useful storage of 1.46 million acre-feet (34 feet drawdown) which would yield a regulated flow of 4,100 c.f.s. Since it appeared that more storage and head would yield a more favorable project, site development studies were carried out using 2.0 and 2.8 million acre-feet of useful storage, and maximum pool levels of el. 810 (from previous studies), and el. 860 (highest practicable level of development). The selected storage volumes would yield regulated flows of 5,150 and 5,950 c.f.s. Regulation to average stream flows, 6,730 c.f.s., was not considered practicable because 5.5 million acre-feet of storage and about 80 feet of drawdown would be required. The studies also considered various methods of operating the Rankin Rapids project to supplement the tidal plant output, so that several installed capacities at the river hydro were considered. These studies were based on preliminary values for costs and benefits; and, as indicated in the summary of the studies on table 12-2, the project with the pool level at 860 and providing 2.8 million acre-feet of useful storage would yield the greatest excess of annual benefits over annual charges. Accordingly, this level of development was selected for further detailed study. Plate 12-5 shows the extent of the reservoir which would be entirely within the State of Maine. A saddle dam of moderate height would be required at Falls Brook for this level of development.

f. Project Layout. A brief study was made to determine whether a concrete gravity dam might be used effectively at the Rankin Rapids site. Such a dam was found to be excessively expensive because bedrock is 80 feet below the stream bed and concrete aggregate would need to be hauled from Deboulie Mountain. Further studies were directed toward securing the most suitable layout using an earth embankment. Numerous studies were made in which the component parts such as embankment, spillway, chute and stilling basin, low-level outlet, intake, pipelines, surge tanks, penstocks and the powerhouse, and the channels associated with these works were placed in varied locations.

The least costly arrangement (plate 12-3) was selected for further study. The powerhouse would be in a deep excavation in the rock of the right abutment. Just upstream from the powerhouse, a surge tank would be provided on each of the pipelines. A power intake structure would connect the pipelines with the excavated approach channel in the reservoir. An excavated tailrace would connect the powerhouse to the Saint John

River channel. The river would be diverted through two 24-foot tunnels in the right abutment before the earth embankment is built. These tunnels would be converted to low-level outlets by the installation of fixed-cone dispersion valves after they are no longer needed for diverting stream flow. The embankment itself would follow an alignment which would permit a minimum length of penstock and tunnels, and the least increase in earth work volume. The spillway would be located in the left abutment and would consist of an approach channel, a concrete crest structure with gates, a paved chute, a stilling basin, and an outlet channel leading back to the Saint John River. Limit of drawdown would be el. 823 which would provide 2.8 million acre-feet of active storage.

g. Spillway.

(1) General. The project layout, shown on plate 12-3, would place the spillway at the left abutment of the embankment. Because of the proximity of the spillway to the embankment, and the direction in which the spillway discharges re-enter the Saint John River, it would be necessary to line the spillway chute with concrete and to provide a concrete stilling basin. Because the dam and powerhouse would be continually attended and to secure maximum economy, a gate-controlled crest structure is planned for the spillway.

(2) Spillway Design Flood. The spillway would provide protection for the project in the event of a maximum possible flood. The spillway design flood has been based on the maximum possible rainfall flood, rather than on a snow-melt flood because (a) the latter can be anticipated and the reservoir drawn down in preparation for the ensuing runoff and (b) the rainfall flood would have a higher peak flow. In accordance with the foregoing, the maximum possible rainfall over the upper and lower Saint John and Allagash drainage areas was determined from Hydrometeorological Report No. 28, "Generalized Estimate of Maximum Possible Precipitation over New England and New York," prepared by U.S. Weather Bureau, Washington, D.C., March 1952. An infiltration rate of 0.05-inch per hour was subtracted from these rainfall values. The infiltration rate was selected on the basis of long-term hydrologic studies in the New England area. The rainfall excess was reduced to 12-hour periods and these periods were arranged to simulate a natural storm which would yield maximum runoff rates. The rainfall excess for each 12-hour period was applied to the selected unit hydrographs developed and presented in appendix 4 and the resulting derived hydrographs were combined with the base flow to determine the natural hydrograph at the dam site for the maximum possible rainfall flood. The flow into a full reservoir was estimated by peaking the maximum ordinate of the maximum rainfall flood hydrograph 16 percent to account for the loss of river valley storage under these circumstances. The hydrograph was then reshaped to the new peak ordinate retaining the original runoff

volume. The unit hydrographs and resulting spillway design flood hydrograph, which has a peak of 290,000 c.f.s., is shown on plate 12-6.

(3) Crest Structure. The spillway design flood was assumed to occur when the reservoir was full. Discharge rating curves for 40- by 25-foot and 40- by 30-foot gated openings, assuming the top of the gate to be at el. 860, were prepared and preliminary routings were made to determine the relationship between gate size, number of gates, surcharge, and maximum rate of flood outflow. A preliminary structural evaluation indicated that the use of the deeper 40- by 30-foot gates would provide more economical structural widths, and this size was adopted. The results of the computations for the 40- by 30-foot gates are summarized on plate 12-7. On the basis of these curves, and the further restriction that the discharge should be less than the 251,000 c.f.s. natural flow at the dam site, six gates were selected. The surcharge would be 2.5 feet and the design discharge 167,000 c.f.s. The crest structure was laid out as an ogee weir section designed for the maximum head which would occur during the spillway design flood. Piers supporting the spillway bridge and gate trunnions would be provided as shown on plate 12-3. The structure was laid out to conform generally with previous similar designs, and was checked for stability. The abutments and wing walls were checked to provide the most economical sections.

(4) Gates and Stoplogs. The six 40- by 30-foot gates would be operated by electric hoists set one to each pier below the bridge floor level. Each opening would be provided with slots for stoplogs to permit maintenance and repair while the reservoir is above the spillway crest at el. 830. Two sets of stoplogs would be provided.

(5) Chute. The crest structure would discharge into the chute which would carry the high velocity flows down the left abutment. The chute would consist of a 3-foot-thick concrete apron anchored to the bedrock with rods to a depth of 10 feet at a 10-foot spacing. The chute would be 280 feet wide, the same width as the crest structure. The chute would have a slope of 13.2 percent and depths for the spillway design flow would decrease from an estimated 9.5 feet at the upstream end to the 6.8-foot normal depth. Chute walls would be 20 feet high to provide approximately a 10-foot freeboard. The chute was laid out to provide a 20-foot rock depth at the shallow, right side as closely as could be determined from the meager information on rock elevation in this area. This was done to assure that the paving would all be founded on rock. The left chute wall was assumed to be a concrete lining anchored to the rock face. The right wall was assumed to be the same except that a semigravity wall would be used where the top of sound rock is less than 20 feet above the chute floor.

(6) Stilling Basin. A standard hydraulic jump stilling basin would be provided at the downstream end of the chute, as shown on plates 12-3 and 12-8, to give necessary control of the high flow velocities which would prevail on the chute. The horizontal apron of the basin would be set sufficiently below river tailwater elevation to assure the formation of a hydraulic jump with spillway design flood flows. The basin would be 280 feet wide, 180 feet long (3.0 times the depth required for a jump), and provided with an endsill. The basin walls would be cut in the bedrock of the site and lined with concrete 65 feet above the basin floor to provide 5 feet freeboard above spillway design flood tailwater. An excavated channel would connect the stilling basin to the river channel.

(7) Outlet Channel. The spillway discharge would return to the Saint John River channel by means of a connecting outlet channel, as indicated on plates 12-3 and 12-8. The channel downstream from the stilling basin would be excavated in rock for a short distance which would provide protection against possible scour at the endsill. The channel would widen and curve to turn spillway releases in the direction of the river channel.

h. Embankment.

(1) Top Level. The top of the embankment was set at el. 875 to provide 15 feet of freeboard over the maximum normal operating pool level and 12.5 feet over the spillway design flood pool. This freeboard was selected on the basis that the 3-mile fetch which extends to the south from the embankment would generate 4.6-foot waves with a 60-mile wind. These waves would ride 7 feet up the 1 on 3-upstream slope of the embankment to el. 869.5, leaving 5.5 feet of freeboard above the zone of wave action.

(2) Earth Section. An earth embankment was selected for the main dam after comparing its cost with that of a concrete dam. Ample quantities of materials for an earth dam are available at or near the dam site. The cross section of the dam, as shown on plate 12-8, is predicated on economical use of structure excavation and adjacent borrow materials consisting of glacial till and terrace deposits of silty sands and gravels. The exterior slopes of the dam are designed for stability during construction and all stages of reservoir level. In view of the substantial layer of silt in the deep valley bottom, the center portion of the dam was designed with a flattened slope in the lower zone. At both upstream and downstream toes of the embankment, the design includes cofferdams for unwatering the foundation area for construction. Design of the transition between zones of different materials and details for surface protection and control of seepage follow conventional practice. A gravel roadway would be provided across the dam for project maintenance purposes. The embankment for the Falls Brook saddle dam would be similar to that of the main embankment.

(3) Slope Protection. Riprap is planned from el. 813 (10 feet below limit of drawdown) to the top of the dam on the upstream face of the embankment. This riprap would be 5 feet thick with a gravel filter and would be constructed from required excavation of the indurated shale bedrock selected for size. The remaining surfaces will also be faced with the shale but not selected for size. This would provide a downstream surface for the embankment which would require a minimum of maintenance.

i. Care of Water during Construction. With an earth embankment project, low-level conduits are required for the following periods:

(1) During initial construction of the embankment in the river channel when the river flow is diverted from the channel to the low-level outlets.

(2) During following periods when low flows need to be passed to maintain downstream discharge, and when flood flows need to be passed to prevent the partly completed embankment from being overtopped.

(3) During initial reservoir filling before the power plant is placed in operation when minimum releases must be passed.

(4) During reservoir operation period when emergency reservoir drawdown may be needed.

Preliminary layout studies of the Rankin Rapids project indicated that power intakes should be relatively high and exposed penstocks should be used because tunnels for power and the associated low-level intakes would increase costs. Further examination indicated that maximum river flow normally occurs during the snow-melt period, and the likelihood of large river flows during the remainder of the year is small. On this basis, low-level outlets could serve for initial diversion as early in the season as possible after the river recedes from the spring breakup. The closure section of the embankment would be raised as high as possible during the remainder of the season to be available for the floods during the following critical spring season. To determine the size of the low-level outlets, the routing studies summarized on plate 12-10 were performed. A construction season flood with a probability of occurrence of once in 10 years and the maximum spring flood of record were used. By using stockpiled material, the closure section could be raised to el. 610 in about 17 days of construction and to about el. 710 by the end of the construction season, in preparation for the following critical spring period. Using these values and the curves on plate 12-10, the two 24-foot tunnels indicated in plates 12-3 and 12-9 were selected to care for water during the construction periods.

j. Low-level Outlets. The two 24-foot tunnels described in the previous paragraph would also be used for releases during reservoir filling, and for emergency reservoir drawdown. Although the discharge requirements for these functions are substantially less than during diversion, the discharge would occur at high heads and cavitation damage might be substantial. On the basis that it would take a discharge capacity of about 2.5 times the average reservoir inflow at levels below the power intake to effectively draw down the reservoir in an emergency, two 90-inch fixed-cone dispersion valves were selected for each of the two 24-foot tunnels. One tunnel could be taken out of service immediately after the critical spring flood season and the valves installed. The valves in the second tunnel could be installed after the first tunnel is returned to service. Reservoir filling could be undertaken at this time. Fixed-cone dispersion valves were selected because they could be used in a 24-foot tunnel and because, by furnishing an air vent and a short energy dissipation chamber, reasonable freedom from cavitation could be expected. Furthermore, this type of valve is simple in design, and is backed by a substantial amount of experience in similar installations. The valves and their 6- by 10-foot vertical lift emergency gates together with operating equipment would be located in a shaft immediately upstream from the centerline of the dam, as shown on plates 12-3 and 12-9. A concrete intake structure equipped with trashracks and facilities for stoplogs would be constructed in the reservoir. Guides for the trashracks and stoplogs would be carried to el. 755, or 68 feet below limit of drawdown. This would permit servicing the racks and installing the stoplogs from a work boat without sending a diver to excessive depths. This method is considered suitable since servicing the racks and installing the stoplogs is expected only a few times during the life of the reservoir. A shaft-type gate structure with a separate intake was selected because this combination was less expensive than a single 300-foot free standing intake structure in the reservoir and the expensive service bridge which would be required. The outlet end of the tunnel would open into the powerhouse discharge channel, as shown on plate 12-3. No stilling basin would be provided since the discharge channel would be in rock and tunnel exit velocities would be relatively low both during diversion and after installation of the valves.

k. Power. As described in appendix 13, "Project Power," the rated generator capacity at the Rankin Rapids project developed as an auxiliary power source for the proposed international Passamaquoddy tidal power project should be 400,000 kw. and dependable capacity should be 460,000 kw. The latter would be developed at minimum head by utilizing the 15 percent continuous overload customarily permitted in addition to the rated generator capacity. Estimated Rankin Rapids minimum, mean, and maximum annual energy outputs are 1,060; 1,120; and 1,150 million kw.-hr., respectively. These energy outputs are based on the assumption that site power storage of 2.8 million acre-feet

would be used to regulate the river discharges to a continuous outflow from Rankin Rapids of 6,000 c.f.s. and inflow in excess of 6,000 c.f.s., when the reservoir is full, is not used for power generation. Since the reservoir would fill on the average 1 year out of 3, energy from inflow above 6,000 c.f.s. into a full reservoir would not be predictable. An average of 100 million kw.-hr. of additional energy per year would, however, be generated if this excess inflow were used to generate energy up to 60 percent load factor. Maximum powerhouse discharge would be about 24,500 c.f.s.

l. Reregulation. The 2.8 million acre-feet of active storage at Rankin Rapids would be used to smooth out the seasonal variations in flow, and to carry over water from wet years to supplement the flow during dry years. The average discharge would be 5,950 c.f.s., or the 6,000 c.f.s. in the previous paragraph less losses estimated at 50 c.f.s. This regulation would benefit the downstream power plants, Grand Falls and Beechwood, both in New Brunswick. Rankin Rapids operating as an auxiliary to the tidal plant would impose another pattern of flow on the 5,950 c.f.s average release. This pattern would have peak flows as high as 24,500 c.f.s. The variations through individual days would be essentially smoothed out when the flow reached Grand Falls, 1 day travel time downstream. However, Saturday and Sunday releases from Rankin Rapids would be considerably less than average because of the small load demand on weekends. The low Rankin Rapids flow would then arrive at Grand Falls as the Grand Falls station undertakes to carry the large weekday load. One solution to this situation, but an expensive one, would be to provide reregulation storage downstream from Rankin Rapids. The problem has been studied and is discussed in appendix 13. No reregulation storage is planned because the storage available at Grand Falls supplemented by an energy exchange between Rankin Rapids and Grand Falls would allow the Grand Falls plant to follow the normal load pattern.

m. Number of Power Units. Under normal circumstances, the least number of generating units at a hydro power development usually results in the least cost per kilowatt, both in first cost and in maintenance. The obvious upper limit to this concept would be manufacturing and shipping limitations. At the Rankin Rapids site, shipping limitations would govern, limiting unit size to 180 inches for a Francis runner. On this basis a study was made of 4, 6, and 8 unit installations. In making these studies, it was assumed that installed rated capacity should be 400,000 kw. and that the plant should be capable of generating 400,000 kw. with one unit out of service. The 400,000 kw. would be achieved by operating the remaining units at overload ratings. Such an assumption was most favorable to an 8-unit plant, as it would permit developing the 400,000 kw. with considerably smaller total installed capacity than either the 4- or 6-unit plant.

Subsequent studies, however, assumed that dependable capacity would be available at minimum net head and 115 percent of rated generator capacity, with all units operating. Even under these conditions the 8-unit plant still showed a small cost advantage, principally in structural costs. The added advantages of the higher plant efficiency, greater flexibility of operation and greater dependability of an 8-unit plant as an auxiliary power source led to selecting the 8-unit plant for further studies.

n. Power Intakes. Since the power intakes would not be needed for diversion or any other low-level water releases, economy in both the penstock and the intake structure with its associated equipment can be realized by keeping the intake at as high a level as practicable. The limit of drawdown would be el. 823, and the need for drawing relatively warmer water from deeper in the reservoir during the winter led to setting the top of the pipeline at el. 796, which is 27 feet below minimum drawdown. Each of the 8 power intakes would consist of a concrete gravity monolith resting on rock as shown on plates 12-3 and 12-8. One 11- by 22-foot vertical lift emergency gate would be provided for each tunnel. Each gate would be equipped with a hoist which could be closed remotely from the powerhouse. The gate would be required to close against unbalanced pressures. Filling the penstock would be accomplished by opening the gate about a foot at half speed with unbalanced head and the remaining distance at full speed after the pressures are balanced. Trashracks and equipment for raking would be provided. Trashrack slots would be designed to receive stoplogs which would permit inspection and repair of the gate slots. An air vent would be provided to keep the penstock from collapsing in the event the emergency gates are closed while the turbine wicket gates remain open. The steel pipeline would be imbedded in the concrete of the intake monolith.

o. Pipeline and Surge Tanks. The pipeline from the power intake to the surge tanks, and the penstock from the surge tank to the powerhouse, plates 12-3 and 12-8, would be of welded steel construction. The penstock would be protected from corrosion by the customary protective coatings. No additional provision would be made for protecting the penstocks from freezing. It is planned that during extended periods of low load, some of the units may be closed down and their penstocks drained to minimize leakage and difficulties due to freezing. The 16-foot-diameter pipeline was selected on the basis of an early study of the project which indicated that the maximum penstock velocity should be 15 feet per second. The pipeline would be designed for the maximum pressures which would accompany rejection of the full turbine load at maximum pool levels. In the initial study, the surge tanks had a diameter of 45 feet, which is 25 percent in excess of the diameter indicated by the Thoma formula. The 25 percent increase is, in usual practice, provided to assure rapid damping of surges due to changes in load. The tanks were assumed to be of the differential type. The bottoms were placed at el. 800 which is 10 feet below the level to

which the tank would be drawn during a sudden increase in demand, 50 percent load to full load, with the reservoir at the limit of drawdown. The top of the surge tanks, el. 896, is 6 feet above the level which would be attained by a sudden rejection of full load with the reservoir at maximum normal operating level, el. 860. A riser 16 feet in diameter and 130 feet long would connect the penstock to the surge tank and extend into the tank another 78 feet. The exposed portion of the riser would be insulated to minimize trouble due to formation of ice. The surge tank would not be insulated, but provision would be made to circulate the warmer penstock water into the tank and to withdraw the cooled water. The surge tank would be supported on a structural steel tower. Normal structural design methods have been used to establish the size of the structural members. The surge tank dimensions, shown on plate 12-8, differ from those given above and are the results of the detailed studies for the Rankin Rapids project described later in this appendix.

p. Powerhouse.

(1) Unit Size. The general project considerations, previously described, established the minimum net head at 269 feet, the average (rated) net head as 284 feet, and the maximum net head as 304 feet. The plant capability of 460,000 kw. would be required at the minimum net head of 269 feet with the turbines operating at full gate. The plant capabilities for the various heads for an 8-unit plant are listed below:

Plant Capability

	Min.	Rated	Max.
Net head in feet	269	284	304
Turbine h.p., full gate	635,000	706,000	790,000
Turbine h.p., limited to 115% of generator rating	635,000	635,000	635,000
Generator kw., limited to 115% of rating	460,000	460,000	460,000
Turbine h.p., best gate	515,000	565,000	608,000
Generator kw., best gate	373,000	410,000	440,000

Generator nominal (60°C) rating = 400,000 kw.
Generator (80°C) rating = 460,000 kw.

(2) Structure.

(a) General. The power plant would be of the indoor type with the 8 generating units spaced on 54.5-foot centers. Maximum tailwater (spillway design flood) would be el. 559, as shown on plate 4-19 of appendix 4. Drive-in level will be el. 567, or 8 feet above

maximum tailwater. Layout studies of the powerhouse cross section indicated that the tailrace deck was the best location for the power transformers. The east end of the plant would offer the best access and, therefore, was selected as the location for office, assembly, and service areas. The above considerations determined the plant layout, a cross section of which is shown on plate 12-9.

(b) Water Passages. Turbine setting and water dimensions were based on information furnished by turbine manufacturers. Contraction joints would be provided between units and the minimum pier thickness would be 6 feet. The draft tube would be provided with a splitter pier and would have a thin slab floor. Uplift pressure on floor slab would be relieved by weepholes through the draft-tube slab from the rock below. A longitudinal gallery would provide access to the draft tubes.

(c) Main Floor. The main floor would also be at the level selected for the draft-tube deck which would provide a minimum of 5 feet of concrete over the steel scroll case. Generators would be mounted on raised concrete barrels. A partial balcony between each pair of generators would provide space for mounting of 13.8 kw. switchgear. Governor and switchboard equipment for the main units would be located on the main floor. Cables and pipes would be in cross galleries at a lower level. The powerhouse concrete walls, 5 feet thick, would be 57 feet apart with a height to crane rails of 43 feet. This arrangement provides adequate clearance for generator erection and for transformer untanking. Clearance for rotor handling determined the wall height.

(d) Galleries. Three longitudinal galleries are planned for the unit auxiliary equipment. The gallery at el. 551 would be used for heat exchangers, water strainers, pipe headers, and other equipment. The cable gallery and drainage access gallery would be located at el. 541.5 and 538, respectively.

(e) Tailrace Deck. The power transformers and draft-tube stoplog gantry crane would be located on the tailrace deck. One set of tracks would serve for the crane and for moving the transformers along the length of the powerhouse. The transformers would be provided with caster wheels to avoid the use of a transfer car.

(f) Roof. The powerhouse roof would consist of multiple ply roofing laid over "Q" decking supported by a rigid steel bent framework.

(g) Station-service and Assembly-bay Area. The station-service and assembly-bay area, about 82 feet long, would be located at the east end of the powerhouse with road and railroad access at main floor level. This level, el. 567, would also be the erection level. The station-service generators would be located in the northeast

corner. Two lower floor levels, el. 532 and 551, would provide space for the various systems and equipment.

(h) Office and Control Structure. The office and control structure would be located to the east of the station-service and assembly-bay area and would contain floors at two levels, housing the control room, cable spreading room, storage, office space, shop areas, toilet facilities, and ventilating equipment area. The structure would be approximately 65 feet long and 89 feet wide.

(3) Turbines and Governors. The power plant would contain eight vertical-shaft, Francis-type, steel spiral-case hydraulic turbines, each of which would develop 70,625 h.p. at best gate, at the rated head of 284 feet, and at 163.6 r.p.m. The bore of the generator and generator barrel would provide sufficient clearance to permit removing the turbine runner and head cover. The weight of the turbine rotating parts plus the unbalanced thrust to be supported by the generator thrust bearing is estimated to be 399,000 pounds. The centerline of the turbine distributors would be set at el. 555. Minimum tailwater would be at el. 548. The governors would be of the oil pressure, relay-valve, actuator type, with electrically-driven speed responsive control elements. The normal operating pressure would be between 250 and 300 p.s.i. The governors would be equipped with means for adjusting the rate of gate movement to any value between 5 and 15 seconds for a full gate-opening or full gate-closing stroke. Each governor would be equipped with two oil pumps, a sump and a pressure tank. This equipment would be located on the main floor near the turbine. A generator-shaft-mounted permanent magnet generator would provide speed change information.

(4) Generators. The power plant would contain eight vertical-shaft, 163.6 r.p.m. generators, each rated 52,600 kv.-a., 60°C. temperature rise, class "B" insulation, 13.8 kv., 95 percent power factor, 3-phase, 60-cycle and with direct-connected, shaft-driven exciter. Reactances, WR^2, runaway speed, and thrust bearing loading would not exceed values available in standard design machines. The generators would be enclosed in steel housings and cooled by water-to-air coolers inside the housings. Fire protection would be by a carbon dioxide system. Voltage regulator would be of the magnetic-amplifier or similar type. Lightning arrester and surge protection equipment would be close-connected to the generator terminals.

(5) Transformers and Generator Connection. Four, 3-phase, 120,000 kv.-a., 13.2-230 kv., 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 with an aerial line. Heat exchangers would be located in the equipment gallery directly under the

transformers. Each generator would be provided with a 1.5 million kv.-a., compressed-air type circuit breaker. Isolated phase bus would connect the generator to the transformer through the air circuit breaker. The 13.8-kv. switchgear would be located on a balcony between each pair of generators.

q. Switchyard. A 230-kv. switchyard would be located 1,200 feet downstream from the powerhouse on the east bank of the tailrace channel. Four incoming aerial lines from the powerhouse and four outgoing lines would be provided. Switchyard operation would be remote-controlled from the powerhouse. A duct bank would be provided between switchyard and powerhouse for electrical cables. Several layout plans were studied, including 2-breaker plan, 1½-breaker plan, and transfer-bus plan. The last plan proved most economical and was selected. This layout would provide a main bus, a transfer bus, a bus-tie breaker bay and a bay for each incoming and outgoing line. Each of the latter bays would be provided with an oil circuit breaker and a motor-operated disconnect switch. Manually operated bus-sectionalizing switches would be located midway in both the main and the transfer bus to permit the plant to be operated at two different voltage levels. Manual disconnect switches would be provided on each side of each oil circuit breaker. Lightning arresters would be provided for each transformer and each transmission line.

r. Permanent Operating Facilities. Because of the remoteness of the project, it is planned that housing be furnished in the immediate vicinity for key operating personnel. The permanent equipment required to service and maintain the reservoir and structures would include a barge and a truck-crane to serve the low-level intakes, the power intake structure, the spillway, and the saddle dam. A power launch would provide access to the various parts of the reservoir. The truck-crane would also be used for land-based maintenance operations. Trucks would be provided for transportation of men and equipment for routine and emergency duties. On this basis, permanent facilities would include the following:

Family housing units	20
Maintenance buildings and garaging, sq.ft.	3,000
Power launch, docking and housing	1
Barge and facilities	1
Trucks	
1-ton	1
Heavy duty	1
Pickup	4
20-ton crane	1

s. Logway. The logway shown on plate 12-3 was added during the detailed studies of the Rankin Rapids project and is described later in this appendix. The estimates of costs for the initial study do not include the cost of this facility.

t. Relocations, Lands, and Damages.

(1) Roads. State Highway 161 parallels the Saint John River upstream from Fort Kent, past the Rankin Rapids site to Dickey. The reservoir would inundate the portion upstream from the site. Since the reservoir would also inundate the farms and dwellings served by the road, no relocation is planned. The rest of the area is served by a poorly developed and continually changing system of private roads which are used for hauling timber out of the area and supplies into the lumber camps. The reservoir would cut these roads where they cross draws at levels below el. 860, or where they traverse areas below this level. The cost estimate is based on providing timber bridges and one small concrete bridge at the most important crossings and providing limited amount of replacement roads. General access into the area, if the reservoir were built, would be by water transportation on the reservoir.

(2) Utilities. An electric power and a telephone line running into the area would be cut off and need no replacement. The value of the lines is considered in the estimate. A wire telephone line of the Maine Forest Service would require a substitute facility.

(3) Cemeteries. Two cemeteries with a total of about 300 graves are located within the reservoir area and would be relocated.

(4) Lands and Damages. An allowance for lands and damages was made in the preliminary estimate of project cost on the basis of previous real estate studies.

u. Reservoir Filling.

(1) General. The dead storage proposed in the Rankin Rapids reservoir is slightly greater than the average annual flow at the site. Since construction of the powerhouse need not be completed until the pool is sufficiently high to permit operation of the generating units, and because only a part of the river flow can be used for reservoir filling, studies were undertaken to determine the interval in which filling to minimum pool level could be accomplished.

(2) Basis. Water needs downstream from Rankin Rapids were assumed to govern the rate at which water could be stored in the reservoir. The Beechwood power plant in New Brunswick uses more water than any other known installation on the river. Based on the installed capacity of 68,000 kw., a net head of 58 feet, and assuming that the plant would operate at a 60 percent load factor, the average flow requirement for Beechwood was computed to be 9,700 c.f.s. It was then assumed that flow at Beechwood could be reduced as low as this 9,700 c.f.s. by storing at Rankin Rapids, except that releases would be 500 c.f.s. or more at all times. It was also assumed that the 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 9,700 c.f.s. level.

(3) Estimated Filling Rate. Using mean monthly flows for the Rankin Rapids site and for Beechwood, a computation on the basis noted in the previous paragraph indicated that 4.14 million of the 4.95 million acre-foot average annual flow at Rankin Rapids could be stored. Of this, 1 million acre-feet could be stored during the June-February period and the remainder during March-May snowmelt runoff period. The 4.14 million acre-feet would fill the reservoir to slightly above the penstock intake, el. 800, as described earlier. This represents the lowest level at which the power units could operate.

v. Construction Schedule. The construction schedule for the Rankin Rapids projects, as shown on plate 12-11, is predicated on the following general considerations:

(1) Construction of the low-level tunnels and the embankment sections at both abutments during the first construction season.

(2) Diversion of the river from its channel to these tunnels after the spring freshet of the second year.

(3) Construction of the embankment across the river channel to at least el. 710 during the second season in anticipation of the spring flood season of the third year.

(4) Installation of regulating gates in the low-level outlets after the spring flood season of the third year.

(5) Start of reservoir filling after regulating valves in the first tunnel are installed.

(6) Completion of two units of the powerhouse early in the fourth year.

(7) Pool filling sufficiently advanced to permit start of generation about midway through the fourth year.

(8) Completion of the powerhouse installation of 8 units about midway in the fifth year at which time reservoir filling should have advanced sufficiently for full powerhouse operation.

Under this program, the construction of all project features except the powerhouse would be completed in 3 years, first power generation in 3.5 years, and full project operation in 4.5 years.

w. Estimate of Cost. The following preliminary cost estimate is based on prices prevailing in January 1958 and is presented here solely for the purpose of selecting one of the previously described combinations as the river hydro auxiliary to the tidal power project. The cost of clearing is not included because it is expected that this work could be accomplished in return for the right to remove all marketable timber and pulpwood in the reservoir area. Costs for the separate items of relocation and construction have been increased by 15 percent to cover contingencies. The total project first cost includes an allowance of about 9 percent of the direct costs for engineering, design, supervision, and administration. Not included below is an allowance for interest during construction since this estimate was used for comparative purposes only. Interest during construction is used in final estimates.

Lands and Damages		$5,000,000
Relocations		
Roads	$402,500	
Cemeteries	86,300	488,800
Dams		
Tunnels	11,323,100	
Embankment	33,829,600	
Spillway	12,207,400	
Intake	7,451,300	
Penstock and surge tanks	12,667,400	77,478,800
Power Plant		
Powerhouse	5,856,100	
Turbines and generators	20,164,100	
Switchyard	2,656,500	
Accessory equipment	4,870,300	
Tailrace	5,591,300	39,138,300
Roads and bridges		569,300
Buildings, grounds, and utilities		598,000
Permanent operating equipment		488,400
Total direct cost		123,761,600
Engineering, design, supervision, and administration		11,238,400
Total project first cost		135,000,000

12-08 INITIAL STUDY; BIG RAPIDS

a. Location. Big Rapids site is located on Saint John River about 6 miles upstream from its confluence with Allagash River as shown on plate 12-1. The Big Rapids site has hydrologic, topographic, and geologic characteristics that are similar to those of the Rankin Rapids site, and the development of the site would be similar. Because of the similarities, the general concepts developed for the Rankin Rapids site were considered applicable to the Big Rapids site, and repetition of comparative economic studies was considered unjustified for this report. On this basis, the Big Rapids project would consist of an earth embankment; the maximum normal pool would be as high as the site would reasonably permit; the storage would be as large as practicable; two low-level tunnels would be used for care of water during construction in a manner similar to that at Rankin Rapids; and the power intakes would be at high level and would serve the surge tanks and powerhouse through exposed steel pipelines. Because of these similarities, the descriptive material for the Big Rapids development has been abbreviated. The topographic sheets of the U.S. Geological Survey provided the only general topography available for the area, and this data was used for both reservoir and dam site studies. Additional surveys performed for the purpose of this study consisted of a profile of the rapids, a profile on the axis of the dam, and topography of a small area on the lower right abutment.

b. Hydrology. Pertinent hydrologic data are summarized below from appendix 4, "Basic Hydrologic Data," for ready reference.

1. Drainage area, 2,419 square miles.
2. Average annual flow, 4,230 c.f.s., or 3,064,000 acre-feet.
3. Minimum annual flow, 1948, 3,084 c.f.s., or 2,239,000 acre-feet.
4. Maximum annual flow, 1947, 5,742 c.f.s., or 4,157,000 acre-feet.
5. The dam at Big Rapids would control essentially the same drainage area as Rankin Rapids except for the drainage area of the Allagash River. The runoff from the Allagash River is normally distributed over a fairly long period of time as is indicated by the flat unit hydrographs on plate 12-6. Therefore, for the construction season flood of 10-year frequency, the peak rate of flow, but not the total volume, would be about the same as for Rankin Rapids or about 32,800 c.f.s.
6. The floods of 1933, 1939, and 1947, the largest of record, had estimated peak flows of 90,400, 87,800, and 84,400 c.f.s. at the Rankin Rapids site.

7. Area and storage capacity at the Big Rapids site would be as follows:

El., ft.	Area, acres	Storage, million acre-feet
800	11,500	0.71
810	13,300	0.84
820	15,500	0.99
830	18,100	1.16
840	21,200	1.37
850	24,800	1.61
860	28,900	1.90
870	33,500	2.24
880	38,400	2.61
890	43,800	3.01
900	49,800	3.48
910	55,600	3.97

c. Geology, Foundations, and Materials.

(1) General. Investigations and analyses pertaining to geology, foundation conditions, and construction materials are presented in detail in appendix 2, and only summary comments are given below for ready reference.

(2) Geology. The Big Rapids dam site is located 13 miles upstream from the Rankin Rapids site and description of the geology of the Rankin Rapids site is applicable to the Big Rapids site.

(3) Foundation Conditions. The Big Rapids dam site is located in a large bend of the Saint John River near the middle of the Big Rapids area about 6 miles upstream from the confluence with the Allagash River. Subsurface exploration, consisting of eight diamond drill holes, was performed in 1957. These borings show that bedrock is from 13 to 30 feet below the surface on the right abutment where the powerhouse, power intakes, low-level outlets, and spillway would be located. The stream bed is covered with boulders ranging up to 5 feet in diameter. The preglacial valley, filled with a dense till containing numerous cobbles and boulders, is under the lower left abutment where bedrock is over 100 feet below the present stream level. The till reaches a maximum depth of more than 200 feet immediately above the preglacial valley. Bedrock outcrops at levels considerably above the top of the dam on the left abutment. Plate 12-12 shows a general plan of the dam and appurtenances on which the locations of the holes have been indicated. Logs of the holes are shown on plate 12-13.

(4) Construction Material. Materials of suitable quality occur in ample quantity at or near the dam site for construction of an earth dam including rock for slope protection. The nearest

and most economical source of suitable concrete aggregate is the granite outcrop at Deboulie Mountain about 24 miles (by highway and logging road) southeast of the Big Rapids site.

d. Site Development. Maximum normal operating pool level has been set at el. 910 on the basis that a higher level would sharply increase costs. The pool would extend into Quebec about 6 miles along St. Roch River, as shown on plate 12-14. Active storage would be 1.54 million acre-feet which corresponds to a drawdown of 35 feet. Regulated flow would be 3,540 c.f.s., excluding losses assumed as 50 c.f.s. By comparison, 3.64 million acre-feet would be needed to regulate to the average flow of 4,184 c.f.s. at the site. Limit of drawdown would be el. 875. Saddle dams as shown on plate 12-14 would be necessary to contain the reservoir to the 910 level. Information available indicates that a saddle dam would be required at Cunliffe Brook and probably others at Campbell Brook and at Blue Brook. These are located 31, 3, and 23 miles south from the dam site. Also shown on plate 12-14 is the outline of the Lincoln School Reservoir at el. 630 as described later in this appendix.

e. Project Layout. Layout studies for the Big Rapids project consisted of determining the arrangement of the power intake, pipelines, powerhouse, low-level intake, spillway and its associated channels, and the main embankment which would yield the least overall cost. The most favorable layout is shown on plate 12-12.

f. Spillway.

(1) General. The spillway would be located in a saddle in the right abutment of the Big Rapids site, as shown on plate 12-12. The site is relatively remote from the embankment and, by enlarging an existing drainage course, all spillway discharges could be directed away from the other project facilities. For these reasons and because the rock abutment is so massive that erosion by spillway releases would not endanger the project, an unlined spillway chute and stilling basin were selected. The crest structure itself would be protected by a lined basin as described later.

(2) Spillway Design Flood. The maximum possible rainfall over the Big Rapids drainage area is very nearly the same as for the Rankin Rapids drainage area. Accordingly, the rainfall excess for each 12-hour period shown in the upper left corner of fig. 5, plate 12-6, was applied to the unit hydrographs for the upper and lower portions of the drainage area of the upper Saint John River, figs. 1 and 3, plate 12-6. The unit hydrographs so derived were combined with the base flow to determine the natural hydrograph. The ordinates of the natural hydrograph were reduced in proportion to the drainage area of Big Rapids to produce the maximum flood at the dam site under existing conditions. The maximum ordinates of the maximum rainfall flood

hydrograph were peaked 16 percent to account for loss of river valley storage for conditions of a full reservoir. The hydrograph was then reshaped to the new peak ordinate retaining the original runoff volume. The spillway design flood, which has a peak of 231,000 c.f.s., is shown on plate 12-15.

(3) Number of Gates. The number of gates for the spillway was determined in the same manner as previously described for Rankin Rapids spillway. Curves showing the relationship between number of gates, surcharge, and maximum rate of flood outflow are summarized on plate 12-16. On the basis of these curves, six gates 40 feet long and 30 feet high were selected. The top of the gates would be set at el. 910, the maximum operating level. Surcharge would be 2 feet for the spillway design flood, and the peak discharge 164,000 c.f.s.

(4) Crest Structure and Gates. The crest structure would be similar to that for Rankin Rapids where tainter gates with electric hoists were planned, as shown on plate 12-17.

(5) Stilling Basins and Chutes. A standard concrete lined, hydraulic jump stilling basin 280 feet wide is planned immediately downstream from the gate structure, as shown on plates 12-12 and 12-13. Its length would be 130 feet, or about four times the depth needed for a hydraulic jump. The basin would have two rows of baffles and an endsill which would have sufficient height to cause a hydraulic jump upstream from it. The basin would slow the velocities of spillway releases to noneroding velocities to reduce the possibility of damage to the unlined flat portion (0.32 percent grade) of the chute, 280 feet wide, which extends for 800 feet across the top of the ridge. This flat chute is followed by a steep chute, also 280 feet wide, on a 13.5 percent grade. The chute would be excavated into a drainage course down the face of the ridge so that spillway design flood flows would be contained within the sides of the rock cut. A flatter slope would follow the steep chute as shown on plate 12-13, to follow the topography of the site. A hydraulic jump stilling basin excavated in rock, but unlined, would slow velocities before discharging them to the river channel. The length of the basin would be 300 feet or about seven times the depth required for the hydraulic jump under maximum flow conditions. This relatively long length was selected because of the unlined nature of the basin and because its excavation would not affect project costs significantly since the material would be used in the embankment. The stilling basin discharges of reduced velocity would not seriously threaten the opposite bank of the river on which the only access road to the project is located.

g. Embankment.

(1) Crest Elevation. The top of the embankment was set at el. 925, 15 feet above the maximum operating pool level, or 13 feet above the spillway design flood level. A 60-mile wind from the southwest, the direction of the longest (2.5 miles) fetch on the embankment, would generate 4.2-foot waves which would ride up 6.3 feet on the embankment. Under the spillway design flood conditions, about 7 feet of freeboard would remain above the level of wave action.

(2) Earth Section. Embankment design for Big Rapids is the same as for Rankin Rapids except that a flattened slope in the midvalley section would not be needed because the silt layer of the Rankin Rapids foundation was not found at Big Rapids. A cross section of the main embankment is shown on plate 12-17.

(3) Slope Protection. Both faces of the dam would be faced with rock from required excavation as at Rankin Rapids. The reservoir side from top of the embankment to 10 feet below limit of drawdown would be faced with a 5-foot layer of dumped riprap, selected for size, on a gravel filter.

h. Low-level Outlets. The principal difference in drainage areas between the Rankin Rapids and Big Rapids site consists of the Allagash River which has a flat hydrograph, as indicated on plate 12-6. For this reason, the diversion requirement is essentially the same at Big Rapids as at Rankin Rapids, and the low-level tunnels were made the same size, 24 feet inside diameter. Two 90-inch fixed-cone dispersion valves are planned for each tunnel, as at Rankin Rapids. The remainder of the low-level outlet design is similar to that for Rankin Rapids. The layout of the low-level outlet system is indicated on plates 12-12, 12-13, and 12-17.

i. Care of Water During Construction. As with the Rankin Rapids project, the first construction season would be spent in constructing the two low-level tunnels and in constructing the embankment at the abutments. Saint John River would remain in its channel during this period. In the second season, as soon as practicable after the spring freshet has receded, the stream flow would be diverted to the tunnels by constructing a small section of the upstream portion of the main embankment as a cofferdam. A similar cofferdam at the downstream toe plus temporary earth blankets on the cofferdams would permit unwatering the river channel to receive embankment fill. The upstream portion would be carried to a specified height during the remainder of the construction season to prepare for the critical flood period of the following spring breakup. The spring runoff would be passed through the two low-level tunnels. Subsequent construction operations would be similar to those at Rankin Rapids.

j. Power. As described in appendix 13, "Project Power," the

rated generator capacity at the Big Rapids project, developed as an auxiliary power source for the proposed international Passamaquoddy tidal power project, would be 300,000 kw. and the dependable capacity would be 338,000 kw. The latter would be developed at minimum head by utilizing part of the 15 percent continuous overload above the nominal generator capacity. The rated capacity at Big Rapids would also be 300,000 kw. for the case in which the Big Rapids - Lincoln School combination is used to firm the tidal plant output. Using the same type of continuous regulation previously described for Rankin Rapids, minimum, mean, and maximum annual energy outputs would be 585, 600, and 615 million kw.-hr., respectively. Regulated outflow would be about 3,540 c.f.s. The above energy outputs are based on the assumption that the site power storage of 1.54 million acre-feet would be used to regulate the river discharges to a continuous minimum outflow from Big Rapids of 3,540 c.f.s. and that inflows, in excess of this amount, when the reservoir is full, would not be used for power generation. Computations indicate that the mean annual energy could be increased by about 95 million kw.-hr. if the inflow to Big Rapids, during periods when the reservoir is full, were utilized up to a 60 percent load factor. As for Rankin Rapids, this energy is not predictable. Peak power plant discharge for 338,000 kw. dependable capacity would be 19,800 c.f.s.

k. Number of Power Units. Preliminary studies of cost were made for a power plant consisting of 4, 6, and 8 generating units considering such variables as the intake structure, pipelines, surge tanks and penstocks, the powerhouse itself, and the switchyard. The six unit plant was found to be the most favorable, and accordingly was selected for study.

l. Power Intakes, Penstocks, and Surge Tanks. The power intakes, penstocks, and surge tanks were laid out in the same manner as for Rankin Rapids. The general layout is shown on plates 12-12, 12-13, and 12-17. Eighteen-foot welded steel penstocks were selected for this study, and the maximum velocity would be 13.3 f.p.s. To obtain a comparison, and without the intricate study used for the Rankin Rapids project, the results of the work for the Rankin Rapids project were used for the surge tanks. Using these results, the diameters would be 45 feet and the bottom and top els. 850 and 946, respectively.

m. Powerhouse and Switchyard.

(1) Unit Size. The general project considerations, previously described, established the minimum net head at 233 feet, rated net head at 263 feet and the maximum net head at 275 feet. The dependable capacity of 338,000 kw. required at the minimum net head of 233 feet would be obtained by operating the turbines at full gate. The plant capabilities for the selected 6-unit plant for the various

heads are listed below. The turbines would be of the Francis type with a speed of 138 r.p.m. and a capacity each of 76,000 hp. at rated head of 263 feet at best gate. Each generator would have a nominal (60°C) nameplate rating of 52,600 kv.-a. at 95 percent power factor and an (80°C) rating of 60,500 kv.-a. at the same power factor.

Plant Capability

	Minimum	Rated	Maximum
Net head in feet	233	263	275
Turbine hp., full gate	466,800	570,000	620,000
Turbine hp. limited to full gate or 115% of generator rating	466,800	477,000	477,000
Generator kw., full gate limited to turbine full gate or 115% of rating	338,000	345,000	345,000
Turbine hp., best gate	387,500	456,000	484,000
Generator kw., best gate	280,000	330,000	345,000

(2) Structure and Equipment. The powerhouse structural layout, equipment, and systems would be similar to the previously described Rankin Rapids powerhouse, consequently a further description will not be given.

(3) Switchyard. The switchyard would be similar to the previously described Rankin Rapids switchyard.

n. Relocations, Lands, and Damages.

(1) Roads. The fact that the reservoir would back water into the Province of Quebec would make it necessary to construct five new permanent bridges to replace existing structures which would be inundated. Another bridge in Maine would be required in the general area. In addition, about 5 miles of private work roads and several associated small bridges would be required in the reservoir area in Maine. As at Rankin Rapids, access to the areas adjacent to the reservoir would best be secured by travel on the waters of the reservoir.

(2) Cemeteries. No cemeteries, as such, will be affected by the reservoir. There are, however, a few isolated graves which would require relocation.

(3) Lands and Damages. As for the Rankin Rapids project, the estimate of cost of lands and damages for Big Rapids project was based on previous real estate studies.

o. Reservoir Filling. Computations similar to those prepared for Rankin Rapids indicated that about 2.4 million acre-feet of the 3.06 million acre-foot annual flow at the Big Rapids site could be stored without reducing downstream power production to less than 60 percent load factor. Thus the 2.4 million acre-foot dead storage of the project could be filled in about one year.

p. Construction Schedule. The construction schedule for the Big Rapids project, as shown on plate 12-18, is essentially the same as for Rankin Rapids project and is based on the same considerations. The major difference results from the use of 6 power units rather than 8 as at Rankin Rapids which would permit somewhat earlier operation of the entire powerhouse. Reservoir filling would be started about half way through the third year, and dead storage would be filled in 1 year at which time the first of the power units could be placed in operation.

q. Estimate of Cost. The following cost estimate is based on prices prevailing in January 1958 and is presented here solely for the purpose of selecting one of the three previously described combinations as the river hydro auxiliary to the tidal power project. Costs for the separate items of relocation and construction have been increased by 15 percent to cover contingencies. The total project first cost includes an allowance of about 9 percent of the direct costs for engineering, design, supervision and administration. Not included is the allowance for interest during construction since this estimate was used for comparative purposes only. The cost of clearing is not included because it is expected that this work could be accomplished in return for the right to remove all marketable timber and pulpwood in the reservoir area.

Lands and Damages		$4,000,000
Relocations		
Roads	$184,000	
Bridges	563,500	
Cemeteries	14,400	761,900
Dams		
Tunnels	12,460,100	
Embankment	20,169,300	
Spillway	7,612,600	
Intake	5,086,500	
Penstocks and surge tanks	11,653,600	56,982,100
Power Plant		
Powerhouse	5,731,700	
Turbines and generators	16,185,700	
Switchyard	2,277,000	
Accessory equipment	4,111,300	
Tailrace	3,359,800	31,665,500
Roads and bridges		1,327,300
Buildings, grounds, and utilities		598,000
Permanent operating equipment		488,400
Total direct cost		95,823,200
Engineering, design, supervision, and administration		8,676,800
Total project first cost		104,500,000

12-09 INITIAL STUDY; LINCOLN SCHOOL

a. General. The Lincoln School site is near a rural school of that name on Highway 161 about two miles downstream from the Rankin Rapids site and 15 miles downstream from the Big Rapids site. Layout studies for the project were based on U.S. Geological Survey quadrangle sheets, the only topography available for the site. A profile on the axis of the dam was determined from a field survey.

b. Hydrology. As developed in appendix 4, the uncontrolled drainage area at the Lincoln School site would be 1,647 square miles (mainly the Allagash drainage) from which mean monthly flows would vary from 155 c.f.s. (February 1948) to 16,638 c.f.s. (May 1947) and average 2,601 c.f.s. Regulated flow from the Big Rapids project would be in addition to these, and would average 3,590 c.f.s. for the selected active storage of 1.54 million acre-feet. Area and storage capacity of the reservoir would be as follows:

El., ft m.s.l.	Area, acres	Capacity, 1,000 acre-feet
580	965	14.2
590	1,500	26.5
600	2,130	45.2
610	3,090	73.0
620	4,353	110.0
630	5,870	158.0

Tailwater levels vary: el. 537 for 2,000 c.f.s.; el. 540 for 10,000 c.f.s. to el. 548 for 229,000 c.f.s., the estimated spillway design flood discharge.

c. Geology, Foundations, and Materials. Studies in this respect are covered in detail in appendix 2, and are summarized here for ready reference. The description of site geology given for Rankin Rapids applies to the Lincoln School site, the two being only 2 miles apart. Site investigation including three test borings was performed in the fall of 1957. The borings indicated that 15 to 30 feet of glacial till covers the bedrock on both abutments. The bedrock outcrops on both banks of the stream and the stream bed are covered with a thin layer of cobbles and gravel. One drill hole near the center of the stream indicated 69 feet of till overlying the bedrock of the preglacial channel. Materials of suitable quality appear in ample quantity at or near the dam site for construction of an earth embankment, including rock for slope protection. The nearest source for suitable material for concrete aggregate is the granite outcrop at Deboulie Mountain, about 14 miles south of the Lincoln School site.

d. Site Development. The upper limit of the development possible at the Lincoln School site is at el. 630 which is tailwater

level for the Big Rapids project. Because of the small pool area at this level, no significant addition to the 1.54 million acre-feet of active storage possible at the Big Rapids site can be provided at the Lincoln School site. Four feet of drawdown or 22,000 acre-feet of active storage are, however, proposed to smooth out Big Rapids discharges, which may peak at 19,800 c.f.s., sufficiently so that all the flow might be used without wastage at the Lincoln School powerhouse with a discharge capacity less than half that at Big Rapids.

e. Project Layout. Because bedrock is located at an excessive depth below the stream bed, a concrete dam at the Lincoln School site was not studied in detail and layout studies were concerned with determining the least costly arrangement for an earth embankment, the spillway and its associated stilling basin and channels, and the powerhouse. The layout selected on the basis of this study is shown on plate 12-19.

f. Spillway.

(1) Design Flood. The 6-sq. mile increase in drainage area at the Lincoln School site over the 4,060 sq. mile drainage area at the Rankin Rapids site was neglected to simplify computation of the spillway design flood for the downstream site. On this basis, the natural hydrograph for the drainage area downstream from the Big Rapids site would be the difference between natural hydrographs developed for the Rankin and Big Rapids sites. The maximum ordinates of this hydrograph were peaked 10 percent to approximate the inflow into the full Lincoln School reservoir. The hydrograph was then reshaped, retaining the original runoff volume. This hydrograph was combined with the routed outflow hydrograph for the spillway design flood on a full reservoir at Big Rapids to produce the spillway design flood at Lincoln School as shown on plate 12-15.

(2) Crest Structure. The spillway crest structure would include tainter gates of the same size considered for the Rankin Rapids and Big Rapids projects. Eight 40-foot by 30-foot gates were selected by using the curves presented on plate 12-20 which would result in a 2.5-foot surcharge for the spillway design flood of 229,000 c.f.s. The top of the gate would be at el. 630, the maximum normal operating pool level. The crest structure was laid out according to the criteria used with the previously described projects.

(3) Chute and Stilling Basin. The chute would have a relatively level grade for a distance of about 350 feet, on which flows would be at velocities faster than critical. This length was selected for economy of excavation. The flat chute would be followed by one on a 40 percent slope which was selected because it is the steepest slope on which paving can be satisfactorily finished without forming. This would be followed by a hydraulic jump stilling basin with its bottom at el. 500. The basin would be 144 feet long and provided with baffles and an endsill. The paving in the chute areas would have a minimum thickness of 2 feet

except in the uplift and stilling basin section where the thickness would be 5 feet. The entire area of the slab would be anchored to the rock. The side walls of the chute would be of concrete anchored to the face of the rock cut. The walls in the stilling basin area would extend to el. 550. During large floods, this level would be overtopped, but no significant effect on stilling basin performance is expected because the steep sides of the rock cut would not leave any large areas for secondary upstream flows at the sides of the hydraulic jump. An excavated channel would convey spillway discharges back to the Saint John River.

g. Embankment.

(1) Crest Elevation. The top of Lincoln School embankment was set at el. 647, or 17 feet above maximum normal operating pool and 14 feet above the spillway design flood pool. A 60-mile wind from the direction of maximum fetch (SW, $1\frac{1}{2}$ miles) would result in 3.5-foot high waves which would ride up 5 feet on the upstream slope. With spillway design flood conditions, there would remain 10 feet of freeboard above the level of wave action.

(2) Earth Section and Slope Protection. The design of the earth embankment and slope protection is similar to that for the previously described projects. Riprap on the upstream face would be 5 feet thick.

h. Power. As described in appendix 13, "Project Power," the rated generator capacity at the Lincoln School project, when used in conjunction with Big Rapids as an auxiliary to the proposed international tidal power project, would be 52,000 kw. Dependable capacity would be 54,000 kw. and would be developed at minimum turbine head by utilizing part of the 15 percent continuous overload customarily permitted above the nominal generator capacity. For a continuous flow of 3,590 c.f.s. from the upstream Big Rapids project, average annual energy output at Lincoln School project would be about 310 million kw.-hr., based on utilizing inflows up to the 8,400 c.f.s. which would be released in developing the 54,000 kw. dependable capacity. The average annual flow at the site, by comparison, is 6,780 c.f.s.

i. Number of Power Units. Preliminary studies of powerhouse costs were made using fixed-blade and Kaplan turbines in one, two, and three unit plants to furnish the needed 54,000 kw. of dependable capacity. A two-unit plant, using Kaplan turbines, was selected on the basis of these studies.

j. Powerhouse.

(1) General. The powerhouse would be an integral part of the intake structure and would be located on the left bank of the river in an excavated channel, as shown on plate 12-19.

(2) Selection of Unit Size. The general project considerations, previously described, established the minimum net head as 81 feet, rated net head as 88 feet, and the maximum net head as 95 feet. The plant dependable capacity of 54,000 kw. would be generated at the minimum net head of 81 feet with the two turbines operating at full gate. Each of the two turbines would be rated at 38,100 hp. at best gate and with a speed of 164 r.p.m. Each generator would be rated at 95 percent power factor, a 60° C. rise at 27,400 kv.-a. and an 80° C. rise at 31,500 kv.-a. The plant capabilities for the various heads are listed below:

Plant Capability

	Minimum	Rated	Maximum
Net head in feet	81	88	95
Turbine hp., full gate	74,600	82,800	91,400
Turbine hp., full gate or limited to 115% generator rating	74,600	82,600	82,600
Generator kw., turbine full gate or limited to 115% of rating	54,000	59,800	59,800
Turbine hp., best gate	68,600	76,200	84,000
Generator kw., best gate	49,700	55,200	59,800

(3) Structure. The powerhouse would be of the indoor type built as an integral part of the intake structure as shown on plate 12-19. Units would be on 65-foot centers with a 70-foot assembly and station service area at the northwest end of the plant. Access level would be at el. 550, which provides a freeboard of 8 feet above normal maximum tailwater and 2 feet above spillway design flood tailwater. The one main power transformer would be located on the tailrace deck, el. 550. Generators would also be located at el. 550 and the main operating floor would be set at el. 531. Scroll case and draft tube access galleries would be provided at els. 511 and 493. Scroll case would be of formed concrete with centerline at el. 515.

(4) Mechanical and Electrical. Conventional equipment and systems normally included in powerhouses of this type would be provided. One 3-phase, 63,000 kv.-a. transformer would serve both generators through 13.8 kv. air circuit breakers. The transformer would be connected directly to the 230 kv. transmission line through a disconnect switch making a separate switchyard unnecessary. Governors and switchboards would be located between the units at el. 531. This area would serve as the station control room. Station service power supply would be from two transformers connected to terminals of the generators.

k. Care of Water during Construction and Reservoir Filling. The Big Rapids project of the Big Rapids - Lincoln School combination is by far the more important as an auxiliary to the proposed international

Passamaquoddy tidal power project. It has been assumed, for this reason, that construction of the Big Rapids project would precede that of the Lincoln School project sufficiently to regulate completely the runoff from its drainage area and therefore the drainage area would not contribute to peak flows from the 1,647 square mile drainage area upstream from the Lincoln School site, but downstream from Big Rapids. The peak flow from this area during the period of record is estimated to be 33,300 c.f.s. It is planned that the river would be diverted initially over the partly completed powerhouse foundation and later over the spillway. The powerhouse, plate 12-19, would be constructed in two stages, the first of which would consist of the upstream power intake to the crest elevation, and the penstock 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 could be initiated by a rockfill cofferdam upstream which would force the river flow through the partly completed powerhouse. The discharge capacity through the partly completed powerhouse would be 33,300 c.f.s. with the pool at el. 590, and thus would be adequate to care for the record spring flood from the Allagash River. 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 rise from about el. 540 to slightly above el. 600 when the river flow could pass over the spillway. A small flow could be passed during the period the pool is being raised to spillway level by leaving one of the powerhouse head gates slightly open. Since about 45,000 acre-feet would be involved in this pool raising operation, it might be advantageous to draw on Big Rapids storage to raise the pool rapidly to the spillway crest. In view of the foregoing, and the low head at the project, plus the fact that all releases for low-water regulation can be made over the spillway, no low-level outlets are planned.

1. Relocations, Lands and Damages.

(1) Roads. The Lincoln School reservoir would inundate nearly all of the 18 miles of State Highway 161 and other roads which extend along Saint John River to about the Big Rapids site. About 16.5 miles of this road would be relocated to serve the remaining existing facilities in the area and to serve as an access road to the Big Rapids project.

(2) Utilities. About 15 miles of electric power and telephone lines would be relocated to serve the existing facilities which would remain after construction of the Lincoln School project.

(3) Cemeteries. Three cemeteries with about 175 graves would be relocated out of the reservoir area.

(4) Lands and Damages. The estimate for lands and damages was made on the basis of early surveys in the general vicinity.

m. Construction Schedule. The tentative construction schedule shown on plate 12-21 is based on the concept of partly completing the powerhouse and using it to pass water while the main embankment is being closed across the river as discussed under "Care of Water During Construction." The first two seasons would be used to prepare the powerhouse for this diversion operation which would then be accomplished early in the third season. Construction would be resumed on one of the two power units after the embankment is sufficiently above the pool level. The embankment and spillway would be finished by the end of the third season, at which time the head gates for the second power unit could be closed and the river flow transferred to the spillway. Construction on the second power unit would be started as early as possible in the fourth year. The first unit would be on the line about 3.5 years after start of construction, and the second unit after about 4.5 years.

n. Estimate of Cost. The following cost estimate is based on prices prevailing in January 1958 and is presented here solely for the purpose of selecting one of the three previously described combinations as the river hydro auxiliary to the tidal power project. Costs for the separate items of relocation and construction have been increased by 15 percent to cover contingencies. The total project first cost includes an allowance of about 9 percent of the direct costs for engineering, design, supervision, and administration. Not included is the allowance for interest during construction since this estimate was used for comparison only. The cost of clearing is not included because it is expected that this work could be accomplished in return for the right to remove all marketable timber and pulpwood in the reservoir area.

Lands and damages		$1,300,000
Relocations		
Roads	$2,185,000	
Cemeteries	50,300	2,235,300
Dams		
Embankment	856,200	
Spillway	8,672,400	9,528,600
Power plant		
Powerhouse	6,428,900	
Turbines and generators	3,364,700	
Switchyard	272,700	
Accessory equipment	1,182,800	
Approach channel	659,100	
Tailrace	626,900	12,535,100
Roads and bridges		366,900
Buildings, grounds, and utilities		126,500
Permanent operating equipment		34,200
Total direct cost		26,126,600
Engineering, design, supervision, and administration		2,373,400
Total project first cost		28,500,000

12-10 SELECTION OF SITE FOR DETAILED STUDY

The following summarizes the major findings in the foregoing portions of this appendix and analyzes them to demonstrate the relative merits of the projects considered. A more detailed comparison is given in table 12-3.

a. Comparative data on the three sites developed during these studies are given in the following table:

Project	Rankin Rapids	Big Rapids	Big Rapids plus Lincoln School
Drainage area, sq. mi.	4,060	2,419	4,066
Maximum normal operating pool, el. feet, m.s.l.	860	910	910 and 630
Active storage, million acre-feet	2.8	1.54	1.56
Average stream flow, c.f.s.	6,780	4,214	6,780
Regulated flow, c.f.s.	5,950	3,450	3,700(1)
Dependable capacity, 1,000 kw.	460	338	392
Average annual energy million kw.-hr.	1,220	695	1,005
Relative cost	1.00	0.77	0.98
Relative annual energy	1.00	0.57	0.82
Relative cost per kw.-hr. of annual energy	1.00	1.35	1.20
Relative dependable capacity	1.00	0.73	.85
Relative cost of dependable capacity	1.00	1.06	1.15

(1) Approximate

b. The Rankin Rapids auxiliary would produce 525 million kw.-hr. per year more than Big Rapids and 215 million kw.-hr. per year more than the combined Big Rapids and Lincoln School project. The increased capacities would be 122,000 kw. and 68,000 kw., respectively.

c. The project first cost per average annual kilowatt hour is 35 percent more at Big Rapids than at Rankin Rapids. The equivalent value for the Big Rapids - Lincoln School combination is 20 percent.

d. Because of the greater drainage area, active storage, and regulated outflow, Rankin Rapids would improve conditions for further power development on the downstream Saint John River to a greater extent than would either of the other projects.

e. The greater production of energy at Rankin Rapids permits placing more of the tidal plant energy under the load curve.

These findings led to selecting the Rankin Rapids project as the river hydro auxiliary for the proposed international Passamaquoddy tidal power project.

12-11 DETAILED STUDY; RANKIN RAPIDS

a. General. The Rankin Rapids site was selected as the river hydro auxiliary to the tidal power project and additional detailed studies were undertaken to refine the Rankin Rapids designs so that the estimates of quantity and cost would be of the same accuracy as those for the tidal power project and the other auxiliaries considered. The additional studies were primarily concerned with the powerhouse, and the designs were refined to about the degree achieved for the tidal powerhouse. The powerhouse studies and other additional studies are described in the following paragraphs. It is emphasized that the estimates presented in the previous paragraphs were made solely for the purpose of selecting a site and are not the same as the estimate used for the analysis of economic feasibility of the tidal power project which is developed in appendix 17, "Estimates of Cost." However, the estimates are sufficiently accurate for the comparison of the plans considered.

b. Embankment Design.

(1) Foundations and Materials. Three principal types of soil occur in the overburden within the foundation area for the proposed dam, all of which are of glacial origin. In the valley bottom is located a deposit of compact silt of low permeability. This material has only low to moderate shear strength and thus must be considered, as discussed subsequently, in design of the embankment cross section. The valley walls are covered with a compact glacial till which is very

nearly impervious and has high shear strength. On the left side of the valley is a deposit of glacial outwash which is pervious and will require a cutoff treatment to control seepage. Materials occurring in the foundation area are essentially the same as those proposed for embankment construction and appear in ample quantity and suitable quality. Rock for surface protection can be obtained from boulders existing in and along the sides of the stream bed, from boulders removed from overburden used for embankment construction, or from bedrock excavated for project structures.

(2) Engineering Properties of Embankment Materials. The foundation and embankment materials described above are essentially the same as those investigated for many other projects. For this reason, no laboratory tests were performed at this stage of project study. The following materials are found at the site, and the engineering properties listed were estimated from test data on similar material from the same general area:

Description	Dry density lb./cu. ft.	Shear strength degrees	Cohesion tons/sq. ft.	Permeability ft./day
Glacial till	140	34	0.10	0.01
Gravel and sand	120	30	0.00	1.00
Foundation silt	98	10	0.05	0.01

(3) Earth Section. Refinement of the design of the embankment over that considered in the initial study consisted of slight modifications to arrive at the section shown on plate 12-9 and an analysis of stability by the circular arc method. The procedure involves determining the forces tending to cause and to resist sliding on an arbitrarily selected circular surface within the dam and foundation. A circle with a ratio of resisting forces to sliding forces of unity indicates incipient failure and a greater number indicates safety against sliding. This ratio is called the "stability ratio." Stability ratios of 1.50 ± 0.25 are considered to indicate sound design. Higher values may be appropriate when unusual or uncertain conditions exist. Most critical circles are determined by successive trials. For the design shown on plate 12-9, and using data in paragraph (2) above, stability ratios of 1.54 and 1.42 were computed for upstream and downstream slopes. The critical case for the upstream slope would occur just after construction of the dam and prior to reservoir filling. For the downstream slope the limiting case is that for full reservoir under operating conditions.

(4) Settlement. Settlement of the dam and its foundation were considered qualitatively only. In the absence of laboratory consolidation tests on the materials involved, no precise evaluation of settlement can be made. However, from general knowledge of material characteristics it can be stated with assurance that settlement of the

dam will be relatively small, particularly after completion of construction.

(5) Seepage. The dense glacial till occurring in the foundation of the dam, and proposed for use in the impervious portion of the embankment is about as impermeable as good quality concrete. Thus, leakage through the dam would be negligible. The clayey silt in the foundation is also relatively tight and no appreciable seepage is anticipated through the foundation. A downstream rock toe has been included in the design to prevent discharge of seepage water on the downstream slope of the embankment.

(6) Cofferdams. Cofferdams of moderate height would be required for stream diversion and unwatering the embankment foundation area. The upstream cofferdam can be constructed of any suitable material and may be left in place as part of the random fill section which is required to provide foundation stability. The downstream cofferdam can be constructed as a separate structure or combined with the downstream rock toe, provided that the impervious portion be removed after the need for this cofferdam has passed.

c. Log Way. In consideration of the factors discussed in paragraph 12-06e, studies were undertaken to incorporate into the project plans for Rankin Rapids means for passing logs over the dam which, under present conditions are floated down the river. Methods considered in these studies included (a) a narrow gate slot adjacent to the spillway, (b) a 30-foot submerging gate at the spillway, (c) a 40-foot submerging gate as part of the spillway, and (d) a chain conveyor system which would elevate the logs to the top of the dam and place them in a water-lubricated flume which would convey the logs to the powerhouse tailrace. A comparison of the sum of the initial construction cost, the capitalized cost of operation and maintenance, and the capitalized value of the water which would be used indicated that the chain conveyor system above was the least costly. This plan was adopted as shown on plate 12-3. The estimate in appendix 17 reflects this refinement. After the dam is closed, logs could not be passed by the project for about 2 years until the dam and logway are completed and the reservoir filled to the limit of drawdown.

d. Retaining Walls. Retaining walls would be used in the project at both sides of the spillway and at both sides of the power intake. In the initial study all retaining walls were assumed to be of the gravity type for all the projects considered and core walls of the same type were assumed to connect the power intakes with the adjoining earth embankment section. After selecting the Rankin Rapids site, additional studies were performed to determine both the optimum location and type for these walls. On the basis of this work, the core walls were abandoned in favor of cantilever wing walls, and cantilever walls were selected for all retaining wall requirements. The quantities and project costs presented in appendix 17, "Estimates of Cost," reflect these refinements.

e. Penstocks and Surge Tanks. After selecting the Rankin Rapids site further studies were undertaken to verify the selection of the 16-foot-diameter for the pipelines and penstocks. These studies compared the value of the increased energy and power which would be provided by larger penstocks with the increased cost of the larger penstocks and appurtenances. It was found that the benefits outweighed costs for penstocks up to the 16-foot-diameter which was retained. During the study, results became available of recent compilations by the Waterways Experiment Station, U.S. Army, Corps of Engineers, of data from tests on large modern penstocks. The data indicated that the Darcy-Weisbach friction factor for penstocks should be 0.01 instead of the 0.02 used for the designs of surge tanks in the initial study. On this basis 53-foot-diameter surge tanks were selected having bottom of tank at el. 797 and the top of tank wall at el. 879. The estimated project cost given in appendix 17 is based on these revised values.

f. Powerhouse.

(1) General.

(a) Description. The powerhouse would be located at the toe of the dam on the right bank of the river, as shown on plate 12-3. The powerhouse would be of the indoor type with 8 generating units driven by vertical-shaft Francis-type hydraulic turbines. Each turbine would be supplied by a 16-foot-diameter penstock extending approximately 2,100 feet from the intake structure. A 53-foot diameter differential surge tank would be connected to each penstock 200 feet upstream from the powerhouse. The penstock diameters would be reduced to 13.7 feet in the reducing elbow above the scroll case extension. Turbine discharge would return to the river in an excavated tailrace which also serves the low-level outlets. The switchyard would be located downstream from the powerhouse on the right bank of the tailrace channel. Three 230-kv. lines would lead out from the switchyard.

(b) Type of Structure. Preliminary studies were made for three types of powerhouses; outdoor, semioutdoor and indoor. The first two types offered some savings in structural costs over the conventional indoor type. This saving was offset, however, by the more costly totally enclosed gantry cranes which would be required, resulting in approximately the same overall costs. The inconvenience of an outdoor and semioutdoor station, particularly in view of the severe winters, resulted in selecting the indoor station as the most desirable type. The selected layout is shown on plates 12-22 through 12-25.

(c) Location of Transformers and Switchyard. Several arrangements were studied to determine the most suitable location for the switchyard and transformers. The first arrangement located the transformers in a switchyard near the east end of the powerhouse and connected the switchyard to the generators with 15-kv. cables. The second

study located the transformers on an upstream deck of the powerhouse with connecting aerial lines over the powerhouse and across the tailrace channel to the switchyard downstream from the powerhouse on the right bank of the tailrace channel. The third study located the transformers on the draft-tube deck of the powerhouse with aerial lines to the switchyard situated as in the previous study. The third arrangement was adopted as the most suitable and economical and is shown on plate 12-3. The arrangement would provide a simple aerial connection to the switchyard and the draft tube deck needs to be widened only 8 feet to accommodate the transformers.

(d) Switching Arrangements. Several switching arrangements were considered with the general arrangement studies described above. Included were studies to determine the most economical type and size of transformers, the best method of paralleling, and provisions for moving them to the assembly bay area. In making these studies, it was assumed that the generators would be paralleled either on the high or low side of the transformers, that the output be stepped-up to 230-kv., that a spare transformer would not be furnished, and that the switching arrangement would provide adequate flexibility to permit feeding the three outgoing 230-kv. lines separately or in parallel at any capacity up to 200 megawatts each. As a result of these studies, type FOW transformers were selected because of their lower cost, smaller space requirement, and because cooling water is readily available. Station flexibility and system stability precluded the paralleling of more than two generators on the low side of a transformer bank, and shipping limitations prevented the use of a 3-phase transformer larger than that required to serve two generators. These factors left for consideration a unit-type scheme using a separate transformer for each generator with switching only on the high side and a scheme with two generators connected to a transformer bank with switching on the low and high side. The latter scheme proved the better of the two and was selected. A bank of three single transformers was also considered but was dropped because the cost would exceed that for the adopted plan.

The switchyard would be of the main and transfer bus type using a single breaker and a motor-operated disconnect switch in each line and transformer bay. The "breaker and a half" and the "double-breaker" schemes did not offer sufficient advantages to justify their higher costs. The selected switching arrangement is shown on the main one-line diagram, plate 12-26.

(2) Structure.

(a) General. The general arrangement of the powerhouse would be as shown on plates 12-22 to 12-25. The main operating floor, erection area, draft-tube deck, control room, offices, and access to the powerhouse would be at a common level, el. 567. The station-service bay and main-unit bays would be housed by a common superstructure and served by two 120-ton bridge cranes. Two station-service generators

would be located on the 551 floor level of the station-service bay. Auxiliary equipment and shops would be located on the lower floor levels of the control and assembly bays and in the three longitudinal galleries located under the draft-tube deck.

(b) Foundation Conditions. The powerhouse would be founded on steeply dipping metamorphosed shale indurated to the extent that it is relatively hard, durable, and dense, and adequate to support the structure. Excavation would expose fresh unweathered rock with tight joints and fractures which should not require grouting.

(c) Substructure. The substructure of the main part of the powerhouse would consist of eight individual blocks, separated by straight-through contraction joints. The blocks would rest on excavated rock and would extend up to the level of the main floor and draft-tube deck. The following criteria were used in determining the principal dimensions and elevations for the substructure.

Maximum tailwater (spillway design flood), el.	559
Minimum concrete cover over turbine scroll case, feet	5
Generator housing diameter, feet	37
Turbine discharge diamter, feet	11.4
Scroll case extension diameter, feet	13.7
Maximum scroll case width, feet	41.5
Turbine distributor centerline, el.	555
Draft tube, lowest point, el.	522
Draft tube, exit width (minimum), feet	42.5
Draft tube, exit height (minimum), feet	11.5
Draft tube, center pier thickness (minimum), feet	6.5
Draft tube, side pier thickness (minimum), feet	6
Draft tube, pitch	1 on 6
Draft tube, length (minimum), feet	43.4

The principal dimensions of generators and turbines were furnished by the equipment manufacturers. With the turbine centerline located at el. 555, the selected main floor level, el. 567, would provide the 5 foot minimum concrete cover over the scroll case. El. 567 was likewise selected for the access road and the draft-tube deck level. This level would provide 8 feet of freeboard above the maximum tailwater with the spillway design flood.

The width between the powerhouse walls was established at 57 feet, with the main-unit centerline 24 feet from the downstream wall. This distance was made as small as possible in order to minimize the horizontal length of the draft tube but still provide space for the main transformers on the draft-tube deck. The downstream wall would be located three feet from the turbine scroll case, plate 12-24, to provide space for turbine erection. This arrangement would also provide a 5½-foot unobstructed aisle on the powerhouse main floor between the

generator barrel and the downstream wall as indicated on plate 12-23. The upstream wall was placed to provide an 8-foot unobstructed aisle between the upstream wall and the cabinets for the unit control boards and the governor. The upstream wall would thus be located 33 feet from the turbine centerline and 57 feet from the downstream wall.

Main unit bay length was established at $54\frac{1}{2}$ feet with the unit centerline offset $2\frac{1}{4}$ feet from the block centerline. The draft tube was oriented so that its centerline at the outlet was on the monolith centerline. The selected length for the main-unit bays would provide draft tube passages and piers that meet the above design criteria. A 3-foot-thick transverse wall at each end of the unit bays would be placed as first stage concrete, as indicated on plate 12-24, and would act as a stabilizing diaphragm for the skeletonized first stage structure. The selected unit-bay length would provide a 3-foot work area between the turbine scroll case and each transverse wall.

The draft-tube deck would be 34 feet wide which is the minimum width on which the main power transformers could be located and transported conveniently. This deck width extended the draft tubes 8 feet beyond the minimum hydraulic requirement. Refinement of the design, subsequent to the initial study, indicated that a heavy floor slab should be used in lieu of the initially considered thin slabs with weep holes, because the latter could not be depended on for the life of the project.

Longitudinal galleries for access and equipment, as shown on plate 12-22, would be located under the draft-tube deck at els. 551 and 541.5. A drainage gallery would be located at el. 538 downstream from the turbines and would provide access to the drainage valves and draft-tube mandoors.

(d) Superstructure. The powerhouse superstructure would extend over the 8 main-unit bays and the station-service bay. The structure would have solid concrete front and rear walls, 5 feet thick, to the level of the crane rails, with rigid frame steel bents and concrete nonload-bearing walls above. The end walls would be concrete, 3 feet thick, carried to roof height. Top of the crane rails would be at els. 610.5 or 43.5 feet above the main floor level. The height required for handling the major equipment over operating units was determined by crane clearance studies, and is shown on plate 12-22. The rail height required for handling an assembled generator rotor was the maximum condition and determined the wall height. Adequate clearance for untanking the power transformers on the main floor is provided.

Generators would be located on circular barrels of massive concrete with the base of the air housing at el. 577.5. This level was based on data from turbine and generator manufacturers, and provides the minimum allowable distance between the turbine centerline and the

base of the generator air housing. A mezzanine balcony, at el. 578.5, would be provided between alternate units for mounting the generator air circuit breakers, as shown on plates 12-22 and 12-23.

The roof of the powerhouse would be supported on rigid frames of steel, 24 feet 9 inches on centers. The base of the frames would be at about the level of the crane rail, el. 610, and the vertical legs of the frame would support a concrete exterior wall between the level of the crane rail and the roof. The roof would be a 5-ply tar and gravel covering on rigid-type insulating plank supported on tubular-steel truss joists.

(e) Main Floor. Equipment on the main floor, plate 12-23, would include the unit control switchboards, governors, governor pressure tanks, unit power panel, generator neutral and surge protection equipment, potential transformer cubicles, and carbon dioxide rack. Steel stairways would provide access to the generator air housings and to the top of the generators from the main floor level. Concrete stairways through openings in the generator barrels would provide access to the turbine pits and to the generator thrust bearings from the main floor level. A transverse gallery at el. 556 extending from the governor and unit control board to the longitudinal equipment gallery, plates 12-22 and 12-24, would carry electrical circuits and piping to the governors and unit control boards. A covered pipe trench in the main floor at each generator would provide access to the piping systems from the cross gallery and governor to the turbine and the generator. The equipment was arranged on the main floor to permit centralized control at each pair of units. Stairways at alternate units would provide access from the main floor to the longitudinal equipment gallery.

(f) Circuit Breaker Mezzanine Balcony. The generator circuit breakers for each pair of units would be located side by side on a concrete balcony at el. 578.5 as shown on plates 12-22 and 12-23. Each of the four balconies would be 54½ feet long, would span between alternate units, and would extend from the downstream wall to near the generator centerline. The balcony slabs would be 18 inches thick and would be supported by concrete columns from the main floor level. Each generator bus would be suspended from the underside of the balcony and enter the breaker through an opening in the slab. Generator surge protective equipment and potential transformers for each of the pair of units would be located under the breaker balcony and close-connected to the generator bus. The line side of each pair of breakers would be tied together and extended through the powerhouse wall to the main transformer on the draft-tube deck. Access to each breaker balcony would be by structural steel stairway from the main floor.

(g) Galleries. Three longitudinal galleries, extending the length of the powerhouse, would be located on the downstream side of the powerhouse as indicated on plate 12-22. These galleries would provide access and space for auxiliary equipment. The equipment gallery

would be located under the draft-tube deck and would be approximately 18 feet wide and 12 feet high with a floor level at el. 551. The downstream wall of the gallery would be 3½ feet thick and would support the transformer and gantry crane rails. The gallery would extend through the station-service and control bays. Transformer heat exchangers, water strainers, pipe headers, station battery, battery charging equipment, auxiliary power board, cable trays, and other miscellaneous equipment would be located in this gallery, as indicated on plate 12-24. The turbine scroll case and the lower galleries would be entered from this gallery. Access to the powerhouse main floor would be provided by stairways at alternate units. The gallery at el. 541.5 under the equipment gallery was provided primarily to save concrete and to provide access to the drainage gallery. One end of the gallery would be used for carbon dioxide bottles. The 6- by 8-foot drainage gallery at el. 538 would be located downstream from the turbine but inside the powerhouse wall. The draft-tube, unwatering-valve floor stands, penstock drain valves, and turbine draft-tube mandoors would be located in this gallery. The gallery would be entered from the station-service area or from stairs from the galleries under the draft-tube deck.

(h) Draft-tube Deck. The draft-tube deck, 34 feet wide at el. 567, would support the main power transformers, draft-tube gantry crane, and powerhouse ventilating equipment, as shown on plates 12-22 and 12-23. One set of rails in the deck would serve both the draft-tube crane and for moving of the transformers from operating position to the assembly area under the crane. The transformers would be located in individual cells on short transverse tracks. A transfer car would not be required since the transformers would be equipped with caster-type wheels. The draft-tube deck would also serve as an access road to the surge tanks, the lower outlet portals, and to the toe of the dam.

(i) Erection Area. The erection area, plate 12-23, would be 78 feet 6 inches long by 57 feet wide and located in the station-service bay at el. 567. The area would provide space for erecting at one time a generator rotor, bearing bracket, turbine runner, and for untanking a transformer. Railroad and transformer rails would enter the area through a door in the downstream wall. The door would be 27 feet wide by 26 feet high and would provide clearance for passing a completely assembled transformer and for any load that would be brought into the powerhouse by truck or rail. The powerhouse bridge cranes would serve the erection and unloading areas. Hatches through the erection-bay floor would permit using the bridge crane to assemble the station-service units and to handle other loads on the 551 floor level. The maintenance shop would be located in the control bay at the same level and adjacent to the erection area. A 10- by 10-foot doorway would provide access to the maintenance shop from the erection area.

(j) Control Room and Offices. These areas, shown on plate 12-23, would be located in the control bay at el. 567. The control

room would be 44 feet long by 38 feet wide and would be provided with a light-diffusing, luminous ceiling. Kitchen and toilet facilities would be provided in adjacent rooms. Offices would be located in the same general area as the control room with a connecting corridor to the exterior entrance, erection area, elevator, and a stairwell to lower floor levels.

(k) Visitor Facilities. The present design does not provide facilities for the sole use of visitors, because they would be few and infrequent. The area at the northeast outside corner of the erection bay and adjacent to the control room could be developed into a 13- by 25-foot room for visitors if this proves necessary. The location is convenient to the parking lot and provides a view into the powerhouse through an opening in the erection-bay wall.

(l) Cable Spreading Room. Plate 12-24 shows the cable spreading room located directly under the control room on the 551-foot floor level. The room would be equipped with racks of cable trays for routing of cables through slots in the floor to the control room above. Cable trays would extend into the spreading room from the longitudinal equipment gallery. The switchyard duct bank would terminate in the east wall of the room. The room would be entered from a corridor doorway and from the longitudinal equipment gallery.

(m) Battery Room and Telephone Equipment Area. The station battery would be housed in a 12- by 37-foot battery room located between units 4 and 5 in the equipment gallery at el. 551, as shown on plate 12-24. The telephone equipment and communication battery would be located in the east end of the cable spreading room at el. 551, as shown on the same plate.

(n) Station-service Equipment Area. The station-service equipment area, shown on plate 12-24, would be located in the station-service bay, at el. 551. The facilities in this area would include station-service generators, station-service auxiliary distribution board, and air compressors. The equipment area would be approximately 57 feet by 79 feet in plan, less the 32- by 37-foot area reserved for water purification facilities and pump room. The room would have a clear height of 14 feet throughout. Access to the cable gallery would be through two 9-foot high openings; one 8 feet wide at the control house end would give access to the station service carbon dioxide bottle rack and control cabinet, and the other opening, 12 feet wide, would give access to the main station-service distribution board. There would also be access to upper and lower levels of the powerhouse and control bay by means of the control-bay stairwell and elevator. A 14- by 24-foot hatch in the ceiling, directly over the station-service units, would permit using the powerhouse bridge crane for handling of the station-service units and other loads.

(o) Unwatering and Drainage Equipment Area. The unwatering and drainage facilities area, shown on plates 12-24 and 12-25, would be located in the station-service bay. The unwatering sump would be of the dry type, 9 by 28 feet in plan, with the bottom at el. 515 and a 2-foot roof at el. 533. The drainage sump would be of the wet type and located adjacent to the unwatering sump and would be 13 by 20 feet in plan with bottom at el. 515 and a 2-foot roof at el. 533. The pump columns, discharge headers and floor stands for operating the header valves would be in the area above the sumps, at el. 533. A short transverse gallery connecting the pump room with the longitudinal drainage gallery would provide convenient access during unwatering operations. The pump room would also be accessible from the 533 floor level of the station-service bay. The sump-pump motors would be located at el. 551 directly above the pump room.

(p) Water and Sewage Treatment Rooms. The equipment for these two systems would be housed in separate rooms, as shown on plates 12-24 and 12-25. The septic tank and related equipment would be located in the station-service bay on the 533 floor level. The septic tank would be 5 by 7½ feet in plan with bottom at el. 534 and top of roof at el. 551, with an adjacent overflow tank 3½ by 5 feet in plan. The tanks would be made watertight with an asphaltic membrane and would be provided with an access hatch in the roof. The water treatment equipment would be located in a 17½- by 36-foot room on the 551 floor level of the assembly bay.

(q) Oil-storage and Purification Rooms. The oil-storage and purification rooms shown on plate 12-24 would be located on the 533 floor level of the station-service bay. The oil-storage room would be approximately 40 by 45 feet in plan with ceiling height of 17 feet. The floor in this area would be depressed 1 foot to prevent oil from spreading to the outside areas if a tank or oil line ruptures. The oil purification room would be adjacent to the storage room and would be 16½ feet wide and 36 feet long. The room would house the fixed oil purifier and also store the portable oil purifier. The rooms would be accessible by an elevator and a stairwell.

(r) Heating and Ventilating Equipment Rooms. Facilities for this system would be located in three separate rooms. Two of the ventilation rooms, shown on plate 12-23, would be located on the draft-tube deck at unit bays 2 and 6. These rooms, 15 by 38 feet in plan, would house the facilities for the powerhouse proper and for fresh air intake. Heating and ventilating equipment for the service areas would be located in a 15- by 25-foot room on 551 floor level in the control bay, as shown on plate 12-24.

(s) Maintenance Shops. Shop areas are shown on plate 12-23. A maintenance shop, combining the facilities of a machine and electrical shop, would be located at el. 567 in the control bay adjacent

to the erection area. A 10- by 10-foot doorway would connect the two areas. The maintenance shop would be 29 feet wide and 65 feet long. A meter room, 17 by 20 feet in plan, would be provided at el. 567 in the office and control room area. The staffs would enter the shops through a doorway from office area corridor.

(t) First Aid Room. A small first aid room, 9 by 11 feet in plan, plate 12-23, would be provided on the 567 floor level of the control bay. The location of the room would be convenient to the elevator, stairwell, offices, and door to the main floor of powerhouse. The room should be equipped for handling only minor first aid cases.

(u) Storage Areas. A record room and two closets, plate 12-23, would be provided in the office area for storing records and small supplies. A 15-by 17-foot storage room and a janitors closet would be provided at el. 551 in the control bay, plate 12-24. Large items such as lifting beams for the bridge cranes, spare transformer bushings, spare generator exciter, and similar items would be stored on the main floor of the powerhouse. An extensive storage space would be available in the 541.5 longitudinal gallery for small supplies and spare parts.

(v) Toilet and Miscellaneous Facilities. Employees facilities would consist of a combination shower, locker, and toilet room. approximately 18 feet wide and 47 feet long, located on 551 floor level in the control bay. A small toilet would be provided in the office and control room area. Kitchen facilities would be provided in a small room adjacent to the control room.

(w) Elevator, Stairs and Access. A combination freight and passenger elevator would be provided in the control bay to serve all floor levels. A stairwell would be provided adjacent to the elevator. Access to the bridge cranes would be by steel stairs located at each end of the powerhouse. Miscellaneous stairs and ladders would be located throughout the plant as needed.

(x) Draft-tube Stoplogs. Ten sets of stoplogs, eight for main units and two for station-service units, would be provided to close the entrances to the powerhouse draft tubes. The construction schedule, plate 2-11, provides for filling the tailrace prior to the completion of equipment installation. The use of stoplogs offers the best solution for keeping the powerhouse dry during this construction period and prior to completing the turbine installation. Two sets of stoplogs for main units and one set for station-service units would be retained as permanent maintenance equipment. Each set of stoplogs for the main units would consist of four sections, two for each of the discharge openings of the draft tubes. The stoplogs would be constructed of welded steel 19 feet wide by 7 feet high with a 3/8 inch skinplate,

and weighing approximately 25,000 pounds. The sides of the stoplogs would bear directly against structural steel seal plates embedded in the concrete slots. The sides, top, and bottom would be sealed with "J" rubber seals. Flat springs would be provided to force the stoplogs against the seal plates. Dogging devices would be provided for storing the stoplogs under the draft-tube deck when not in use. The openings through the deck would be provided with structural steel gratings. The stoplogs would be handled by a gantry crane equipped with a lifting beam. The station-service stoplogs would be similar to that for the main units except that they are smaller in size and are of one section construction for each of the two units.

(y) Contraction Joints. Transverse contraction joints would be provided between powerhouse bays, extending from the foundation to the roof. Rubber water stops would be used across the joints to prevent water from entering the powerhouse. Leakage around the water stops would be collected and carried through drains to the station drainage system. Additional rubber water stops would be used around galleries at the contraction joints.

(z) Architectural Treatment. The primary consideration in the architectural treatment of the powerhouse would be utility. The generator room and erection-bay area would have granolithic concrete steel trowel finished floors, painted wainscot and walls and an exposed but painted roof construction. The equipment rooms, shop areas, and galleries would have trowel finished concrete floors and painted concrete walls and ceiling. The control room and office areas would have rubber tile floors, painted plaster walls, wainscot and suspended ceiling except for the control room which would have a suspended luminous ceiling. The washroom area would have ceramic tile floors and wainscot, plaster walls and suspended ceiling. The exterior treatment of the powerhouse structure would be simple, in keeping with the purpose of the building. The large expanse of vertical surface would be broken by vertical grooves along the contraction joints between powerhouse bays. In addition to the architectural effect, these grooves will prevent spalling.

(3) Structural Design. Layout studies of the powerhouse necessarily made use of a number of structural dimensions. Initially these were estimated from existing powerhouse designs known to have been analysed under conditions similar to those at Rankin Rapids. When the powerhouse layout had progressed to near its final form, the major structural members were checked for the following loadings:

Design loads	Lb. per sq. ft.
Roof	50
Oil purification rooms	200
Transformer deck	250
Equipment gallery	300
Generator floor	1,000
Erection bay floor	1,000
Storage rooms	200
Wind on walls	30

Moving loads and floor loads were considered in accordance with standard engineering practice. The foundation is adequate to support the structure. Concrete was classified and designed in accordance with exposure and loads to which it would be subjected. The design stresses for concrete and reinforcing steel are given below.

Exposure	Compressive stress, concrete, p.s.i. f'_c= 3,000 p.s.i.	f'_c= 2,000 p.s.i.	Tensile stress, reinforcing steel, p.s.i.
Floors and exposed walls	750	675	16,000
All other concrete	1,050	875	18,000

f'_c = Ultimate compressive strength of 28-day concrete.

Intermediate grade new billet steel reinforcing bars would be used. Preliminary design for the structural steel powerhouse roof truss was made on the basis of an allowable stress of 20,000 p.s.i.

(4) Selection of Main Units. The eight-unit plant and the plant capability criteria described in the initial studies for Rankin Rapids were used as the basis for the further detailed powerhouse studied in this paragraph. On this basis, each of the eight turbines and generators would be rated as follows:

Generator rating:	nominal (60°C.) rating	50,000 kw. @ .95 P.F.
115 percent	nominal (80°C.) rating	57,500 kw. @ .95 P.F.
Turbine rating:	88,250 hp. at 284 ft. net head and full gate.	
Speed	163.6 r.p.m.	

Each of the eight hydraulic turbines would drive a generator of the unbrella type. The nominal capacity (60°C. rise) of the generator would correspond with the turbine output when operating at best gate and rated head. The generators would have "Class B" insulation and would be capable of continuous operation at 115 percent nominal rating without exceeding a temperature rise of 80°C. This higher rating was selected to match the turbine output when operating at full gate at minimum head. The abnormally low ambient temperature of the generator

cooling water and the cyclic nature of the load when firming the tidal power plant output would permit safe operation of the units slightly above 125 percent of their nominal rating without exceeding the allowable 80° C. rise. This maximum generator output corresponds with the turbine output when operating at full gate and rated head.

(5) Turbines and Governors. The turbines would be vertical-shaft, single-runner, Francis-type with plate-steel spiral casing and elbow-type draft tubes. The units would rotate clockwise when viewed from the top. The spiral casings would be embedded in the concrete substructure of the main-unit bays. Each turbine would be constructed so that all removable parts, including the runner, shaft, guide bearing, guide bearing support, head cover, gate-operating mechanism, and wicket gates could be removed from above. The governors would be of the oil-pressure, relay-valve, actuator type with electrically driven speed-responsive elements designed for regulating the speed and controlling the gate operation of the turbines. The speed responsive elements would be driven by an alternating current motor receiving its power from a permanent-magnet generator directly connected to the exciter shaft of the main generating unit being governed. Each governor unit would consist of an actuator, restoring mechanism, motor driven pumping units, pressure tanks, sump tank, and other necessary controls and appurtenances. The governors would operate at a pressure between 270 p.s.i. and 300 p.s.i. and the equipment would be sized to operate the wicket gates from fully open to fully closed position, or vice versa, in 5 seconds under the most adverse head conditions with an oil pressure of 250 p.s.i. at the pressure tanks. The rate of gate movement would be adjustable from 5 to 30 seconds. The governor assembly, including pressure tanks, would be grouped in pairs and located on the generator floor at el. 567 between each pair of main generating units. The pumping units would be mounted on the sump tank of each governor and would be provided in duplicate. The connecting piping between the governor assembly and the generating unit would be carried in a covered trench beneath the generator room floor.

(6) Electrical System Characteristics. The power generated at Rankin Rapids powerhouse would be transmitted to markets in Maine and New Brunswick by transmission as described in appendix 14, "Power Markets and Transmission Lines." Interrupting ratings of 1 million kv.-a. and 5 million kv.-a., respectively, were selected for the generator and line circuit breakers. These ratings are based on 3-phase fault conditions with an infinite bus assumed at Bangor, Maine, and at Fredericton, New Brunswick, and with 795,000 c.m., ACSR line conductors. Normal impedances were assumed for generators and transformers at Rankin Rapids.

(7) Generators. Plates 12-22 and 12-23 indicate the physical relation of the generators to the rest of the powerhouse facilities, and plate 12-26 shows the main one-line diagram. On the

basis presented in the preceding paragraph (h), each generator would be rated 52,600 kv.-a., 13.8 kv., 3 phase, 60 cycles, 95 percent power factor, 163.6 r.p.m., 60° C. temperature rise, Class "B" insulation, with a direct-connected shaft-driven main exciter. Generator reactances, WR^2, runaway speed, and thrust bearing loading would not exceed values available in standard design machines. The generators would be enclosed in steel air housings and cooled by air-to-water coolers inside the housing. Generators would be equipped with air brakes, carbon dioxide fire protection system, magnetic-amplifier voltage regulator, excitation cubicle, amortisseur winding, electric heaters to prevent condensation, and other devices normally provided with equipment of this type. The stator windings would be divided into two groups per phase and brought out separately to terminals, thus making possible the use of a split-winding type differential protection. The generator would be capable of withstanding 3-phase short circuit and would be grounded through a neutral device described below.

Generator surge protection, plate 12-26, would be provided by station-type lightning arresters connected in parallel with capacitors between each phase of the generator bus and the station ground. The equipment would be enclosed in a metal-clad housing located directly below the generator air circuit breakers. The arresters would be of the thyrite type rated 15 kv. maximum line-to-ground voltage. The capacitors would be single-phase rated 13.8 kv. and 0.25 microfarads. An arrestor and a capacitor would be used for each phase. Generator grounding would be of the distribution transformer - resistor type and would limit ground current to approximately 10 amperes.

(8) 15-kv. Switchgear and Bus.

(a) General. Two generators would be connected to each of four transformers, as previously described and as indicated on the main one-line diagram, plate 12-26. Cubicle type, 15-kv. air circuit breakers would be located on a balcony, el. 578, between each pair of units, as shown on plates 12-22 and 12-23. Each of the pair of generators would be connected to its circuit breaker by bus. The breakers would be connected on the load side to a common bus which would extend through the wall and connect to the power transformer on the draft-tube deck, as shown on plate 12-22. Potential transformers and surge protective equipment would be located on the main operating floor directly under and close-connected to the generator side of the air circuit breaker.

(b) Air Circuit Breakers. The generator circuit breakers would be of the metal-enclosed, indoor, station-cubicle type units having a 3,000 ampere current rating and a 1 million kv.-a. interrupting rating. This selection was based on the previously described short-circuit computations which indicated that 0.88 million kv.-a. would be the maximum interruption required of the generator

breakers. The circuit breakers would be of the fixed, air-insulated, and air-blast type operated by pneumatic mechanism. Each breaker would be provided with an air storage tank of sufficient size to operate the breaker through two complete open-close cycles without recharge. Air for the storage tanks would be provided by the station high-pressure air system. Each breaker would have a manually-operated disconnect switch on the line and load sides to isolate the breaker from the generator and transformer as shown on plate 12-26. The breakers, disconnect switches, and cubible housing doors would be mechanically interlocked to insure safe and proper operation. Bushing-type current transformers would be provided in each breaker. The breakers would be controlled by 125-volt d.c. circuits from the main and unit control switches. Local control switches, properly interlocked, would be provided for maintenance.

(c) Isolated Phase Bus. An isolated-phase bus would connect the generators to the breakers and the breakers to the transformers. The generator to breaker section would be rated 3,000 amperes, and the breaker to transformer section, 5,500 amperes. These ratings would provide an adequate margin of safety for 115 percent generator output, which would be 2,530 and 5,060 amperes respectively for the two sections of bus discussed above. Bus work would be rigidly secured by structural steel members fastened to the concrete surfaces with anchor bolts.

(9) Transformers.

(a) Rating. Four 3-phase, 120,000 kv.-a., 13.2-230-kv. delta-star connected, type FOW transformers would be provided. Each transformer would be connected to two generators and were sized to operate continuously at a capacity equivalent to 115 percent nominal rating of the two generators.

(b) Bushings. The high-voltage bushings would be rated 195 kv. and provided with taps for future potential devices. The neutral bushing and the neutral end of the high-voltage winding would be rated 46 kv. A current transformer for relay purposes would be used in the grounding circuit of the transformer neutral. Low-voltage bushings would be housed in a metal enclosure adapted for connection of isolated phase bus. Each transformer would be provided with a manual-operated, no-load, tap changer.

(c) Cooling. The transformers would be oil-immersed, forced-oil-cooled, with water-cooled heat exchangers in the gallery below the draft-tube deck. Each transformer would be provided with an automatically controlled inert-gas cushion above the oil. Each transformer would have two separate oil circulating pumps and exchangers, piped for parallel operation. Both systems would be sized to permit the transformer to operate at 70 percent rated capacity with only one

system in operation. Water- and oil-flow switches would prevent the energizing of the transformer unless the cooling system were in operation.

(d) Transfer Facilities. Each transformer would have flanged, caster-type wheels for moving it from the operating position on the draft-tube deck to the assembly area in the powerhouse. Embedded rails in the tailrace deck would be used for moving the transformer and the draft-tube gantry crane. The doorway into the assembly bay area would be large enough to pass the assembled transformer with high voltage bushing in place.

(e) Fire Protection. Firewalls would be provided on each side of the transformer. Spreading of burning oil would be further restricted by a removable barrier placed between the firewalls in front of the transformer. Drains inside this enclosure would empty into the tailrace below minimum water level. A water-fog fire protection system would be provided for each transformer.

(f) Lightning Protection. The high-voltage side of each transformer would be protected from lightning by 195-kv. thyrite, single-pole, station-type outdoor arresters. The arresters would be of the self-supporting type and mounted on a knee-brace structural steel frame supported on the powerhouse wall above the transformers, as shown on plate 12-22.

(10) Powerhouse to Switchyard Connection. Four aerial lines over the tailrace channel consisting of 795 M c.m. ACSR conductors and ½-inch galvanized steel static wires would connect the main transformers on the powerhouse draft-tube deck to the switchyard. The lines would be connected at an angle of about 50° to the downstream wall of the powerhouse above each transformer and the lightning arresters as indicated on plate 12-23.

(11) Control System.

(a) General. The powerhouse control system consists of all devices and circuits provided for starting, stopping, switching, loading, metering, and protecting the generators and associated power-handling equipment. It is expected that an abnormally high frequency of adding or dropping of units would be necessary at Rankin Rapids because of its function as an auxiliary to the tidal power project. As much automatic equipment as practicable would be used to minimize operating personnel and to reduce human errors.

(b) Control Locations. Normal powerhouse operation would be conducted from a main control room located at the ground entrance level, el. 567. The main operating desk would be located in the center of the room with a view of the graphic instrument switchboard on the right and the main control switchboard to the left. A

small communications switchboard would be located in the desk. Each unit control switchboard would be located adjacent to the respective governor switchboards at el. 567, as shown on plate 12-23. These boards would be grouped in pairs in a right- and left-hand arrangement opposite the four corresponding transformer banks. Although normal operation would be from the main control room, transfer switches and necessary instruments would be provided for testing and emergency operation at the unit boards. The two station-service, unit control switchboards would be located adjacent to the main unit boards in the main control room. Local control at the units would be provided for emergency operation.

(c) Types of Equipment. Control cables would be rubber insulated, multiconductor, neoprene, or similarly jacketed, with conductor size not less than No. 19/22 AWG. Cables would be carried on expanded aluminum trays in the switchyard tunnel and in the equipment gallery (el. 551) from the units to the main control room. A 3- by 4-foot duct bank, approximately 650 feet long, would carry the control cables from the switchyard, at el. 635, to the main control room. A duct bank was selected in preference to a tunnel because of the heavy rock excavation, the large difference in elevation, and the steep rise necessary to stay above rock near the powerhouse. Manholes and cable supports would be provided as required. All control switchboards would be of the vertical duplex type with a depth of 72 inches and height of 90 inches. Switchboard panels and doors would be constructed of 1/8 inch or No. 11 U.S.S. gage smooth select steel with angle or channel edges bent to approximately a 1/4 inch radius. The interior and exterior surfaces of the panels would be finished in light gray lacquer. A light-colored finish would be used on all exterior surfaces including the annunciator cabinets and window frames. Instruments, relays, meters, and similar equipment would be supplied in cases for flush or semiflush mounting and with a dull black finish on exposed areas. Relays and watt-hour meters would be of the drawout type. Test blocks would be furnished for maintenance of indicating and graphic instruments.

(d) Main Control Switchboards and Panels. The selected design for the two switchboards in the main control room is shown on plate 12-27. The instruments would be arranged logically in relation to operating requirements. A panel 36 inches wide would provide adequate space for all indicators and controls for two generators and the associated transformer switchyard bay. Two standard 26-inch-wide panels would contain the station-service unit controls. The three line bay controls would be grouped together on a 36-inch-wide panel near the center of the board and the line relays would be located on the rear panel of the same section. The rear panels of the main-unit sections would contain the unit-load controllers, watt-hour meters, and transformer ground relays. The automatic synchronizing equipment would be located on the rear panel of units 1 and 2. The 125-volt d.c.

distribution panel, in the main control room, would be located inside the rear panel of the station-service section. Two swinging-type, synchronizing indicator panels would be provided to expedite resynchronizing after a fault. The right-hand unit would also serve for paralleling the station-service units. Each breaker closing circuit would be interlocked through the corresponding synchronizing switch located adjacent to it. Only one keyed synchronizing switch would be provided for each synchroscope either for manual or automatic closing. The following indicators would be provided on each unit panel: ammeter, voltmeter, wattmeter, varmeter, voltage regulator output, speed adjustment, speed indicator, gate position, bus voltmeter, unit symbol lamp, and switching indicator lamps. Control switches would be provided for starting, switching, and loading each unit. A selector switch would also be provided for automatic load or frequency control. The annunciator system indicator cabinets would be placed on top of the corresponding group panels.

(e) Unit-control Boards. The selected unit-control switchboard arrangement is shown on plate 12-28. The generator control panel would be placed between the governor cabinet and excitation equipment to eliminate dual controls. Only those instruments would be provided that are necessary for emergency operation or testing. One swinging type synchronizing panel would be provided. The conventional type temperature, pressure, and flow indicator would have adjustable alarm contacts for signalling abnormal conditions to the main control room. Three 16-point strip-chart temperature recorders with adjustable alarm settings would be furnished in the odd-numbered unit boards for indicating and for continuous or periodic recording of bearing and winding temperatures. These recorders would serve the two units and transformers. Space would be provided for the exciter field breaker, field rheostat, and the voltage regulator at the switchboard end nearest the generator. The 125-volt d.c. unit distribution panel for two units would be located in the even-numbered unit boards. The molded-case type breakers would be concealed by a hinged door panel but would be readily accessible for maintenance and testing. Generator and transformer protective relays would be located in the rear panels of the respective control sections.

(f) Protective Relays. The major relay protective system selected is shown on the one-line diagram, plate 12-26. The generator protective relays and the transformer differential relays would be located on the rear panels of the unit control switchboards near the generators. The line impedance or distance relays and the transformer neutral ground relays would be located on the rear panels of the main control boards. All relays would be of the flush drawout type with dull black finish. Each generator would be provided with split-stator type differential, time-delay voltage-restraint overcurrent, and ground relay protection in addition to the conventional bearing and winding temperature thermal relays. The principle protective

relays would operate to trip spring-loaded, hand reset type auxiliary or "shut-down" relays. The complete shutdown relay (86GC) would be energized by generator differential action which would also release carbon dioxide into the generator housing and actuate an alarm. The complete shutdown relay in turn would act to trip the main breaker, the exciter field breaker, the governor shutdown solenoid, and the annunciator. The 86GC relay might also be energized by manually operated emergency switches in the main control board and governor cabinets and also by release of carbon dioxide, mechanical tripping of the governor shutdown solenoid, and by tripping the generator ground time-delay auxiliary relay. Carbon dioxide would be released directly by operation of thermal relays near the generator windings or from a break-glass station outside the generator barrel. The partial shutdown relay (86GP) would be tripped by the generator ground, overcurrent, and overspeed relays to energize the governor speed-no-load solenoid and open the main breaker. The time-delay shutdown relay (86GT) would be energized by high bearing temperature or very low governor oil pressure to immediately operate the governor shutdown solenoid in which case tripping of the main breaker would be delayed until the wicket gates are closed to the speed-no-load position. An overvoltage relay (59) would be used for energizing the quick-lower contactor (39) to protect the generator winding against high voltage resulting from malfunction of the regulator, excess excitation, or load rejection while under manual control. The generator ground relay would be of the simple overvoltage type connected across the generator neutral ground resistor. Time-delay auxiliary relays would be connected so that the partial shutdown relay of the odd-numbered unit tripped immediately by closure of the ground relay contacts followed, after a short time delay, by complete shutdown of whichever unit has the sustained ground. The 230-kv. breaker would also be tripped in case of a sustained ground on the even-numbered unit. The transformer lockout relay (86T) would be tripped by high winding temperature, differential or ground relay action, and by low oil or cooling water flow. Both generator breakers and the associated switchyard breaker would be tripped by relay 86T. Fog release would be initiated only by the transformer differential relays. The line lock-out relays (86L) would be located on the rear panels of the main control board line section. These would be energized by the impedance (distance) relays located on the same panel. All shutdown or lockout relays would have contacts for tripping off the load control system. The 1,250-kv.-a. station-service generators would be protected by induction overcurrent relays set to coordinate with the feeder breaker settings. A broken-delta ground relay scheme would be provided for ground annunciation on the 480-volt system. Conventional bearing temperature, air temperature, water flow, and governor low-oil-pressure relays would be provided for warning of abnormal conditions or for automatic shutdown of the unit.

(g) Control Transfer - Switchyard Auxiliary Bus. The basic switching scheme selected is shown on the main one-line diagram, plate 12-26, and would consist of two main buses and one transfer bus with two spare breakers. Provision would be made for switching the middle 230-kv. line to either main bus. The transfer bus would be used primarily during maintenance or emergencies. Two spare breakers would be provided for flexibility of switching to handle most abnormal situations. Key interlocks would be used to prevent closure of more than one motor-operated disconnect switch onto the transfer bus. Electrical interlocks would be provided to prevent operation of the disconnect if either spare breaker is closed. A transfer switch would be mechanically linked to the disconnect operating mechanism or control to shift the transformer differential relay circuit, synchronizing potential, and trip circuit to the spare breakers. The 230-kv., motor-operated disconnect switches on Line No. 2 would be interlocked to block closure onto either main bus if the line breaker were closed. Transfer switches would be provided to supply the proper synchronizing potential from the selected main bus potential device. All 230-kv. manually operated isolating disconnect switches would be key-interlocked to prevent movement of the disconnect if the corresponding breaker were closed.

(h) Load-control System and Telemetering. A considerable amount of automatic load-control equipment would be required to maintain the desired combined output of the Quoddy-Rankin system; however, the desired control would be attained with standard, conventional load - frequency control equipment. A block diagram of the selected system is shown on plate 12-26, and the selected physical arrangement of the load recorder controllers on the graphic instrument board is shown on plate 12-27. Two independent control systems would be provided so that the Maine and New Brunswick loads could be controlled separately, if desired. The dual system would also add flexibility for maintenance or emergency conditions. Each generator would be provided with a load controller and a load recorder which are supplied from separate thermal converters in the metering circuits. The output of each group of four units would be totalized in each system-total recorder. The Quoddy system megawatt generation would be received via carrier-current impulse telemetering from metering and coding devices located at the Quoddy load metering centers. Carrier-current, variable-frequency telemetering would be used to transmit the metered load from each of the four lines at Presque Isle substation, 70 miles distant. All telemetered load values would be recorded continuously on strip-chart instruments in the graphic instrument board. Carrier-current receiving equipment would be provided on two phases of each of the three lines. Transmitters would be provided for communication and telemetering of the plant total to the dispatcher if required. Adequate switching would be provided so that the various carrier circuits could be interchanged when lines or equipment are out of service.

The system load requests would be received by carrier telephone from a system dispatcher located at Quoddy or elsewhere. The Rankin operator would then set the system load controllers accordingly. The tie line recorder - controller, master controller, and unit controllers would initiate and route the governor and raise or lower pulses to the various units in preselected proportions to maintain the required constant combined output regardless of the diminishing or increasing proportion of the load furnished by the Quoddy plant. The equipment would be adaptable to a system of direct dispatcher control, should this prove desirable in the future. A frequency recorder-controller is also provided for each system. The rear panels of the graphic instrument switchboard would be reserved for carrier terminal equipment. Time-standard equipment would be provided for control of the station-service units through the frequency recorder-controller and to supply the master clock. This equipment would be located in the rear panel of the station-service control board.

(12) Annunciator System. The annunciator system, shown on plate 12-29, would provide visual and audible signals in the control room, at the unit control boards, and at the station-service main 480-volt switchboard in the event of trouble or abnormal conditions. Audible signals in the control room would be produced by a soft-tone gong, whereas in the generator room they would be produced by two horns equally spaced and located on the powerhouse wall 12 feet above floor level. A horn having a different tone would also be provided in the generator room for annunciating station-service trouble. Visual signals would be provided by groups of annunciator windows on the above-mentioned boards. Closure of a trouble contact on any unit would give a visual signal on its board and in the main control room, and would also energize the unit-in-trouble lights located high enough on the powerhouse wall to be seen the full length of the powerhouse. The system would be provided with switches for testing and resetting the visual alarms and also for silencing the audible alarms. Design of the annunciator system assumes operators in the control room and only roving operators on the generator floor but available for duty at the unit control boards, station-service units, or elsewhere in the plant as needed. Annunciation of switchyard trouble would also be provided in a manner similar to that described above. The annunciator system would be powered by the station 125-volt d.c. system.

(13) Station Service.

(a) Power Supply. In selecting the method of supplying power to the station-service system primary emphasis was placed on reliability rather than initial cost. Consideration was given to transformers connected to the main unit bus, separate station generators, and a combination of the two. The transformer method showed some economy but did not provide suitable reliability and voltage regulation was poor. The two-generator method was selected because it offers the necessary reliability and is not affected by the outages and disturbances associated with main units and transmission lines.

(b) Station-Service Units. Power for the station-service system would be supplied by two station-service generators driven by hydraulic turbines each supplied by separate penstocks from the surge tanks of main units 1 and 2. The units should be located in the station-service bay as shown on plates 12-24 and 12-25. The generators would be rated at 1,250 kv.-a., 480 volts, 0.8 power factor, 3 phase, 60 cycles with a speed of 720 r.p.m. An evaluation of the station-service loads indicated a total of 1,650 kv.-a. could be expected, or a demand load of 1,235 kv.-a. with a diversity factor of approximately 70 percent. The selected generator capacity, 1,250 kv.-a., is such that one unit only would be required to supply the normal station load. The second unit would provide a standby source of power and would be available to supplement the first unit during heavy load conditions in the plant. The turbines would be of the vertical-shaft, Francis-type and of adequate capacity to supply the normal station-service load under minimum head conditions. Preliminary calculations for the station-service turbines indicated a speed greater than 900 r.p.m. It would have been necessary to add approximately 75 percent WR^2 to a 920-r.p.m. standard generator in order to achieve the flywheel constant required for stability. The additional WR^2 would be difficult to obtain on this unit without the use of a flywheel, but the necessary stability could be obtained by using a 720-r.p.m. turbine with either a 2,000 kv.-a., 720-r.p.m. standard generator, or a 1,250 kv.-a., 720-r.p.m. generator with 53 percent added WR^2. Cost comparisons showed the smaller unit with added WR^2 would be most economical and was selected. Water for the turbines would be supplied by separate 3-foot penstocks connected to the surge tanks of main units 1 and 2. This was the most suitable arrangement since separate penstocks extending to the forebay would have an unwarranted cost. Also connections made to the main penstocks at the powerhouse would cause less stable operation of the small units, because they would be subjected to pressure changes caused by main unit wicket gate movement.

(c) 480-Volt Main Switchboard. The 480-volt main switchboard, shown on plates 12-24 and 12-25, would be located adjacent to the station-service generators in the mechanical equipment gallery at el. 551. All power from the station-service generators would be delivered to this switchboard, from which it would be distributed to the various load centers and auxiliary equipment as shown on the 480-volt, one-line diagram, plate 12-30. The switchboard would be of the metal-enclosed, cubicle type and would contain two main buses with a bus-tie breaker, a breaker for each station-service generator, main feeder breakers, and branch circuit breakers for certain nearby auxiliary equipment. Also located on the board would be the controls, relays, meters, and miscellaneous devices necessary for the local control of the station-service units. The bus tie breaker and the generator breakers would be of the drawout type, electrically controlled, and operated from this switchboard and from the control room. The main

feeder breakers would also be of the drawout type but manually operated. All breakers would be of the air break type.

(d) Control. The station-service units would normally be started and controlled from the main control room in a manner similar to that for the main units. A schematic diagram of the metering and control circuits is shown on the 480-volt one-line diagram, plate 12-30. The normal control panels are shown on main control switchboards, plate 12-27, and the local operating control panels are shown on the 480-volt main switchboard, plate 12-31. All necessary operating controls and indicators would be provided on the latter control panels for emergency or test operation. Separate adjacent panels would contain the exciter field breaker and manual field control equipment. The station-service panels in the control room would contain one frequency controller-recorder with time-error indicator, a voltage regulator for each unit, and provision for synchronizing. Cooling water and brake controls would be automatic to provide fast starting of the standby unit.

(e) Distribution System. A cost and engineering study comparing 480-volt and 2,400-volt distribution systems indicated the 480-volt system to be adequate for the size of the loads and distances involved and was less costly particularly the switchgear. The 480-volt system was accordingly adopted for the station-service distribution system in the plant and the switchyard. Feeder voltage for the dam and project housing area would be stepped-up to 4,160 volts and transmitted by aerial lines from the powerhouse. Duplicate feeders from the 480-volt main switchboard (one from each section of the dual bus) would be provided to all of the important load centers. While it is expected that both sections would be normally tied together, this arrangement provides duplicate feeders and also presents considerable flexibility in the segregation of generators, or loads, to meet unusual operating conditions. The switching arrangements at the load ends of duplicate feeders would be mechanically interlocked to prevent paralleling at the load.

(f) Motor Control Centers. The 480-volt one-line diagram, plate 12-30, indicates several power panels and load centers distributed throughout the plant. The selected physical layout of the principal motor control centers is shown on plate 12-32. The unit power panels would be grouped in pairs which conform to the two-generator-per-transformer arrangement. The standard industrial load center, NEMA Type B, with front access to the bus, was selected for floor mounting against the wall opposite the odd-numbered generators. The location was selected to be near the loads without interference with passage at the control boards. The unit load centers would serve the governor, turbine, thrust bearing, transformer oil pumps, voltage regulator, generator housing heater, and high bay lighting. Each motor-controller cubicle would include a molded case breaker with instantaneous and thermal overload trip and a contactor with suitable thermal overload

trip device. A similar motor control center would be provided for the station auxiliary equipment located in the station-service bay such as air compressors, oil purifiers, water pumps, ventilating fans, and duct heaters. A smaller auxiliary control center of similar type would be provided in the equipment gallery, between units 4 and 5, to serve the battery charger motor-generator sets, ventilating fans, and water circulating pumps. The same type equipment would be provided at the intake-structure load center to serve the gate hoists, drainage pumps, and lighting. The main load center would be located in the control room for intake gate 1 and individual centers would be provided at the control center for each gate. The low-level control structure load center would similarly feed the elevator, bridge crane, valves, sump pump, and lighting. The spillway load center would serve the gate hoist motors, gate seal heaters, and lighting. Power receptacles would be provided at all locations for use of portable welders or other equipment. Contactors would not be required in receptacle and lighting supply sections.

(14) Direct Current System. The 125-volt d.c. system and station battery, shown on plate 12-33, would include a 125-volt battery, two battery-charging motor-generator sets, battery board, d. c. distribution panels, and distribution circuits. The battery, battery board, and battery chargers would be located midway of the plant in the equipment gallery at el. 551 as shown on plate 12-24. Principal normal loads on the battery would be annunciation, control, and indication circuits. Emergency loads imposed on the battery would be turbine-bearing d.c. oil pumps, emergency lights, and emergency inverter set for certain communication circuits. The 230-kv. oil circuit breakers in the switchyard and the 15-kv. air circuit breakers for the generators would be operated by compressed air and would require only a small current for d.c. control. A 60-cell battery would provide adequate capacity for the above loads and would be used as source of power for the 125-volt d.c. system. Each battery charger would be rated at 5 kw. and would be of the diverter-pole type permitting the battery to normally "float" on the line to provide current for sudden large demands only. One battery charger would be considered as a spare but could be operated concurrently if required.

(15) Telephone and Code Call System. Local communication and signaling facilities would be provided by a private 60-station automatic exchange (PAX) system, complete with a code call system as an integral part. The telephone system would consist of a PAX of the step-by-step type, automatic code call equipment, and a manually operated switchboard. The switchboard would be mounted on the operator's desk in the main control room. The automatic switching equipment, relay racks, distribution frame, and powerline transmitter-receivers would be located in the cable-spreading room as shown on plate 12-24. The PAX cabinet would be equipped for 60 lines with provisions to expand to 100. The PAX would provide for interconnecting all telephones in the

powerhouse, switchyard, intake, low-level works, dam, and spillway. The system would provide automatic ringing, dial tone, executive right-of-way, and busy tone. Two trunk lines from the public utility telephone company would be provided for calls outside the station area.

(16) Lighting. A riser diagram for station lighting system is shown on plate 12-33. Power for lighting would be supplied from lighting panelboards fed from adjacent dry-type, 3-phase, 480-120/208-volt transformers with the exception of generator room high-bay and tailrace deck lighting which would be supplied directly at 480 volts. Generator room high-bay fixtures and tailrace lighting would consist of mercury vapor units. High-bay fixtures would be color-corrected. A 3-phase 120/208-volt system was selected as being more economical than a single-phase 120/240-volt system. For purposes of distribution, economy, and reliability, the lighting system would be divided into four sections; assembly and control bays, generator room, longitudinal galleries, and exterior area. Lighting feeders for generator room and exterior lighting would be supplied from the main unit power boards. The other sections would be fed from the station-service main 480-volt switchboard. Lighting circuits would overlap throughout the structure in such a manner that lighting at a reduced level would be available if any particular feeder is lost. Duplicate feeders, one from each bus of the station-service main 480-volt switchboard, would be provided to the main unit power boards from which the lighting of the generator room is supplied thus providing additional reliability for this critical area.

Generator room high-bay fixtures would be of the mercury vapor, color-corrected type with ballasts mounted on the powerhouse wall above the bridge crane rails. This type of high-bay lighting is the most economical and the color-correction overcomes objection to the bluish mercury-arc light. Point-by-point studies indicate that nine 1,000-watt luminaires per main unit bay would provide an intensity of 18 foot-candles at main floor level, el. 567. Supplemental lighting of unit control switchboard would be supplied by 60°-angle incandescent luminaires mounted on the powerhouse wall in front of the switchboard and would provide an intensity of 25 foot-candles on the vertical surfaces of the control boards.

Main control room lighting would be provided by a luminous ceiling type system using slim-line fluorescent lamps. Illumination on the vertical surfaces of the control boards would be approximately 30 foot-candles. The low-level and even brightness of the luminous ceiling would prevent specular reflections on the instrument faces when viewed from the control desk. Incandescent emergency lights would be located to permit observation and operation of the control boards during power failure.

Office and shop areas would be lighted by fluorescent-type fixtures and would provide an illumination level consistent with the function of the area. Incandescent-type fixtures would be used to illuminate all other areas such as turbine pits, generator interiors, longitudinal and transverse galleries, battery room, oil facility rooms, mechanical equipment rooms, and miscellaneous areas. Intensity level of illumination would be consistent with the function of the area.

An emergency lighting system would be provided in the control room, stairways, galleries, turbine pits, and unit control boards. The emergency lighting system would be supplied from emergency panel boards which would be connected through automatic transfer switches to either the normal a.c. system or to the 125-volt d.c. system. Loss of a.c. voltage would automatically connect the emergency lighting load to the d.c. system, and return it to the normal a.c. source upon restoration of power.

(17) Grounding. The station grounding system, shown on plate 12-34, is designed to protect personnel and to prevent equipment damage as far as practicable. It would consist of an interconnected network of copper conductors throughout the powerhouse and connected to the ground mat by two 500 M c.m. copper cables. Connections would also be made to the penstocks and to the switchyard. Ground currents would be conducted to earth through the penstocks, the ground mat in the switchyard, and the station ground mat located in the river bed below water level and covered by the toe of the dam. The system would be designed to obtain a resistance of 0.5 ohms, which is in accordance with good practice, to insure potentials that are safe to human life and to equipment. The ground mats would consist of a network of bare copper cables arranged to form a grid and supplemented by 3/4-inch by ten-foot copperweld ground rods driven at points of intersections. Cables would be brazed to the ground rods to insure good contact. The noncurrent-carrying parts of all electrical equipment would be grounded as would all major nonelectrical equipment such as turbines, penstocks, structural steel, handrails, etc. The grounding of generator and transformer neutrals and of lightning arrestors would be to the main ground system through separate conductors for each. Ground test stations would be provided to permit testing by removal of bolted-type connections.

(18) Compressed Air Systems.

(a) General. Compressed air systems for the powerhouse, shown schematically on plates 12-35 and 12-36, would include a low pressure system for general service and a high pressure system for the turbine governors and the generator air circuit breakers. All compressor equipment and controls would be located in the equipment room of the service bay at el. 551 and would draw their air supply

from within the room. Compressors would be installed in duplicate for each system, one of which would be sufficient to supply the normal system needs, and the other would serve as a standby. An automatic switch would alternate the units to equalize wear. The sizes of the compressed air systems and components are based upon sizes of similar installations in existing powerhouses.

(b) Low-pressure System. The low-pressure air system would supply compressed air at a pressure of 115 p.s.i. for generator braking and for general plant use. The compressors for this system would be rated at 150 c.f.m., 115 p.s.i., and would be two-stage, water-cooled, automatically controlled units, with intercoolers and after-coolers. Two 36- by 96-inch air receivers would be provided, and control of the compressors would be by means of a pressure governor and a manual selector switch to select either compressor loading or motor control. Compressors would start in an unloaded condition. The compressors would be stopped automatically by low lubricating oil pressure, high cooling water temperature, or low cooling water pressure. All intercoolers, aftercoolers, and receivers would be equipped with automatic float operated water traps to draw off condensed moisture. Low-pressure air would be distributed through a 2-inch header at el. 562 in the equipment gallery. The header would supply air to branch lines serving each station-service and main-unit generator brake, and to air outlet connections throughout the powerhouse. A 2-inch header at el. 545 in the drainage gallery would supply air to a "connection" in each main penstock drain for use in blowing out debris that might clog the drains. Branch lines would also be installed on the el. 562 header to supply air to the station-service draft tube and penstock drain blowout lines, septic tank sludge removal line blowout, and air connection outlets in the shop and equipment room areas. Air would be supplied to the water treatment room at 115 p.s.i. for maintaining pressure on the potable water storage tank.

(c) High-pressure System. The high-pressure air system would supply compressed air at a pressure of 350 p.s.i. for the governor oil pressure tanks and for the generator air circuit breakers. The compressors for this system would be rated at 40 c.f.m., 350 p.s.i., and would be two-stage, water-cooled, automatically controlled, with integral intercooler and separate after-cooler. Two 30- by 84-inch air receivers would be provided, and pressure would be maintained between 310 and 350 p.s.i. by a pressure governor and a manual selector switch to permit either compressor unloading or motor control. Automatic unloading would be provided for starting. The compressors would be stopped automatically by low lubricating oil pressure, high cooling water temperature, or low cooling water pressure. All aftercoolers and receivers would be equipped with automatic float operated water traps to draw off condensed moisture. High pressure air would be distributed at 310 p.s.i. through a 2-inch header at el. 562 in the equipment gallery. A pressure reducing station near the

compressors in the equipment room would reduce the fluctuating storage and compressor discharge pressure to a constant 310 p.s.i. Air at 310 p.s.i. would be supplied to the main unit governor tanks through branch lines. Air for station-service governors would be supplied at 210 p.s.i. from the receiver discharge main through a pressure reducing valve in the compressor room. Air for circuit breakers would be supplied at 255 p.s.i. through a 2-inch header parallel to the 310 p.s.i. header in the equipment gallery. The pressure reducing station for this service would be located in the equipment gallery where the two headers branch.

(d) Piping. All piping would be standard-weight, galvanized steel. Branch line connections would be taken off at top of mains. Drip legs with drain cocks would be provided at bottom of all vertical risers and at the end of all headers or long branch lines. Low points in runs of pipe would be equipped with automatic float-operated water traps to remove condensed moisture.

(19) Unwatering and Station Drainage System. The unwatering system shown schematically on plate 12-37 would be a closed type installation for unwatering the penstock, scroll case, and draft tube of each main generating unit and each station-service unit. Each main unit draft tube would be drained through a 12-inch mud valve with screened inlet in the splitter pier and connected directly to a 16-inch header, as shown on plate 12-22. The mud valves would be opened and closed manually by geared-head floor stands in the gallery at el. 538. Screens for the mud-valve intakes would be flush with the sides of the pier and the draft-tube floor. The unwatering header would extend under all draft tubes at el. 518 and would end in a valved manifold in an unwatering sump located beneath the lower level of the station-service bay, as shown on plate 12-25. The penstocks and scroll cases would be drained by an 8-inch line discharging into the draft-tube roof, and controlled by an 8-inch valve where the line passes through the 538 gallery, as shown on plates 12-22, and 12-25. The water passages would be refilled by first filling the draft tube from an adjacent unit by opening the proper draft-tube drain valves. When the head has been equalized the draft-tube gates would be removed. The penstock could then be filled by "cracking" the intake gate to permit the penstock and scroll case to flood. The station-service units would be drained by a 6-inch line from each draft tube and a 4-inch line from each penstock connected into an 8-inch header which in turn would join the main unit 16-inch header in the unwatering sump. All valves would be located in the unwatering pump room at el. 533 as shown on plate 12-25.

The station drainage system would drain to the station drainage sump located adjacent to the unwatering sump. A 10-inch drainage header located above the draft tubes, plates 12-22 and 12-25, approximately at el. 535, and extending from unit 8 to the station drainage

sump would serve all main unit bays. An 8-inch drainage header located under the penstocks at the upper face of the powerhouse, approximately at el. 543, and extending the full length of the powerhouse would collect all drainage from the penstock area drains on the upstream side of the powerhouse. A series of headers would also be provided for all area and floor drains in the station-service area and the control house. In addition to picking up floor and gutter drains, provision would be made to carry drainage from turbine glands, compressor cooling water systems, and similar sources. Roof and deck drainage from the draft-tube side of the powerhouse would be carried directly to the tailrace.

The unwatering sump would be equipped with two unwatering and one sump pump. The unwatering pumps would be vertical-shaft, two-stage, mixed-flow propeller type, each rated at 3,000 g.p.m. against a 40-foot head, and driven by a 40-hp. electric motor. The pump suctions would be connected in parallel at the end of the unwatering header to form a closed system. A shutoff valve, operated from floor stands in the pump room, would be provided in each suction line. Another valve operated from a floor stand would drain the unwatering header into the sump so that incidental leakage during unwatered period could be handled by the 1,000-g.p.m. sump pump. The unwatering sump would be interconnected with the station drainage sump through a 10-inch overflow line to enable the unwatering sump pump to assist the station-drainage sump pump when abnormal drainage requires it. The sump would be sealed at the floor at el. 533 and vented to the tailrace above maximum tailwater. The sump pump in the unwatering sump would be similar to the unwatering pumps, but would be rated at 1,000 g.p.m. against 40-foot head, and would be driven by a 15-hp. electric motor. This pump was sized to handle the leakage from one unwatered main unit. The pump would be controlled by a float switch with a high-water alarm. The station drainage sump would contain a single pump, rated at 1,000 g.p.m. and otherwise similar to the same size pump in the unwatering sump. The gravity drain lines to the drainage sump would be provided with flap gates to prevent backflow. The pump would be float-controlled and be equipped with high-water alarm. The sump would be sealed at the floor at el. 533, with a vent extending above maximum tailwater.

All pumps would be vertical column, oil-lubricated type, with a below-grade discharge header and driver by vertical, hollow-shaft, squirrel-cage induction motors. The pump motors would be located at el. 551 in the station-service bay with the pump discharge header hung from the ceiling of the pump room below, at el. 547. The 1,000-g.p.m. pumps would be controlled by float switches, with a selector switch to permit manual control. The 3,000-g.p.m. pumps would be started manually but stopped automatically. The automatic control would stop the pumps before the water level in the header becomes low enough to admit air into the pumps. Each pump discharge line would contain a gate

valve and a check valve, and then a flexible section connecting the pump discharge to a common 12-inch header. The header would run to the tailrace and terminate with a flap gate at el. 560. All piping for the unwatering system would be steel. Area, floor, and equipment drainage pipes in 4- and 6-inch size would be cast iron, all other sizes would be steel. Roof drainage lines would be steel. Provision would be made for movement at all points where pipe crosses contraction joints.

(20) Treated Water.

(a) General. The powerhouse treated water system would be as shown schematically on plate 12-38. The water purification room located at el. 551 of the station-service bay, as shown on plate 12-24, would contain equipment to supply both filtered and potable water to units of the plant requiring it. Raw water would be obtained from the station-service unit penstocks. As no accurate analysis of the water was available, an average treatment consisting of neutralization, coagulation, filtration, and chlorination was assumed for planning.

(b) Filtered Water. Raw water would first pass through a duplex basket strainer after which it would be neutralized and coagulated by addition of soda ash and alum. Twin sand filters would filter the water. One of the filters could furnish the required maximum flow of 110 g.p.m. while the other is being backwashed. Of the 110-g.p.m. filtered water flow, approximately 64 g.p.m. would be used without further treatment for turbine gland cooling water.

(c) Potable Water. The remaining 46 g.p.m. of the filtered water would be treated further by chlorination. Chlorine would be injected as required by a flow controlled hypochlorinator. A 2,600-gal. storage tank would provide a 30-minute detention period for chlorination, and also provide a minimum reserve supply. The storage tank would be an air-cushion type, and the flow of air into the tank would be controlled by float operated controls to maintain a 115 p.s.i. pressure when the tank is fully charged. A low limit control would prevent the discharge of air into the water system. The potable water would be supplied to all drinking fountains, sanitary fixtures, showers, and service sinks. Pressure reducing valves would reduce powerhouse domestic water to 75 p.s.i. before distribution.

(21) Raw Water Systems.

(a) General. The raw water system for the powerhouse, shown schematically on plates 12-39 and 12-40, would consist essentially of an individual system for each main generating unit. A screened inlet in each main unit scroll case would provide the water at headwater pressure of 123 p.s.i. The intake lines would each contain a fine

mesh, duplex, basket-strainer to remove the solids which might pass the intake screens. Each pair of main units would be connected by a 6-inch tie line for flexibility. Further, the first four units would be interconnected through the plant heating supply and return headers. Water for the station-service generators would similarly be obtained from the station-service scroll cases with an additional connection to furnish raw water for air compressor cooling. Raw water from each main unit scroll case would be supplied to generator surface air coolers, generator thrust bearing oil coolers, turbine runner seals, turbine bearing oil coolers, transformer heat exchangers, transformer fire protection system, hose bibbs, and, during summer only, the water coils in the ventilation system. Raw water lines would normally discharge to tailrace. The static head at the powerhouse would be ample without pumping for all cooling water requirements. Pressure reducing valves would be provided as necessary. Available data indicate a maximum water temperature of 69° F. during the summer months.

(b) Quantities of Water Required. The estimated raw water requirements and pressures are summarized below. The generator and transformer requirements have been estimated from the averages for similar installations.

	Requirement g.p.m.	Pressure, p.s.i.
Generator air coolers, 8 units @ 1,000 g.p.m.	8,000	45
Generator thrust bearings, 8 units @ 100 g.p.m.	800	45
Transformer cooling, 8 heat exchangers @ 200 g.p.m.	1,600	13
Turbine runner seals, 8 units @ 80 g.p.m.	640	123
Turbine bearing coolers, 8 units @ 20 g.p.m.	160	45
Turbine packing glands, 8 units @ 7 g.p.m.	56	45
Transformer fire protection, 4 units @ 330 g.p.m.	1,320	123
Hose bibbs, 20 @ 10 g.p.m.	200	60
Ventilation system, 2 units @ 500 g.p.m.	1,000	90
Air compressors, 380 c.f.m. total @ 2.8 g.p.m./100 c.f.m.	11	60
Station-service units		
Generator cooling and bearings, 2 units @ 26 g.p.m.	52	75
Turbine glands, 2 units @ 4 g.p.m.	8	75
Total	13,847	

The maximum requirement would be slightly less than total shown as only one transformer fire system and only a few hose bibbs would be operating at any one time.

(c) Generator Cooling. Separate supply and discharge connections would be provided for generator air housing coolers and thrust bearing oil coolers. Flow meters of the indicating type would be provided in each supply line. The flow to the thrust bearing would be started and stopped automatically as the unit is started and stopped by means of a pneumatically operated gate valve in the supply line. Volume would be controlled by a manually adjusted globe valve in the discharge line. The air housing cooler flow would be controlled by a pneumatically controlled modulating valve in the discharge line which would respond to variations in air housing ambient temperature. Flow would be regulated to maintain a generator housing temperature of 35° C. (95°F). During normal operation the cooling water would be discharged to the tailrace. During the winter, when waste heat from either unit 1, 2, 3, or 4 would be used for powerhouse heating, the water from the unit would be recirculated, and only sufficient water would be released to tailrace to maintain a generator housing temperature of 40° C. (104°F.). The higher temperature setting would be required to provide water at a temperature high enough to insure adequate heat transfer to the air handling system. The discharge lines from generator air housing coolers would be at el. 564 within the draft-tube gate wells. The connection to the plant heating supply and return headers would be made at a manifold recess in the concrete generator barrel at approximately el. 570.

(d) Transformer Cooling. The two oil-cooling heat exchangers for each power transformer would be located beneath the transformer in the 551 gallery. Cooling water would be supplied from the 6-inch tie header between pairs of main generating units reduced to 13 p.s.i. before entering the heat exchangers connected in parallel. Each heat exchanger would have a raw water capacity of 200 g.p.m. The cooling water discharge from each pair of exchangers would be combined and discharged to the tailrace, at el. 560, through a 6-inch line. The system has been designed to maintain cooling water flows with maximum tailwater.

(e) Transformer Fire Protection. Each of the four power transformer vaults would be equipped with a waterfog system capable of delivering 330 g.p.m. The system was designed in accordance with the applicable provisions of NBFU Pamphlet No. 15, entitled "Water Spray for Fire Protection." Water for the system would be taken from the generator cooling water tie line between pairs of units, and would be conveyed at unreduced pressure through a 6-inch header and 4-inch branch lines to the automatic control valve in the equipment gallery, at el. 551, directly below each transformer. The 4-inch riser beyond the solenoid valve would be dry with an automatic drain valve to protect the system from freezing. The solenoid valve to discharge the waterfog would operate from the

transformer differential relay or from a remote manual switch. The valve would be reset manually to stop the fog system and drain the outside header. Each vault would be equipped with sixteen 3/4-inch fog nozzles which would deliver 21 g.p.m. each, at 80 p.s.i. nozzle pressure. The supply lines and branches were sized to deliver 80 to 100 p.s.i. at the nozzles with a minimum reservoir level and maximum pipe friction. Each nozzle would be equipped with an integral strainer.

(f) Air Compressor Cooling. Raw water for cooling the two high-pressure and two low-pressure air-compressors would be supplied at 75 p.s.i. from the raw water supply line to the water treatment facilities. The flow would be controlled by a solenoid valve in each supply line which would open and close automatically as the compressor starts and stops. Rate of flow would be controlled by a thermostatic modulating valve on the discharge line set to control jacket water temperature between 95° F. and 115° F. The cooling water would discharge through a funnel drain into the station drainage system.

(g) Ventilation System. During the summer months when it is desired to cool the air being circulated through the powerhouse, 500 g.p.m. of raw water would be circulated through the water coils of each of the two main air handling units. Water would be supplied from the raw water intakes of main units 1 and 2, and would feed directly into the heating and cooling system supply header, by-passing the generator coolers. The water would discharge through a return header directly to tailwater. During other periods, the raw water flow in this system would be considerably less than 500 g.p.m.

(22) Oil Systems.

(a) General. Complete and separate systems would be provided in the powerhouse to receive, store and transfer the light insulating oil for the power transformers, and the viscous lubricating oil for the generator thrust bearings, turbine guide bearings, generator brakes and jacking system, and in the governors. A third system would be located in the switchyard for handling circuit breaker insulating oil. Piping diagrams for these systems are shown on plates 12-41 and 12-42.

(b) Storage. Storage tanks for the powerhouse lubricating and insulating oil systems would be installed in the oil storage room in the station-service bay at el. 532, as shown on plate 12-25. All tanks would be horizontal, cylindrical steel tanks of 6,000 gal. capacity. Two tanks each would be provided for the clean insulating oil and for the dirty insulating oil, and separate tanks would be provided for the clean and for the dirty lubricating oil. The two circuit breaker insulating oil tanks in the switchyard,

one for clean and the other for dirty oil, would be identical to the other tanks in size, but would be installed on concrete saddles above ground. The tanks were sized on the basis of the best information available on the oil requirements for the various items of equipment. One clean lubricating oil tank would have sufficient capacity for all the oil required to fill the generator thrust bearing sump (2,000 gal.) and the governor system (2,500 gal.) of one main unit with an allowance for the oil for the turbine bearings and the supply header. Similarly, two 6,000-gal. insulating oil tanks would be sufficient to hold all the oil required to fill one main power transformer (10,200 gal.), the transformer oil cooling system (550 gal.), and the supply header (100 gal.). One 6,000-gal. tank in the switchyard would be sufficient to hold the circuit breaker insulating oil from one complete 3-phase circuit breaker (5,040 gal.), with an allowance for piping. All storage tanks would be equipped with breather vents. The vents on the outdoor tanks would be equipped with dehydrators.

(c) Transfer. Rotary transfer pumps for handling the oil would be located near the storage tanks in the oil storage room and the switchyard. Separate clean and dirty oil pumps would be furnished for both the lubricating and insulating oil systems in the powerhouse. In the switchyard, one transfer pump would handle both clean and dirty insulating oil. Each of the three insulating oil pumps would be rated at 50 g.p.m., 60 p.s.i., for oil with a viscosity of 150 S.S.U. at 50° F., and each pump would be driven by a 2 hp. electric motor. Each of the two lubricating oil pumps would be rated at 25 g.p.m., 60 p.s.i., for oil with a viscosity of 1,000 S.S.U. at 50° F. and each pump would be driven by a 3 hp. electric motor.

In the lubricating oil system, there would be a small pump at each main generating unit to circulate the oil from the turbine guide bearing sump to the bearings. This pump would also be used to lift the oil to the return header, at el. 562, in the equipment gallery, when the unit is drained. The operating pump would be driven by an a.c. motor, but a d.c. motor would also be provided for emergencies. In the insulating oil system there would be two centrifugal circulating pumps in each power transformer cooling oil system. These pumps would be located adjacent to the transformer heat exchangers in the equipment gallery at el. 551, beneath the transformer vault. Each pump was rated at 400 g.p.m. of 50° F. insulating oil against a total head of 36 feet. A 5-hp. motor would be required.

(d) Purification. Both types of oil would be purified in the powerhouse with a stationary oil purifier system consisting of a 7½-hp. pumping unit, a 72-kw. electric heater for the oil, a centrifuge with a 3-hp. motor, a filter press and a totalizing meter. The unit would handle insulating oil at 1,200

g.p.h., and the heavier lubricating oil at 600-g.p.h. A 1,250 watt drying oven for filter paper and a dielectric tester for checking insulating oil would complete the installation in the oil purification room.

A portable unit rated at 900 g.p.h. for insulating oil and 450 g.p.h. for lubricating oil would also be furnished. The portable unit would consist of a 5-hp. pumping unit, a 54-kw. heater, a centrifuge with 3-hp. motor, filter press, and a totalizing meter. The portable purifier would be used for the circuit breaker oil in the switchyard and for cleaning the oil in any powerhouse unit rather than changing the oil completely and cleaning with the fixed purifier.

(e) Piping. All oil systems were arranged so that the equipment may be drained by gravity to the dirty oil storage tank. Oil which could not be reclaimed would be pumped into a tank car or truck through the discharge connection on the 567 deck. Fresh oil would be delivered to the storage tank from the same point by gravity through a separate piping system. Oil in the dirty oil tanks which is to be reused would be circulated through the oil purifier with the purifier pump. The cleaned oil could be delivered directly to the equipment through the supply headers or to the clean oil storage tanks. Oil from the clean oil tanks could either be delivered directly to the equipment by the clean oil pump, or could be circulated through the purifier before delivery to the equipment.

All clean oil and circulating lines would be constructed of type L copper tubing with soldered fittings, and all dirty oil lines of black steel pipe. All piping would run exposed in the galleries and equipment spaces. Connections between steel and copper piping and fittings would be made up with insulating gaskets and bolt sleeves to minimize corrosion.

(23) Carbon Dioxide Fire Protection System.

(a) General. A fixed carbon dioxide system would be installed to protect the generators and the oil storage and handling facilities from fire. The system would consist of several banks of 75-lb. carbon dioxide cylinders, with necessary controls and accessories. The system is diagrammed on plate 12-43. Portable 15-lb. and wheel-mounted, 50-lb. carbon dioxide cylinders would be located at various points in the powerhouse for protecting other equipment.

(b) Main Generator Protection. One group of 22 carbon dioxide cylinders would be provided for each four main generators. The system has been designed to maintain a 25 percent concentration of carbon dioxide within the generator housing for at

least 30 minutes. This protection would be achieved by discharging 11 of the cylinders initially into the generator air housing through eight 7/16-inch diameter nozzles; and discharging the remaining 11 cylinders after a delay through eight 3/16-inch diameter nozzles. The system would be controlled automatically by thermostat detectors in the air passages of the generator, or by differential relays. Manual control would be provided by remote break-glass stations on the generator barrels. The carbon dioxide would be routed automatically to the proper unit by a valve controlled by the actuating devices. The two groups of cylinders, with frames, routing valves, and relay cabinets would be located between units 3 and 4 and between units 6 and 7 at el. 567, near the downstream wall of the generator room. A 2-inch pipe header between the two groups would provide adequate reserve capacity, as well as standby protection during maintenance and cylinder replacement. Provision would be made to de-energize the individual carbon dioxide system when personnel enter the generator air housing.

(c) Station-Service Generator Protection. One group of 4 carbon dioxide cylinders would be provided to protect the station-service generators. The group would consist of 2 main cylinders to be discharged one after the other and 2 reserve cylinders. Each generator air housing would be provided with two 7/32-inch-diameter initial discharge nozzles and one 7/32-inch delay discharge nozzle which would maintain a 25 percent carbon dioxide concentration within the housing for at least 30 minutes. The actuation and control of this carbon dioxide system would be similar to the system described for the main generators. The cylinders, frames, routing valves, and relay cabinet would be located in the equipment gallery at el. 551, near the station-service generators.

(d) Oil Storage Protection. The oil storage room and the oil purification room would each be provided with a separate carbon dioxide fire protection system. A single system for the two rooms was found uneconomical because of the great difference in room size. The systems were designed to supply 1 lb. of carbon dioxide gas per 18-cu. ft. of protected space, and would require 26 cylinders to protect the oil storage room and 8 cylinders for the oil purification room. Twenty-eight 5/16-inch nozzles are required in the oil storage room, and sixteen $\frac{1}{4}$-inch nozzles in the oil purification rooms. The systems would be actuated by ceiling mounted thermostatic detectors which would automatically energize the relay system upon a sharp temperature rise or at a temperature of 180° F. The relay would be a time-delay type which would sound an audible alarm for 30 seconds before discharging carbon dioxide. Pressure switches would be provided in the carbon dioxide headers to de-energize all electric equipment in the oil rooms and to close the doors and ventilation openings.

The two banks of cylinders would be located in the lower equipment gallery, at el. 543, opposite the first main generating unit and near the oil rooms in the station-service area at els. 532 and 533.

(e) Power and Piping. Direct current for the control relays for the carbon dioxide protection system would be supplied from the station emergency bus. All header and distribution piping, 3/4 inches and larger, would be steel pipe zinc coated inside and out. Cylinder manifold piping and the ½-inch headers on the station-service generator would be standard copper pipe. All fitting would be screw type.

(24) Heating and Ventilating System.

(a) General. The powerhouse would be heated and ventilated by a forced air circulating system as shown schematically on plate 12-44. Two large air handling units, located in rooms on the draft-tube deck, would circulate tempered air to all parts of the plant. A small fan would supplement the air circulation in the control house. The discharge water from the cooling system of the generators would provide most of the heat for the powerhouse. Electric resistance-type heaters located in the air supply ducts would provide additional heat where higher temperatures are required. Ventilation would be assured by two-speed roof ventilators in the generator room and by exhaust fans where else required.

(b) Water Use. Water for heating would be piped from any one of the first four main generators to the heat exchanger coils of the two main air handling units. Water at the rate of 500 g.p.m. at 78° F. would be supplied to each main air unit heat exchanger. The fresh air and recirculating air dampers of the air handling units would be thermostatically controlled by modulating controls to maintain the temperature of the tempered air at 68° F. Under the extreme conditions assumed for design, the heating water would return to the generators at about 72° F. If the temperature within the air housing should rise above 104° F. (40° C.), because of low demand on the heating system, a thermostatic element in the generator air housing would bypass a part of the recirculated generator cooling water to the river. The bypassed water would be replaced by cold water from the penstock. When a generator is placed on the plant heating circuit, the air housing temperature control would be reset automatically from 95° F. (35° C.) to 104° F. (40° C.) to heat the water sufficiently (to 78° F.) for efficient heat transfer in the water coil heat exchangers. In the summer, the heating and ventilating system may be used for cooling by circulating water from the penstocks through the air handling unit water coils.

(c) Design Criteria. The design criteria for heating and ventilating are tabulated below:

Outdoor conditions

Design minimum temperature	-25° F.
Design maximum temperature	90° F.
Design wind velocity	15 m.p.h.

Indoor temperatures (heating)

Control rooms and offices	70° F.
Locker and rest rooms	75° F.
All other spaces	60° F.

(d) Detail Design. It was calculated that, with a -10° F. outside temperature, 2,230,000 B.t.u./hr. would be required to maintain a 60° F. interior temperature, assuming a minimum fresh air intake of 12,800 c.f.m. One generator could supply about 3,200,000 B.t.u./hr., sufficient to maintain design conditions even if the fresh air intake were increased to 25,000 c.f.m. An additional 86,000 B.t.u./hr. required to raise the temperature of certain areas above the 68° F. supply air would be furnished by electric resistance duct heaters. The air circulation within the powerhouse would be divided into four zones as shown on plate 12-44 and described below:

Zone I - Drainage gallery, sump pump room, and oil rooms
Zone II - Generator room (el. 567)
Zone III - Equipment gallery and room (el. 551)
Zone IV - Offices, shops, and control room areas

Warm air for Zone I would be discharged by the two main air handling units downward into the equipment gallery at el. 551. Some of this air would circulate downward through floor vents and stairwells to the lower gallery at el. 543 and then to the drainage gallery at el. 538. Half of the air would be exhausted from the west (Unit 8) end of the drainage gallery by an exhaust fan, and the remainder would circulate through the sump pump and oil rooms before being exhausted by a fan in the oil storage room.

The air for Zone II would be circulated from the equipment gallery through the governor access piping tunnels and would be emitted into the generator rooms through the unit control boards and ventilation outlets. A portion of this air, ranging from a minimum of 7,500 c.f.m. to a maximum of 60,000 c.f.m., would be exhausted through the generator room roof ventilators. The remaining air would be picked up by return air registers, mounted on the downstream wall of the generator room, and returned to the air handling units through sheet metal ducts. Normally during the heating season the roof ventilators would be operated on slow speed and the number in operation reduced as the severity of the weather increased. A minimum exhaust of 7,500

c.f.m., the capacity of one ventilator at slow speed, would be maintained at all times. The operation of the roof ventilator fans would be controlled manually from local push-button stations on the generator room wall.

Air for Zone III would leave the equipment gallery through the cable spreading room, circulate through the equipment room at el. 551, and thence up the stairwell to the generator room and erection bay at el. 567. From here the air would mix with Zone II air for return or exhausting. About 750 c.f.m. of the gallery supply would enter the battery room and be exhausted by the battery room fan.

Air for Zone IV would be supplied from the equipment gallery through the cable spreading room to the intake of the number 3 air handling unit, located in the ventilation room at el. 557 of the control house. The air handling unit would be sized to handle about 6,400 c.f.m. and heat would be added to the air by duct heaters, before discharge to the locker and rest rooms, the offices and control areas, and the small rest room at el. 567. Approximately 2,150 c.f.m. of the air would be exhausted by a number of small exhaust fans in various areas, and the remainder would return through the hallway to the generator room, where it would join the Zone II circulation system.

(e) Equipment. The two main air handling units would each consist of an intake equipped with automatically controlled, modulating fresh air and recirculating air dampers, a viscuous type filter, a centrifugal fan rated for 62,000 c.f.m. at 1¼-inch static pressure and driven by a 20-hp. electric motor, and a water-coil, finned-tube heat exchanger rated for an output of 1,500,000 B.t.u./hr. when supplied with 500 g.p.m. of water at 78° F. The modulating dampers would be thermostatically controlled to maintain the temperature of the heated air discharged from the unit at 68° F. The fresh air intake dampers would be arranged to prevent complete closure, so that a minimum of about 6,500 c.f.m. of fresh air would be supplied to each unit at all times. The air units would not be equipped with humidifying coils, as a major function of the ventilating system would be removal of excessive moisture from the galleries for which dry air is needed. The small air handling unit for the control house area would consist of a centrifugal fan rated at 6,730 c.f.m. at 1-inch static pressure, and driven by a 2-hp. motor. This unit would be manually controlled from a local push-button station. The duct type electric resistance heaters would be controlled by duct thermostats to maintain the air temperature at the desired level. Exhaust fans would be located at various points throughout the plant to insure adequate air changes where needed. Locations have been selected to assist in maintaining a proper circulation of the heated air. The fans would be electric-powered, centrifugal, single-speed fans, except the roof ventilators which would be two-speed, axial-flow propeller type units. All fans would be manually controlled from local push-button stations.

(25) Powerhouse Cranes. Two 120-ton powerhouse bridge cranes would be provided in the generator room to handle generator and turbine parts and miscellaneous equipment during erection and repair, to untank the main power transformers, and to handle other heavy equipment as required. The capacity of the cranes has been established by the estimated weight of the generator rotor assembly, 185 tons. This value was the largest of the estimated weights for this assembly furnished by three major generator manufacturers in the United States. Each crane would be equipped with two trolleys. Both cranes and all four trolleys, equipped with the necessary lifting beams, would handle the generator rotor assembly. Each trolley would be equipped with one main hook rated at 60 tons, with a maximum lifting speed of 8 f.p.m., and one auxiliary hook rated at 25 tons, with a maximum lifting speed of 25 f.p.m. The auxiliary hooks would be used for handling small parts and subassemblies, and would have enough line to lower equipment to the pump and equipment room at el. 551. The motors for the hoists, bridge, and trolley travel would operate on 440-volt, 3-phase, 60-cycle power, supplied from the main station-service bus through a trolley feed rail. Each hoist would be equipped with an automatic load brake of the electrical type. Each hoist, bridge, and trolley motor would be provided with a spring set, electrically released, shoe type brake rated at 150 percent of the full load torque of the motor. The bridge would also be equipped with a hydraulic service brake to control its travel. All control equipment would be located in the operator's cab. Limit switches would control the upper hoist positions, and bridge and trolley travel. The elevation of the top of the crane rail has been tentatively set at el. 610.5 based on preliminary dimensions of the generator, generator rotor, turbine runner and shaft, and transformers. Plate 12-22 shows a crane clearance diagram, the assumed equipment dimensions, and the estimated weights of various items of equipment. The operator's cab and the trolley bus would be on the downstream side of the powerhouse. Access to the cranes would be by means of an access ladder and platform at each end of the generator room.

(26) Draft-tube Crane. The draft-tube crane would be of the fixed-hoist, traveling gantry type, with a capacity of 16 tons. Each draft-tube bulk-head section would weigh about 25,000 lb. and the lifting beam 1,000 lb. Since the bulkhead sections would always be handled under balanced head, only a small allowance was made for friction. Each draft-tube bulkhead would be in two sections, each approximately 7 feet high by 19 feet long. A lift of about 11 feet above deck was selected as adequate, since the gates would be transferred one section at a time. The hook travel would be sufficient to reach el. 537, or 30 feet below the tailrace deck, where it would grapple the lower stoplog section. Power would be supplied from the main station-service bus by 480-volt, 3-phase, 60-cycle circuits to conveniently located plug receptacles and thence to the crane through a flexible portable cable. The receptacles would be located approximately every 110 feet on the downstream parapet of the draft-tube deck. The

gantry would be equipped with a cable retrieving device to take up and pay out the cable as the gantry crane travels. Hoist and travel motors would be of the totally enclosed wound rotor type provided with spring set, electrically released brakes. The travel motor would also be provided with a hydraulic service brake. Both motors would be controlled from a push-button station mounted on a leg of the gantry at a point convenient to an operator standing on the tailrace deck. Controls would permit either full speed or inching movement. Limit switches would control the upper position of the hoist and limits of gantry travel. The crane rails would be heavy section crane of railroad type mounted flush with the deck. The rails would also be used to transfer the main power transformers from the vaults into the powerhouse.

(27) Maintenance Shops. A maintenance shop, combining the facilities of a machine and electrical shop, would be provided at el. 567 of the control house adjacent to the powerhouse erection area as shown on plate 12-23. The maintenance shop would have an area of about 2,100 sq. ft. and would provide space and facilities for minor repairs and overhauling of equipment for the dam and powerhouse. The maintenance shop area would be separated completely from the offices and control rooms at the same level by a concrete wall without openings which would prevent the noise and dust of the shop from invading the control room. A list of equipment normally provided for a shop of this nature follows.

Bench lathe	10 by 48 in.
Shaper	24 in.
Radial drill	36 in.
Power hacksaw	9 by 9 in.
Drill press (floor)	21 in.
Drill press (bench)	14 in.
Pedestal grinder	10 in.
Bench grinder (2)	7 in.
Arbor press	75 ton
Portable pipe threader	¼ to 3 in.
Portable pipe threader	3 to 8 in.
Welding machine	300 amp.

Benches, power outlets, service air and water, electrical test panels, and other items would be provided at convenient locations in the shop area. A forklift truck or caster-mounted floor-crane would be provided for handling equipment. As also shown on plate 12-23, a separate meter room would be provided near the control room for repair and maintenance of electrical instruments.

(28) Elevator. One combination passenger and freight elevator would be provided in the control house adjacent to the erection bay, as indicated on plates 12-24 and 12-25. The elevator would be

equipped with doors at both ends of the car for access to either the powerhouse or the control house, and would serve els. 533, 551, and 567 in the powerhouse, and els. 551 and 567 in the control house. The elevator would be a geared traction type and have a capacity of 5,000 lb. and a speed of 150 feet per minute. The machinery would be located in a machinery room on the roof of the control house at el. 583. Controls would be fully automatic push-button type. The elevator would be used mostly to move small equipment from the gallery and equipment levels of the powerhouse to the machine shop level. The heaviest single unit to be handled by the elevator would be the portable insulating oil purifier which would be stored in the oil purification room at el. 533.

(29) Plumbing. The plumbing schematic is shown on plate 12-37, "Unwatering, Drainage, and Sewer Systems," and on plate 12-38, "Treated Water System." The main toilet facilities for plant personnel would be located in the locker room on the lower level of the control building at el. 551 as shown on plate 12-24. The room would be equipped with four water closets, three urinals, four lavatories, two stall showers, and a drinking fountain. A 40-gallon storage tank with a 13-kw. electric heater element would be installed adjacent to the locker room to supply the 52-g.p.h. hot water demand. Kitchen and toilet facilities would also be provided for shift operators and supervisors adjacent to the control room at el. 567, as shown on plate 12-23. The facilities would consist of a lavatory, water closet, urinal, and kitchen sink. A drinking fountain would be located in the control room. An additional water closet and lavatory would be provided in the first aid room at el. 567 of the control house.

Service sinks would be provided in both the janitor's closet and the ventilation equipment room in the control house. An acid resistant service sink would be provided in the battery room in the equipment gallery at el. 551 near unit number 4.

Drinking fountains will be provided throughout the plant; two in the generator room at el. 567, one in the equipment room at el. 551 of the station-service bay, and one each in the machine shop and the corridor of the control building at el. 567.

All toilet facilities would drain by gravity to the septic tank at about el. 545. Service sinks, drinking fountains, shower, and floor drains will drain by gravity to the station drainage sump at el. 515. Supply piping would run concealed above suspended ceilings in the control room areas and exposed in the equipment galleries. Hot water lines would be gravity circulating with return line and would not be insulated. Sanitary and station-service lines would be cast iron soil pipe embedded to the greatest practical extent.

The septic tank would consist of a two compartment concrete tank in the station-service area below el. 551. Sewage treatment would consist of 24-hour detention in a settling compartment, and chlorination in a second compartment. Two sewage pumps controlled by high and low level float switches would pump the effluent to the higher water levels of the tailrace. The pumps would also pump the sludge from the settling compartment when required. The septic tank would be designed for 27 persons, the expected load during construction, but 3 times the load during normal operation of the project.

g. Switchyard

(1) Location. The switchyard would be located on the right bank of the tailrace, as shown on plate 12-3, at el. 635, approximately 700 feet from the powerhouse. The location would provide the most favorable take-off angle for the 230-kv. aerial connection between the powerhouse and switchyard. The site would be excavated to grade and the excavated earth and rock would be used to construct the dam across Saint John River.

(2) Switching Arrangement. The general switching arrangement, selected as previously described, is indicated on the main one-line diagram, plate 12-26. As indicated by the plan on plate 12-45, a main and a transfer bus would extend the full length of the switchyard. Each transmission and powerhouse line would connect to the main bus through an oil circuit breaker and to the transfer bus through a motor-operated disconnect switch. Two bus-tie breaker bays, one at each end of the switchyard, would facilitate maintenance and satisfy certain operational switching requirements. The main bus would be sectionalized by two motor-operated disconnect switches, located midway of the switchyard. This switching arrangement would permit the feeding of any one or a combination of lines from any one or a combination of transformers. Any of the breakers could be repaired without disrupting the power flow by using the transfer bus and a bus-tie breaker. All relay action controlling the circuit breaker normally in use would become effective on the relief breaker.

(3) Layout. The switchyard would be of the extended ground type construction, plate 12-45, which is preferred for 230-kv. switchyards, provided sufficient area is available. This type is characterized by low, flat construction with buses, disconnecting switches, and take-off towers supported on individual footings. The layout would provide separate bays for each of the four powerhouse feeders and the three transmission lines, and in addition, two bus-tie bays. All bays for like services would be similar in arrangement and equipment used. The layout would permit removing and replacing of any major piece of equipment without disturbing the other equipment. All circuit breakers and motor-operated disconnecting switches would be remote-controlled from the main control room in the powerhouse. Underground conduit

would extend from the circuit breakers, disconnect switches, current transformers, potential devices, coupling capacitors, etc., to a 5- by 7-foot tunnel running lengthwise of the switchyard. A duct bank would be used to connect the tunnel with the powerhouse. All secondary electrical circuits would be routed to the powerhouse through the tunnel on cable trays and then by ductline to the control room where the controls and relays would be located.

(4) Structural Steel. Overhead structures would be fabricated from structural steel and would consist principally of towers for terminating transmission lines, transformer lines, overhead ground wires, and for supporting rigid buses. Bus conductors would be supported by individual columns. Switches would be mounted on raised latticework steel frames. Concrete footings would be used. The switchyard would be designed for heavy loading. All conductor and equipment clearances would be sufficient to assure safe continuous operation.

(5) Tunnel. A 5- by 7-foot tunnel, with top at switchyard ground level, would extend the length of the switchyard, 8 feet from the centerline of the oil circuit breakers. The tunnel would be constructed of reinforced concrete having 12-inch walls, roof, and floor. Conduit, cable trays, oil piping, electrical equipment, and circuits would be located in the tunnel. Access would be by covered stairway located near the center of the switchyard. Manholes with hinged weathertight covers would be located in the tunnel roof at alternate bays. A ventilating fan would be provided in the stairway kiosk.

(6) Cable Duct. Power and control circuits between the powerhouse and switchyard would be run in a 3- by 4-foot duct bank. The duct bank would consist of thirty 2-inch fiber ducts encased in a concrete envelope. Pull boxes and manholes would be provided as required for cable installation.

(7) Grading and Fencing. The yard would be graded level to el. 635 and covered with 6 inches of crushed stone or gravel. The switchyard would be enclosed by a chain link fence, with 6-foot high posts anchored in concrete. The enclosed space would provide 10-foot cleared areas along each side and 30-foot work areas at each end.

(8) Buses. The buses would be constructed of tabular aluminum, rigidly supported on pedestal insulators mounted on steel columns. This arrangement results in uniform bays, provides adequate supports, and presents a symmetrical appearance. Two-inch i.p.s. standard aluminum tabular conductor would be used for all buses except for the transfer bus, the main bus, and the horizontal portion

of the tap connections to the main and transfer bus at each bay. These portions would be of 3-inch i.p.s. standard aluminum pipe to provide additional structural strength for the longer spans. Centerline spacings would be 11 and 13 feet respectively, for longitudinal and transverse buses. The buses would not sag more than one conductor diameter under heavy loading conditions. Slide-bus supports and flexible connectors would be used where necessary to provide for thermal expansion.

(9) Oil Circuit Breakers. Oil circuit breakers would be of the pneumatic operated type, rated 1,200 amperes continuous, 3-cycle tripping time, and 5 million-kv.-a. interrupting capacity. Each breaker would be equipped with self-contained air compressor and receiver. The compressor motor would be driven by a 440-volt motor and automatically controlled to maintain the proper operating air pressure. Breakers would have bushing type current transformers as required for metering and for relay protection. The breaker would be mounted and bolted to a concrete pad. The breakers would be controlled by d.c. circuits from the main powerhouse control room.

(10) Disconnecting Switches. Disconnecting switches would be gang operated, 3-pole, nonload break, rated at 1,200 amperes continuous, and provided with arcing horns. The contact-making mechanism would give a rolling action to insure good contact between the movable and stationary portions of the switch. The switches would be mounted on a lattice type steel framework, 20 feet high, to give adequate clearance for maintenance and operating activities. All disconnecting switches connected to the transfer bus would be motor-operated and controlled from the main powerhouse control room. The remaining disconnect switches would be operated manually from the ground to isolate breakers. Ground switch blades would be provided on those disconnect switches connected to the powerhouse and transmission lines. All switches and breakers would be interlocked, both electrically and mechanically (key) to assure proper sequence of operation.

(11) Lightning Arresters. Lightning arresters would be provided on each phase of the transmission lines. They would be of the self-supporting, thyrite, single-pole, outdoor-station type and rated at 195 kv.

(12) Potential Devices. A line-to-ground coupling capacitor with a potential device would be connected to each transmission line conductor. The potential from these devices would be used for synchronizing, metering, and relaying. These same coupling capacitors, in conjunction with wave traps, would connect the carrier current circuits to the lines. Similar line-to-ground coupling capacitors with potential devices would be connected to the same phase conductor

of the main bus and the transfer bus. The single phase potential from these devices would be used for synchronizing to the buses.

(13) Lighting. The switchyard lighting system would be fed from a 3-phase, dry-type 30-kv.-a. transformer located in the switchyard tunnel. The lighting would consist of substation type lighting units of two piece prismatic glass refractor construction for illuminating disconnecting switches and other equipment above ground. A prismatic bottom diffuser on the luminaire would provide ground illumination. The luminaires would be mounted on steel structures.

(14) Power. Two 480-volt, duplicate-feeder, power circuits, would run from the powerhouse to a power distribution panel in the switchyard tunnel. Power receptacles (480-volt, 3-phase), would be installed in alternate bays near the circuit breakers for maintenance work.

(15) Buried Grounding. The switchyard grounding system, shown on plate 12-34, would consist of an interconnected network of copper conductors throughout the switchyard and connected to the station ground mat by two 500 M c.m. copper cables. Connections would also be made to the overhead grounding wires and to the powerhouse ground buses. Ground currents would be conducted to earth through the ground mat in the switchyard and the station ground mat located in the river bed below water level and covered by the toe of the dam. The switchyard ground mat would consist of a network of bare copper cables arranged to form a grid and supplemented by 3/4-inch by 10-foot copperweld ground rods driven at points of intersections. Cables would be brazed to the ground rods to insure good contact. Structural steel would be grounded to the mat at each separate footing. Circuit breakers, potential devices, lightning arresters, fences, and all such equipment would be grounded to the switchyard mat by direct copper connections.

(16) Overhead Shielding. An overhead static network of galvanized steel cables would be installed over the switchyard proper as a protection against direct strokes of lightning. This network would be supported by steel towers as shown on plate 12-45. A copper cable connected to the network at each tower would extend down and connect to the buried ground mat.

(17) Insulating Oil System. Provisions would be made in the switchyard to handle, store, and purify the oil of the circuit breaker. This system is described in paragraph 12-11 f (22) of this appendix.

h. Lands and Damages. The estimate, given in appendix 17, of the cost for lands and damages which would be required for the dam and reservoir is based on a gross appraisal made specifically for the study being considered in this report. The appraisal classifies the land involved as well as the improvements. Value of standing timber is included in the estimated land values.

i. Clearing. It is planned that the reservoir would be cleared below el. 818 which is 5 feet below the limit of drawdown in accordance with the practice at Corps of Engineers reservoirs in the United States. This amount of clearing also conforms to the requirements of the laws of the State of Maine, as cited in "Correspondence" with this appendix. No cost is indicated in appendix 17 for this clearing because it is expected that this work could be accomplished in return for the right to remove all marketable timber and pulpwood in the reservoir area.

j. Access. Access to the Rankin Rapids project, both during construction and after completion, would be from St. Francis, Maine. The Bangor and Aroostook Railroad, with connections to both United States and Canadian railroads, extends upstream along Saint John River to terminate at St. Francis which is 3.6 miles downstream from the Rankin Rapids project. Maine Highway 161 reaches St. Francis from Fort Kent, 15 miles downstream, where there are connections to State Highways 11 and 161 to the south, U.S. Highway 1 to the east, and by bridge across Saint John River with New Brunswick Highway 20. From St. Francis, Maine Highway 161 extends upstream to the Rankin Rapids site and about 10 miles beyond the vicinity of Dickey, Maine. Downstream from the dam site, is a third-grade road paved with bitumin and gravel. In view of the large amounts of heavy equipment and material which would need to be transported from the rail head to the project site, studies were made to determine whether highway transport or an access railroad would provide this service at least cost. These studies indicated the cost of an access railroad would be approximately the same as the combined costs of constructing a heavy duty highway from the railhead to the site and the rehandling charges on the equipment and material transported. On the basis that railway access would facilitate operation and maintenance of the project to a greater extent than a highway, and because a heavy duty highway would serve no nonproject use other than served by the existing road system, an access railroad was selected. The railroad would parallel Maine Highway 161 to the site, where it would be extended to the erection bay of the powerhouse as shown on plates 12-3 and 12-23.

APPENDIX 12

CORRESPONDENCE

C O P Y

MEMORANDUM FOR THE RECORD, NEW ENGLAND DIVISION, CORPS OF ENGINEERS

SUBJECT: Flood Damage - Saint John River, Maine

FROM: K. B. Woodworth,
Civil Engineer

9 July 1958

1. Records of flood damage on Maine portion of Saint John River in the reach that could be benefited by the Rankin Rapids project are sparse. The gaging station just downstream from Fort Kent, Maine shows the flood of May 1953 as the maximum discharge of record, 121,000 c.f.s., crest 25.0 feet. An ice jam flood in March 1936 produced stages as high or higher than the 1933 flood. Although newspaper articles stated that the principal damage center in both of these floods was in Fort Kent, Maine, no estimate of actual damage is available. Damages were also sustained by the railroad and highway in the reach between Grand Isle and Van Buren. It is probable that the damages occasioned by the floods of May 1933 and March 1936 were not as extensive as that occasioned by the April 1958 flood because during these floods the ground was still frozen and there was little if any seepage.

2. The estimated direct damage to properties, business establishments, utilities, etc., in the Fort Kent area caused by the flood of 25 April 1958 was $139,200. This 1958 flood crested at 24.73 feet and flooded about a mile of the Fort Kent business district. There were 46 stores, 55 homes, a school, a church, the town hall, post office, fire station and a utility building affected by the flood. A substantial portion of the damage was caused by seepage, the balance was caused by water entering the first floor through doors and windows, by water flowing through the streets at a depth from one to four feet, and by pressure on basement floors and walls.

3. As indicated, the direct damage was $139,200; and although neither time nor funds were available for a thorough investigation of associated or indirect damages, a conservative estimate based on prior damage evaluations places the associated damage at $71,300 or a total of $210,500 for direct and associated damage. While it is true that no actual damage survey was made in either 1933 or 1936, it is known that the damage in those two years was less due to frozen ground. If we assume that the damage for 1933 as 75% of 1958 and damage for 1936 as 50% of the 1958 storm, we are probably conservative. The following table indicates values thus obtained. (1958 price levels.)

C O P Y

SUBJECT: Flood Damage -- Saint John River, Maine

Year	Estimated Direct Damage	Estimated Associated Damage	Estimated Total Damage
1933	$104,400	$ 53,400	$157,800
1936	69,600	35,600	105,200
1958	139,200	71,300	210,500
TOTALS	$313,200	$160,300	$473,500

4. On the basis of the above damages the average annual direct loss would be about $12,500, associated loss $6,400 and total loss $18,900.

5. There is no doubt that construction of the Rankin Rapids project would have a beneficial influence upon flood stages at Fort Kent since a large portion of the spring runoff from 4,060 square miles of the upper Saint John can be stored.

/s/ K. B. WOODWORTH
Civil Engineer

C O P Y

MEMORANDUM FOR THE RECORD, NEW ENGLAND DIVISION, CORPS OF ENGINEERS

SUBJECT: Flood Damages, Fort Kent, Maine

FROM: Mr. Woodrow Boucher, Construction Analyst

1. On my recent visit to Fort Kent, Me. for the purpose of evaluating the damages caused by the flood of April 25, 1958 on the St. John River. It has been established that the flood of 1933 was the flood of record water elevation at the station, 25.0'. The flood of April 1958 crested at 24.73'.

2. The damages of 1933 were not as substantial as that of 1958. Due to the fact that in 1933 the ground was still frozen and there was less seepage. Mostly all of the stores were flooded by seepage except for a few that at the crest, water was entering from doors or windows. A great deal of seepage could be regulated with proper construction of foundation walls and flooring although some of the good floors gave out due to pressure.

3. The water flowed across Main St. East of the Masonic Home to a depth of 12" to 14", and filled a hollow in the rear of Main St. to a depth ranging from 1' to 4', after the river receded. The hollow remained filled. There was no outlet to the River. The Town used an irrigation pump to drain most of it. The grounds are saturated with water. Incidently, 2 weeks later, 10 stores had water in their cellars even with continuous pumping.

4. The amount of damage caused by the flood is estimated by the writer to be $139,200.00. Affected by the flood were 46 stores, 55 homes, 1 school, 1 church, town hall, post office, fire station, and 1 Utility building. The majority was cellar flooding. One building on Audibert St. with six small apartments with no cellars, had 22" on the first floor. Eight more buildings had water ranging from 4" to 18" on their first floor. Most of these stores and homes are troubled every year by seepage. Also a source of the trouble was caused by sewerage backing up.

5. In the plus stage 15 more stores and 18 more dwellings would be affected to the extent of 1 to 2" on the first floor.

6. Minor shut-down affected the Page Starch Company and Charcoal plant on the Fish River. The town garage had 1' of water on its floor. The town reported no damage.

Woodrow BOUCHER
Construction Analyst

C O P Y

DEPARTMENT OF NORTHERN AFFAIRS
AND NATIONAL RESOURCES

SAINT JOHN RIVER ASSESSMENT OF FLOOD DAMAGE

24 April 1958

BASIN:

Saint John River Basin is situated in Maine, Quebec and New Brunswick between the Penobscot River to the South, the St. Lawrence River to the North and numerous coastal streams to the East. It is approximately 450 miles long and has a drainage area of some 21,600 square miles of which 7,600 square miles are situated in the State of Maine, 2,750 square miles are situated in the Province of Quebec and 11,250 square miles in the Province of New Brunswick.

GENERAL:

Floods are not a serious problem in the Saint John River Basin. Natural storage in the headwaters, heavy forestation in the upper two-thirds of the watershed and the wide deep-banked channel characteristics of the main river combine to minimize flooding. However, heavy spring rains occurring when snow is melting and river ice breaking up can cause overbank flow. Soil erosion on portions of the cropland where no protective measures are taken is a serious problem. Riverbank erosion on the main stem and on a large percentage of the tributaries is very minor indeed.

FLOODS:

Records of flood damage are sparse, but it is generally conceded that the worst flood occurred in 1887. Since that time the flood of May 1923, which approached to within inches of the mark established in 1887, and the ice jam flood of March 1936 have caused extensive damage in the Province of New Brunswick and the State of Maine. The ice jam flood in March 1936 appears to have caused the greatest loss on the upper Saint John. The principal damage center was Fort Kent which experienced some four feet of water in parts of the town. No estimate of monetary damage is available. Bank erosion and overbank flooding were experienced at scattered points between Madawaska and Van Buren, Maine.

C O P Y

The record flood on the Aroostook River occurred in 1923, when the business district of Fort Fairfield was flooded. The flooding of this town has been caused by ice jams or high discharge or a combination of both and this record flood of 1923 has since been approximated three times owing to ice backup with moderate flows.

This flood of 1923 completely carried away the hydro plant on the Meduxnekeag River supplying the town of Woodstock, New Brunswick while on the Aroostook River the water covered the floor of the Maine and New Brunswick Electric Power Company's plant to a depth of twelve inches. There was a short interruption in service. At Fredericton, New Brunswick the railroad bridge spanning the Saint John River failed. It is generally conceded that from the stand point of widespread severity and financial loss, this flood was the worst ever experienced in New Brunswick.

Only generalized estimates of the source of floods on the upper Saint John River are possible from the data on hand. It appears, however, that the largest contributors to floods at Fort Kent are the upper Saint John River above Dickey, Maine and the St. Francis River, though the latter is dampened considerably by natural storage areas. The flow of the Allagash River which enters the Saint John River just downstream from Dickey, shows the effect of considerable lake storage in its headwaters, which substantially reduces its contribution of flood flows on the Saint John River. The Fish River run-off is considerably influenced by the large lakes in its drainage area with the result that flood peaks for this tributary are low and long. The Madawaska River, entering from the northwest at Edmundston, New Brunswick, also has considerable natural lake storage in its upper and middle reaches which dampens out excessive peak discharges thus tending to reduce its flood producing potentialities. The Tobique and Aroostook Rivers, on the other hand, lack these extensive natural storage areas, particularly in their middle and lower reaches, and therefore contribute substantially to peak flood flows on the lower Saint John River. Damaging flood stages along the Saint John River are more often caused by ice jams than by high rates of flow. This condition complicates the evaluation of the flood potentiality of the basin, as it is not practicable to determine from available records the tributary contributions to an ice jam.

C O P Y

May 1, 1958

FISHERIES IN THE LOWER ST. JOHN RIVER

The Commercial Fisheries in the tidal waters of the River, that is from its mouth to just above Fredericton are controlled by the Department of Fisheries of Canada. They are principally salmon, shad, sturgeon and bass, and are generally caught by set nets. The owners of these set nets pay a fee of $1.00 a year and must be the owner of the shore adjacent to the waters in which the net was set. There would possibly be about 75 to 100 set nets in the lower reaches of the River, and their annual catch is estimated at $500.00 per year each.

Possibly the only species that would be affected by dams in the upper reaches of the River would be salmon. On the main river, the natural barrier to salmon is Grand Falls, above which no salmon exists. One of the favorite spawning grounds of the salmon is the Tobique River. In 1952, the N.B. Hydro-Electric Power dam was placed near the mouth of the River where it joins the St. John. Incorporated in this dam was a very elaborate and modern fishway.

By actual count the number of salmon passing the Tobique dam for each year since it was built is as follows:

1953 - 4,656
1954 - 4,986
1955 - 3,775
1956 - 3,724
1957 - 595

The figure for 1957 is hardly a sixth of what passed through it the year previously. This is blamed mostly on the obstruction of the Beechwood Cofferdam.

However, in 1957 - 1,127 salmon passed over the Beechwood dam. Apparently less than half of these went up the Tobique. Besides the Tobique as a spawning ground, there is the Salmon River just below Grand Falls, a favorite haunt of the salmon.

Licenses to fish salmon in the upper reaches of the St. John River, that is from Fredericton north, is under the control of the Provincial Government.

C O P Y

The revenue from licenses in this area is estimated at $12,000.00 per year. Besides the actual revenue from the licenses, the investment in boats, camps, equipment, etc. is a fairly heavy investment and is roughly estimated at about $150,000.00. The combined value of the Commercial and Sporting fisheries in the St. John River is estimated at about $50,000.00 per year. Besides these figures the wages paid help, caretakers and wardens annually is considerable.

Just what effect the dam at Crock's Point would have on the salmon run is difficult at present to say. No doubt another year or two's statistics of the salmon passing Beechwood and Tobique dams would enable us to make a fairly concrete estimate.

C.D.McAllister,
Engineer, D.P.W.

C O P Y

MEMORANDUM FOR THE RECORD, NEW ENGLAND DIVISION, CORPS OF ENGINEERS

TO: Chief, Legal Branch DATE: 26 February 1958

FROM: Chief, Passamaquoddy Survey Division

SUBJECT: Legal Requirements for Dams and Transportation on the upper Saint John River

1. In connection with the study of the international Passamaquoddy tidal power survey, investigations are being conducted on three river hydro sites on the upper Saint John River for purposes of obtaining river hydro power to firm up tidal power. In this connection two questions have arisen where the legal opinions may affect the design and estimates being prepared.

2. The first question is the effect of the Mill Act (?) of 1905 which, it is believed, requires that all storage reservoirs be cleared. If this is still in effect, will it be enforced on the Federal project?

3. The second question involves the boundary treaty between His Brittanic Majesty and the United States of 9 August 1842. This treaty provides the use of the Saint John River by United States citizens where Canadian land lies on both sides of the river and similarly, it provides use of the Saint John River to Canadian citizens in areas where the river is entirely in the United States and can be used as a waterway between two areas of Canadian territory. Particular reference is made to the necessity of providing a sluiceway for logs on any dam that might be built upon the upper Saint John River. The headwaters of the Saint John are in Canada and it then flows through the United States and into Canada again and it has been the practice of some Canadian owners to run logs and pulpwood down the Saint John River through the United States areas.

/s/
R. D. FIELD
Chief, Passamaquoddy Survey Division

C O P Y

NEDVL-13 (26 Feb 58) 1st Memo Ind MR. VOTOLATO/feb
SUBJECT: Legal Requirements for Dams and Transportation on the upper Saint John River

Chief, Legal Branch, 14 March 1958

TO: Chief, Passamaquoddy Survey Division

EFFECT OF THE "MILL ACT"

1. The statute in question is found in Revised Statutes of Maine, 1954, Chapter 141, Section 16, and provides as follows:

"Sec. 16. Bushes, trees and stumps removed from area flowed by dam erected on public water. - Whoever hereafter erects a dam on any of the public waters of this state shall, within 3 years after a head of water is held and flowage created thereby, remove from the flowed area all trees, bushes and stumps that he can legally remove therefrom, to such an extent that the tops of all trees, bushes and stumps left thereon shall be at least 5 feet below the surface of the mean low-water level maintained during the period beginning June 1st and ending December 1st next following of each year and shall within said 3-year period remove such growth as he can legally remove from the edge of the flowed area to such an extent that no dri-ki and debris shall form to be carried away by the water; and for the purpose of protecting the right of the public in the navigation of the waters over said flowed area the owner of such dam shall, after the creation of flowage thereby, have the right to cut and remove from the flowed area all trees, bushes and stumps remaining thereon, and the damage to the owner thereof caused by such removal shall be ascertained in the same manner as is provided for the ascertainment of the damages caused by the flowage.

"Any dam erected hereafter which is maintained in violation of the provisions of this section shall constitute a public nuisance, and be subject to the provisions of section 15.

"This section shall not apply to dams which are created solely for log driving purposes where the water is stored for not exceeding 3 months of each year, nor shall the same be interpreted in any instance to require the removal of stumps below the swell of the roots. (R.S. C.128, Sec. 14)."

2. The above statute is still in force and forms a part of the so-called "Mill Act" of the state of Maine.

3. The question asked is whether the "Mill Act" can be enforced against the federal project with respect to the requirement for the clearing of storage reservoirs.

C O P Y

4. There has been no adjudication of this specific point, but when applied to the St. John River, it would seem that the subject statute is unenforceable against the federal government.

5. In 45 Corpus Juris 419 (Sec. 19) the following principle is stated:

"By virtue of the commerce clause of the federal constitution and the clause empowering congress to make all laws necessary to carry into execution the federal judicial power in admiralty and maritime matters, "navigable waters of the United States," which include waters over which by themselves or in connection with other waters commerce may be carried on between states or with foreign countries, and of which admiralty has jurisdiction, are under the control of Congress which has power to legislate in regard thereto so far as commerce is concerned. While this power is limited to control of the waters for purposes of navigation, it is a sovereign and supreme power within its appropriate sphere of action, and it is not lost or weakened by reason of previous inaction or acquiescence by congress in the exercise of authority by a state, but the federal power, when and to the extent exercised, is exclusive of state authority..... It is for congress to determine when and to what extent its power shall be brought into activity, and it may be exercised through general or special laws. The power of Congress extends to the whole expanse of a navigable stream and is not dependent on the depth of the water; also it follows natural changes in the channel or banks and is not limited by former conditions."

6. It is well-established that in determining whether Congress has occupied any field of legislation, the test is, not whether the state legislation is in conflict with the details of the federal law or supplements it, but whether the state has any jurisdiction of a subject over which Congress has exerted its exclusive control, and where the federal legislation evidences an intention to cover the whole field, state legislation, although consistent, is inoperative.--State v. Atlantic Coast Line R. Co., 81 Fla. 168, 87 So. 773; State v. Missouri Pac. R. Co., 323 Mo. 653, 19 S.W. (2nd) 879; Minneapolis, etc. R. Co. v. Railroad Commn., 183 Wis. 47, 197 N.W. 352.

7. In Hirschi v. U.S., 67 Ct. Cl. 637, 642, it was stated, "Where the constitutional powers of the Federal Government and the states conflict, those of the states must give way."

8. Since the St. John River is a navigable stream and since Congress has exclusive constitutional control with respect to commerce and navigation over such navigable streams, it follows that the statute in question, as applied to federally-constructed dams in the said St. John River, is inoperative.

C O P Y

9. However, as a matter of practical consideration, it might be well to consult with local officials concerning the proposed project in the interests of avoiding possible misunderstanding of the Government's position.

TREATY OF AUGUST 9, 1842

1. The treaty of August 9, 1842, between the United States and Great Britain, commonly known as the "Webster-Ashburton Treaty," provides in part as follows:

"In order to promote the interests and encourage the industry of all the inhabitants of the countries watered by the River St. John and its tributaries, whether living within the Province of New Brunswick, or the State of Maine, it is agreed, that where by the provisions of the present Treaty, the River St. John is declared to be the line of boundary, the navigation of the said river shall be free and open to both parties, and shall in no way be obstructed by either; that all the produce of the forest, in logs, lumber, timber, boards, staves, or shingles, or of agriculture, not being manufactured, grown on any of those parts of the State of Maine watered by the River St. John or by its tributaries, of which fact reasonable evidence shall, if required, be produced, shall have free access into and through the said river and its said tributaries having their source within the State of Maine, to and from the seaport at the mouth of the said River St. John, and to and around the falls of the said river, either by boats, rafts, or other conveyance; that when within the province of New Brunswick, the said produce shall be dealt with as if it were the produce of the said province; that in like manner the inhabitants of the territory of the upper St. John, determined by this Treaty to belong to Her Britannic Majesty, shall have free access to and through the river for their produce in those parts where the said river runs wholly through the State of Maine:--provided always that this agreement shall give no right to either party to interfere with any regulations not inconsistent with the terms of this Treaty which the Governments, respectively, of New Brunswick or of Maine may make respecting the navigation of the said river, where both banks thereof shall belong to the same party."

2. The Webster-Ashburton Treaty is still in force, but a search of the cases and authorities reveals no adjudication or interpretation of the Article in question.

3. In the absence of such adjudication or interpretation, it would seem that the practice by Canadian owners of running logs and pulpwood down the Saint John River is sanctioned by the Treaty, and that the design of any dam upon the upper Saint John River should take this fact into consideration.

/s/ F. V. BONZAGNI
Chief, Legal Branch

C O P Y

THE NEW BRUNSWICK
ELECTRIC POWER COMMISSION

May 16, 1958

PLEASE REFER TO
OUR FILE: 3-333
Passamaquoddy
X ref: Rankin Rapids

Mr. R. D. Field,
Chief, Passamaquoddy Survey Division,
Corps of Engineers, U.S. Army,
Office of the Division Engineer,
150 Causeway Street,
Boston, 14, Mass.

Dear Mr. Field:

At our sub-committee meeting of February 24th and 25th, 1958, in Saint John, I agreed to obtain data on the effects future development of the Saint John River would have on timber operations and wildlife.

After some unavoidable delay I have received from Mr. K. C. Irving some preliminary points which I list:

"The extent to which our timber operations would be affected by such development will vary greatly depending on which of the power plant or plants are built.

1. The building of the Rankin Rapids plant would cause us the greatest loss of timber lands.

2. It also would provide the greatest storage and would have the greatest effect on the natural flow of the river during the spring run-off.

3. It may or may not simplify the browing of logs along the river bank above the dam. Much will depend upon the effect that the operation of the power plants may have on the ice and the operation policy respecting the maintaining of water levels in the head ponds.

4. The dead water created above the dam or dams may necessitate the booming and towing of logs to the sluiceway.

5. More shore line would be created and due to the dead water would be more difficult to stack than the present river banks.

C O P Y

6. The effect on the log drive below the dam would depend greatly:

(a) on the amount of water allowed to flow through the dams during our log driving period. This could affect the drive all the way to Maugerville, including the planned date for release of timber from Beechwood;

(b) on whether or not there was a continuous or an intermittent flow of water. An intermittent flow would create great difficulties. You know what trouble we were caused by the Tobique and Grand Falls dams in 1955 and 1956.

The facts would all have to be known before one could state with any degree of accuracy the effect the development could have on our operations."

The Director of the Northeastern Wildlife Station in Fredericton, Mr. Bruce S. Wright, has informed me that the part of the St. John River above Fredericton has not had the extensive study the lower part has had by their organization. A survey of the upper part of the river is planned to investigate probable effects of flooding on wildlife habitat in early September, and until this is completed he hesitates to go into any detail about this region.

He does say:

"The most important wildlife species that will be affected are ducks and muskrats. The drastic fluctuations in water level that now take place during the nesting period of the ducks are a serious limiting factor on the numbers of local breeding ducks. Any work on the upper river that would reduce these fluctuations would be beneficial to ducks. Muskrats also are adversely affected by these fluctuations as they cannot build houses in the marshes in the normal way and must exist in bank burrows. The most important area for ducks and muskrats is the estuary from Fredericton to St. John.

The upper river above Fredericton is important as a fall resting and feeding area for the migrating ducks from eastern Quebec, Newfoundland, and Labrador. The extent that the existing waterfowl areas will be affected by the new dams will not be known until after the fall survey. It may be that any loss of habitat on the upper river will be compensated for by improvement of the estuary, but this is speculation at this point."

I trust the above will assist in identifying the log driving and wildlife aspects of the problem of downstream benefits.

Yours very truly,

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION

/s/ R. E. Tweeddale,
Chief Engineer.

C O P Y

JAMES F. MACLAREN ASSOCIATES
Condulting Engineers
Toronto and Saint John, N. B.

April 28, 1958

Dr. John S. Bates,
Room 620,
1980 Sherbrooke Street West,
Montreal 25, P. Q.

Re: Pollution Control - Saint John River

Dear Dr. Bates:

In response to the request from H. E. Marshall of the New Brunswick Electric Power Commission, we are forwarding herewith a brief report outlining the effects of large storage reservoirs on pollution control in the Saint John River.

The impoundment of surface waters in large storage reservoirs is generally beneficial with respect to pollution control. Undesirable physical, chemical and biological characteristics are normally reduced during storage resulting in an overall improvement in water quality. This combined with possible benefits to be derived from flow regulation will usually create stream conditions which could not be attained without storage.

During storage, silt, organic impurities and other finely divided suspended matter are removed in the quiescent zone formed by the head pond, thereby reducing the turbidity and colour of the flowing water. In addition, suspended and dissolved organic solids are continually being stabilized through the natural phenomenon of biological degradation causing a reduction in the undesirable characteristics associated with putrescible organic matter. Storage tends to confine this activity within a comparatively short stretch of river leaving proportionately larger area with a water reasonably free from contaminants.

It is normally very difficult to remove organic colour from water. Biological activity and bleaching through prolonged exposure to the sun both contribute reductions in organic colour during storage.

Pathogenic organisms and other bacteria of intestinal origin do not normally survive for prolonged periods under the unfavourable environment created by stream conditions. Storage therefore aids natural purification and reduces the danger with respect to the public health aspects of stream pollution.

Upstream fluctuations in water quality are equalized in large reservoirs during storage resulting in the discharge of a water with essentially uniform characteristics to downstream areas.

Flow regulation is particularly beneficial to pollution control when it minimizes extreme low flow conditions by maintaining a minimum discharge in excess of that which would occur without storage. The greater dilution available for downstream wastes combined with a higher velocity of flow would tend to maintain downstream reaches in superior condition, thereby enabling greater utilization of the resource either for recreational purposes or by reducing the degree of waste treatment required to maintain established standards of water quality. If during replenishment of stored water the flow is reduced below the minimum, that would result without storage, the overall effect would be detrimental to water quality and pollution control.

There are also disadvantages associated with the effects of large storage reservoirs on pollution control. The major problem is the possible development of plant and animal life to the extent that the stored water possesses undesirable characteristics that were absent from the same water before storage.

Algae and other microorganisms develop rapidly when sufficient food is available. The nature and extent of these growths depends primarily on the storage time, the quantity of available food and the season. If storage is sufficiently short there will be insufficient time for the generation of significant numbers.

The quantity of available food depends primarily on the adequacy of clearing and grubbing prior to filling the reservoirs and the waste load carried by the source. Accummulation of bottom deposits with time contributes to algal problems in older reservoirs even when the organic matter carried by the river is not excessively high.

Deterioration of stored water due to algal and other biological growths may take the form of tastes and odours, high colour and turbidity, increased iron and manganese content and a low dissolved oxygen content. However, the poor physical and chemical quality is usually seasonal in nature due to thermal stratification in the reservoir, extreme deterioration resulting only from complete mixing within the reservoir at the time of the spring and autumn overturns.

C O P Y

Since the advantages associated with water storage pertain throughout a greater portion of the year the overall effect of large storage reservoirs on pollution control may be considered beneficial. In some instances a control programme may be necessary to minimize the effects of algal growths.

With particular reference to the Saint John River, it is our opinion that a storage reservoir at Rankin Rapids would be advantageous with respect to pollution control. The previously outlined advantages will predominate provided algal growth is effectively controlled resulting in an overall improvement in water quality. The effects of downstream pollution would be minimized through flow regulation but the required degree of treatment would not be materially reduced.

Storage at Beechwood and other power sites along the river will also be more effective than detrimental with respect to pollution control.

Yours very truly,

/s/ J. W. MacLaren.

C.J.Burry:JM
cc: Dr. J. S. Bates,
c/o Lord Beaverbrook Hotel,
Fredericton, N.B.

APPENDIX 12

TABLES

TABLE 12-1

UNDEVELOPED HYDROELECTRIC POWER SITES IN THE VICINITY OF THE PROPOSED TIDAL POWER PROJECT

River basin and project	Location River - State	Drainage area sq. mi.	Installed capacity kw.	Average annual energy 1000 kw.-hr.	Critical period load factor percent	Average annual capacity factor percent	Usable storage acre-feet	Gross static head feet	Estimated first cost $1000 (1949 levels)	Estimated annual cost $1000 (private financing)	Cost per installed kw. dollars	At site cost average annual energy mills/kw.-hr. 2/
St. John River Basin							1,460,000)					
Rankin Rapids	St. John, Me.	4,060	230,000	900,000	30	45	2,400,000)	255	65,490	6,858	285	7.6
Grand Falls (existing)	" " N.B.	8,450	57,000	400,000		80	Pondage	132	-	-	-	-
Morrill 1/	" " " "	8,770	44,000	240,000		62	"	53	17,487	1,360	292	5.7
Beechwood 1/	" " " "	13,300	68,000	320,000		54	"	60	24,654	1,893	252	5.9
Hawkshaw 1/	" " " "	15,300	75,000	415,000		63	"	55	34,376	2,600	364	6.2
Total undeveloped			417,000	1,875,000			2,400,000					
Total existing			92,000				448,000					
Penobscot River Basin												
The Arches	West Branch, Me.	1,415	22,500	94,250	45	48	Pondage	90	10,092	1,149	445	12.2
Sourdnahunk	" " "	1,435	24,000	109,450	45	52	"	95	11,386	1,288	475	11.8
Debsconeag	" " "	1,545	15,000	69,000	45	52	"	58	8,774	984	585	14.3
Allagash Lake	East Branch, Me.	79	-	-		-	32,500	-	547	66	-	-
Grand Pitch	" " "	280	5,000	22,270	45	51	Pondage	90	2,878	343	595	15.1
Grand Lake	" " "	548	15,000	58,930	45	45	181,900	140	12,849	1,446	855	24.5
Grand Falls	" " "	686	6,000	28,100	45	53	Pondage	50	2,989	358	497	12.7
Whetstone Falls	" " "	985	30,000	116,700	45	44	255,000	135	28,739	3,165	955	27.0
Meadow Brook	" " "	1,070	12,000	48,600	45	46	Pondage	50	7,589	847	632	17.5
Stratton Rips	Mattawamkeag, Me.	1,484	40,000	170,060	40	49	863,000	140	44,222	4,835	1,100	28.4
Bonnie Brook	Piscataquis, Me.	1,254	20,000	76,500	23	44	57,400	91	13,611	1,515	680	19.8
Winn	Penobscot, Me.	4,870	12,000	89,170	85	85	Pondage	23	8,701	970	725	10.9
Mohawk Rapids	" "	5,131	8,000	61,620	85	88	"	16	9,711	1,065	1,210	17.3
Bangor Diversion	" "		52,000	317,600		69			52,259	5,755	1,000	18.1
Sunkhaze		7,268	12,000	94,600	65	90	"	28				
Diversion		7,553	40,000	223,000	35	64	"	115				
Basin Mills	" "	7,686	12,000	93,150	80	89	"	27	6,888	780	573	8.4
Total undeveloped			273,500	1,355,400	45	57	1,348,500		221,175	24,566	810	18.1
Total existing			112,200	700,000			1,570,000					
Kennebec River Basin												
Moosehead	Kennebec, Me.	1,242	24,000	66,700	30	31	Pondage	64	10,093	1,108.8	417	16.5
Cold Stream	" "	1,416	90,000	259,350	30	33	"	195	29,799	3,247.3	330	12.5
The Forks	" "	2,460	48,000	166,300	30	37	"	110	28,180	3,016	585	18.1
Grand Falls	Dead, Me.	769	-	-	-	-	226,900	-	11,902	1,234.8	-	-
Pierce Pond	Pierce Stream, Me.	788	180,000	459,000	29	29	10,000	690	49,102	5,801.1	339	15.3
North Anson	Kennebec, Me.	2,797	10,000	54,250	60	62	Pondage	29	6,405	706.1	640	13.0
Madison	" "	3,230	24,000	146,780	60	70	"	64	7,772	873.5	323	6.0
Greenleaf	Sandy, Me.	513	10,000	41,600	30	48	100,000	120	11,329	1,205.4	1,130	29.0
Total undeveloped			386,000	1,193,000	32	35	317,070(Net)		154,600	19,042.8	403	14.4
Total existing			209,255	756,000			1,263,830					
Androscoggin River Basin												
Aziscohos	Magalloway, Me.	214	10,000	49,080	50	56	159,300	245	3,558	416.7	356	8.5
Errol	Androscoggin, N.H.	1,045	24,000	56,800	25	27	314,000	55	14,687	1,632	612	28.7
Mollidgewock	" " "	1,152	22,500	53,550	25	27	Pondage	45	8,840	1,013.3	392	19.0
Pontook	" " "	1,214	12,000	88,410	80	84	"	80	6,457	756	537	8.5
Pulsifer Rips	" " "	1,363	6,000	42,640	75	81	"	40	3,555	413.2	590	9.7
Gilead	" " "	1,592	8,000	56,570	75	81	"	40	8,818	945.4	1,100	16.7
Dixfield	" " "	2,205	10,000	49,310	35	56	"	25	7,061	772.0	706	15.7
Total undeveloped			92,500	396,360	44	49	182,700(Net)		52,976	5,948.6	573	15.0
Total existing			146,544	774,990			725,000					

1/ St. John River Interim Report - public financing - initial installations.
2/ Costs shown do not account for storage benefits at downstream plants.

Source of data: NENYIAC Report and Saint John River Engineering Board Interim Report, dated April 6, 1953

TABLE 12-2

SUMMARY OF DEVELOPMENT STUDIES

FOR RANKIN RAPIDS SITE

Annual load factor, percent	Assumed capacity, thousand kw. 1/	Maximum pool elevation, feet, m.s.l.	Active storage, million acre-feet	Total comparative cost, millions of $	Excess of annual benefits over annual charges, millions $
60	463	860	2.12	113.7	13.5
60	480	860	2.80	117.4	13.9 2/
60	430	810	2.12	88.6	11.7
60	447	810	2.80	93.8	11.9
80	350	860	2.12	100.7	11.1
80	372	860	2.80	103.2	11.7 2/
80	305	810	2.12	73.9	8.9
80	325	810	2.80	77.9	9.7
100	244	860	2.12	89.0	8.8
100	256	860	2.80	90.5	9.5 2/
100	220	810	2.12	63.4	7.6
100	232	810	2.80	66.2	8.2

1/ Preliminary capacities were selected to firm the combined tidal plant and Rankin Rapids outputs to the annual load factors shown.

2/ Maximum excess of annual benefits over annual charges.

TABLE 12-3

PERTINENT DATA USED FOR SELECTION

OF RIVER HYDRO AUXILIARY TO TIDAL PROJECT

PROJECT	RANKIN RAPIDS	BIG RAPIDS	LINCOLN SCHOOL
Drainage area, sq. mi.	4,060	2,419	4,066
Stream flow			
Average annual run-off, ac.-ft.	4,950,000	3,076,000	4,950,000
Max. discharge, c.f.s.	90,400	59,250	90,400
Min. discharge, c.f.s.	373	220	373
Ave. discharge, c.f.s.	6,780	4,214	6,780
Ave. regulated, c.f.s.	5,950	3,450	3,700 *
Reservoir			
Elevations, ft., m.s.l.			
Max. normal operating pool	860	910	630
Limit of drawdown	823	875	626
Storage (million ac.-ft.)			
Total	8.23	3.97	.158
Carryover	2.80	1.54	.022
Dead	5.43	2.43	.136
Areas (1000 acres)			
Max. normal operating pool	93.3	55.6	5.8
Limit of drawdown	60.5	35.9	5.2
Main Embankment			
Crest Length, feet	7,400	6,500	3,500
Max. height, feet	333	300	130
Crest el., ft., m.s.l.	875	925	647
Spillway			
No. of 40- by 30-ft. tainter gates	6	6	8
Crest el., feet, m.s.l.	830	880	600
Chute and stilling basin	Lined	Unlined	Lined
Design flow, c.f.s.	167,000	164,000	229,000
Low-level outlets			
Number	2	2	0
Dia. of tunnels, feet	24	24	--
No. of 90-in. Howell-Bunger Valves	4	4	--

* Approximate

TABLE 12-3 - (Continued)

PERTINENT DATA USED FOR SELECTION

OF RIVER HYDRO AUXILIARY TO TIDAL PROJECT

PROJECT	RANKIN RAPIDS	BIG RAPIDS	LINCOLN SCHOOL
Powerhouse			
Number of units	8	6	2
Net head, feet			
Maximum	304	275	95
Average (rated)	284	263	88
Minimum	269	233	81
Turbine	Francis	Francis	Kaplan
Speed	164	138	164
Total generator nameplate rating, kw.	400,000	300,000	52,000
Dependable capacity, kw.	460,000	338,000	54,000
Project cost	$135,000,000	$104,500,000	$28,500,000
Average annual energy[1] million kw.-hr.	1,120	600	- -
Additional average[2] annual energy, million kw.-hr.	100	95	- -
Total average annual energy, million kw.-hr.	1,220	695	310[3]

1. Energy computed on basis of average annual regulated flow.

2. Energy generated (up to 60% load factor) from flows which would otherwise be wasted over spillway.

3. Energy computed on basis of utilizing all flows up to plant capability of 8,400 c.f.s.

APPENDIX 12

PLATES

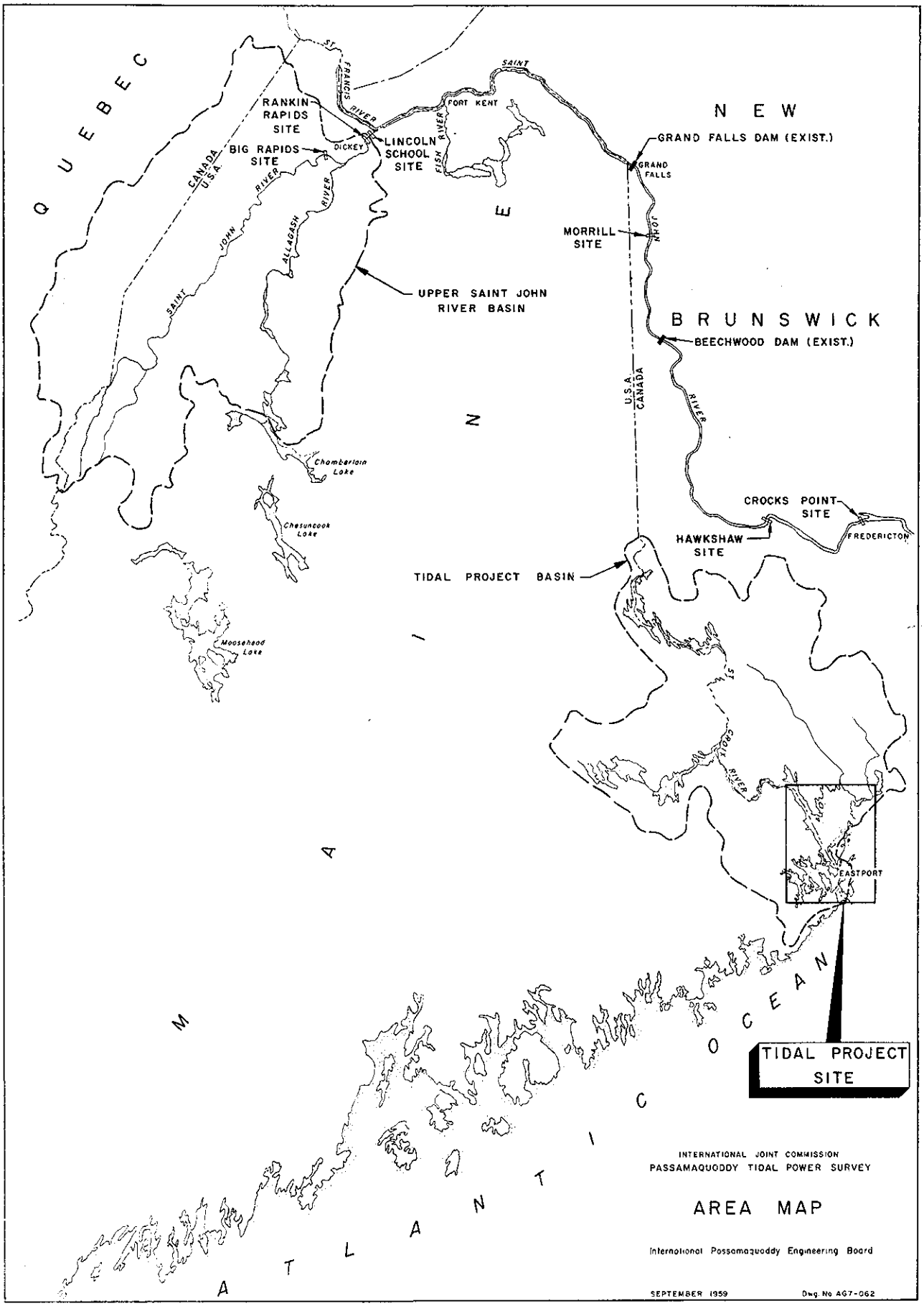

QUEBEC
NEW BRUNSWICK
MAINE
ATLANTIC OCEAN
RANKIN RAPIDS SITE
BIG RAPIDS SITE
DICKEY
LINCOLN SCHOOL SITE
ST. FRANCIS RIVER
FORT KENT
FISH RIVER
SAINT JOHN RIVER
ALLAGASH RIVER
CANADA
U.S.A.
GRAND FALLS DAM (EXIST.)
GRAND FALLS
MORRILL SITE
UPPER SAINT JOHN RIVER BASIN
BEECHWOOD DAM (EXIST.)
U.S.A.
CANADA
Chamberlain Lake
Chesuncook Lake
Moosehead Lake
CROCKS POINT SITE
HAWKSHAW SITE
FREDERICTON
TIDAL PROJECT BASIN
ST. CROIX RIVER
EASTPORT
TIDAL PROJECT SITE
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
AREA MAP
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No AG7-062

PLATE 12-1

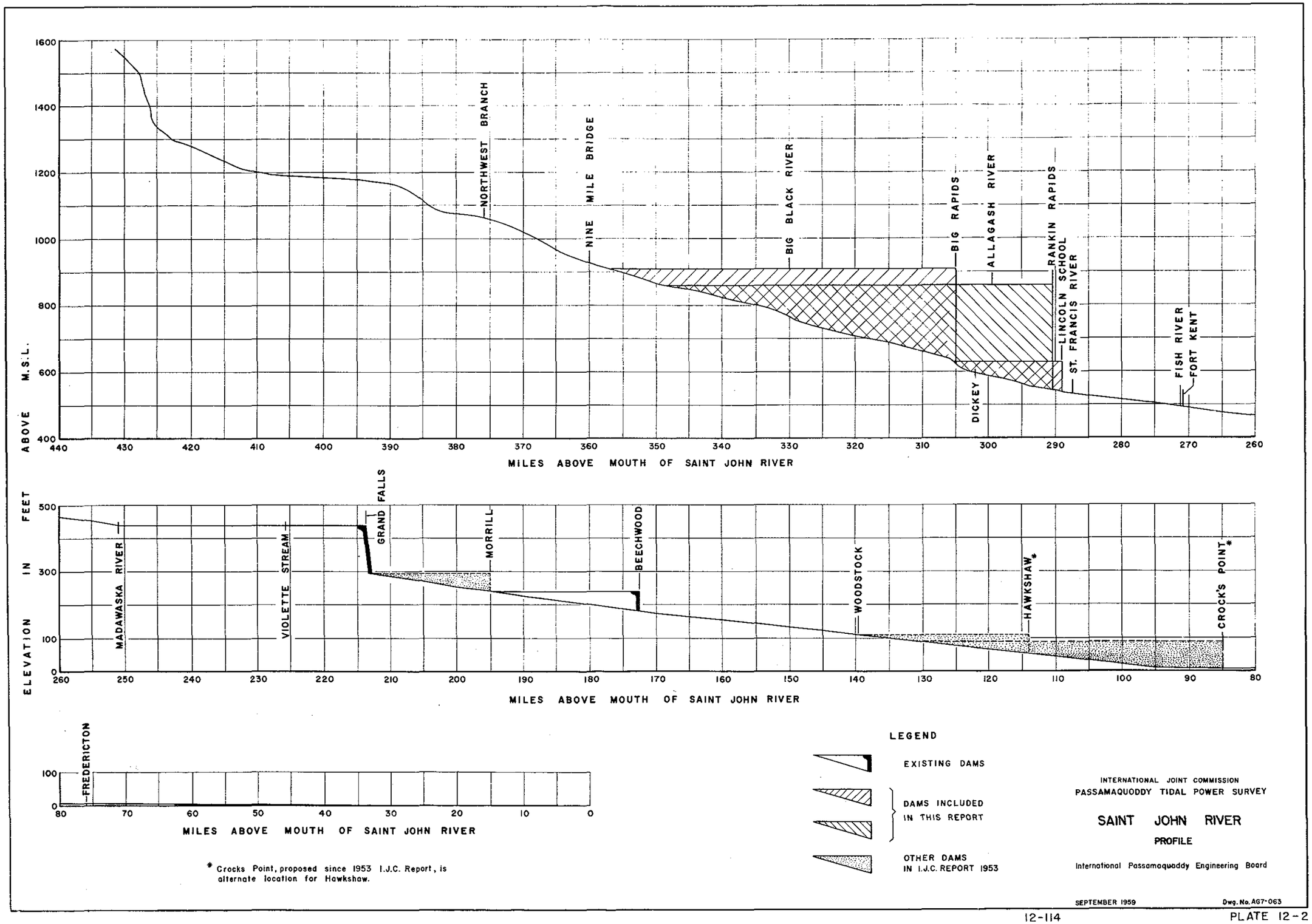
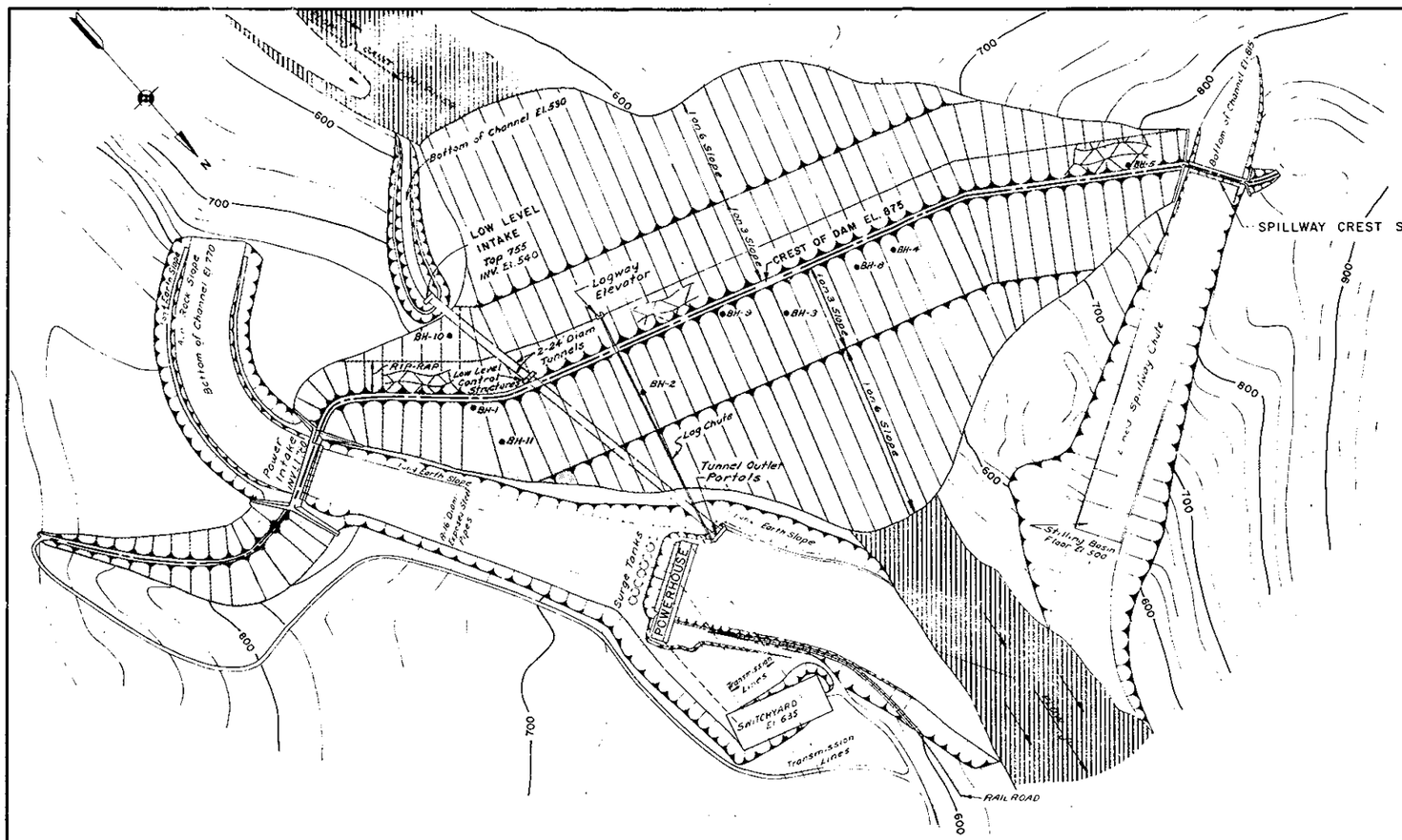

ELEVATION IN FEET ABOVE M.S.L.
MILES ABOVE MOUTH OF SAINT JOHN RIVER
NORTHWEST BRANCH
NINE MILE BRIDGE
BIG BLACK RIVER
BIG RAPIDS
ALLAGASH RIVER
RANKIN RAPIDS
LINCOLN SCHOOL
ST. FRANCIS RIVER
DICKEY
FISH RIVER
FORT KENT
MADAWASKA RIVER
VIOLETTE STREAM
GRAND FALLS
MORRILL
BEECHWOOD
WOODSTOCK
HAWKSHAW*
CROCK'S POINT*
FREDERICTON
LEGEND
EXISTING DAMS
DAMS INCLUDED IN THIS REPORT
OTHER DAMS IN I.J.C. REPORT 1953
* Crocks Point, proposed since 1953 I.J.C. Report, is alternate location for Hawkshaw.
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
SAINT JOHN RIVER
PROFILE
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. AG7-063

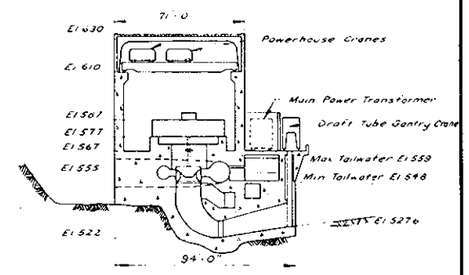
PLATE 12-2



GENERAL PLAN

SCALE IN FEET

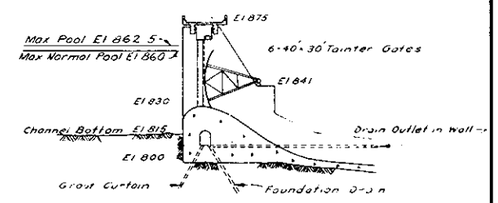
200 0 200 400 600 800 1000



POWERHOUSE SECTION

SCALE IN FEET

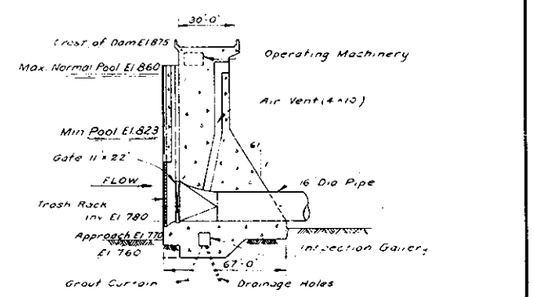
20 0 20 40 60 80 100



SPILLWAY CREST STRUCTURE

SCALE IN FEET

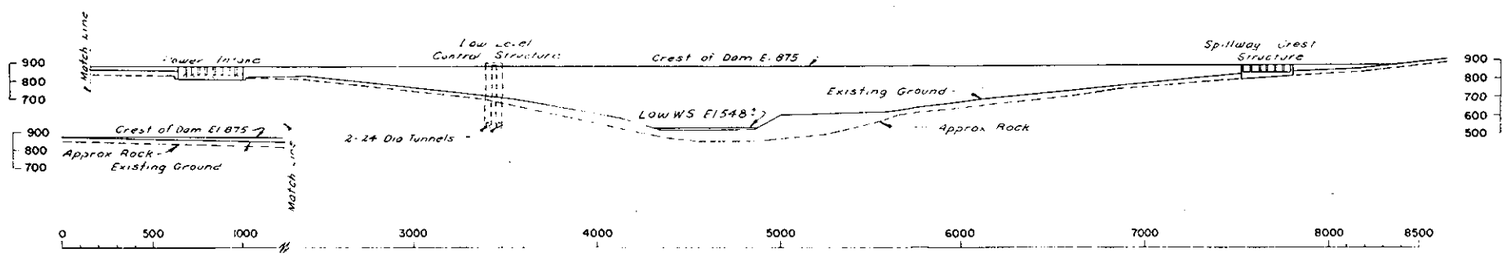
20 0 20 40 60 80 100



SECTION THRU POWER INTAKE

SCALE IN FEET

20 0 20 40 60 80 100



PROFILE OF DAM

SCALE IN FEET

200 0 200 400 600 800 1000

ELEVATIONS IN FEET, M.S.L.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

PLAN, PROFILES, AND SECTIONS

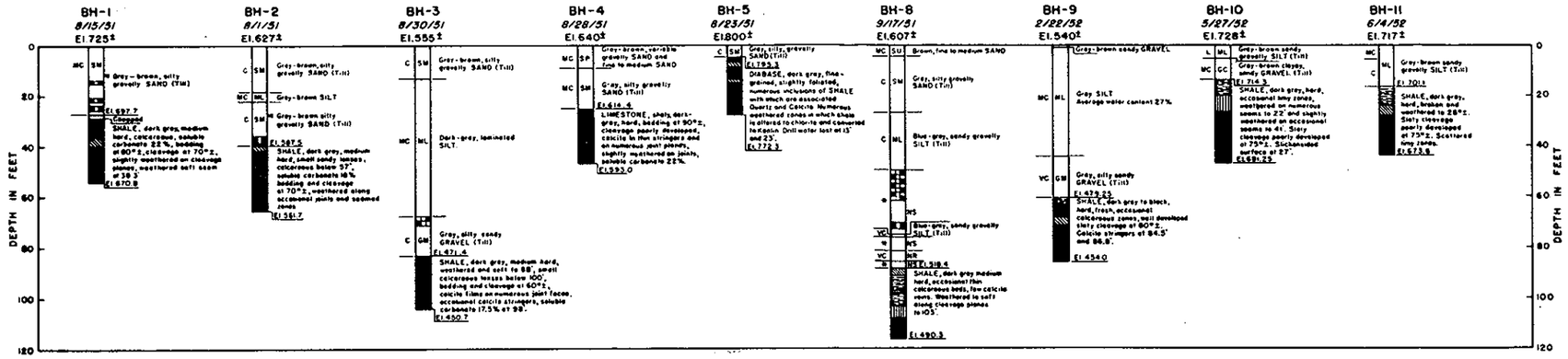
SHEET 1

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg No AG7-064

PLATE 12-3

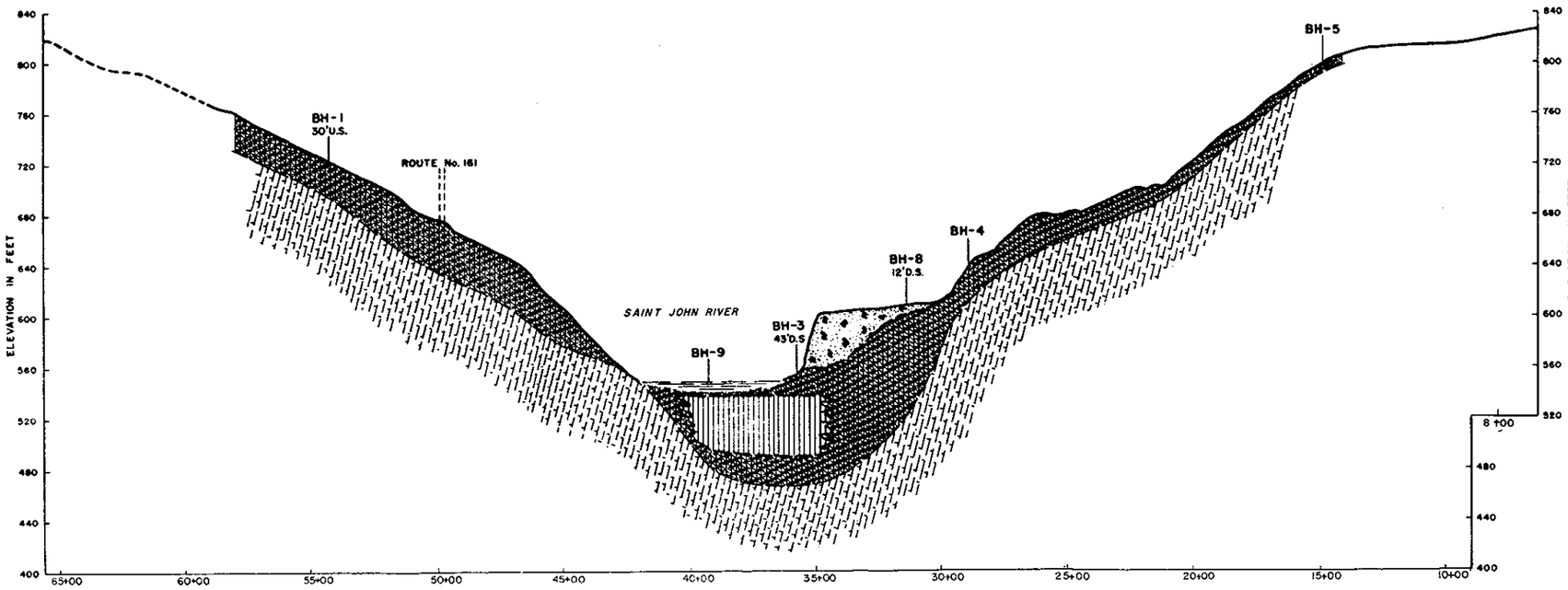


LEGEND FOR GRAPHIC LOGS

BH-1	Test boring number.
12/9/52	Month/day/year exploration completed.
El. 521	Elevation of ground surface.
	Ground water table at time of exploration.
GM	Department of the Army Uniform Soil Classification System Symbol.
NR	No satisfactory soil samples recovered.
NS	Not sampled.
VC	Symbol for compaction in accordance with legend shown below. Compaction determined by number of blows per foot of penetration of sample spoon.
*	Blow count not recorded in error or not considered representative.
	Boulder
	Boulders (continuous or nested).
El. 450.2	Elevation of bedrock surface.
	Rock core recovery 0-25%.
	Rock core recovery 25-50%.
	Rock core recovery 50-75%.
	Rock core recovery 75-90%.
	Rock core recovery 90-100%.
El. 426.4	Elevation of bottom of exploration.

COMPACTION SYMBOLS

VL	Very loose overburden
L	Loose overburden
MC	Medium compact overburden
C	Compact overburden
VC	Very compact overburden



GEOLOGIC SECTION
(LOOKING UPSTREAM)

LEGEND FOR GEOLOGIC SECTION

- Stratified Terrace SANDS and GRAVELS
- Medium Compact SILT (30 blows per foot is representative of penetration resistance using a 2 ½ inch O.D. sample tube driven by 350# hammer falling about 18 inches).
- TILL, medium compact to very compact, silty gravelly SAND, sandy gravelly SILT, or clayey sandy GRAVEL.
- Calcareous SHALE or shaly LIMESTONE showing approximate dip of cleavage.

NOTES:—

For location of explorations see plate 12-3.

Borings BH-6 and BH-7 not shown graphically were made during site selection studies at Golden Rapids approximately 2 miles upstream.

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

GEOLOGIC PROFILE

International Passamaquoddy Engineering Board

SEPTEMBER, 1959

Dwg. No. AG7-065

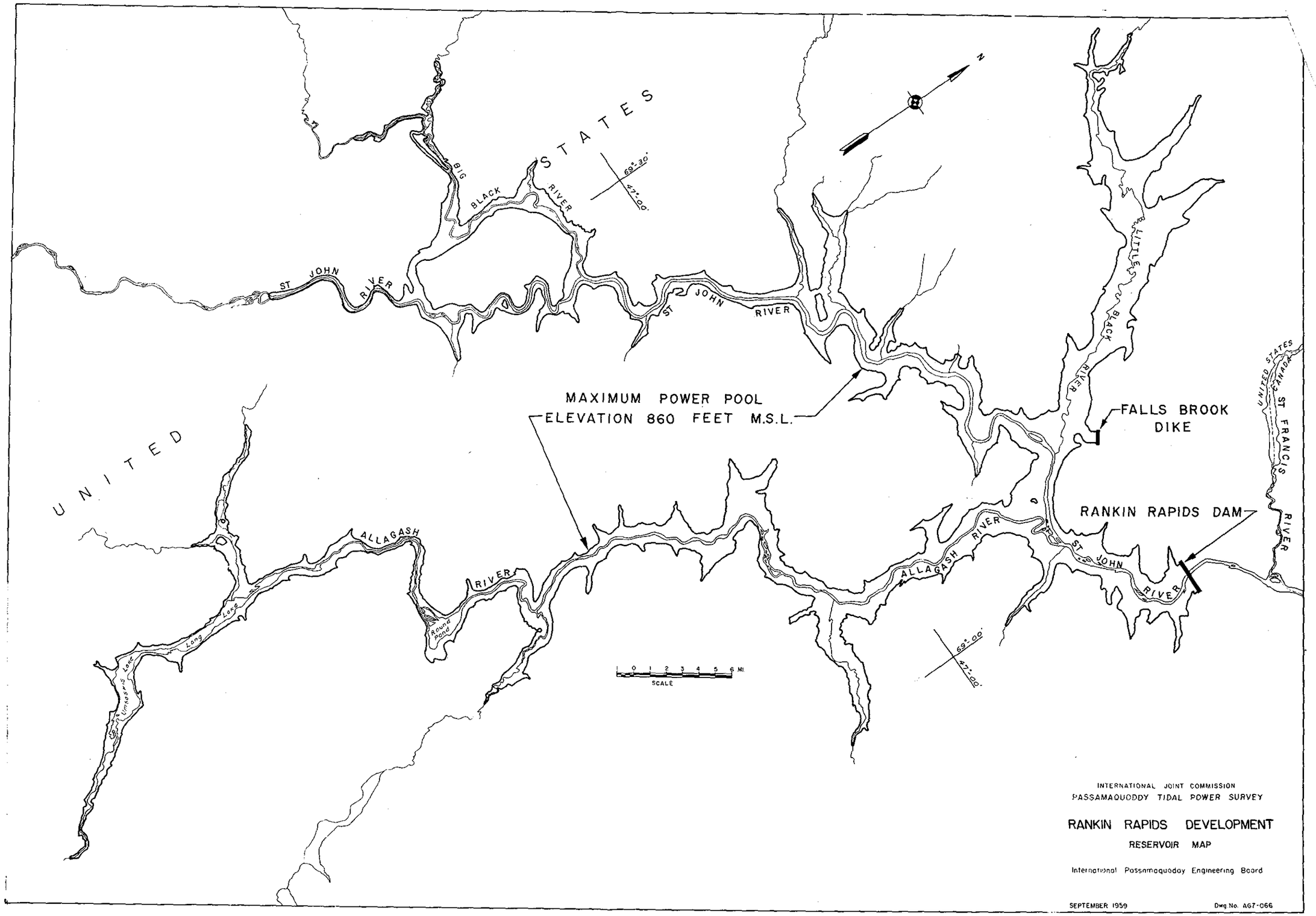

UNITED STATES
ST JOHN RIVER
BIG BLACK RIVER
ST JOHN RIVER
LITTLE BLACK RIVER
UNITED STATES
CANADA
ST FRANCIS RIVER
MAXIMUM POWER POOL
ELEVATION 860 FEET M.S.L.
FALLS BROOK
DIKE
RANKIN RAPIDS DAM
ALLAGASH RIVER
ALLAGASH RIVER
ST JOHN RIVER
Round Pond
Long Lake
Umsaskis Lake
69°-30'
47°-00'
69°-00'
47°-00'
0 1 2 3 4 5 6 MI
SCALE
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
RANKIN RAPIDS DEVELOPMENT
RESERVOIR MAP
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. AG7-066

PLATE 12-5

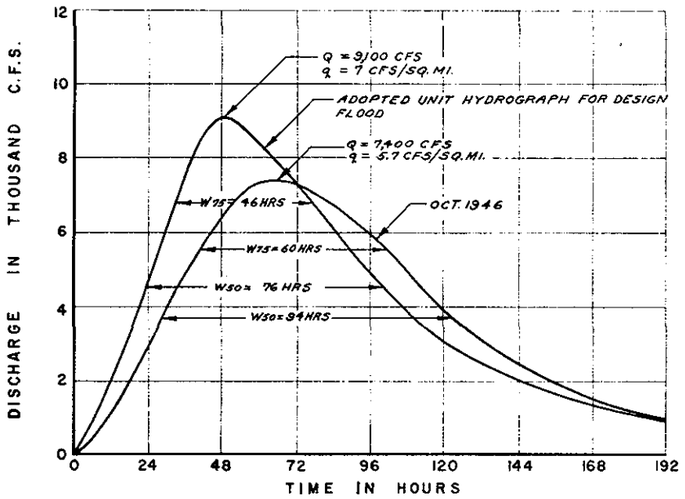


FIG. 1 - SAINT JOHN RIVER UPPER AREA 12 HR. UNIT HYDROGRAPHS

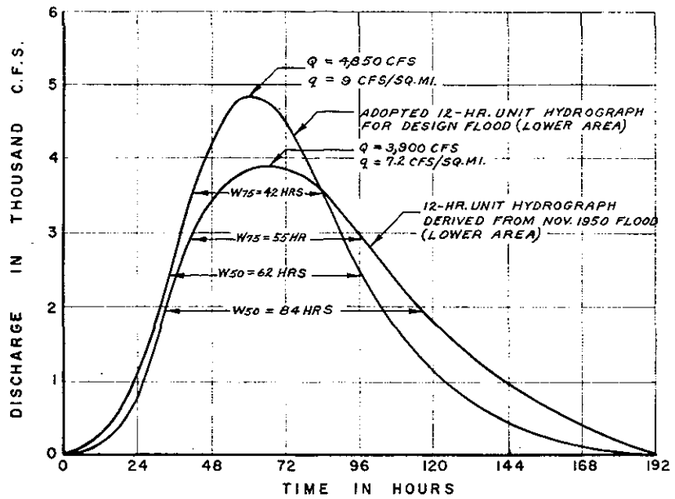


FIG. 2 - ALLAGASH RIVER LOWER AREA 12 HR. UNIT HYDROGRAPHS

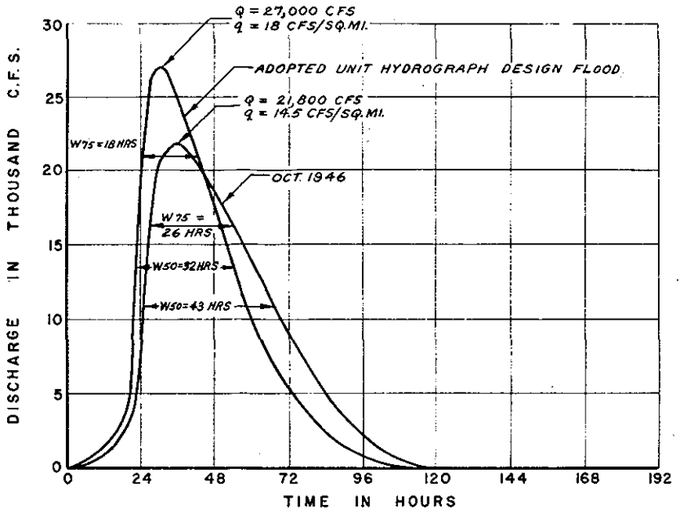


FIG. 3 - SAINT JOHN RIVER LOWER AREA 12 HR. UNIT HYDROGRAPHS

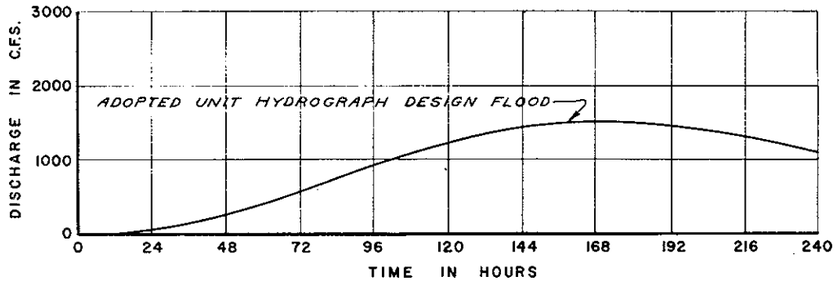


FIG. 4 - ALLAGASH RIVER UPPER AREA 12 HR. UNIT HYDROGRAPH

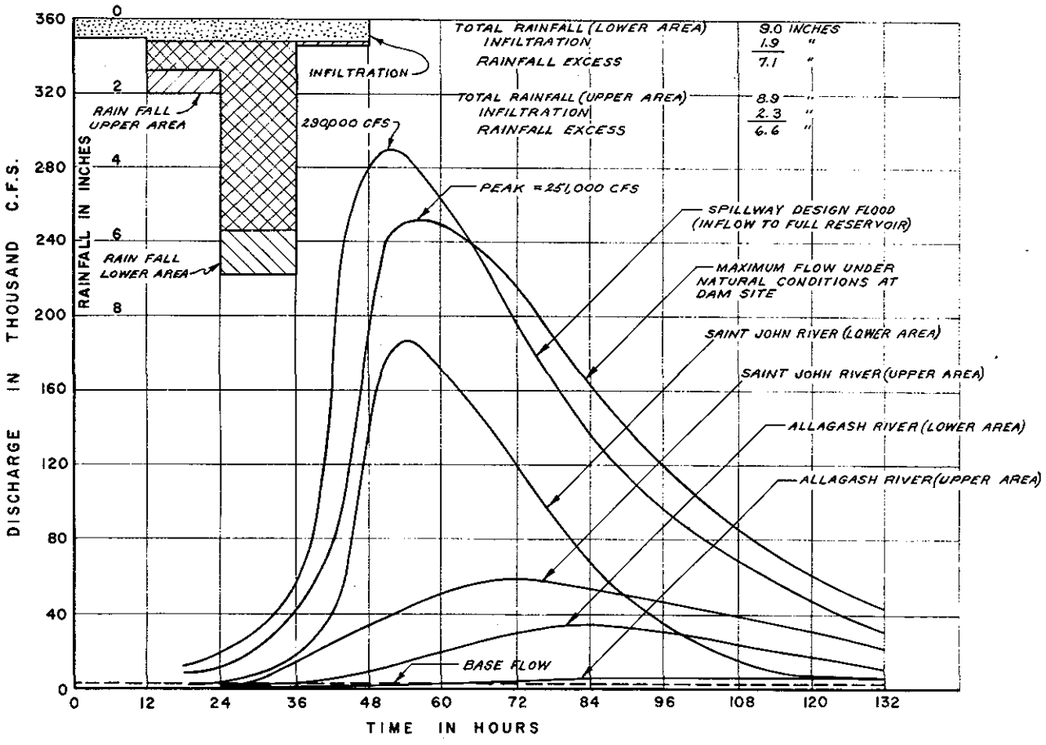


FIG. 5 - RANKIN RAPIDS SPILLWAY DESIGN FLOOD

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

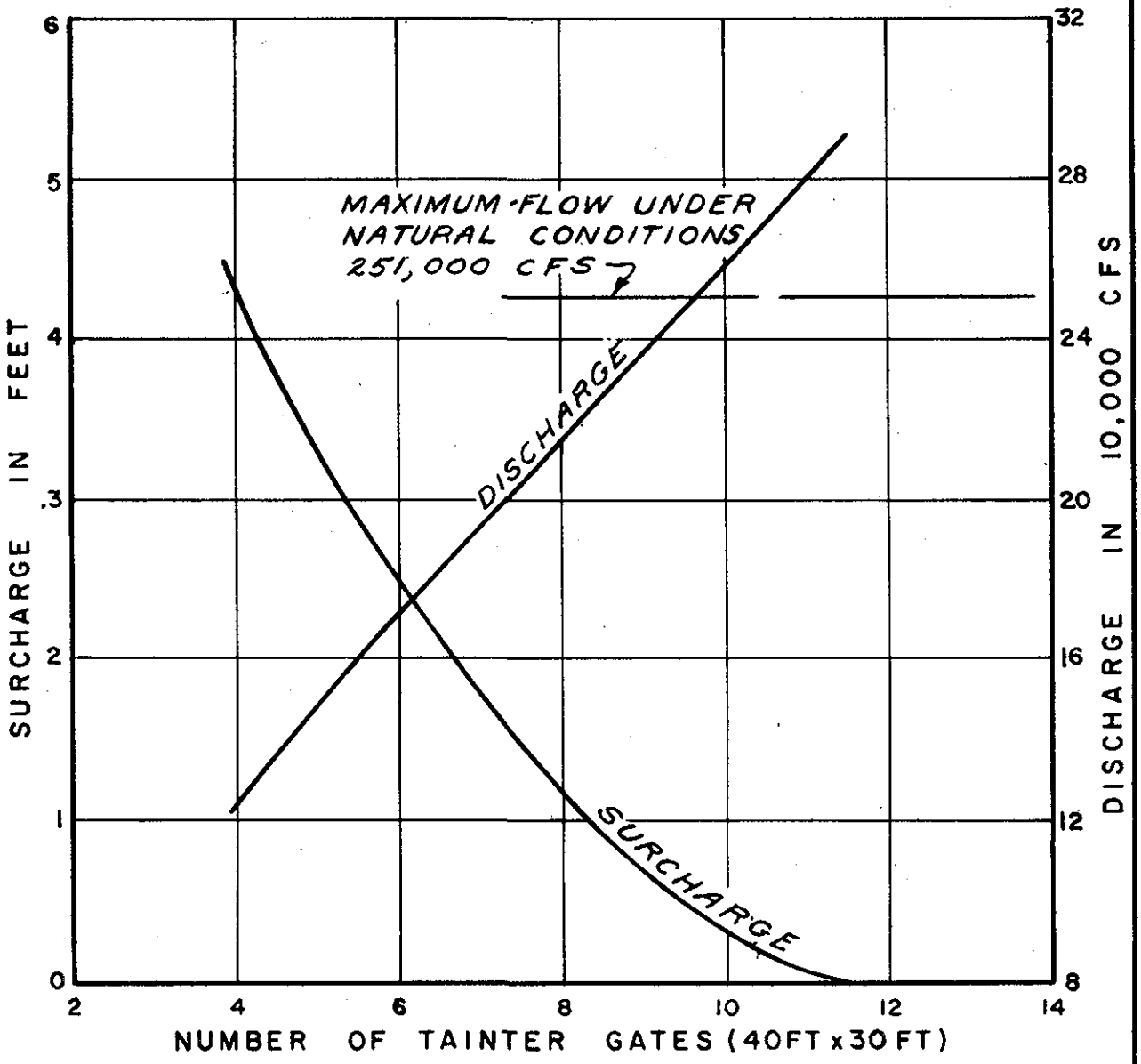
RANKIN RAPIDS DEVELOPMENT

SPILLWAY DESIGN FLOOD

HYDROGRAPHS

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-067



INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

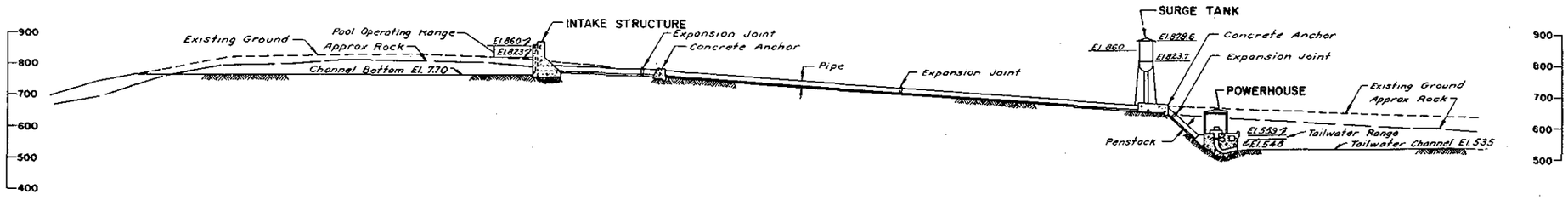
RANKIN RAPIDS DEVELOPMENT

SPILLWAY GATES VS SURCHARGE

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg No. AG7-068

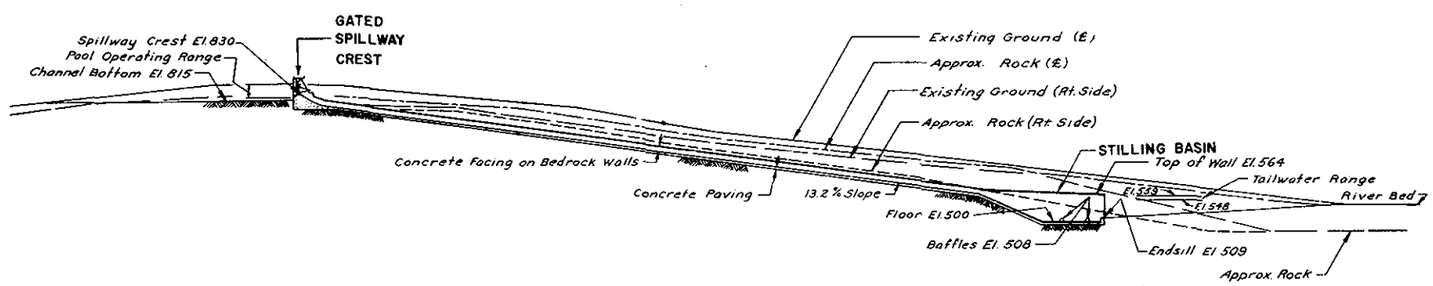
12-119 PLATE 12-7



PROFILE - POWER FACILITIES

SCALE IN FEET

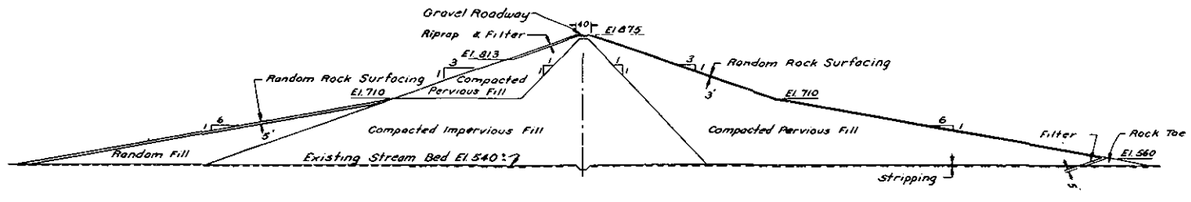
100 0 100 200 300 400 500



PROFILE - SPILLWAY

SCALE IN FEET

100 0 100 200 300 400 500



DAM SECTION

SCALE IN FEET

100 0 100 200 300 400 500

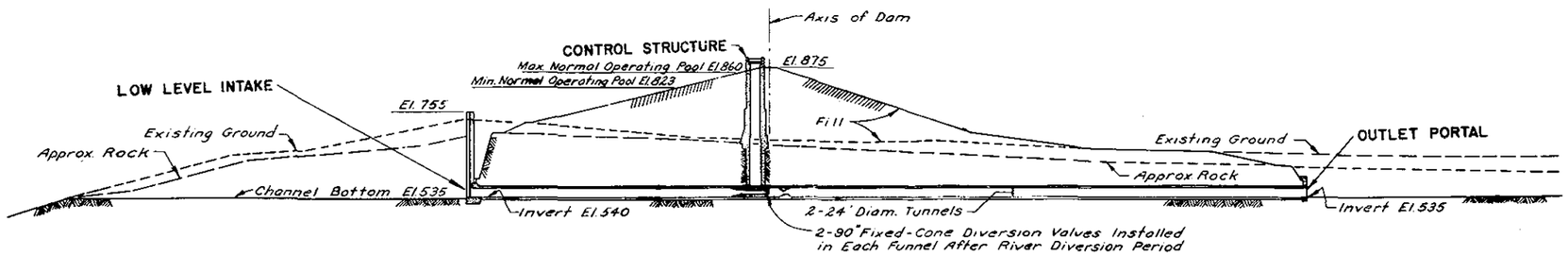
Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

PLAN, PROFILES, AND SECTIONS
SHEET 2
International Passamaquoddy Engineering Board

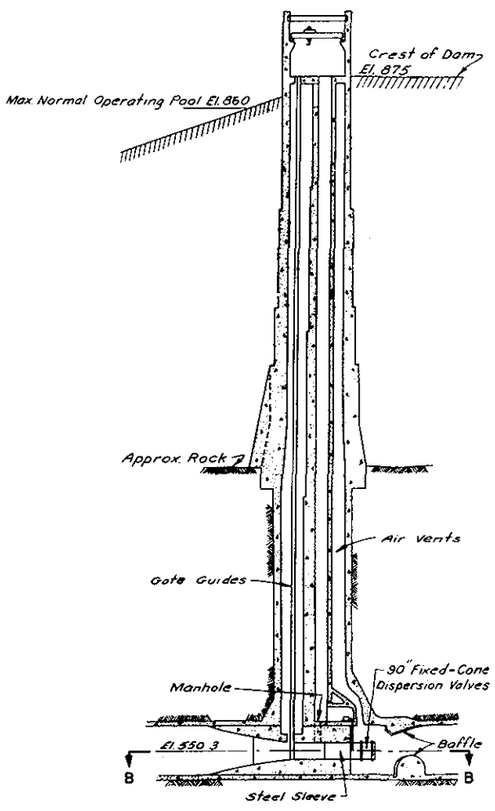
SEPTEMBER 1959 Dwg. No. AG7-069



PROFILE - DIVERSION & LOW LEVEL OUTLETS

SCALE IN FEET

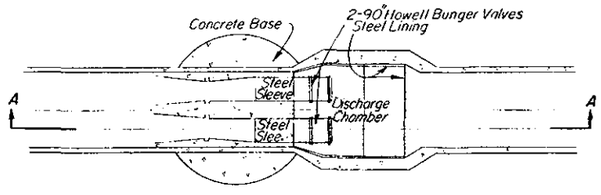
100 0 100 200 300 400 500



LOW LEVEL CONTROL STRUCTURE

SCALE IN FEET

20 0 20 40 60 80 100

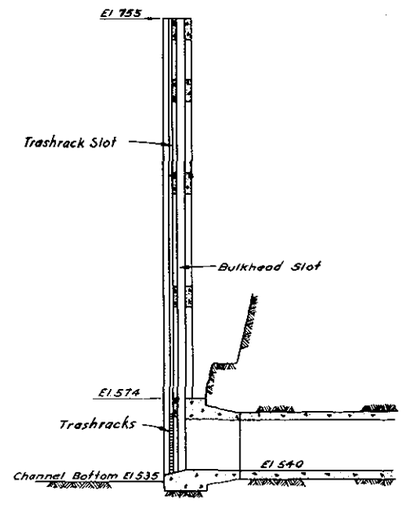


SECTION PLAN B-B

LOW LEVEL CONTROL STRUCTURE

SCALE IN FEET

20 0 20 40 60



LOW LEVEL INTAKE

SCALE IN FEET

20 0 20 40 60 80 100

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

PLAN, PROFILES, AND SECTIONS
SHEET 3

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-070

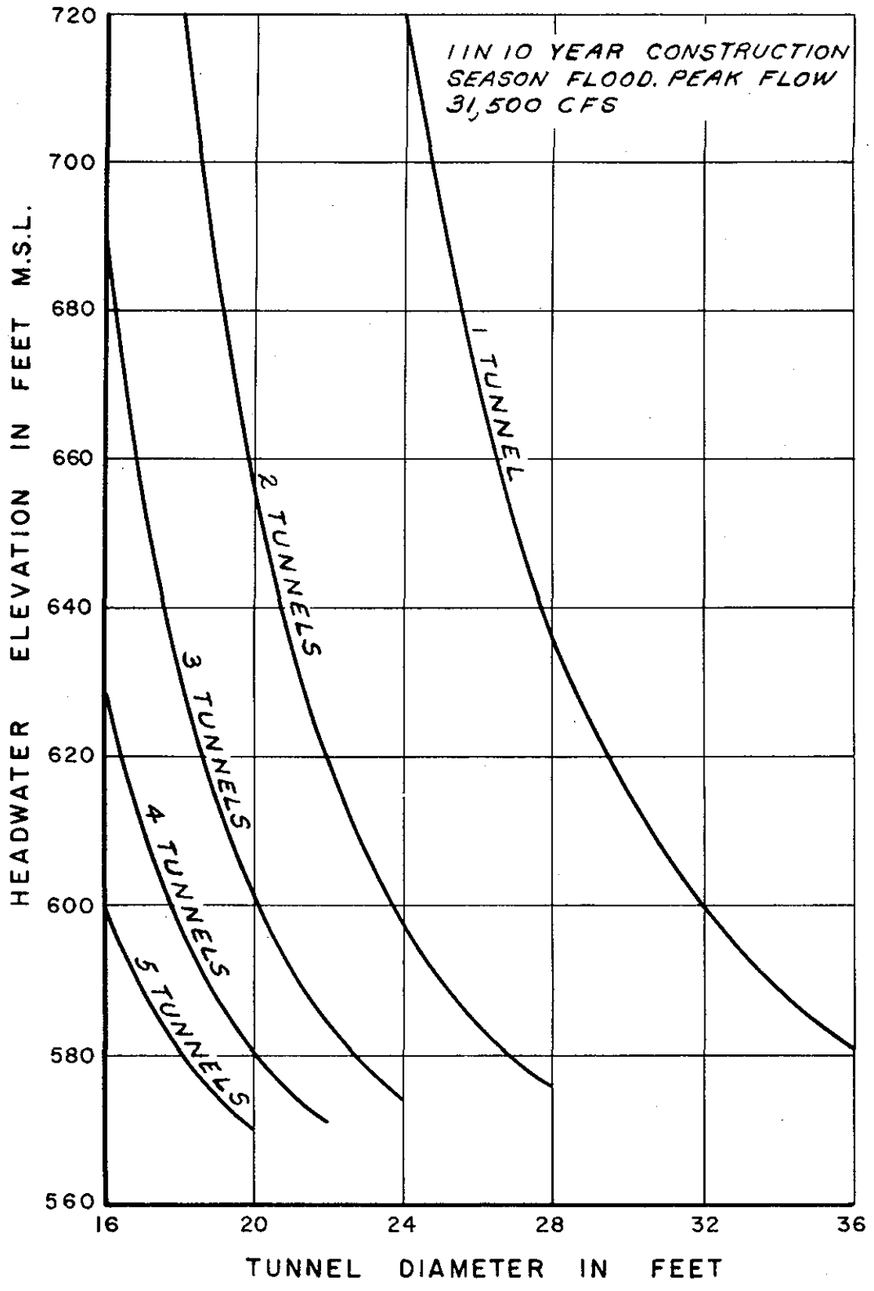


FIG.1 – CONSTRUCTION SEASON FLOOD

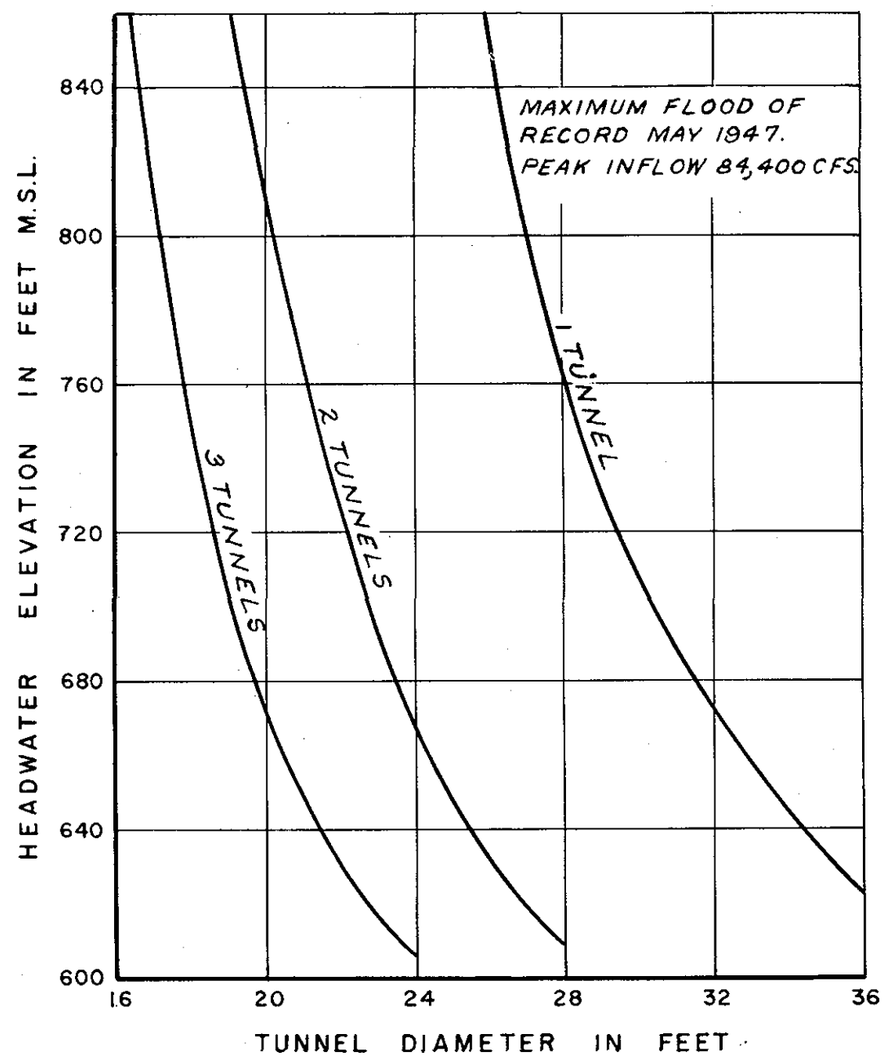


FIG.2 – SPRING FLOOD

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

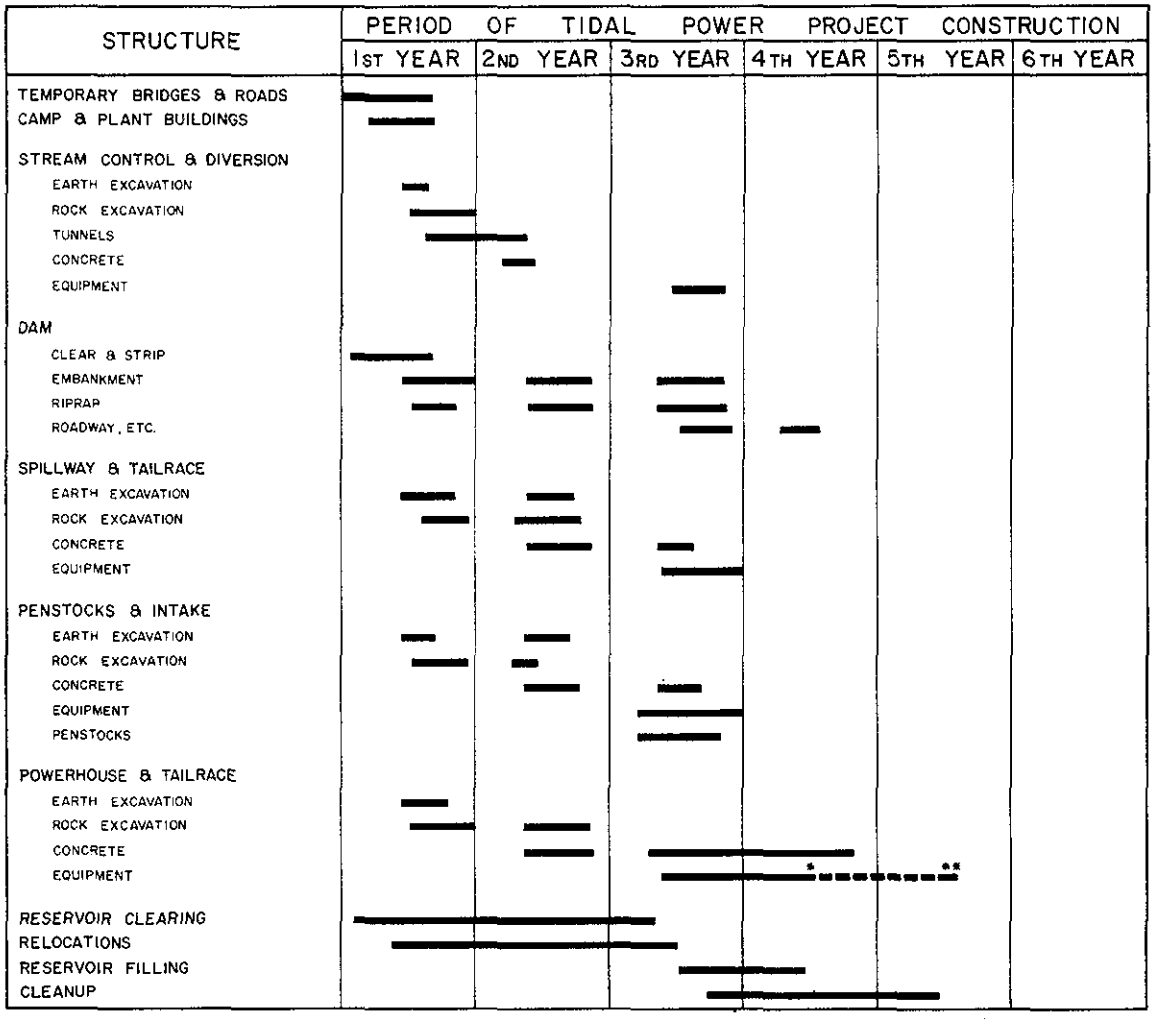
DIVERSION TUNNEL DIAMETERS

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-071

12-122 PLATE 12-10

CONSTRUCTION SCHEDULE



* 2 Units in operation
** 8 Units in operation

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

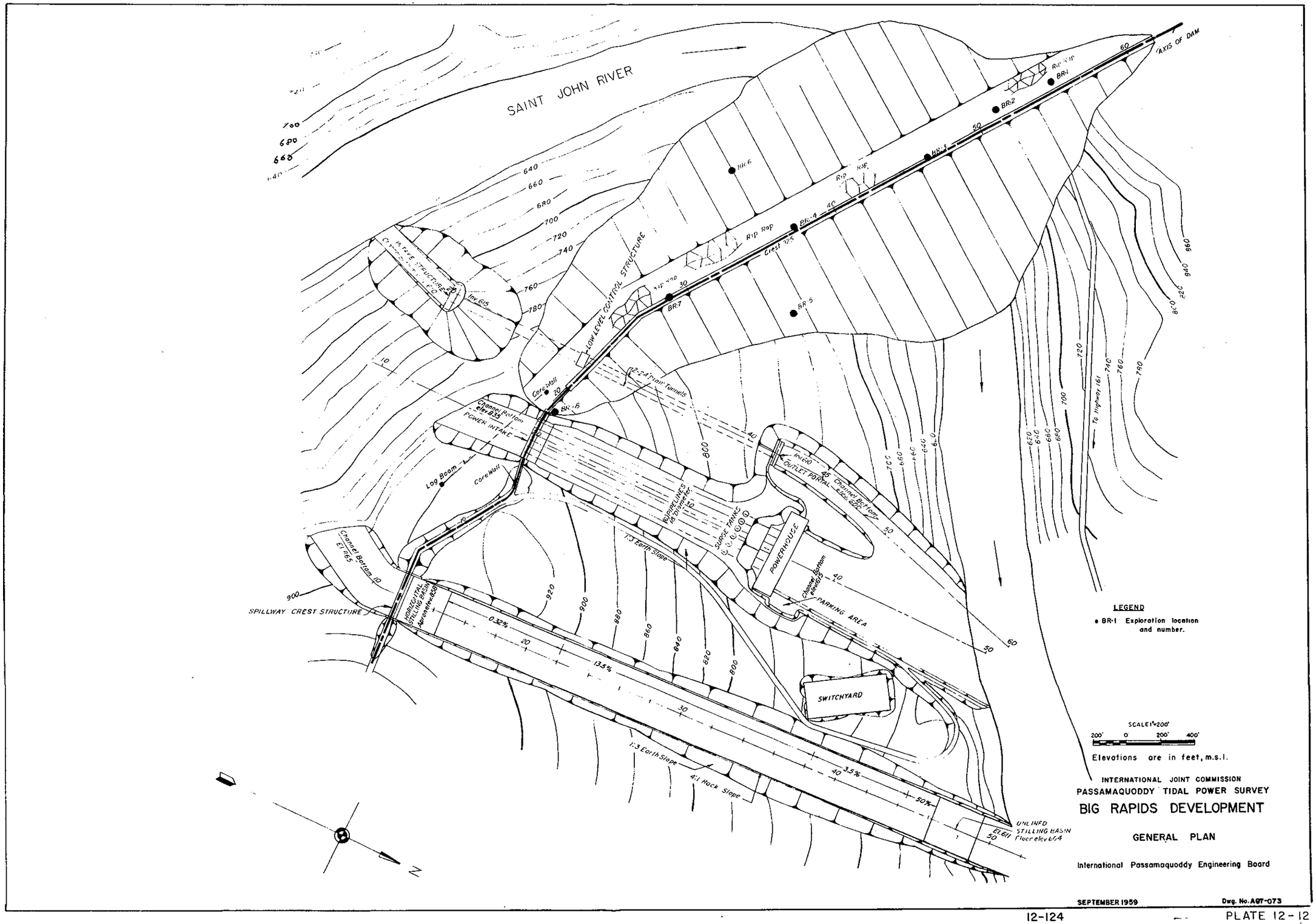
RANKIN RAPIDS DEVELOPMENT

CONSTRUCTION SCHEDULE

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-072

PLATE 12-11



INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

BIG RAPIDS DEVELOPMENT

GENERAL PLAN

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. A97-073

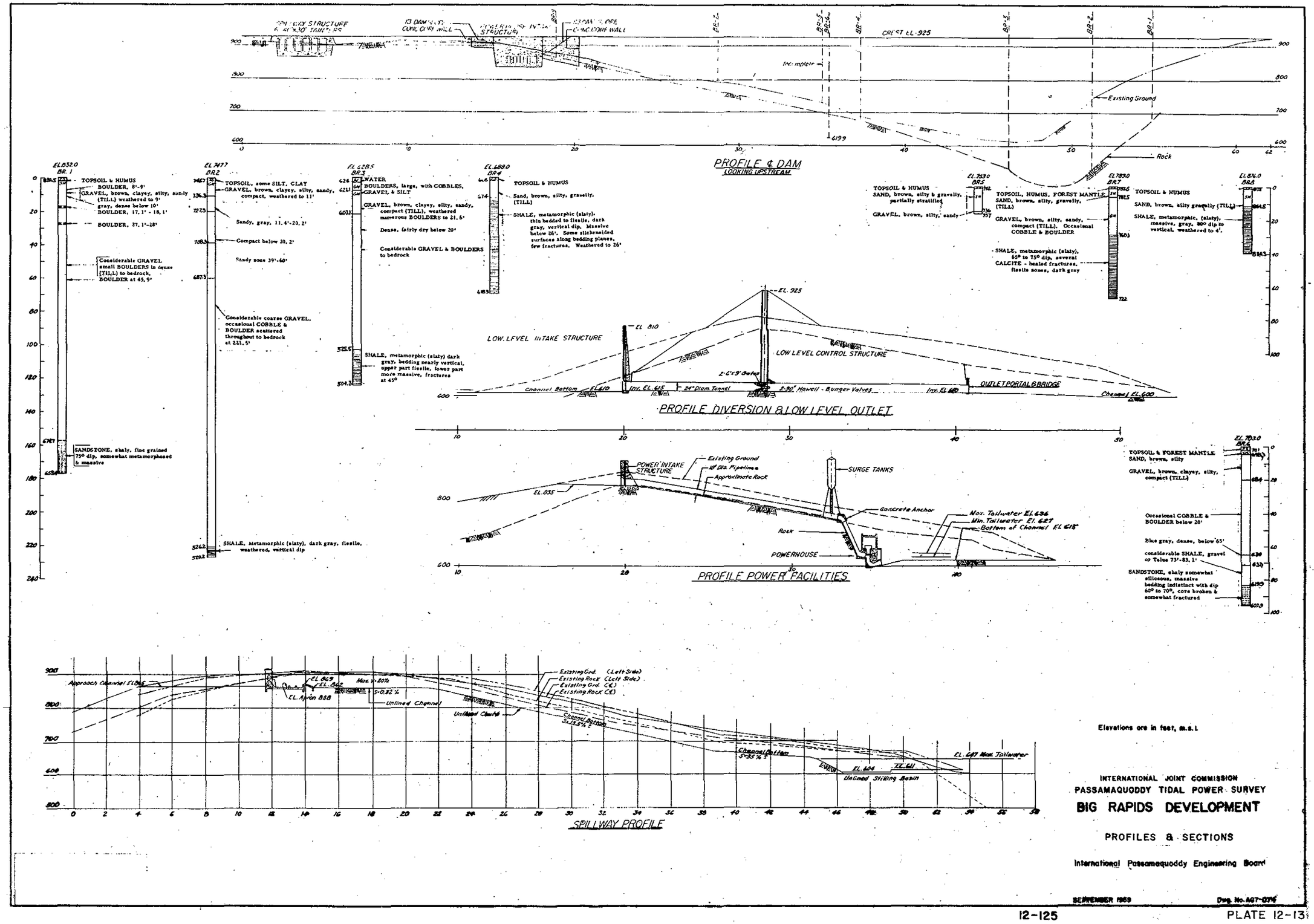

CREST EL. 925
Existing Ground
Rock
PROFILE ℄ DAM
LOOKING UPSTREAM
EL. 832.0 BR. 1
TOPSOIL & HUMUS
BOULDER, 8'-9'
GRAVEL, brown, clayey, silty, sandy (TILL) weathered to 9'
gray, dense below 10'
BOULDER, 17.1' - 18.1'
BOULDER, 27.1'-28'
Considerable GRAVEL small BOULDERS in dense (TILL) to bedrock.
BOULDER at 45.9'
SANDSTONE, shaly, fine grained 75° dip, somewhat metamorphosed & massive
EL. 747.7 BR. 2
TOPSOIL, some SILT, CLAY
GRAVEL, brown, clayey, silty, sandy, compact, weathered to 11'
Sandy, gray, 11.4'-20.2'
Compact below 20.2'
Sandy zone 39'-60'
Considerable coarse GRAVEL, occasional COBBLE & BOULDER scattered throughout to bedrock at 221.5'
SHALE, Metamorphic (slaty), dark gray, flexile, weathered, vertical dip
EL. 628.5 BR. 3
WATER
BOULDERS, large, with COBBLES, GRAVEL & SILT
GRAVEL, brown, clayey, silty, sandy, compact (TILL), weathered
numerous BOULDERS to 21.6'
Dense, fairly dry below 20'
Considerable GRAVEL & BOULDERS to bedrock
SHALE, metamorphic (slaty) dark gray, bedding nearly vertical, upper part flexile, lower part more massive, fractures at 45°
EL. 688.0 BR. 4
TOPSOIL & HUMUS
Sand, brown, silty, gravelly, (TILL)
SHALE, metamorphic (slaty), thin bedded to flexile, dark gray, vertical dip. Massive below 26'. Some slickensided surfaces along bedding planes, few fractures. Weathered to 26'
EL. 753.0 BR. 5
TOPSOIL & HUMUS
SAND, brown, silty & gravelly, partially stratified
GRAVEL, brown, silty, sandy
EL. 783.0 BR. 7
TOPSOIL, HUMUS, FOREST MANTLE
SAND, brown, silty, gravelly, (TILL)
GRAVEL, brown, silty, sandy, compact (TILL). Occasional COBBLE & BOULDER
SHALE, metamorphic (slaty), 65° to 75° dip, several CALCITE - healed fractures, flexile zones, dark gray
EL. 874.0 BR. 8
TOPSOIL & HUMUS
SAND, brown, silty gravelly (TILL)
SHALE, metamorphic, (slaty), massive, gray, 80° dip to vertical, weathered to 4'.
EL. 925
EL. 810
LOW LEVEL INTAKE STRUCTURE
LOW LEVEL CONTROL STRUCTURE
2-6'x9' Gates
Channel Bottom EL. 610
Inv. EL. 615
24" Diam. Tunnel
2-30" Howell - Bunger Valves
Inv. EL. 610
OUTLET PORTAL & BRIDGE
Channel EL. 600
PROFILE DIVERSION & LOW LEVEL OUTLET
POWER INTAKE STRUCTURE
Existing Ground
18' Dia. Pipeline
Approximate Rock
SURGE TANKS
EL. 835
Concrete Anchor
Max. Tailwater EL. 636
Min. Tailwater El. 627
Bottom of Channel EL. 618
Rock
POWERHOUSE
PROFILE POWER FACILITIES
EL. 703.0 BR. 6
TOPSOIL & FOREST MANTLE
SAND, brown, silty
GRAVEL, brown, clayey, silty, compact (TILL)
Occasional COBBLE & BOULDER below 20'
Blue gray, dense, below 65'
considerable SHALE, gravel or Talus 73'-83.1'
SANDSTONE, shaly somewhat siliceous, massive bedding indistinct with dip 60° to 70°, core broken & somewhat fractured
Approach Channel EL. 865
EL. 869
EL. 862
EL. Apron 858
Max. 1.01%
S=0.32%
Unlined Channel
Unlined Chute
Existing Grd. (Left Side)
Existing Rock (Left Side)
Existing Grd. (℄)
Existing Rock (℄)
Channel Bottom S=15.8%
Channel Bottom S=35%
EL. 604
EL. 611
Unlined Stilling Basin
EL. 627 Max. Tailwater
SPILLWAY PROFILE
Elevations are in feet, m.s.l.
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
BIG RAPIDS DEVELOPMENT
PROFILES & SECTIONS
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. AGT-0714

PLATE 12-13

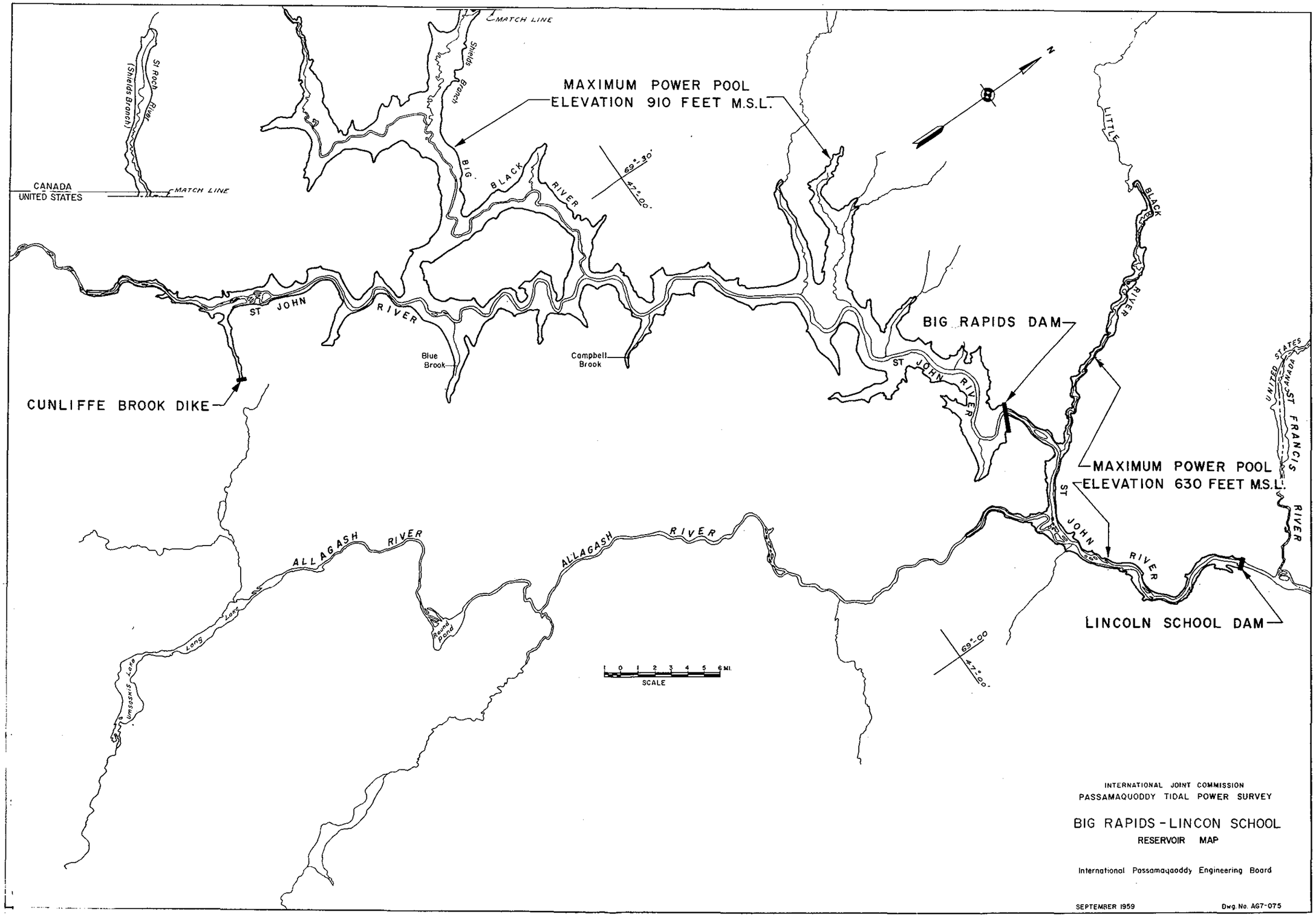
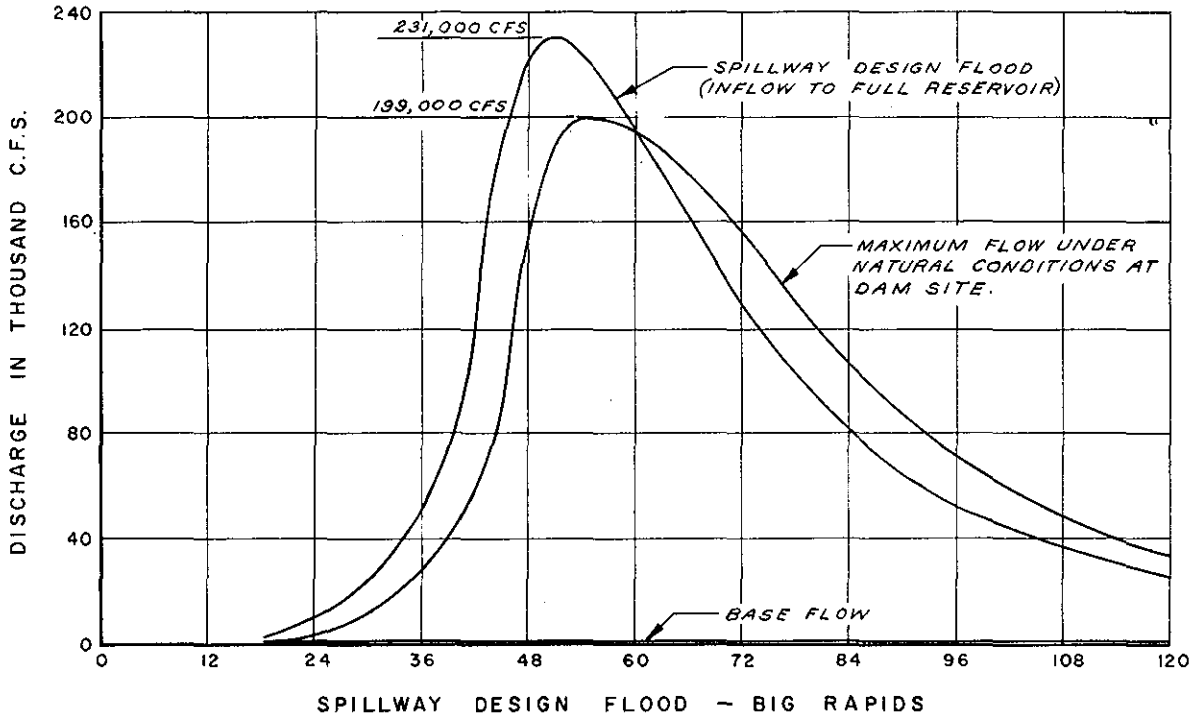
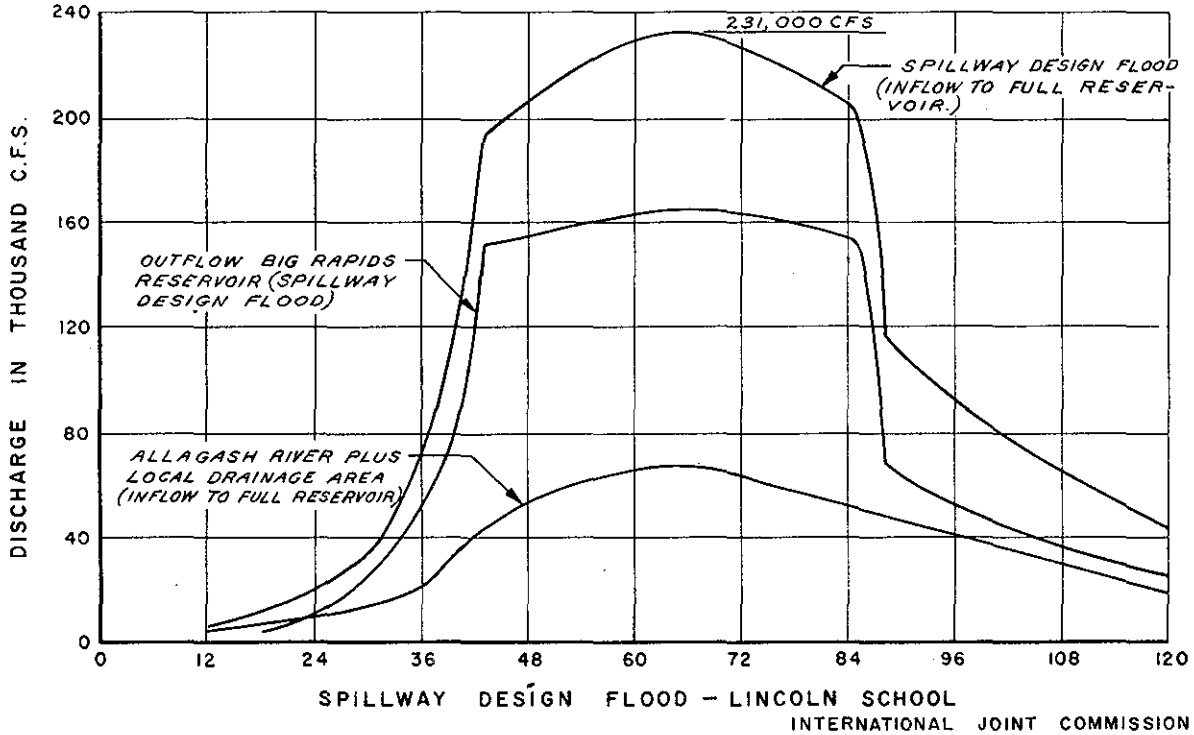

MATCH LINE
Shields Branch
St Croix River
(Shields Branch)
CANADA
UNITED STATES
MATCH LINE
MAXIMUM POWER POOL
ELEVATION 910 FEET M.S.L.
BIG BLACK RIVER
69°-30'
47°-00'
N
LITTLE BLACK RIVER
ST JOHN RIVER
Blue Brook
Campbell Brook
BIG RAPIDS DAM
ST JOHN RIVER
CUNLIFFE BROOK DIKE
UNITED STATES
ST FRANCIS RIVER
MAXIMUM POWER POOL
ELEVATION 630 FEET M.S.L.
ST JOHN RIVER
ALLAGASH RIVER
ALLAGASH RIVER
Long Lake
Umsaskis Lake
Round Pond
1 0 1 2 3 4 5 6 MI.
SCALE
69°-00
47°-00'
LINCOLN SCHOOL DAM
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
BIG RAPIDS - LINCON SCHOOL
RESERVOIR MAP
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. AG7-075

PLATE 12-14



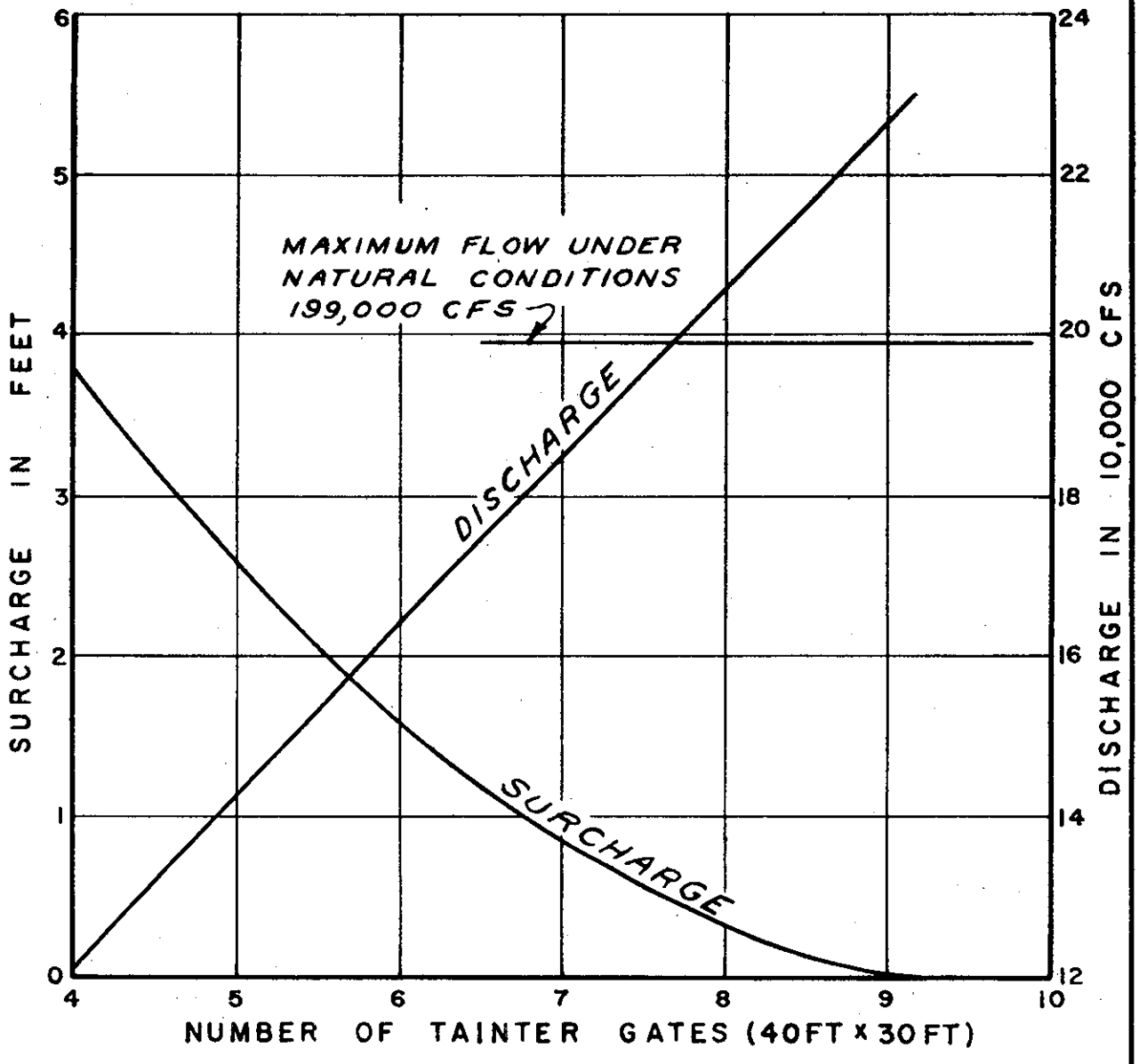


INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

BIG RAPIDS-LINCOLN SCHOOL DEVELOPMENT
SPILLWAY DESIGN FLOOD
HYDROGRAPHS

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg.No. AG7-076



INTERNATIONAL JOINT COMMISSION

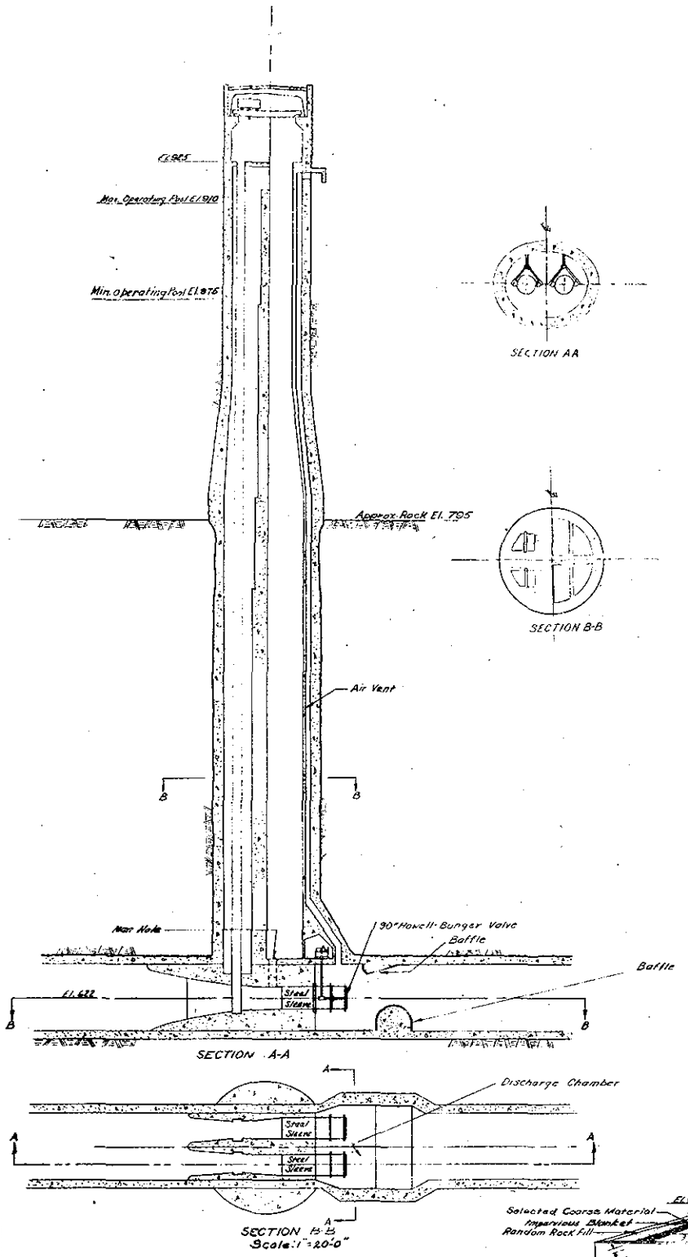
PASSAMAQUODDY TIDAL POWER SURVEY

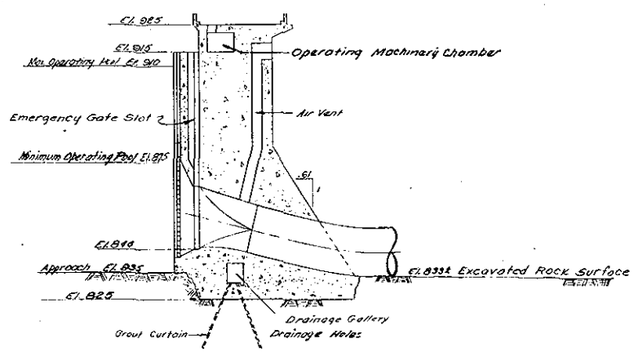
BIG RAPIDS DEVELOPMENT

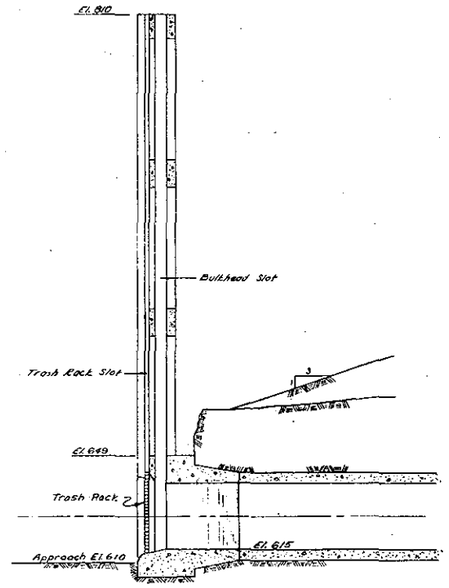
SPILLWAY GATES VS SURCHARGE

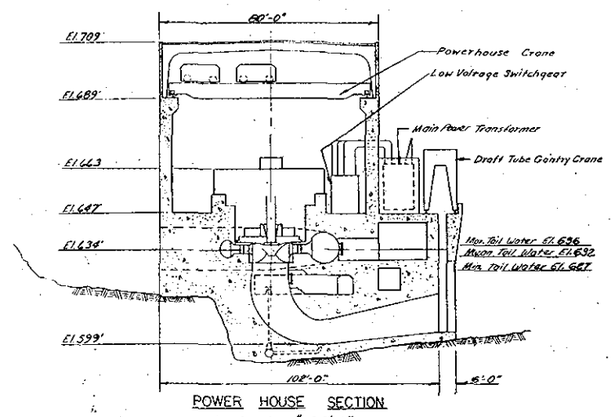
International Passamaquoddy Engineering Board

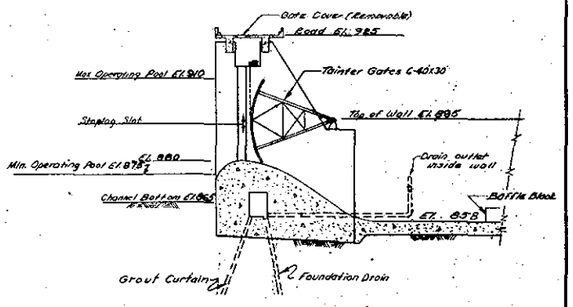
SEPTEMBER, 1959 Dwg. No. AG7-077

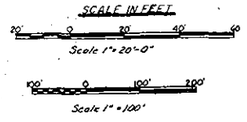


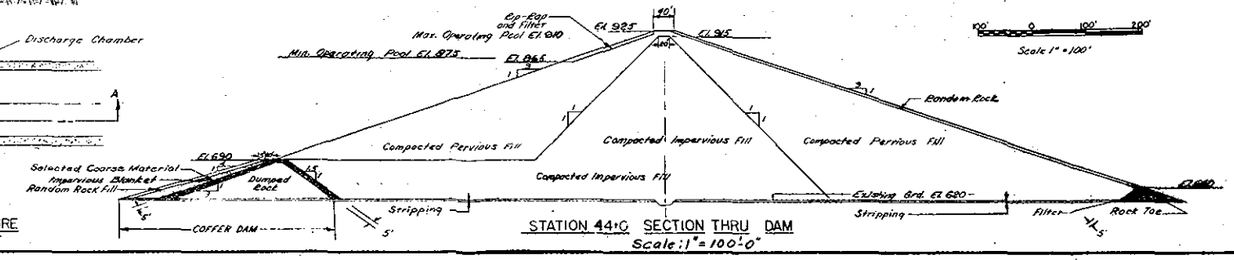












Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

BIG RAPIDS DEVELOPMENT

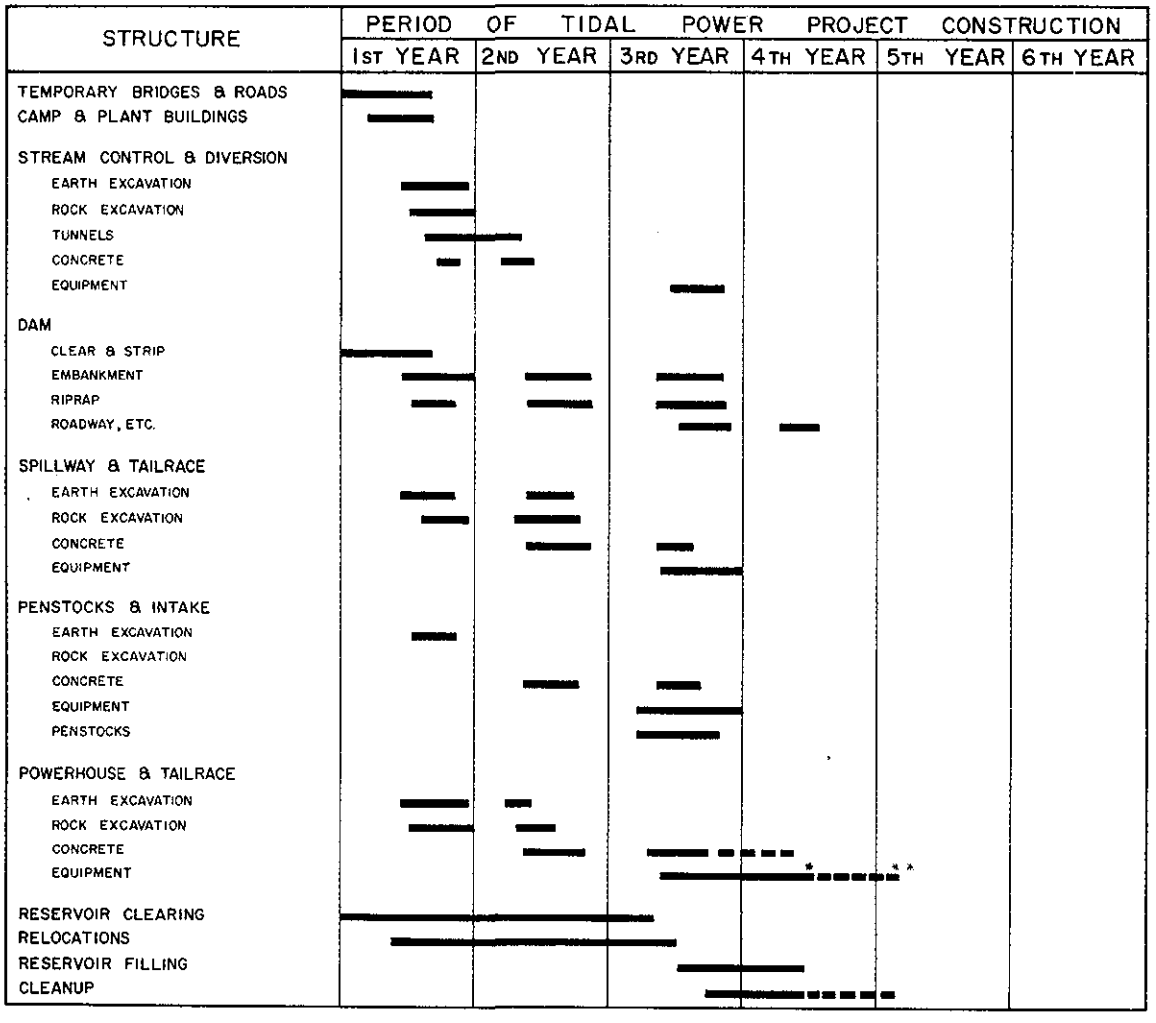
SECTIONS

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. AG7-078

CONSTRUCTION SCHEDULE



* 2 Units in operation
** 6 Units in operation

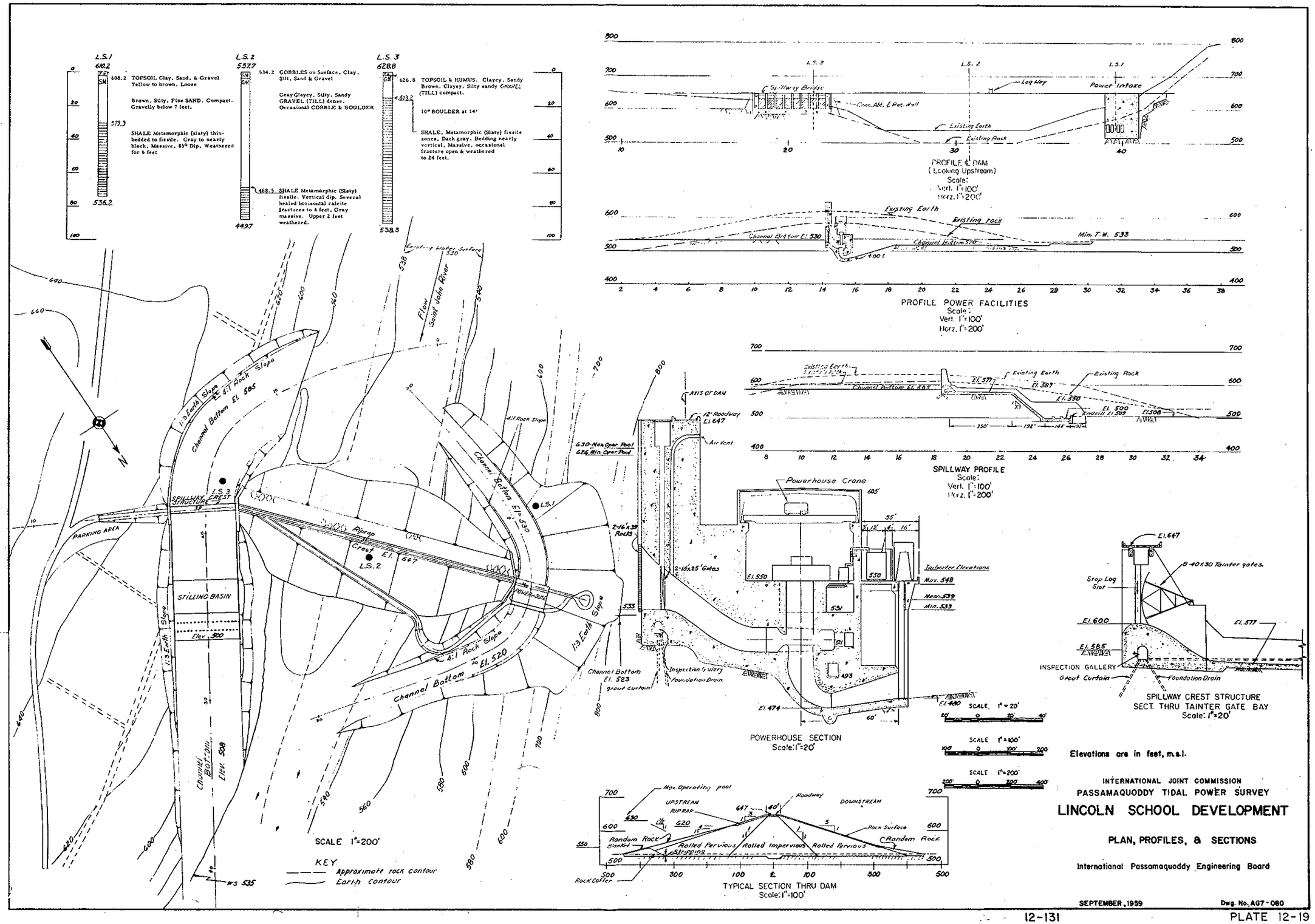
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

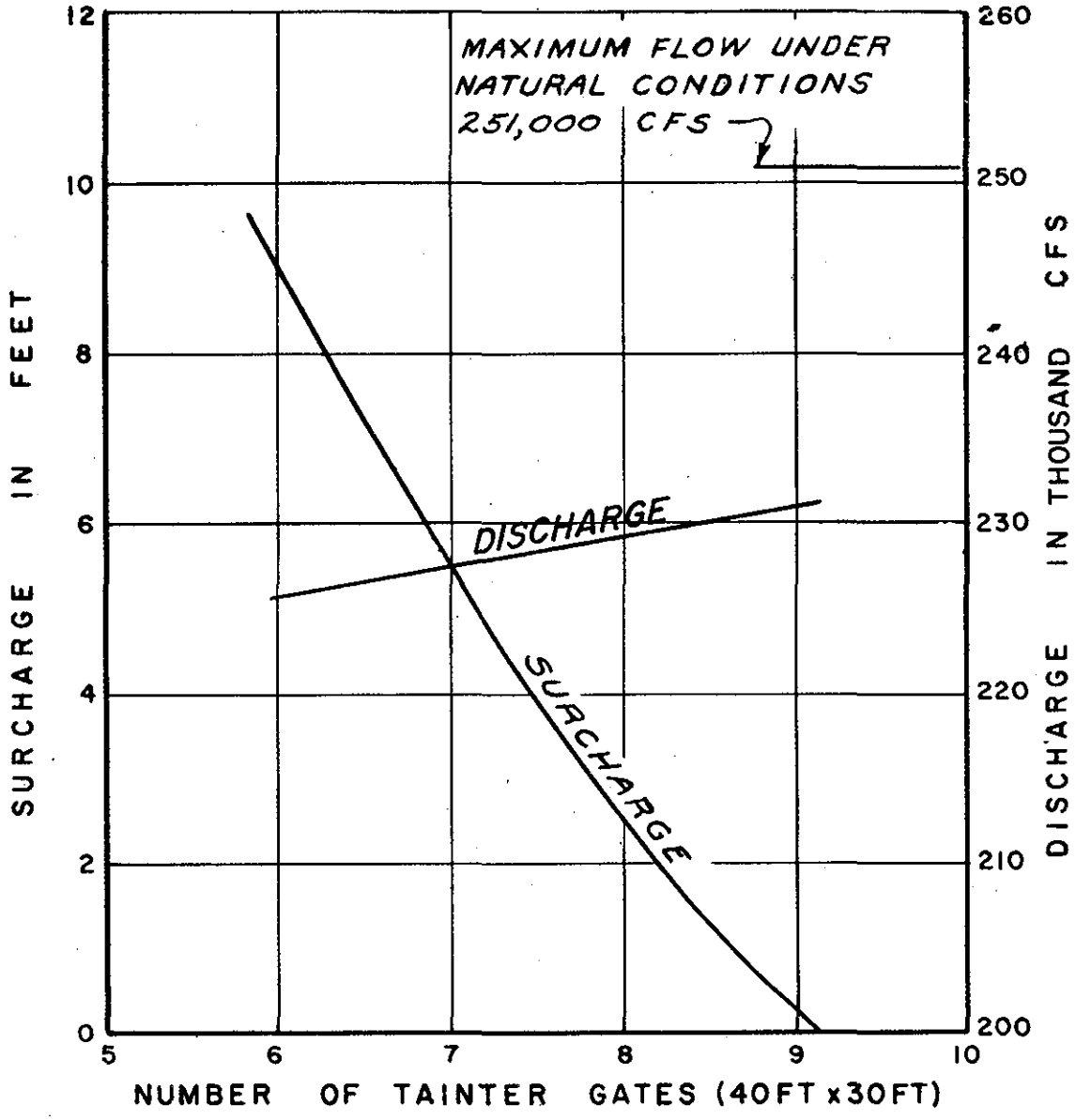
BIG RAPIDS DEVELOPMENT
CONSTRUCTION SCHEDULE

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-079

PLATE 12-18


L.S.1
610.2
698.2 TOPSOIL Clay, Sand, & Gravel Yellow to brown, Loose
Brown, Silty, Fine SAND. Compact. Gravelly below 7 feet.
579.3
SHALE Metamorphic (slaty) thin-bedded to fissile. Gray to nearly black, Massive, 85° Dip. Weathered for 6 feet
536.2
L.S.2
537.7
534.2 COBBLES on Surface, Clay, Silt, Sand & Gravel
Gray Clayey, Silty, Sandy GRAVEL (TILL) dense. Occasional COBBLE & BOULDER
468.5 SHALE Metamorphic (Slaty) fissile. Vertical dip. Several healed horizontal calcite fractures to 4 feet. Gray massive. Upper 2 feet weathered.
449.7
L.S.3
628.8
626.8 TOPSOIL & HUMUS. Clayey, Sandy Brown, Clayey, Silty sandy GRAVEL (TILL) compact.
613.2
10" BOULDER at 14'
SHALE, Metamorphic (Slaty) fissile zones, Dark gray. Bedding nearly vertical, Massive, occasional fracture open & weathered to 24 feet.
538.3
Existing Water Surface
Flow Saint John River
Channel Bottom El. 585
1:3 Earth Slope
4:1 Rock Slope
Channel Bottom El. 530
Channel Bottom El. 520
Channel Bottom El. 508
Riprap Crest El. 647
SPILLWAY STRUCTURE
CREST
PARKING AREA
STILLING BASIN
Elev. 500
POWERHOUSE
Channel Bottom El. 523
grout curtain
Inspection Gallery
Foundation Drain
WS 535
SCALE 1"=200'
KEY
Approximate rock contour
Earth contour
PROFILE ℄ DAM
(Looking Upstream)
Scale:
Vert. 1"=100'
Horz. 1"=200'
Spillway Bridge
Log Way
Power Intake
Conc. Abt. & Ret. Wall
Existing Earth
Existing Rock
Channel Bottom El. 530
Min. T.W. 533
PROFILE POWER FACILITIES
Scale:
Vert. 1"=100'
Horz. 1"=200'
Channel Bottom El. 585
Existing Earth
Existing Rock
El. 571
El. 587
El. 530
El. 500
Sill El. 509
SPILLWAY PROFILE
Scale:
Vert. 1"=100'
Horz. 1"=200'
AXIS OF DAM
12' Roadway El. 647
Air Vent
630-Max. Oper. Pool
626-Min. Oper. Pool
2-16'x39' Racks
2-16'x25' Gates
Powerhouse Crane
El. 550
Tailwater Elevations
Max. 548
Mean 539
Min. 533
El. 474
POWERHOUSE SECTION
Scale: 1"=20'
El. 647
8-40'x30' Tainter gates.
Stop Log Slot
El. 600
El. 585
El. 577
INSPECTION GALLERY
Grout Curtain
Foundation Drain
SPILLWAY CREST STRUCTURE
SECT. THRU TAINTER GATE BAY
Scale: 1"=20'
SCALE 1"=20'
SCALE 1"=100'
SCALE 1"=200'
Max. Operating pool
UPSTREAM
DOWNSTREAM
Roadway
RIPRAP
Rock Surface
Random Rock Blanket
Rolled Pervious Stripping
Rolled Impervious
Rolled Pervious
Random Rock
Rock Coffer
TYPICAL SECTION THRU DAM
Scale: 1"=100'
Elevations are in feet, m.s.l.
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
LINCOLN SCHOOL DEVELOPMENT
PLAN, PROFILES, & SECTIONS
International Passamaquoddy Engineering Board
SEPTEMBER, 1959
Dwg. No. AG7-080



INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

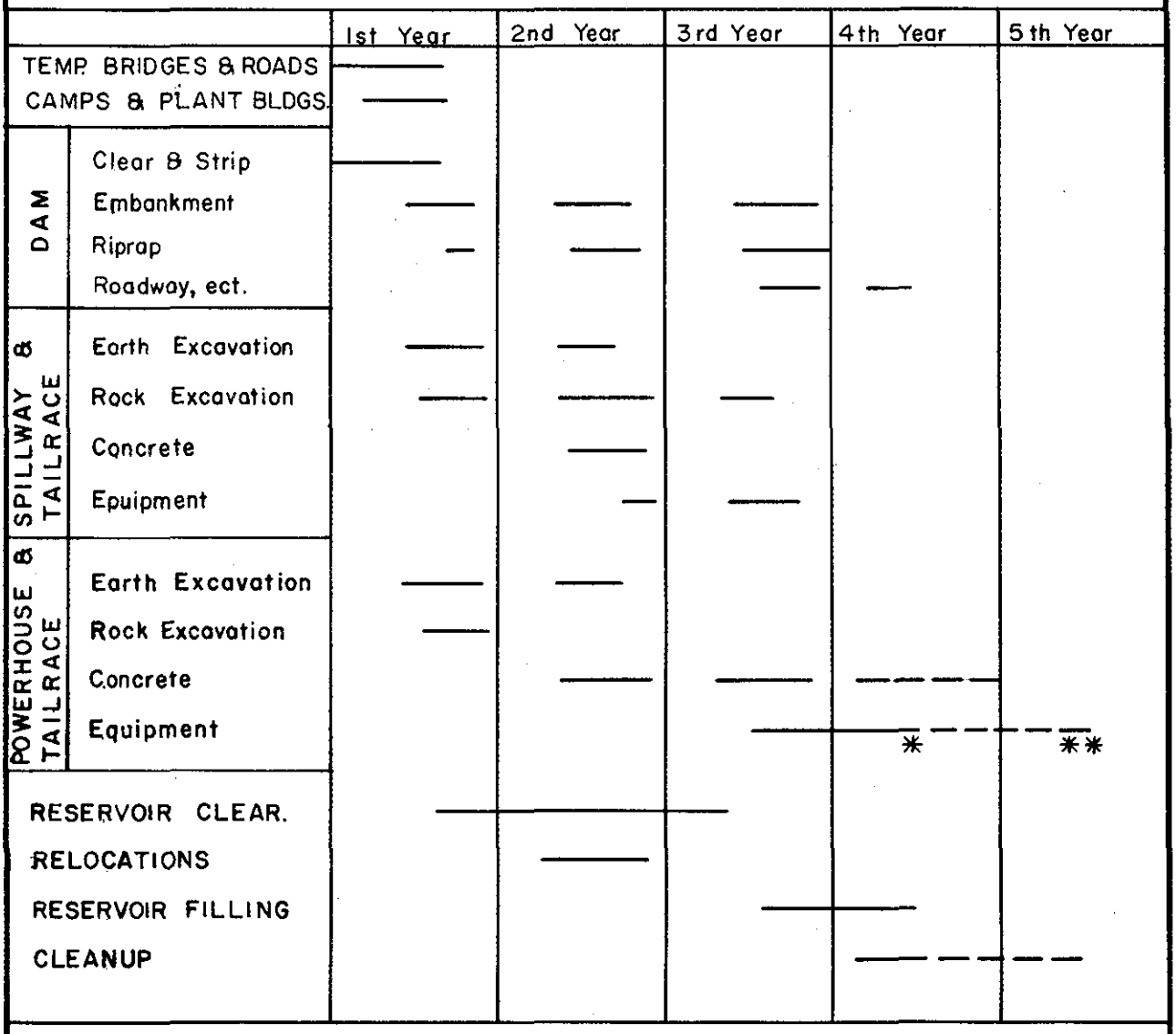
LINCOLN SCHOOL DEVELOPMENT

SPILLWAY GATES VS SURCHARGE

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-081

CONSTRUCTION SCHEDULE



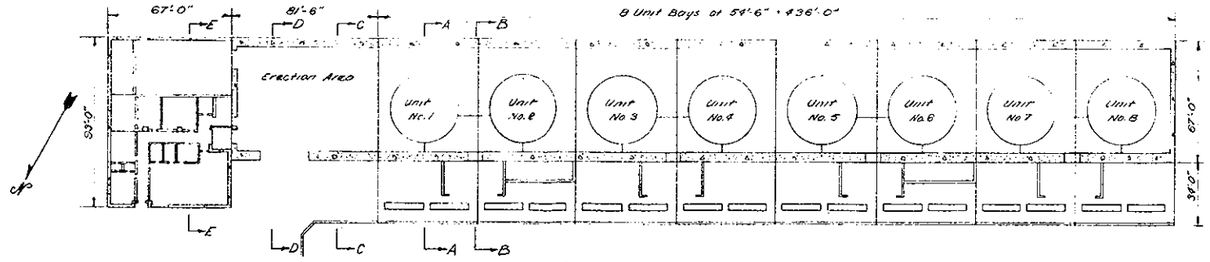
* 1 Unit in operation
** 2 Units in operation

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

LINCOLN SCHOOL DEVELOPMENT
CONSTRUCTION SCHEDULE

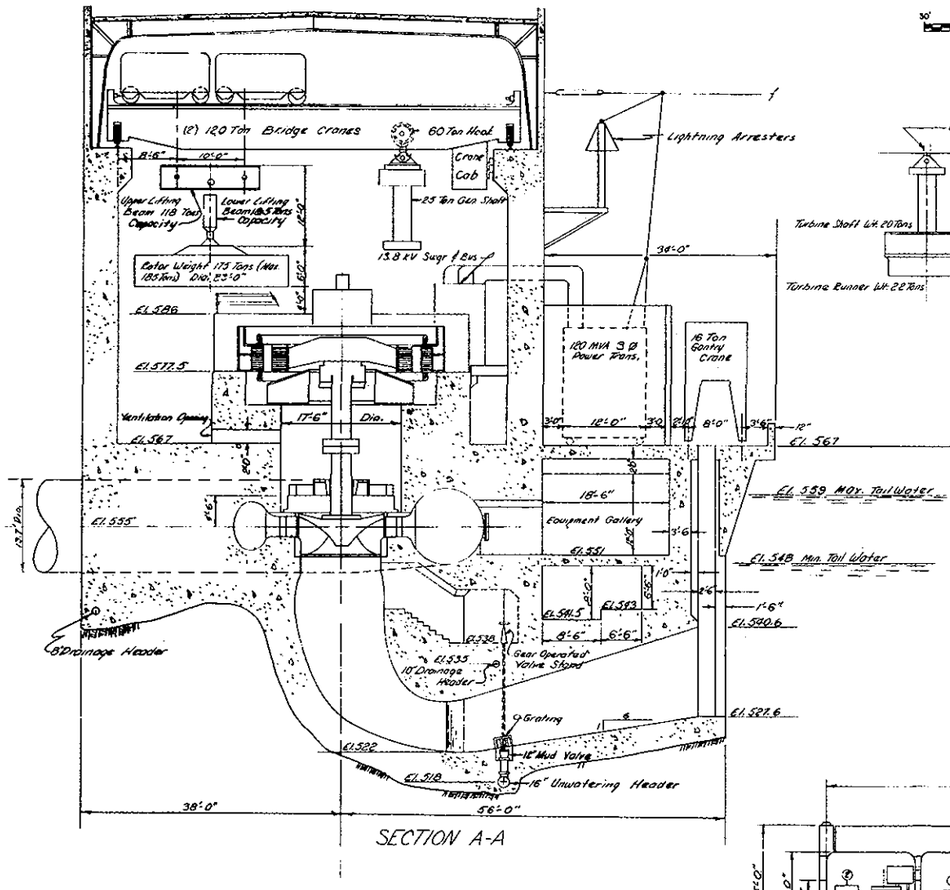
International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-082

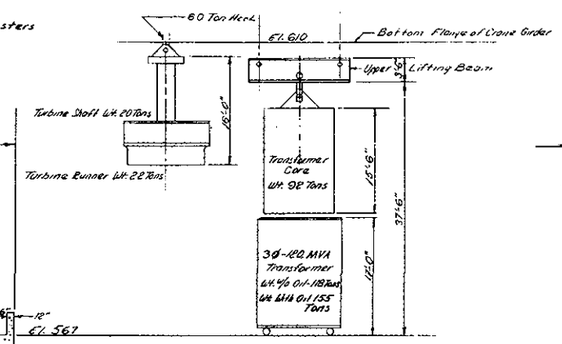


GENERAL PLAN

SCALE 1" = 30'

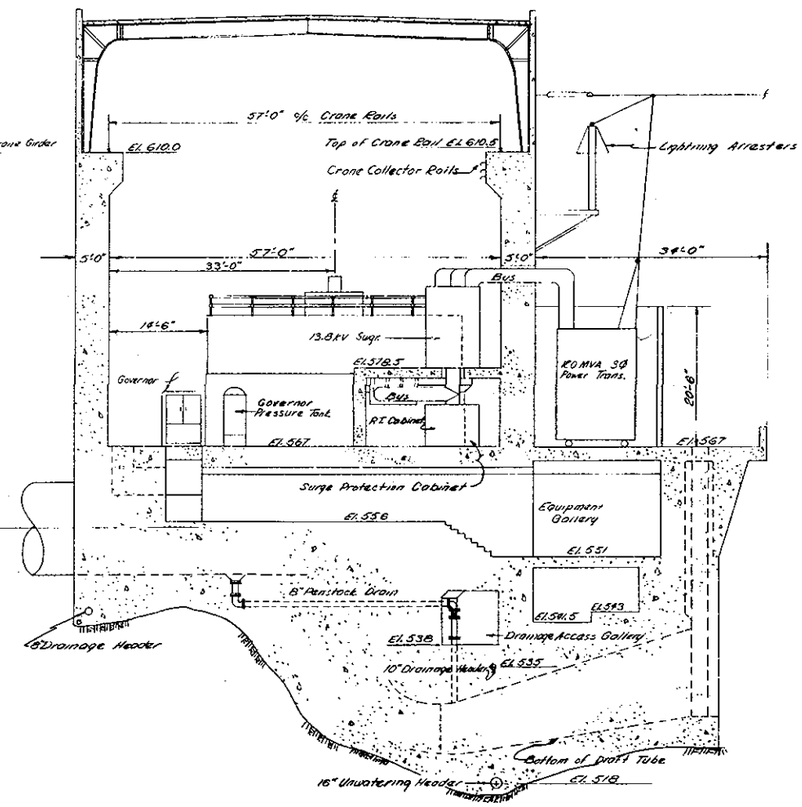


SECTION A-A

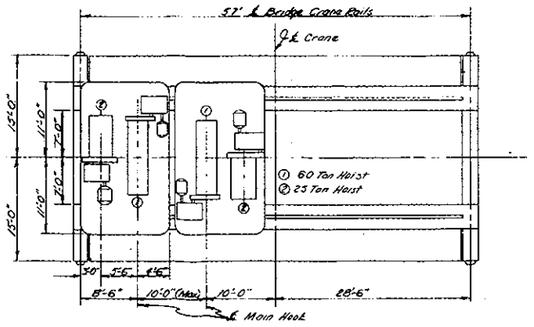


ELEVATION

Crane Clearance Diagram



SECTION B-B



PLAN

120 Ton Bridge Crane

SCALE 1/8" = 1'-0"

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

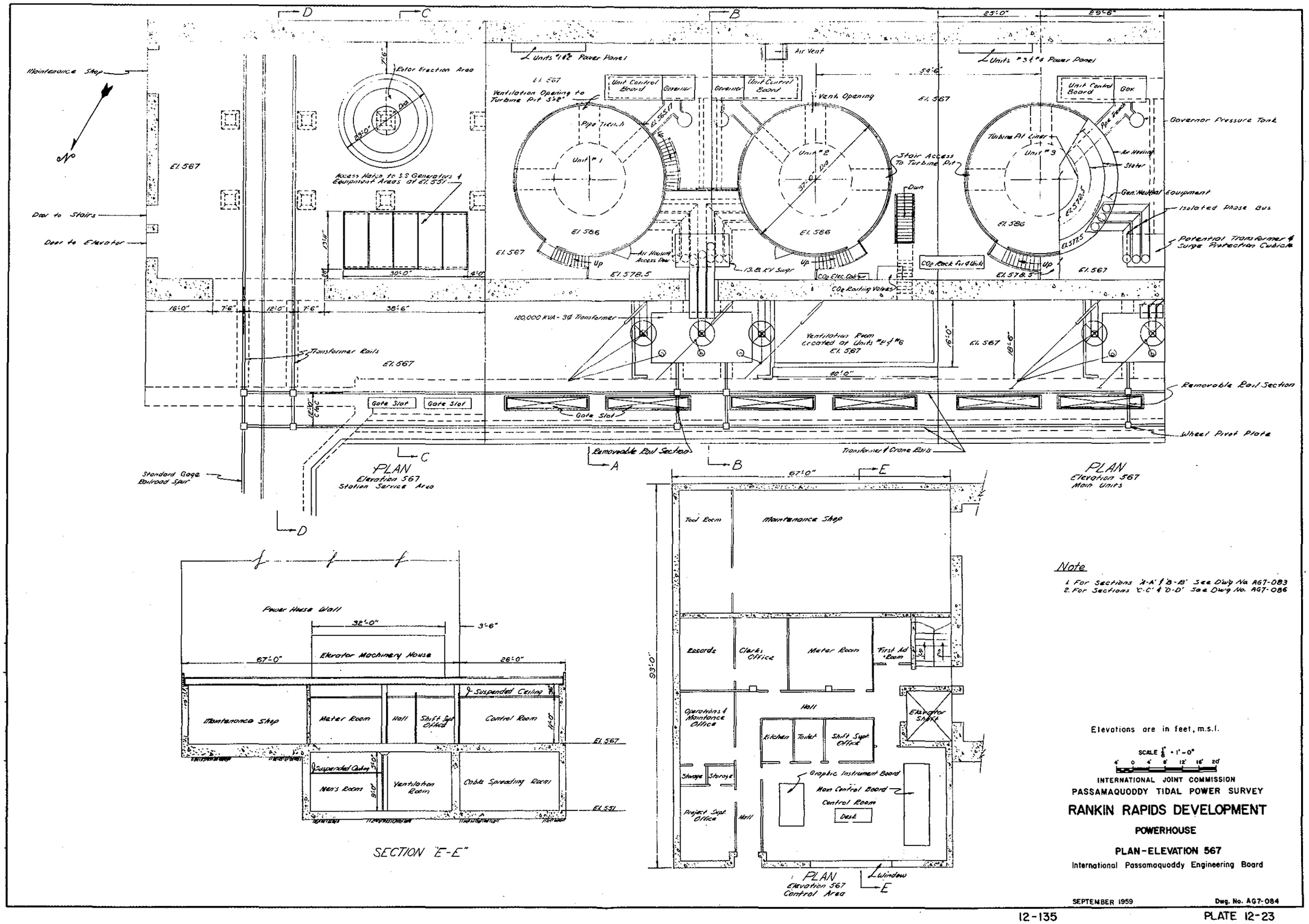
POWERHOUSE

GENERAL PLAN & SECTIONS

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. AG7-083



Note

1. For Sections 'A-A' & 'B-B' See Dwg No. AG7-083
2. For Sections 'C-C' & 'D-D' See Dwg No. AG7-086

Elevations are in feet, m.s.l.

SCALE 3/8" = 1'-0"

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

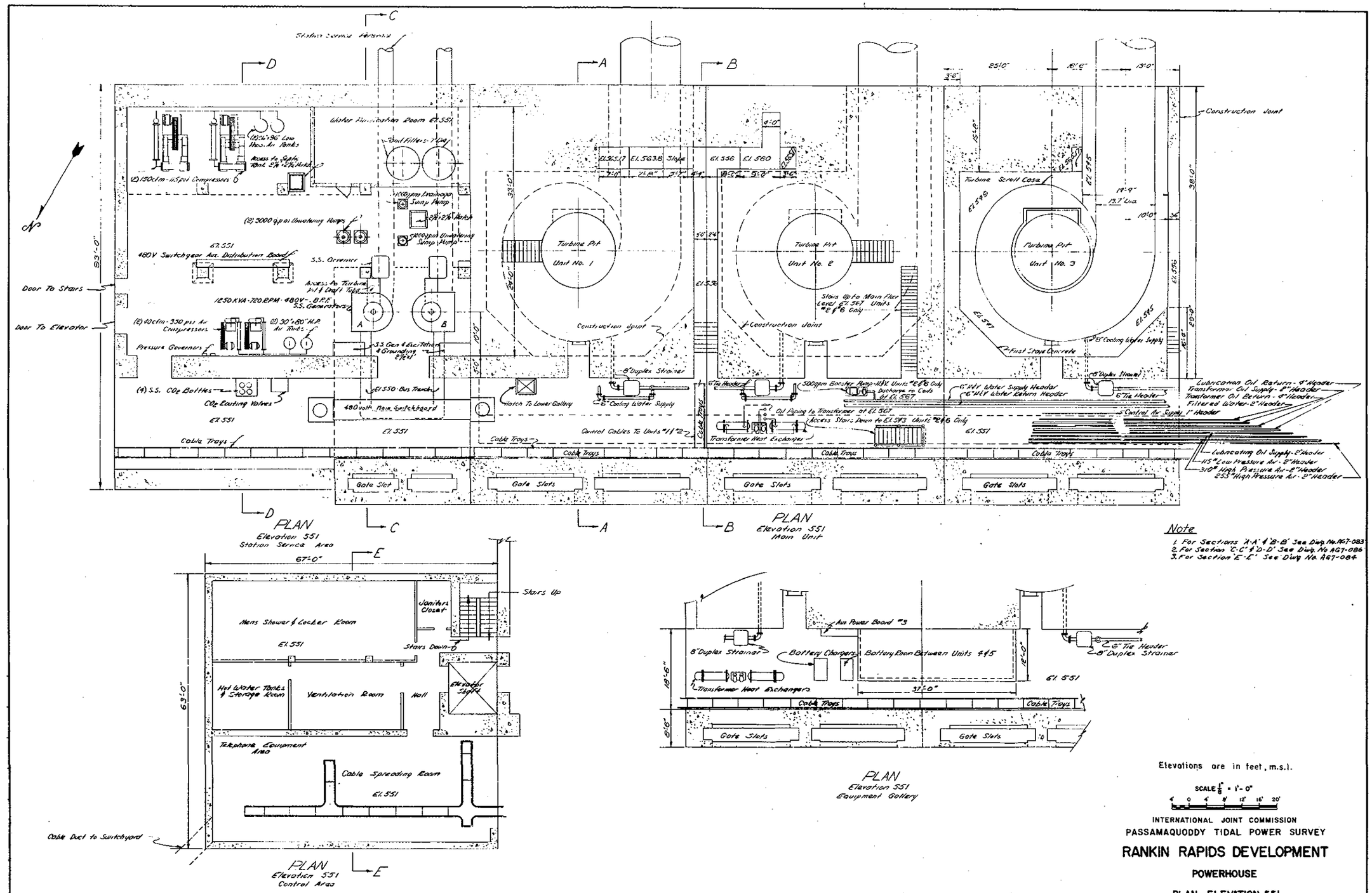
POWERHOUSE

PLAN-ELEVATION 567

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. AG7-084



Note

1. For Sections 'A-A' & 'B-B' See Dwg. No. AG7-083
2. For Section 'C-C' & 'D-D' See Dwg. No. AG7-086
3. For Section 'E-E' See Dwg. No. AG7-084

Elevations are in feet, m.s.l.

SCALE 1/8" = 1'-0"

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

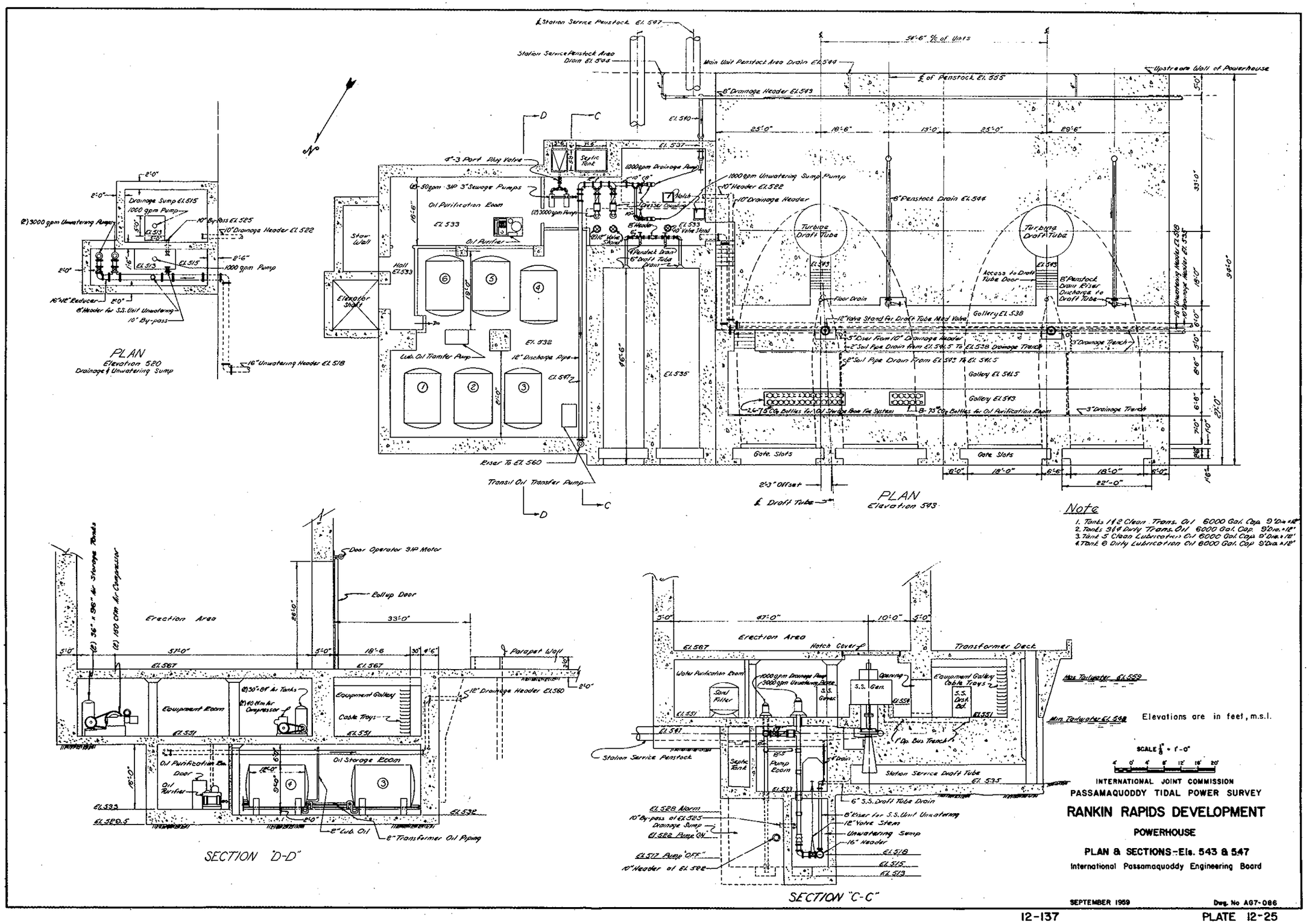
POWERHOUSE

PLAN-ELEVATION 551

International Passamaquoddy Engineering Board

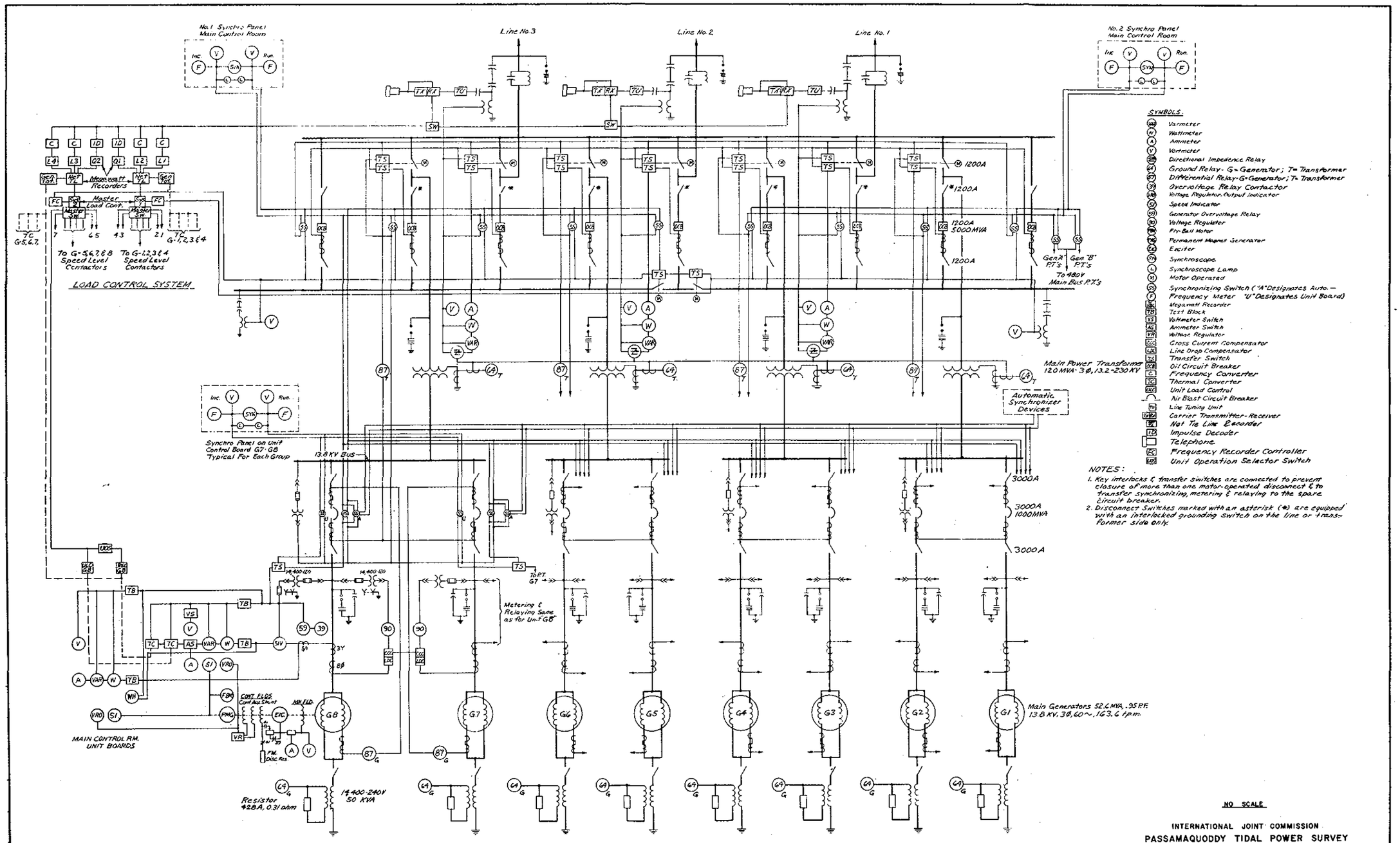
SEPTEMBER 1959

Dwg. No. AG7-085



Note

1. Tanks 1 & 2 Clean Trans. Oil 6000 Gal. Cap. 9' Dia. x 18'
2. Tanks 3 & 4 Dirty Trans. Oil 6000 Gal. Cap. 9' Dia. x 18'
3. Tank 5 Clean Lubrication Oil 6000 Gal. Cap. 9' Dia. x 12'
4. Tank 6 Dirty Lubrication Oil 6000 Gal. Cap. 9' Dia. x 12'



NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

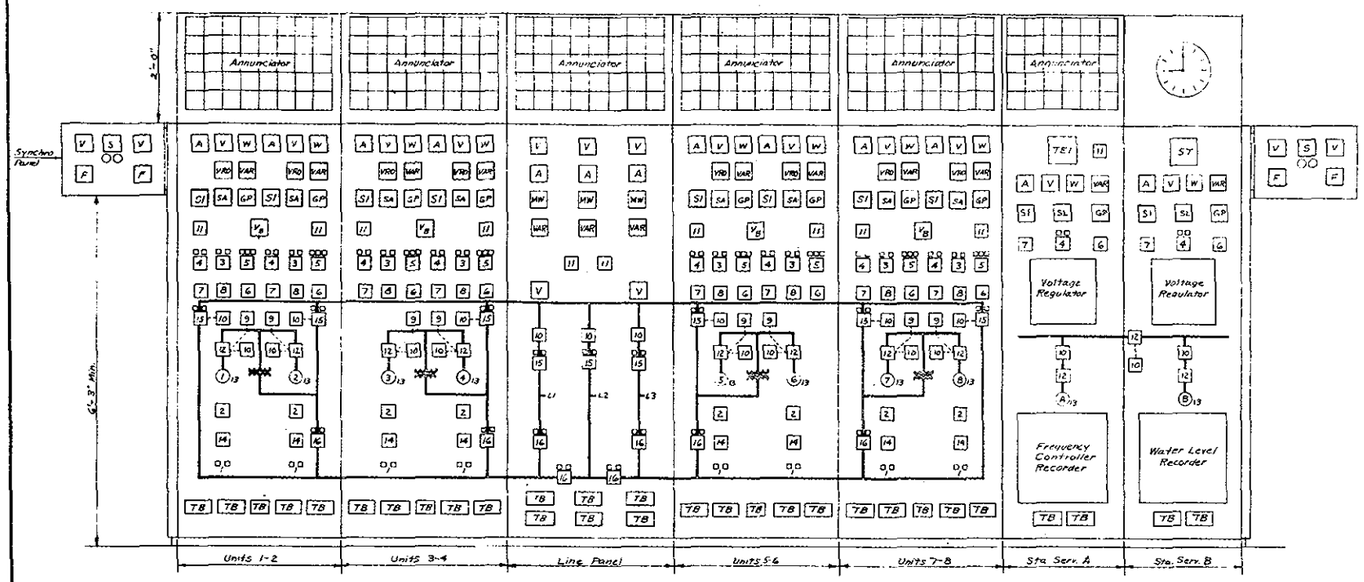
POWERHOUSE

MAIN ONE-LINE DIAGRAM

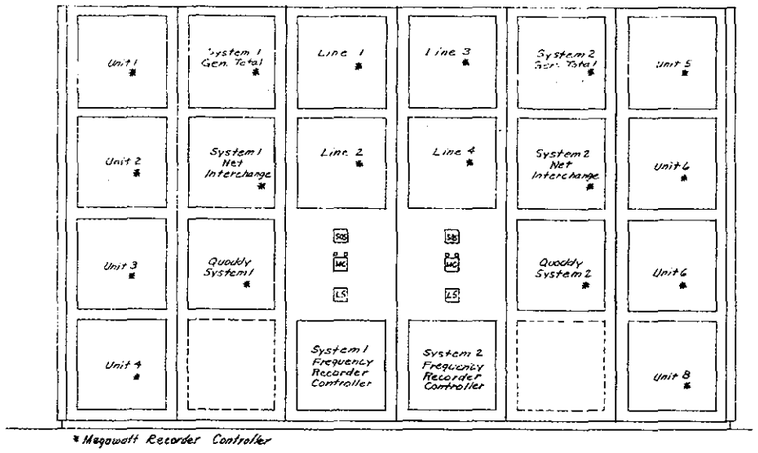
International Passamaquoddy Engineering Board

SEPTEMBER 1959

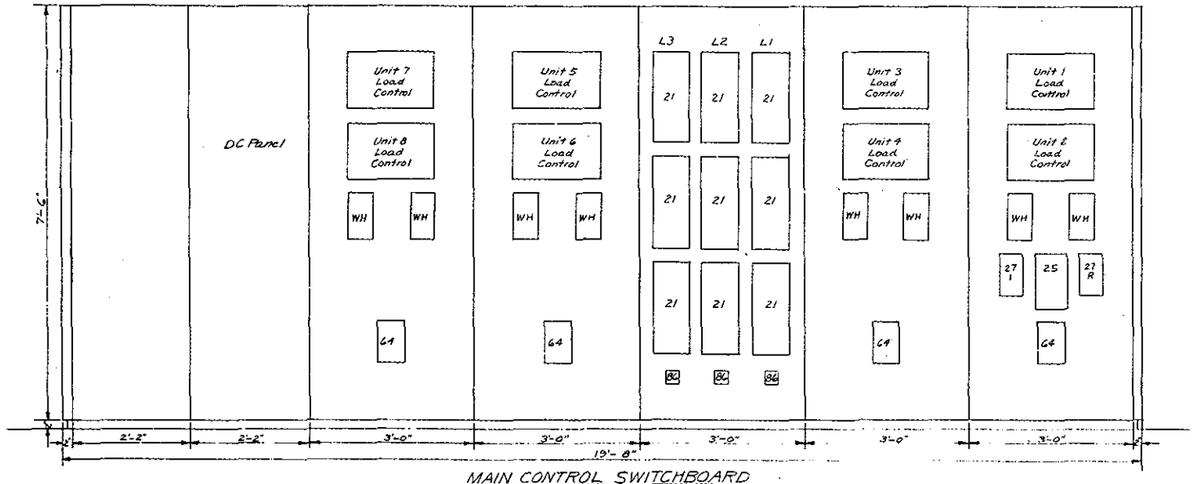
Dwg. No. AG7-087



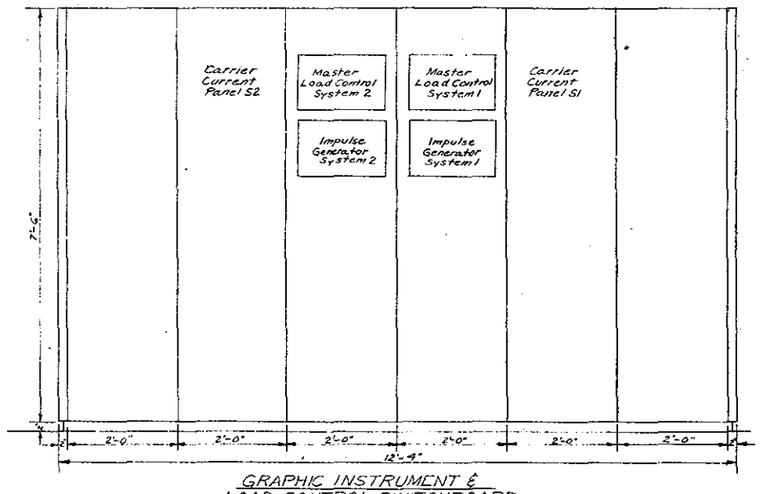
MAIN CONTROL SWITCHBOARD
FRONT PANELS



GRAPHIC INSTRUMENT &
LOAD CONTROL SWITCHBOARD
FRONT PANELS



MAIN CONTROL SWITCHBOARD
REAR PANELS



GRAPHIC INSTRUMENT &
LOAD CONTROL SWITCHBOARD
REAR PANELS

NOMENCLATURE

1. Local-Remote Control Indicating Lights.
2. Emergency Stop
3. Voltage Regulator Transfer (Man-Ind-Reg) with Normal Response Lights
4. Voltage Adjusting Rheostat Control with Limit Lights
5. Field Raise-Lower (Manual) with Limit Lights.
6. Gate Limit Control
7. Speed Adjustment
8. Unit Operation Selector Switch (L-F Control)
9. Automatic Synchronizer Selector Switch
10. Synchronizing Switch-Manual
11. Annunciator Control Switch
12. Circuit Breaker Control
13. Generator Symbol with Light
14. Governor Motor Response Rheostat (L-F Control)
15. 230 KV Bkr. Control Switch
16. Motor Operated Disc. Switch
21. Distance Relay
25. Automatic Synchronizer
27. Voltage Relay, I-Incoming Synchro Bus, R-Running Synchro Bus
64. Transformer Ground Relay
86. Line Lockout Relay

A Ammeter or Amber Light
F Frequency Meter 55-65 ~
GP Gate Position Indicator
SA Speed Adjustment Indicator
SI Speed Indicator
S Synchroscope
V Voltmeter
V_B Voltmeter-Bus Potential
VAR Varmeter
W Wattmeter
ULC Unit Load Controller
VRO Regulator-Output Indicator
TB Test Block
TEI Time Error Indicator
ST Standard Time Clock
SOS System Operation Selector Switch
MC Master Control Switch
WH Watthour Meter
LS Line Selector

NOTE:
Depth of Panels Shown on this Plan = 6'-0"

SCALE 1" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

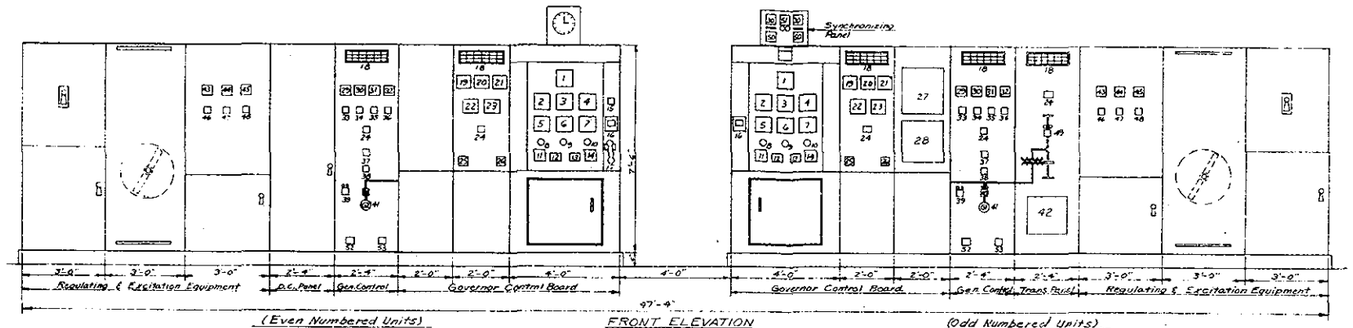
POWERHOUSE

MAIN CONTROL SWITCHBOARDS

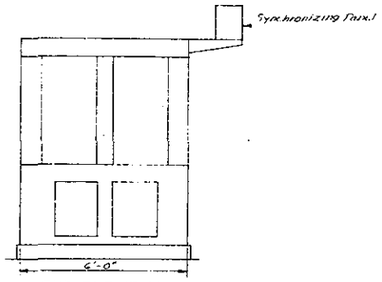
International Passamaquoddy Engineering Board

SEPTEMBER 1959

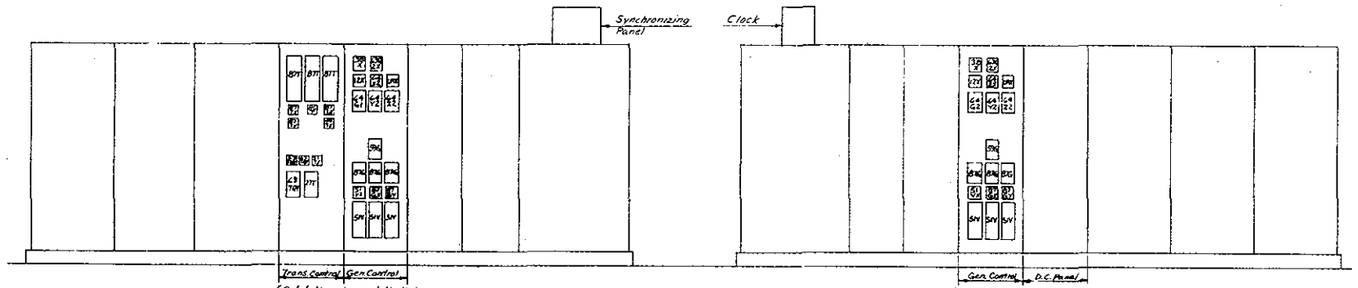
Dwg. No. AG7-088



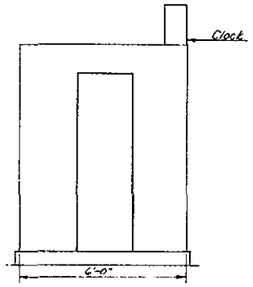
FRONT ELEVATION
(Looking toward Generators)



END ELEVATION
Governor Control Board



REAR ELEVATION



END ELEVATION
Regulating & Excitation Panel

NOMENCLATURE FOR FRONT OF BOARDS			
1	Speed Indicator	30	Voltmeter
2	Duplex Air Pressure Gauge	31	Voltmeter
3	Oil Pressure Gauge	32	Voltmeter
4	Transfer Valve Position Indicator	33	Ammeter Switch-3 Cir.
5	Speed Droop Indicator	34	Voltmeter Switch-3 Cir.
6	Gate Position & Gate Limit Indicator	35	Lockout Relay-86GC (Complete)
7	Speed Adjustment Indicator	36	Lockout Relay-86GP (Partial)
8	Speed Droop Control Knob	37	Lockout Relay-86GT (Time)
9	Gate Limit Control Knob	38	Synchronizing Switch
10	Speed Adjustment Control Knob	39	Local Remote Control Selector Switch w/key
11	Cabinet Light Switch & Pilot Lights	40	Circuit Breaker Control Switch
12	Generator Air Brake Control Knob	41	Generator Symbol w/light
13	Transfer Valve Control Knob	42	Transformer Temperature Recorder
14	Emergency Shutdown & Reset	43	Ammeter-Generator Field
15	Clock Reset	44	Main Excitation Voltmeter
16	Generator CO2 Break Glass Station	45	Voltage Regulating Meter
17	PAX Telephone	46	Voltage Adjusting Rheostat Switch
18	Annunciator	47	Trip Relay Switch
19	Generator Thrust Bearing Temp. Ind.	48	Voltage Regulating Control Switch
20	Generator Thrust Bearing Oil Temp. Ind.	49	230KV Bkr. Emergency Trip
21	Turbine Bearing Oil Temp. Indicator	50	Frequency Meter
22	Turbine Bearing Temp. Indicator	51	Synchroscope
23	Turbine Scroll Case Pressure Gauge	52	Current Test Outlet
24	Annunciator Test & Reset C.S.	53	Potential Test Outlet
25	Control Sw. For AC & DC Turb. Brg. Pump		
26	Head Gate Emergency Close		
27	Stator Temperature Recorder		
28	Bearing Temperature Recorder		
29	Ammeter		

NOMENCLATURE FOR REAR OF BOARDS	
12	Overspeed Device
27	Voltage Relay-Picks up on normal Voltage
T	Transformer
38	Bearing Thermal Relay
49T	Transformer Overheat Relay
51V	Overcurrent Relay with voltage Restraint
59G	Generator Voltage Relay
63	Fluid Pressure or Flow Device
Q	Governor Oil Pressure
TQ	Transformer Oil Flow
TW	Transformer Water Flow
64	Ground Relay
G	Generator
86	Lockout Relay
87	Differential Relay
G	Generator
T	Transformer
URX	Unit Run Relay
X,Y,Z	Auxiliary Relays

SCALE $\frac{1}{2}$" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

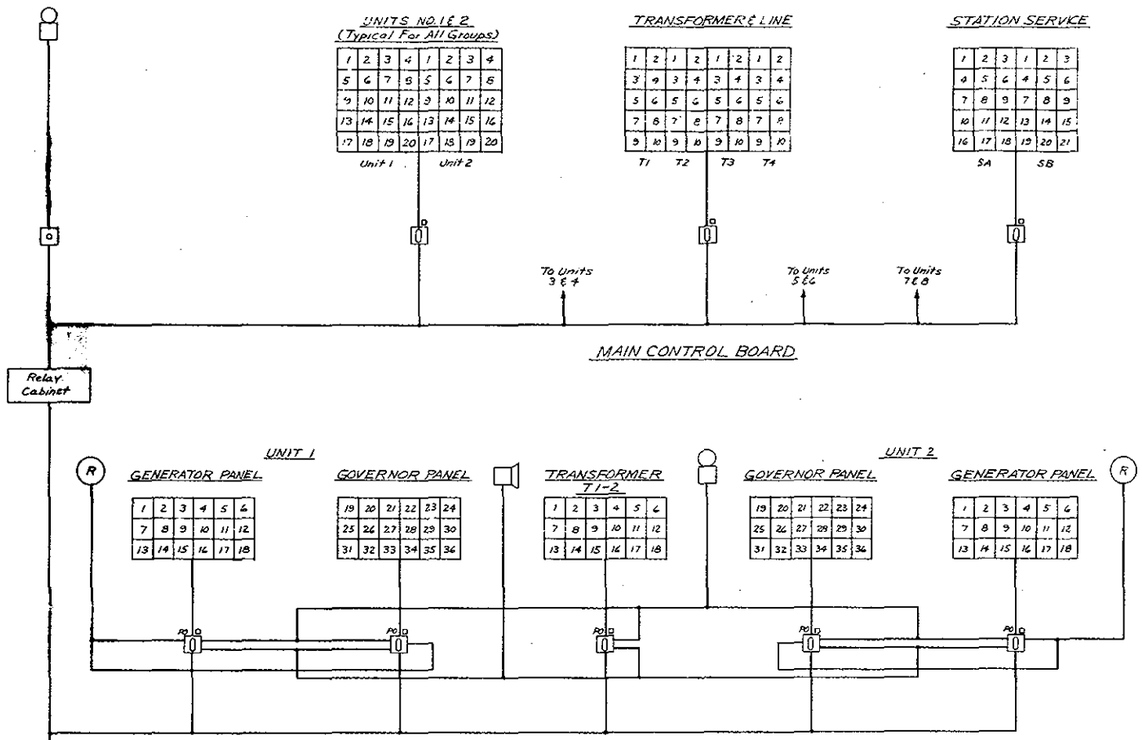
RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

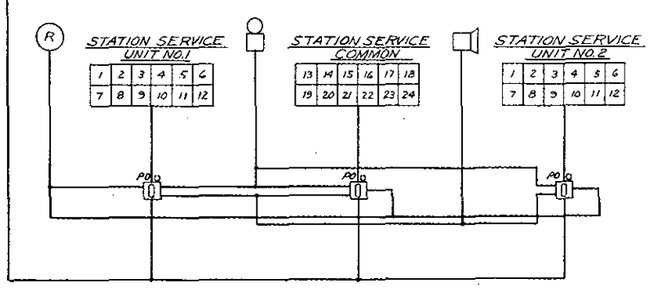
UNIT CONTROL SWITCHBOARD

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-089



UNIT CONTROL BOARD - GROUP NO. 1-2
(Typical For Group Nos. 3-4, 5-6 & 7-8)



STATION SERVICE CONTROL BOARD

MAIN CONTROL BOARD					
MAIN UNIT		TRANSFORMER & LINE		STATION SERVICE	
1	Differential Trip	1	Differential Trip	1	Differential Trip
2	Ground Trip	2	High Temp. Trip	2	Ground Trip
3	Overcurrent Trip	3	Diaphram Rupture	3	Overcurrent Trip
4	Emergency Shutdown	4	Transformer Cooling Trouble	4	Emergency Shutdown
5	Hot Bearing Trip	5	Transformer High Temp.	5	Hot Bearing Trip
6	Overspeed	6	H.V. Ground Trip	6	Governor Low Oil Pressure
7	Overvoltage	7	Line Relay Trip	7	Thrust Oil High Temp.
8	CO-2 Release	8	Line Pilot Trouble	8	Main Breaker Trip
9	Governor Low Oil Pressure	9	H.V. ACB Low Air	9	Spare
10	Thrust High Temp.	10	System No1. Load Limit	10	Battery Charger Failure
11	Turbine Bearing High Temp.			11	D.C. Supply Trip
12	Turbine DC Pump On			12	Tie Breaker Trip
13	Turbine Bearing Low Oil			13	Sump High Water
14	Stator High Temp.			14	CO-2 Release
15	Generator Field High Temp.			15	Unit 480V Trip
16	Cooling Water Low Flow			16	Load Control Trip
17	High Air Temp.			17	Carrier Trouble
18	480V Supply Trouble			18	Carrier Current Supply Failure
19	15KV Ground			19	Standard Time Trouble
20	Spare			20	Frequency Control Trip
				21	Spare

UNIT CONTROL BOARD					
GENERATOR PANEL		GOVERNOR PANEL		TRANSFORMER PANEL	
1	Differential	19	Emergency Shutdown	1	Differential
2	Ground	20	Low Governor Oil Trip	2	230KV Ground
3	Overcurrent	21	Hot Bearing Trip	3	High Temp. Trip
4	Overvoltage	22	Thrust High Temp.	4	High Oil Temp.
5	CO-2 Release	23	Turbine Bearing High Temp.	5	Low Oil Flow
6	Stator High Temp.	24	Overspeed	6	Low Water Flow
7	Field High Temp.	25	Turbine D.C. Pump On	7	H. or L. Oil Level
8	Cooling Water Low Flow	26	Turbine Bearing Low Oil Flow	8	H. or L. Gas Pressure
9	High Air Temp.	27	Bearing Oil Level	9	Diaphram Rupture
10	Spare	28	Spare	10	Fog Release
11	Spare	29	Spare	11	OCB Low Air
12	Spare	30	Spare	12	Spare
13	CO-2 OFF	31	D.C. Control OFF	13	D.C. Supply Trip
14	Voltage Regulator Trip	32	480V Trouble	14	480V Trouble
15	ACB Low Air	33	D.C. Bkr Trip	15	Oil Pump Trip
16		34	Brakes On	16	Line Relay Trip
17		35	Grease Failure	17	15KV Ground
18		36		18	Spare

STATION SERVICE BOARD			
STATION SERVICE UNIT PANEL		COMMON PANEL	
1	Differential DC or Ground Trip	13	480V Bus Undervoltage
2	Hot Bearing Trip	14	480V System Ground
3	Governor Low Oil Pressure Trip	15	Battery System Grnd
4	CO-2 Discharge	16	Battery Charger Trouble
5	Emergency Trip	17	Vent System Trouble
6	Spare	18	Sump High Water
7	Cooling Water Low Flow	19	Oil Room CO-2 Discharge
8	Bearing High or Low Oil	20	125V Supply Trip
9	High Air Temp.	21	CO-2 DC Supply OFF
10	Bearing High Temp.	22	
11		23	
12	Spare	24	Spare

LEGEND

- Annunciator Lamp Cabinet (Typical)
- Gong
- Horn
- Annunciator Switch - Silence, Reset & Test
- Annunciator Switch - Silence, Test & Pull-Out For Reset
- Pushbutton Alarm
- Unit Trouble Lamp-Red

NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

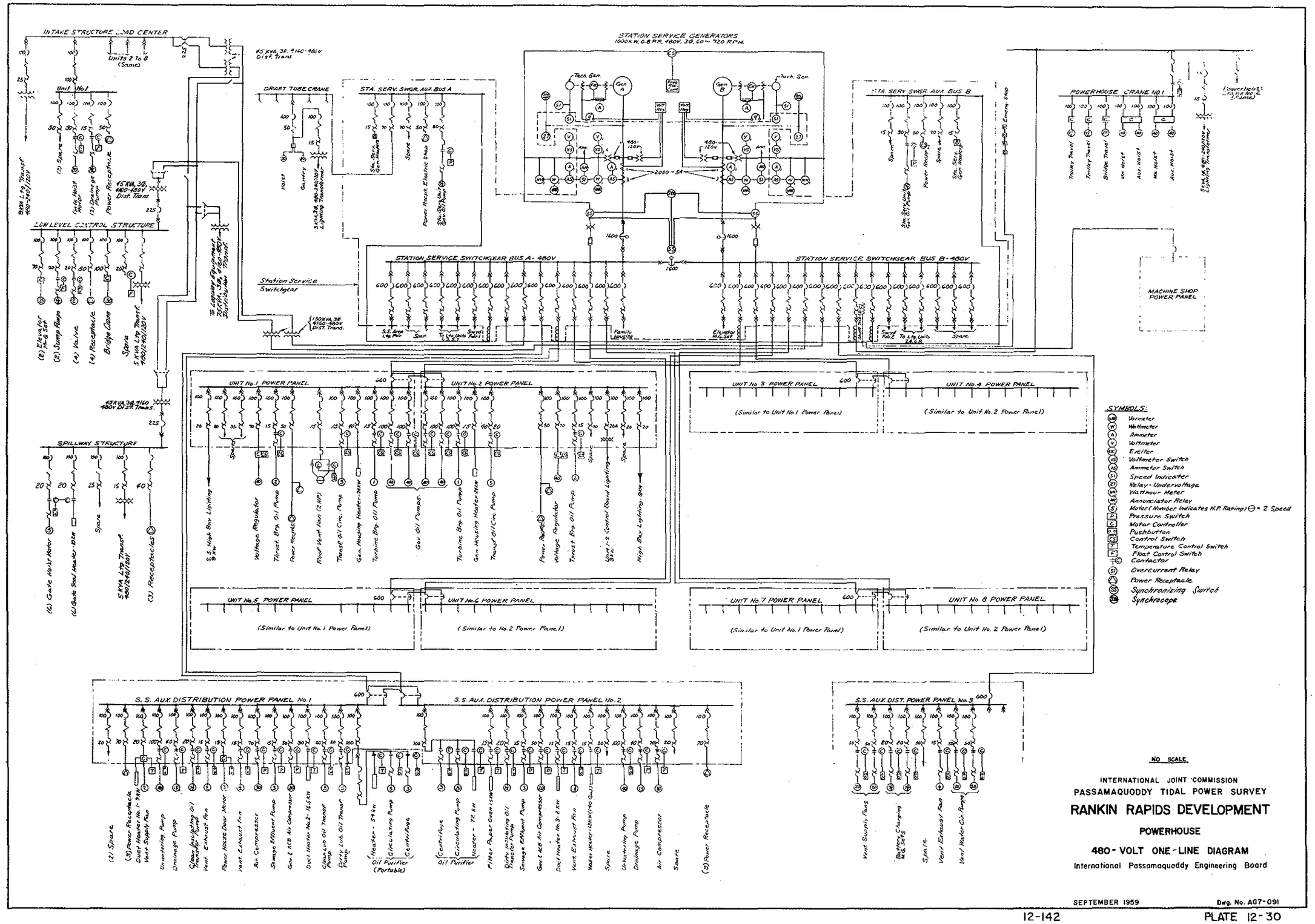
RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

ANNUNCIATOR SYSTEM

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-090



NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

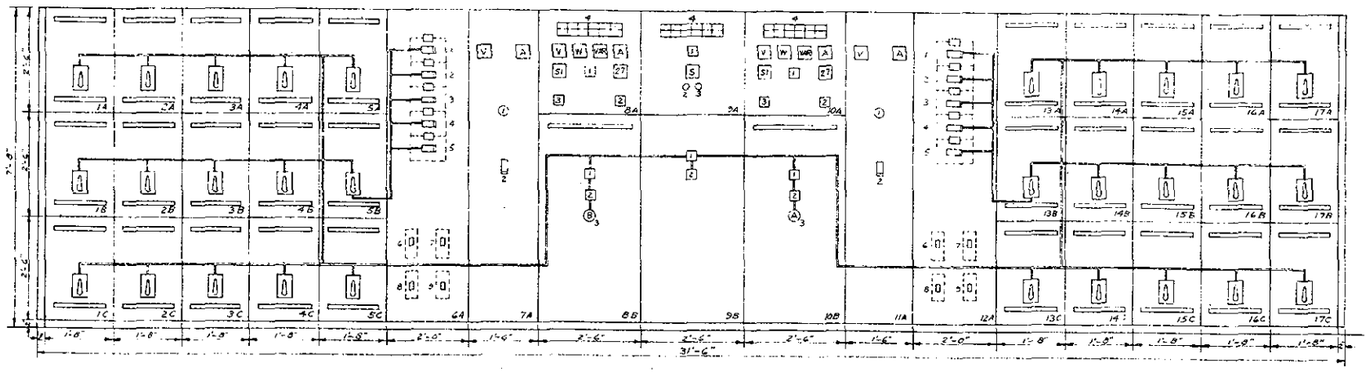
RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

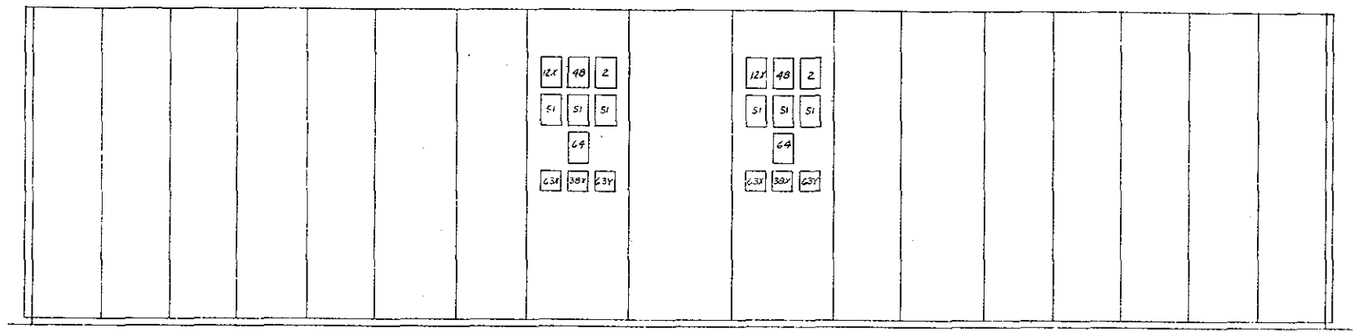
480-VOLT ONE-LINE DIAGRAM

International Passamaquoddy Engineering Board

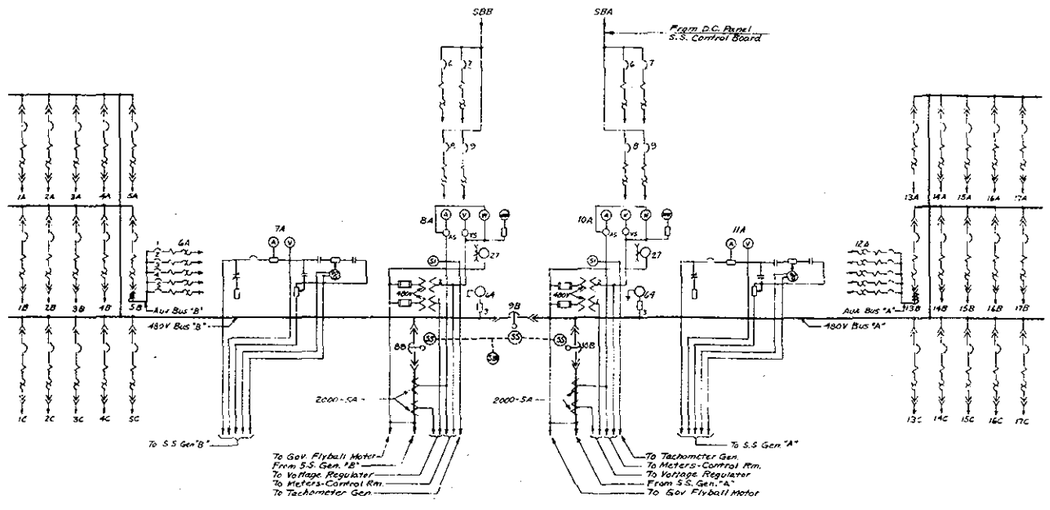
SEPTEMBER 1959 Dwg. No. AG7-091



FRONT PANELS



REAR PANELS



SINGLE LINE DIAGRAM

CIRCUIT BREAKER SCHEDULE		
Cir. No.	DESIGNATION	Fr. Size
1A	Unit No 1 Power Panel	600
1B	Space	
1C	Switchboard Feeder	
2A	Unit No. 3 Power Panel	
2B	Lighting Units No. 2 & 4	
2C	S.S. Area Lighting	
3A	Unit No 5 Power Panel	
3B	Station Service Hot-Wax Units	
3C	Family Housing Feeder	
4A	Unit No. 7 Power Panel	
4B	Lighting Units No. 5 & 6	
4C	Machine Shop Feeder	
5A	Dam Feeder	
5B	S.S Aux. Bus "B"	
5C	S.S Aux. Dist Power Panel No. 1	
6A1	S.S. Generator "B" Heaters	100
6A2	Dry Tube Crane	
6A3	Spare	
6A4	F.H. Recp. Electric Shop	
6A5	S.S. Gen. B. Gov. Oil Pump	
6A6	S.S. Gen "B" ACB Control	
6A7	S.S. Annunciator Supply	
6A8	Tie Bkr Control	
6A9	Emergency DC Lighting	
7A1	Field Cir. Bkr	
8B	Incoming - S.S. Gen "B"	1600
9B	Bus Tie	
10B	Incoming - S.S. Gen "A"	
11A1	Field Cir. Bkr	100
12A1	S.S. Generator "A" Heaters	
12A2	Space	
12A3	F.H. Recp. S.S. Area	
12A4	S.S. Gen. "A" Gov. Oil Pump	
12A5	Space	
12A6	S.S. Gen "A" ACB Control	
12A7	Annunciator Supply	
12A8	Tie Bkr. Control	
12A9	Emergency DC Lighting	
13A	Dam Feeder	400
13B	S.S. Aux. Bus "A"	
13C	S.S. Aux. Dist. Power	
14A	Unit Power Panel No. 2	
14B	Lighting Units No's 1 & 3	
14C	F.H. Elevator	
15A	Unit No 4 Power Panel	
15B	S.S. Aux. Dist Power Panel No. 3	
15C	Power House Crane	
16A	Unit No. 6 Power Panel	
16B	Lighting Units No. 5 & 7	
16C	Space	
17A	Unit No. 8 Power Panel	
17B	Space	
17C	Switchboard Feeder	

EQUIPMENT SCHEDULE	
No.	DESIGNATION
7A1	Exciter Field Rheostat
8B1	Annunciator Reset Sw.
8A2	Ammeter Switch
8A3	Voltmeter Switch
8A4	Annunciator Panel
8B1	Synchronizing Switch
8B2	Bkr Control Switch
9A3	Generator Symbol with Light
9A1	Annunciator Reset Switch
9A2	Synchroscope Ind Lamp
9A3	Synchroscope Ind Lamp
9A4	Annunciator Panel
9B1	Synchronizing Switch
9B2	Bkr Control Switch
10A1	Annunciator Reset Switch
10A2	Ammeter Switch
10A3	Voltmeter Switch
10A4	Annunciator Panel
10B1	Synchronizing Switch
10B2	Bkr Control Switch
10B3	Generator Symbol with Light
11A1	Exciter Field Rheostat
V	Voltmeter
W	Wattmeter
VAR	Varmeter
A	Ammeter
S1	Speed Indicator
27	Undervoltage Relay
3	Time Delay Bkr Closing Relay
12Z	Over Speed Aux Relay
38Z	Bearing Temp. Aux. Relay
48	Incomplete Sequence Relay
51	Overcurrent Relay
63A	Cooling Water Flow Aux. Relay
63B	Gov. Oil Pressure Aux. Relay
64	Ground Relay

NOTE:
Depth of Panels on this Plan = 4'-6"

SCALE $\frac{3}{4}$" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

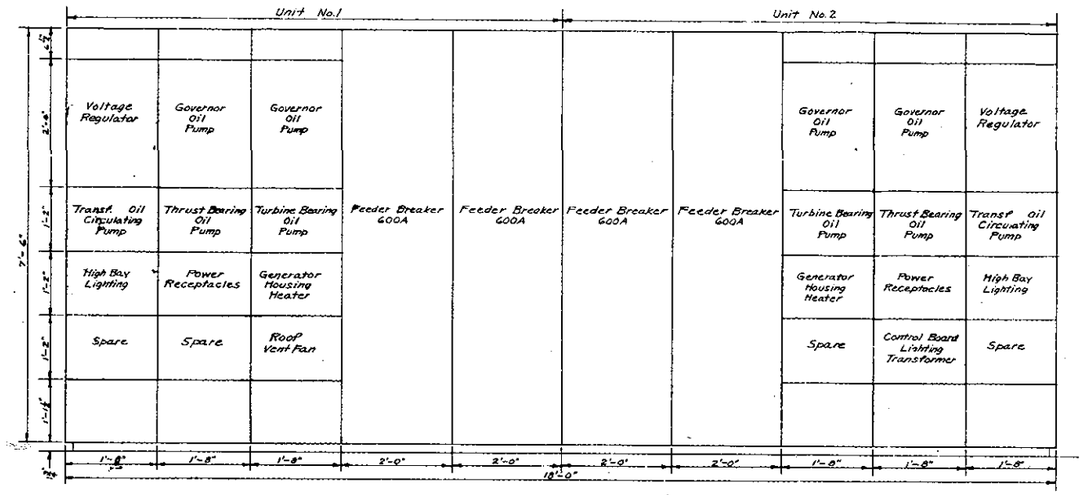
RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

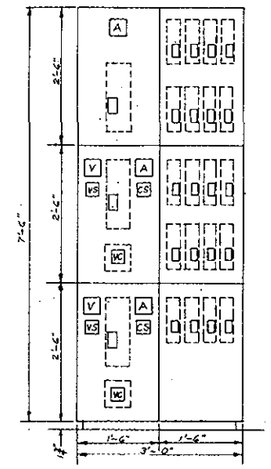
480-VOLT MAIN SWITCHBOARD

International Passamaquoddy Engineering Board

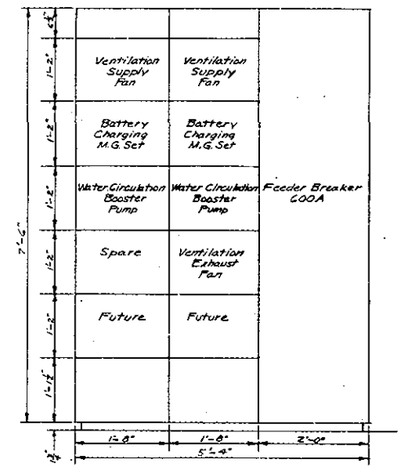
SEPTEMBER 1959 Dwg. No. AG7-092



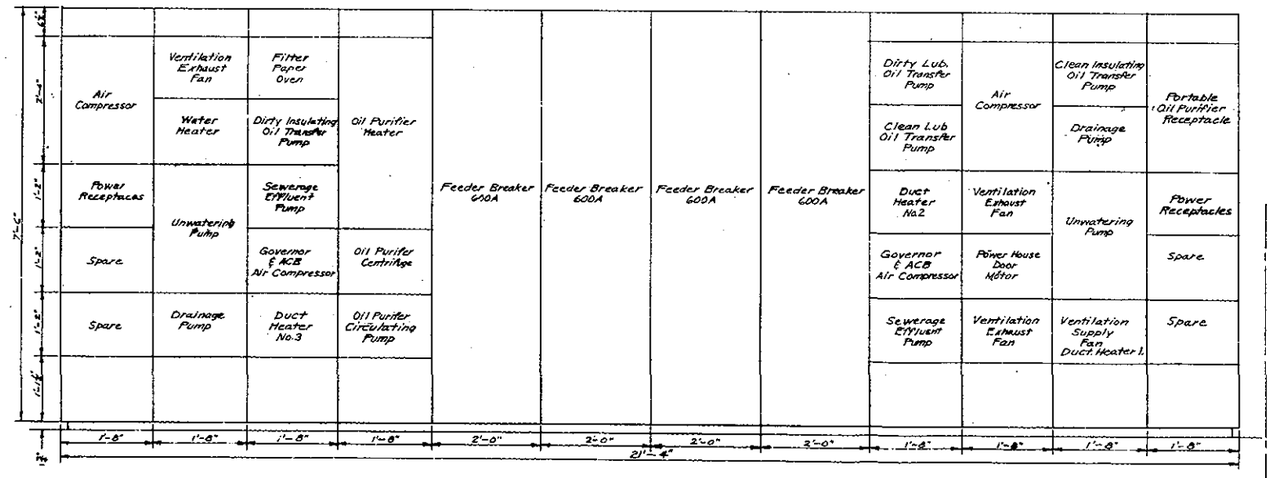
TYPICAL MOTOR CONTROL CENTER FOR UNIT POWER PANELS



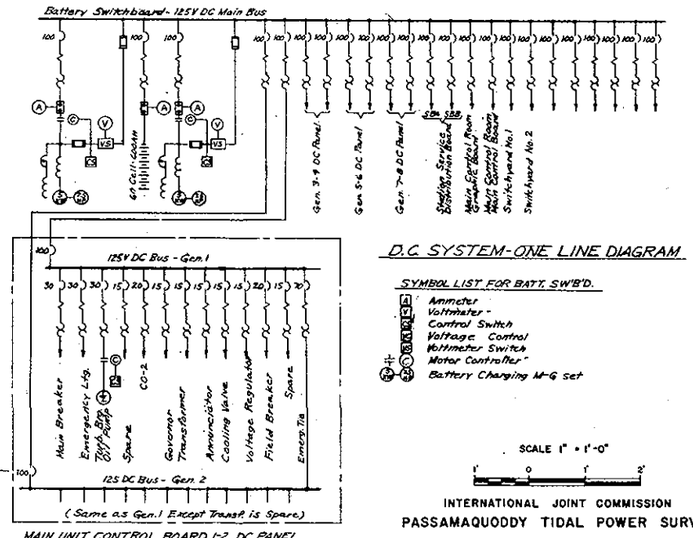
BATTERY SWITCHBOARD



MOTOR CONTROL CENTER FOR AUXILIARY DISTRIBUTION POWER PANEL No. 3



FRONT PANELS
MOTOR CONTROL CENTER FOR AUXILIARY DISTRIBUTION POWER PANEL NOS 1 & 2



MAIN UNIT CONTROL BOARD 1-2 DC PANEL

D.C. SYSTEM-ONE LINE DIAGRAM

SYMBOL LIST FOR BATT. SW'B'D.

- A — Ammeter
- V — Voltmeter
- CS — Control Switch
- VS — Voltage Control
- VS — Voltmeter Switch
- M — Motor Controller
- B — Battery Charging M-G set

SCALE 1" = 1'-0"

1' 0 1' 2'

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

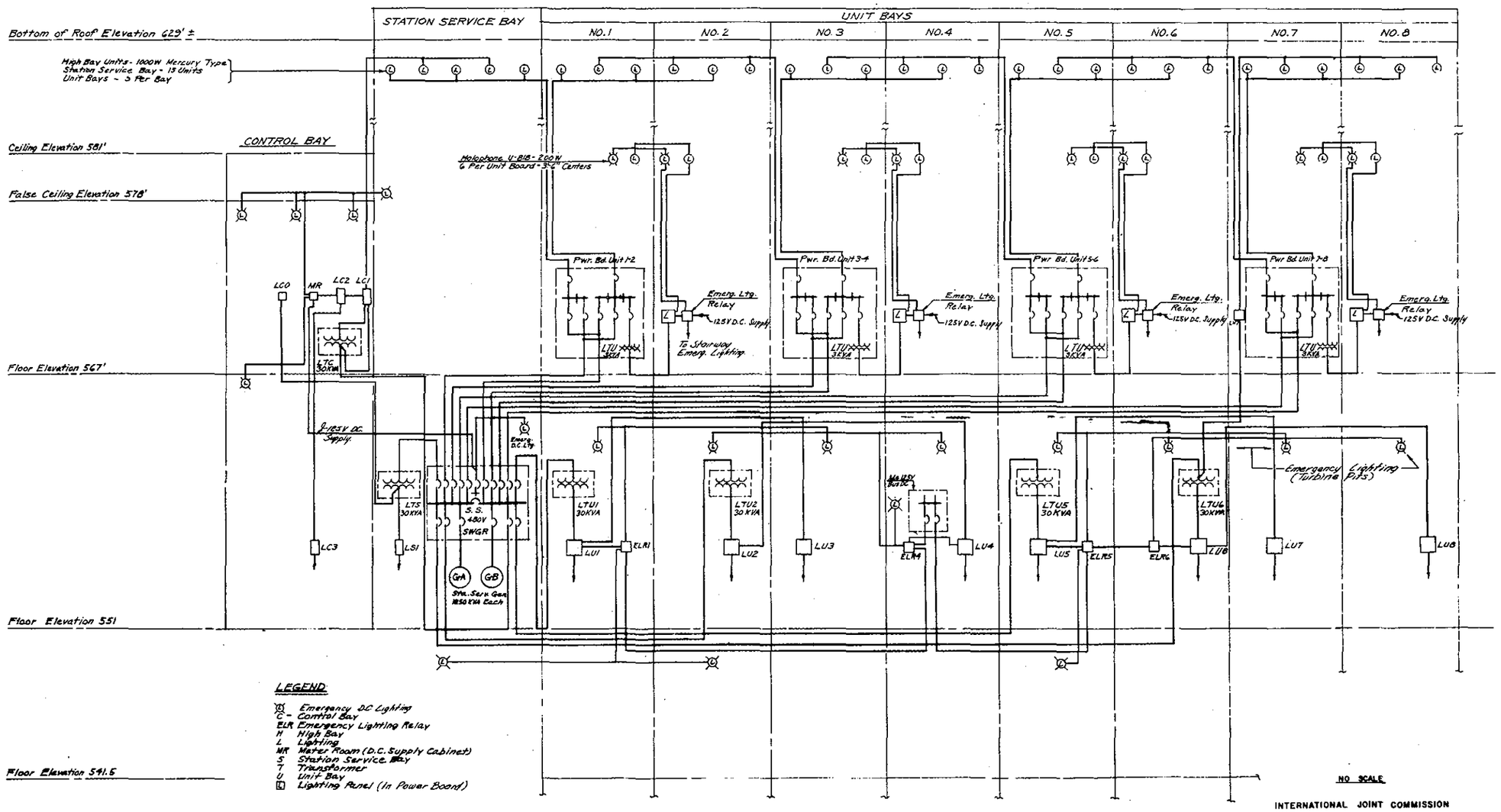
POWERHOUSE

MOTOR CONTROL CENTERS

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. AG7-093



NO SCALE

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

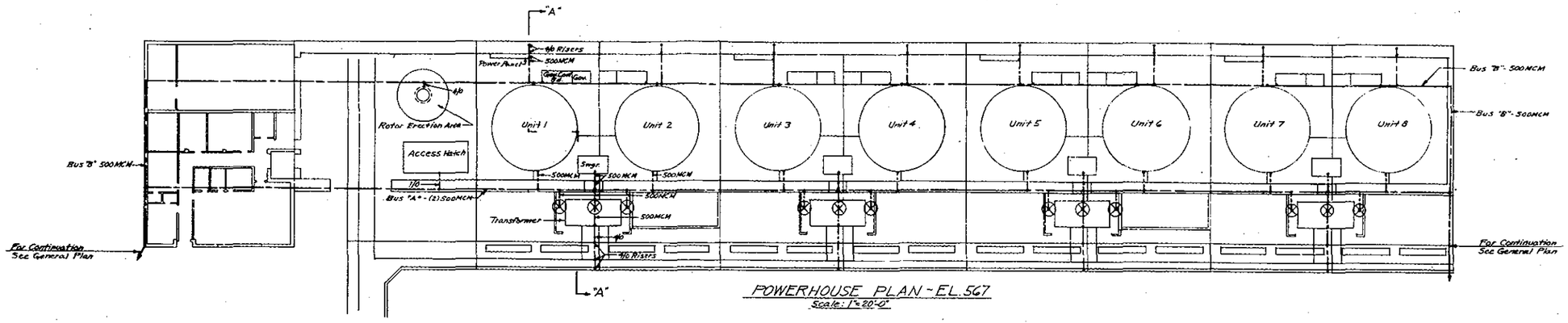
LIGHTING RISER DIAGRAM

International Passamaquoddy Engineering Board

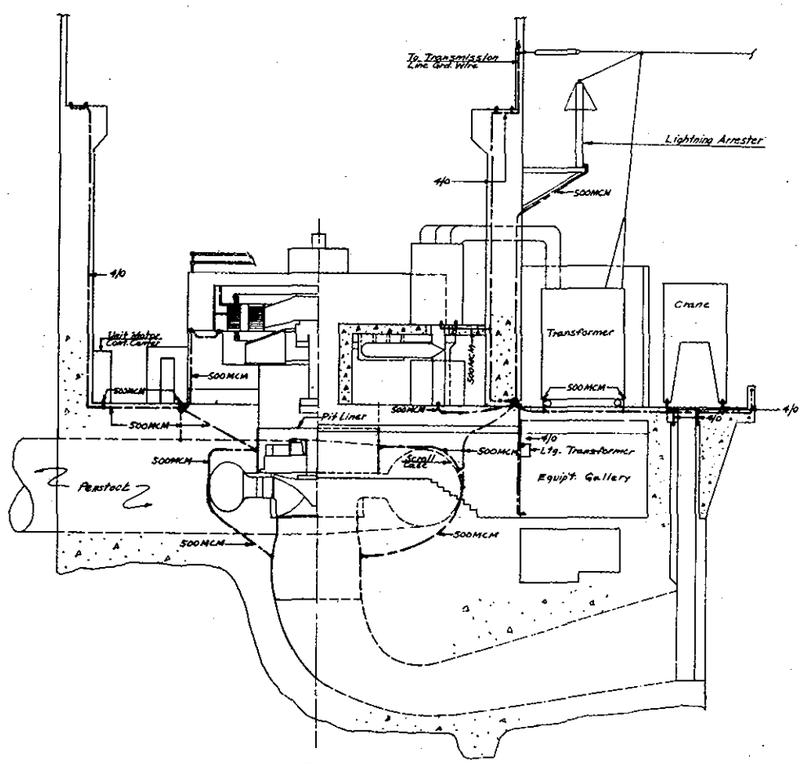
Elevations are in feet, m.s.l.

SEPTEMBER 1959

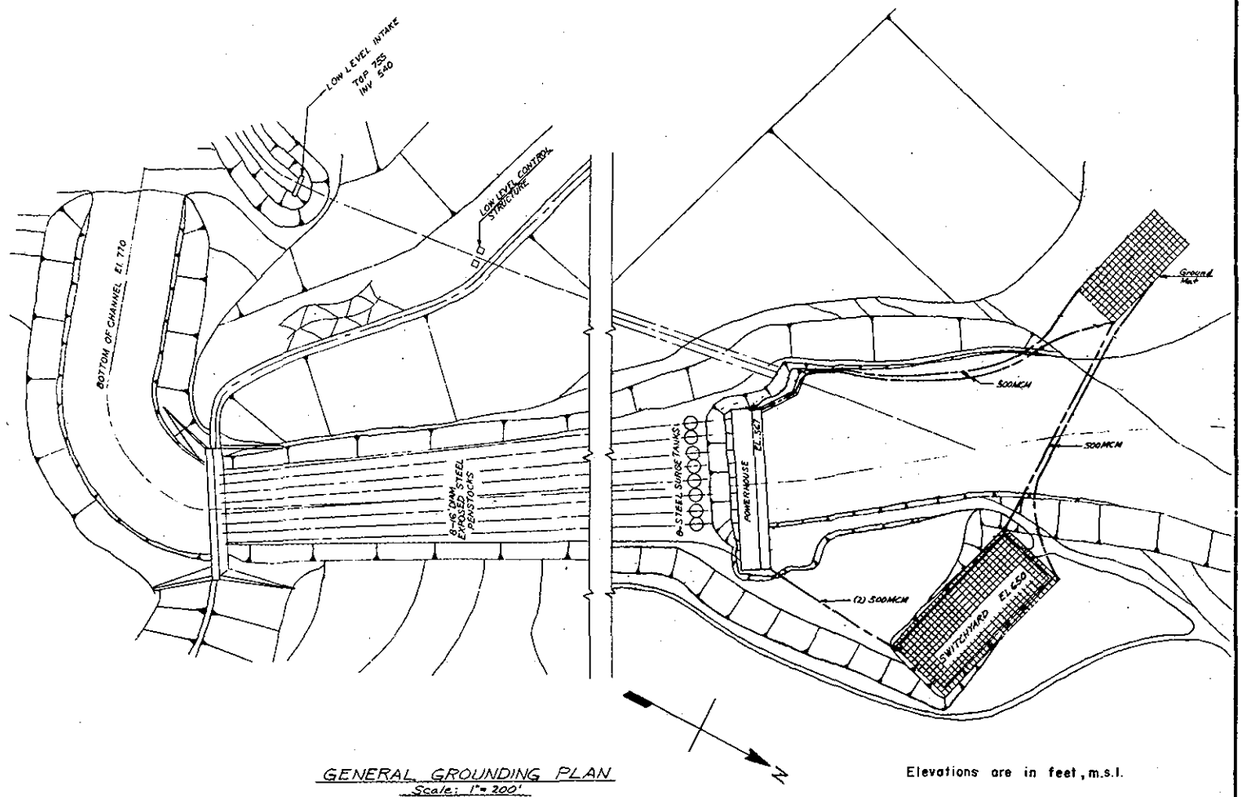
Dwg. No. AG7-094



POWERHOUSE PLAN - EL. 567
Scale: 1" = 20'-0"



SECTION A-A
Scale: 1/8" = 1'-0"



GENERAL GROUNDING PLAN
Scale: 1" = 200'

Elevations are in feet, m.s.l.

SCALE 1" = 200'
200' 0 200' 400'

SCALE 1" = 20'
20' 0' 20' 40'

SCALE 1/8" = 1'-0"
4' 0 4' 8' 12' 16' 20'

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

STATION GROUNDING

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. AG7-095

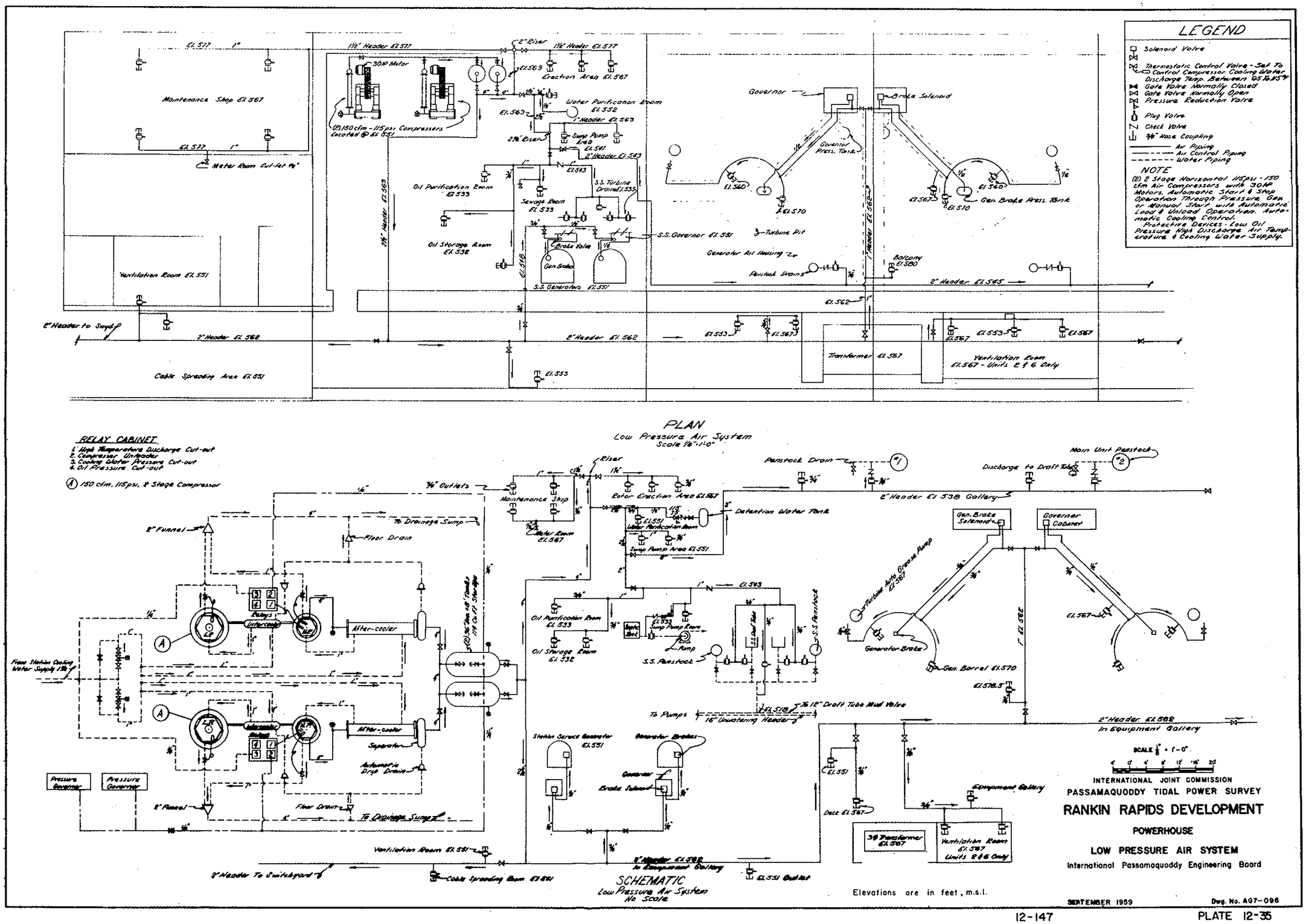
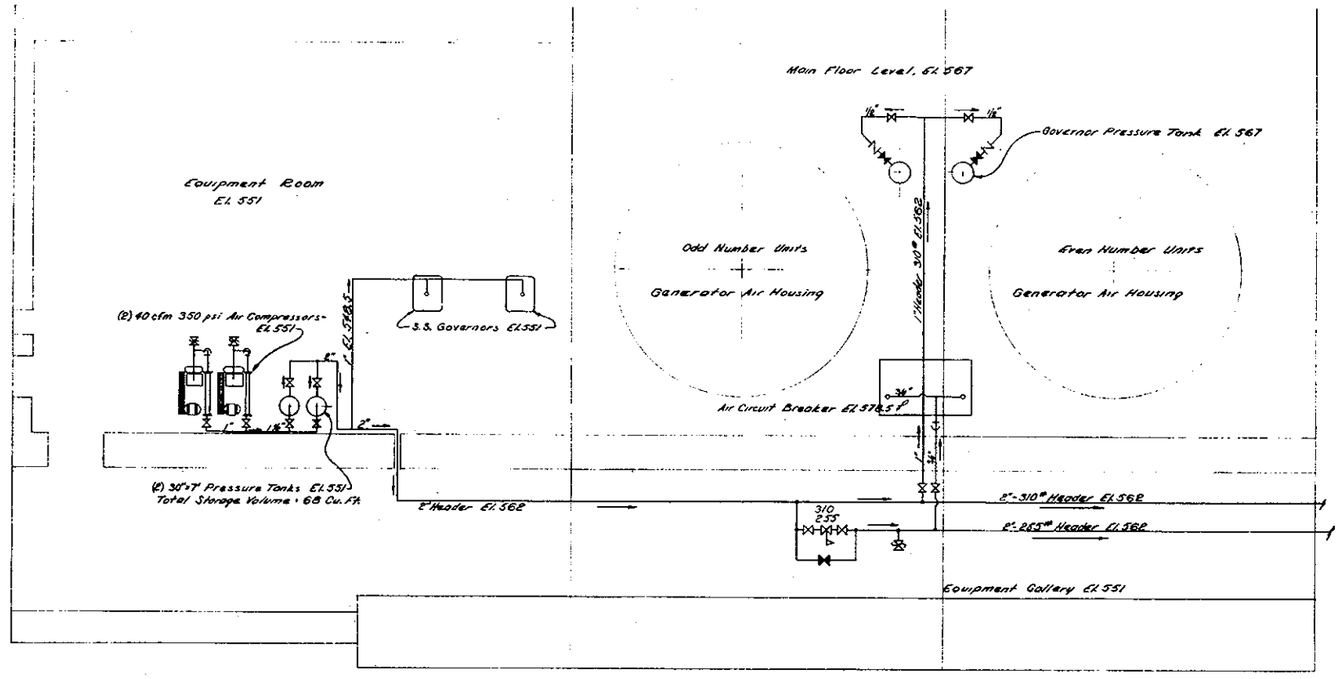
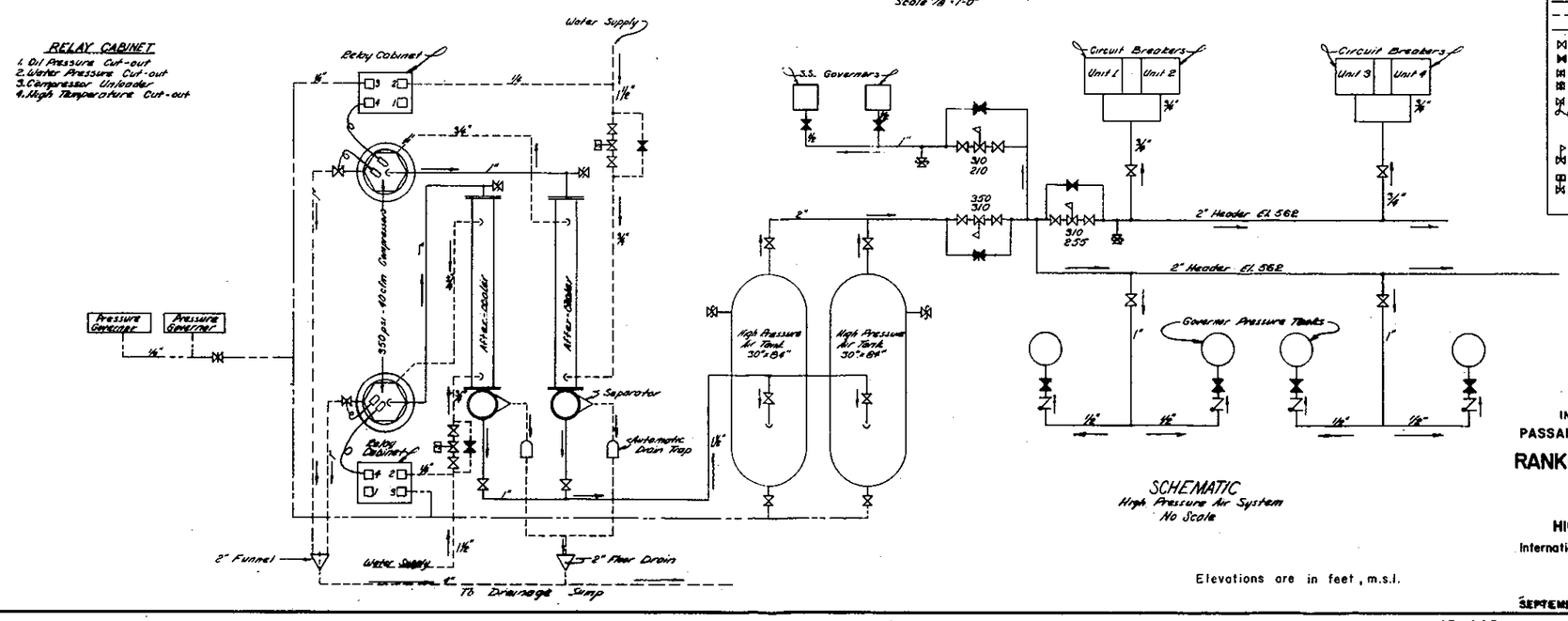

LEGEND
Solenoid Valve
Thermostatic Control Valve - Set To Control Compressor Cooling Water Discharge Temp. Between 95 To 115°F
Gate Valve Normally Closed
Gate Valve Normally Open
Pressure Reduction Valve
Plug Valve
Check Valve
3/4" Hose Coupling
Air Piping
Air Control Piping
Water Piping
NOTE
(2) 2 Stage Horizontal 115psi - 150 cfm Air Compressors with 30HP Motors. Automatic Start & Stop Operation Through Pressure Gov. or Manual Start with Automatic Load & Unload Operation. Automatic Cooling Control.
Protective Devices - Low Oil Pressure High Discharge Air Temperature & Cooling Water Supply.
PLAN
Low Pressure Air System
Scale 1/8" = 1'-0"
RELAY CABINET
1. High Temperature Discharge Cut-out
2. Compressor Unloader
3. Cooling Water Pressure Cut-out
4. Oil Pressure Cut-out
(A) 150 cfm, 115psi, 2 Stage Compressor
SCHEMATIC
Low Pressure Air System
No Scale
Elevations are in feet, m.s.l.
SCALE 1/8" = 1'-0"
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
RANKIN RAPIDS DEVELOPMENT
POWERHOUSE
LOW PRESSURE AIR SYSTEM
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. AG7-096

PLATE 12-35



PLAN
High Pressure Air System
Scale 1/8" = 1'-0"



SCHEMATIC
High Pressure Air System
No Scale

LEGEND

- Air Piping
- Water Piping
- Control Air Piping
- Gate Valve (Normally Open)
- Gate Valve (Normally Closed)
- Needle Valve
- Safety Valve
- Thermostatic Control Valve Set To Control Temp. Of Discharge Water Between 95° To 115°F.
- Pressure Reducing Valve
- Solenoid Valve

SCALE 1/8" = 1'-0"

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

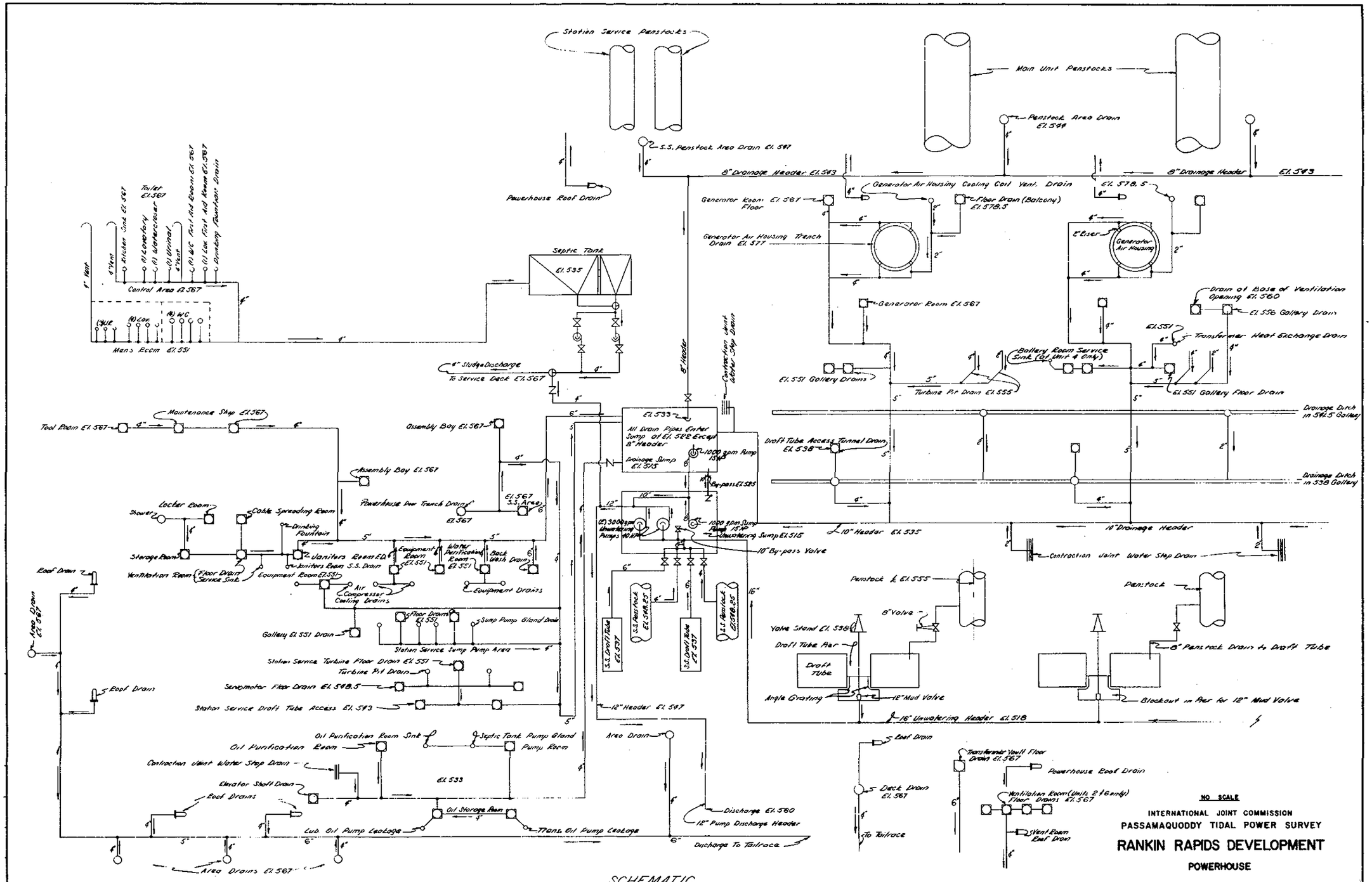
POWERHOUSE

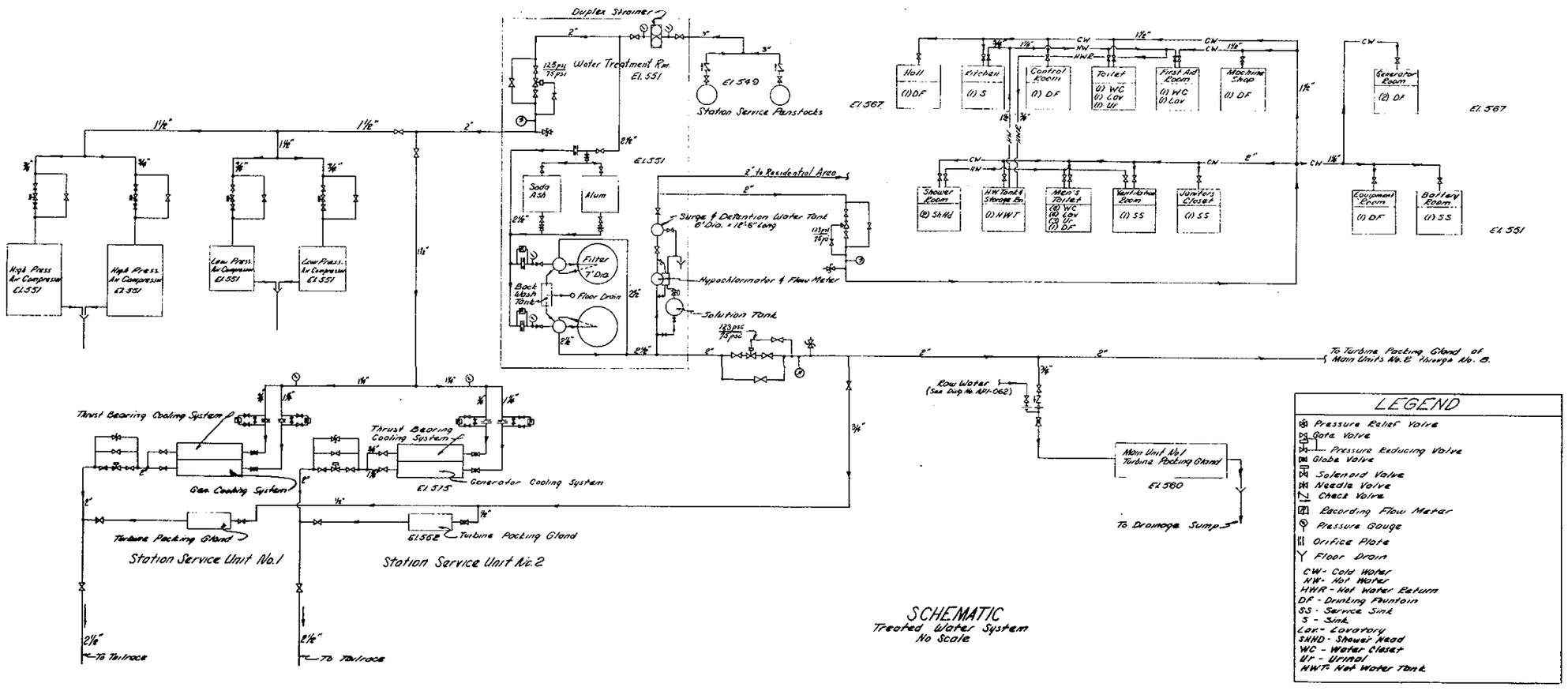
HIGH PRESSURE AIR SYSTEM

International Passamaquoddy Engineering Board

SEPTEMBER, 1959

Dwg. No. AG7-097


Station Service Penstocks
Main Unit Penstocks
Penstock Area Drain El. 594
S.S. Penstock Area Drain El. 597
8" Drainage Header El. 543
Powerhouse Roof Drain
Generator Room El. 567 Floor
Generator Air Housing Cooling Coil Vent. Drain
Floor Drain (Balcony) El. 578.5
Generator Air Housing Trench Drain El. 577
Generator Air Housing
Generator Room El. 567
Septic Tank El. 535
Central Area El. 567
Men's Room El. 551
4" Sludge Discharge To Service Deck El. 567
Drain at Base of Ventilation Opening El. 560
El. 556 Gallery Drain
Transformer Heat Exchange Drain
Gallery Room Service Sink (at Unit 4 Only)
El. 551 Gallery Drains
Turbine Pit Drain El. 555
El. 551 Gallery Floor Drain
Drainage Ditch in 541.5 Gallery
Maintenance Shop El. 567
Tool Room El. 567
Assembly Bay El. 567
El. 533
All Drain Pipes Enter Sump at El. 582 Except 8" Header
Drainage Sump El. 575
1000 gpm Pump
Draft Tube Access Tunnel Drain El. 538
Drainage Ditch in 538 Gallery
Locker Room
Shower
Cable Spreading Room
Drinking Fountain
Powerhouse Door Trench Drain
Storage Room
Janitors Room El. 551
Janitors Room S.S. Drain
Equipment Room El. 551
Water Purification Room El. 551
Back Wash Drains
Equipment Drains
Ventilation Room
Floor Drain Service Sink
Air Compressor Cooling Drains
Roof Drain
Area Drain El. 567
Gallery El. 551 Drain
Floor Drains El. 551
Sump Pump Gland Drain
Station Service Sump Pump Area
Station Service Turbine Floor Drain El. 551
Turbine Pit Drain
Servomotor Floor Drain El. 548.5
Station Service Draft Tube Access El. 543
Oil Purification Room Sink
Septic Tank Pump Gland
Oil Purification Room
Pump Room
Contraction Joint Water Step Drain
Elevator Shaft Drain
Roof Drains
Oil Storage Room
Lub. Oil Pump Leakage
Trans. Oil Pump Leakage
Area Drains El. 567
Area Drain
Discharge El. 560
12" Pump Discharge Header
Discharge To Tailrace
(2) 3000 gpm Unwatering Pumps 90 HP
1000 gpm Sump Pump 15 HP
Unwatering Sump El. 515
10" By-pass Valve
10" Header El. 535
16" Drainage Header
Contraction Joint Water Step Drain
Penstock & El. 555
8" Valve
Penstock
Valve Stand El. 536
Draft Tube Pier
Draft Tube
Angle Grating
12" Mud Valve
8" Penstock Drain to Draft Tube
Blockout in Pier for 12" Mud Valve
16" Unwatering Header El. 518
12" Header El. 597
S.S. Draft Tube El. 537
S.S. Penstock El. 548.25
Deck Drain El. 567
To Tailrace
Transformer Vault Floor Drain El. 567
Powerhouse Roof Drain
Ventilation Room (Units 2 & 4 only) Floor Drains El. 567
Vent Room Roof Drain
NO SCALE
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
RANKIN RAPIDS DEVELOPMENT
POWERHOUSE
UNWATERING, DRAINAGE & SEWER SYSTEMS
International Passamaquoddy Engineering Board
SCHEMATIC
Unwatering, Drainage & Sewer Systems
No Scale
Elevations are in feet, m.s.l.
SEPTEMBER 1959
Dwg. No. AG7-098



NO SCALE

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

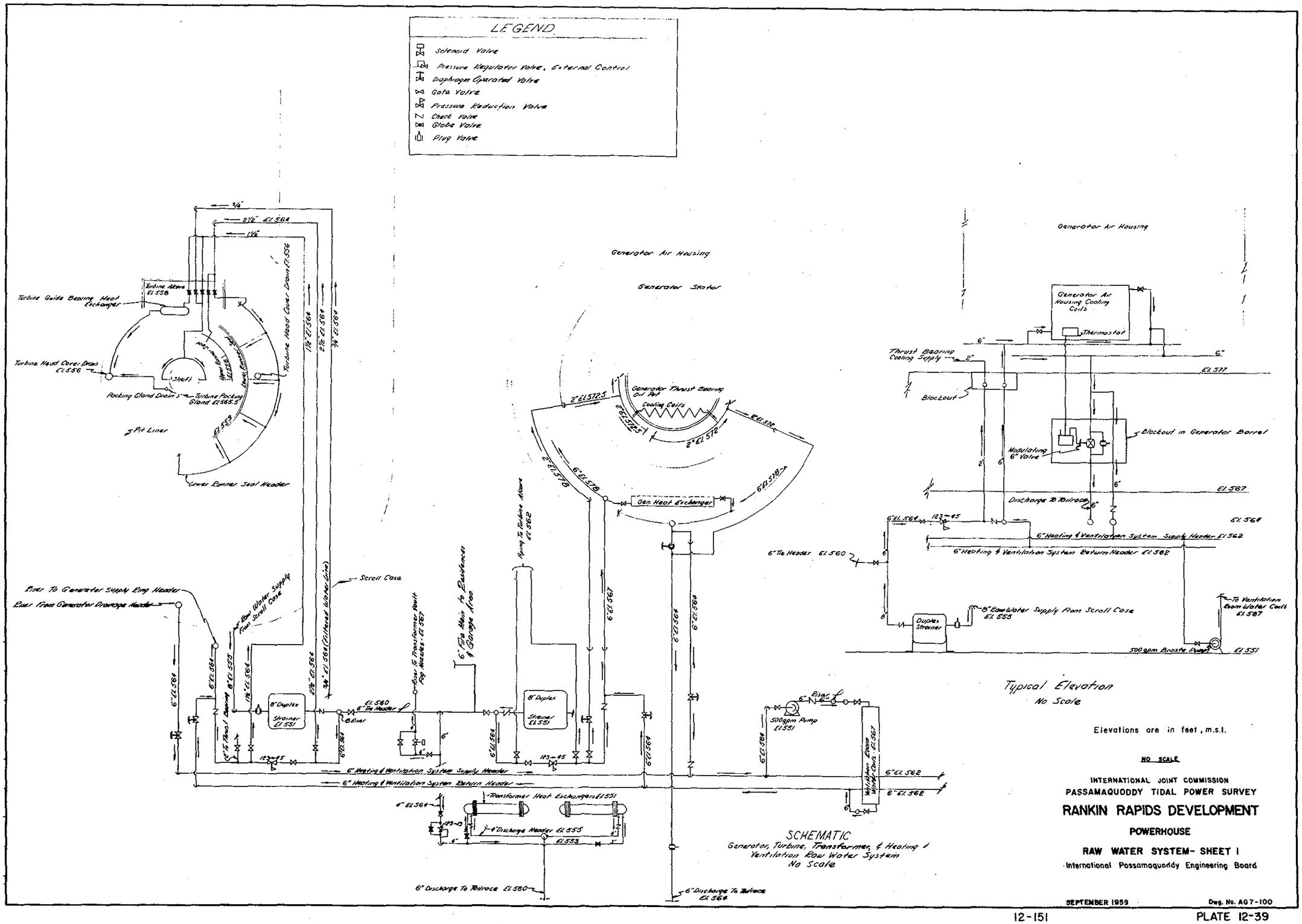
TREATED WATER SYSTEM

International Passamaquoddy Engineering Board

Elevations are in feet, m.s.l.

SEPTEMBER 1959

Dwg. No. AG7-099



Elevations are in feet, m.s.l.

NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

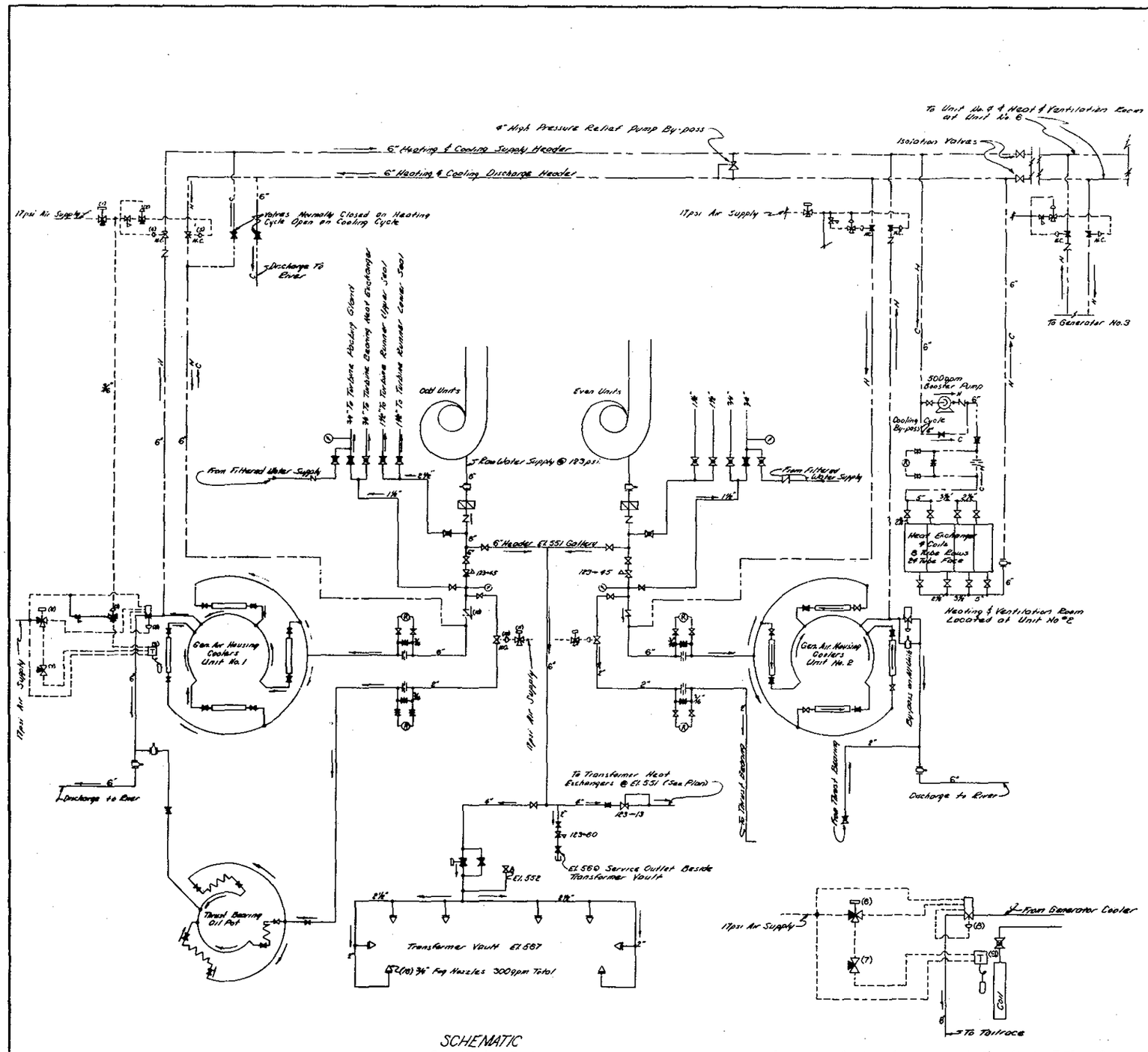
POWERHOUSE

RAW WATER SYSTEM- SHEET I

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. AG 7-100



SCHEMATIC
Raw Water System

Pneumatic Control Arrangement For Units 5 Thru 8
Generator Cooling Water

LEGEND

(N) Solenoid Valve Number
All 3-Port Valve Ports Marked Similar
Pneumatic Control Relay
Pneumatic Thermostat (Number Indicate Ports) Reverse Acting
Port 1 - Reset Pneumatic Diaphragm
Port 2 - Control Air To Valve (8)
Port 3 - 17psi Air Supply
Control Pressure Reduction Valve
Modulating Pneumatic Controlled Valve with Positioner
Port 1 - Controlled Air From Positioner
Port 2 - Controlled Air From Thermostat (9)
Port 3 - 17psi Air Supply
Gate Valve
Globe Valve
Duplex Basket Strainer
Check Valve
Diaphragm Operated Valves
Pressure Gage
Orifice
Indicating Flow Meter
Needle Valve
Hose Connection
Cooling Coil
Solenoid Valve
Fog Nozzle
External Controlled Pressure Reduction Valve
Automatic Drain Valve
Plug Valve
Thermostat
500gpm Booster Pump - 93' Head - 20HP Motor 1800 rpm
Valves Normally Closed (Valving Shown For Normal Operation On Heating Cycle With Water Supplied From First Unit Only)
Piping Marked H → C, C → H (Exist Between Units 1 Through 4 Only)

NOTE
All control headers 3/4" Galvanized steel pipe.
All control piping to instruments - 3/8" Copper.
All piping except pneumatic control piping to be Galv. Steel.

Normal Operation of Heating Cycle

First generator supplying warm water at 78°F to ventilation rooms at units #2 & #6.

All other units isolated from heating system & discharging cooling water direct to river.

(1) Solenoid (1) energized & port 1 open to port 2, placing 17psi air to valves #2 & #3 & valve #4.

A. Relay (2) port #1 opens to port #2 placing reduced control press. to valve #3. This arrangement allows manual adjusting of the flow of return water to the generator.

B. 17psi control pressure is placed on valve #4 to completely open the valve.

C. Unit #1 cooling system is now connected to the two booster pumps located in the ventilation rooms & the water circulation is through the generator coolers, to the booster pumps, to the heat exchangers & back to the generator. The solenoids (1) of the other three units on the system are energized, port 2 open to port 3 & valves #2 & #3 are closed.

(2) Relay (3), port 1 open to port 3, placing reduced pressure to thermostat temp. control reset diaphragm port 1. Pressure reduction valve, manual adjustment, to increase temp control point of thermostat (9) on heating cycle. Thermostat set to control generator air housing air temp. at 40°C on heating cycle & 35°C when off heating cycle.

(3) Solenoid (6) energized, port 2 open to port 3, placing valve (8) on control from thermostat (9) through valve (7).

A. When generator is shut down solenoid (6) is energized, port 1 open to port 2, 17psi control air is placed on valve (8). Thermostat (9) is by-passed, & valve (8) is closed thus stopping the flow of cooling water through the generator.

B. The 3 port manually operated valve (7) is normally open port 1 to port 2. In emergency or for maintenance, valve (7) can be manually changed to port 1 open to port 3 which opens valve (8) diaphragm to atmospheric pressure & normal open position.

(4) Valve (8) a modulating pneumatic controlled valve with valve positioner is regulated by thermostat (9). On heating cycle, thermostat (9) is set to regulate valve (8) to maintain 40°C generator air housing temp. On a rise in air housing temperature thermostat (9) reduces control pressure to valve (8) which modulates & opens to discharge water to the river, cold water is brought into the generator cooling system to reduce the cooling water temperature. Incase air supply is lost valve (8) will automatically open.

Control Air Lines
Heating & Cooling Water Lines

Elevations are in feet, m.s.l.
NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

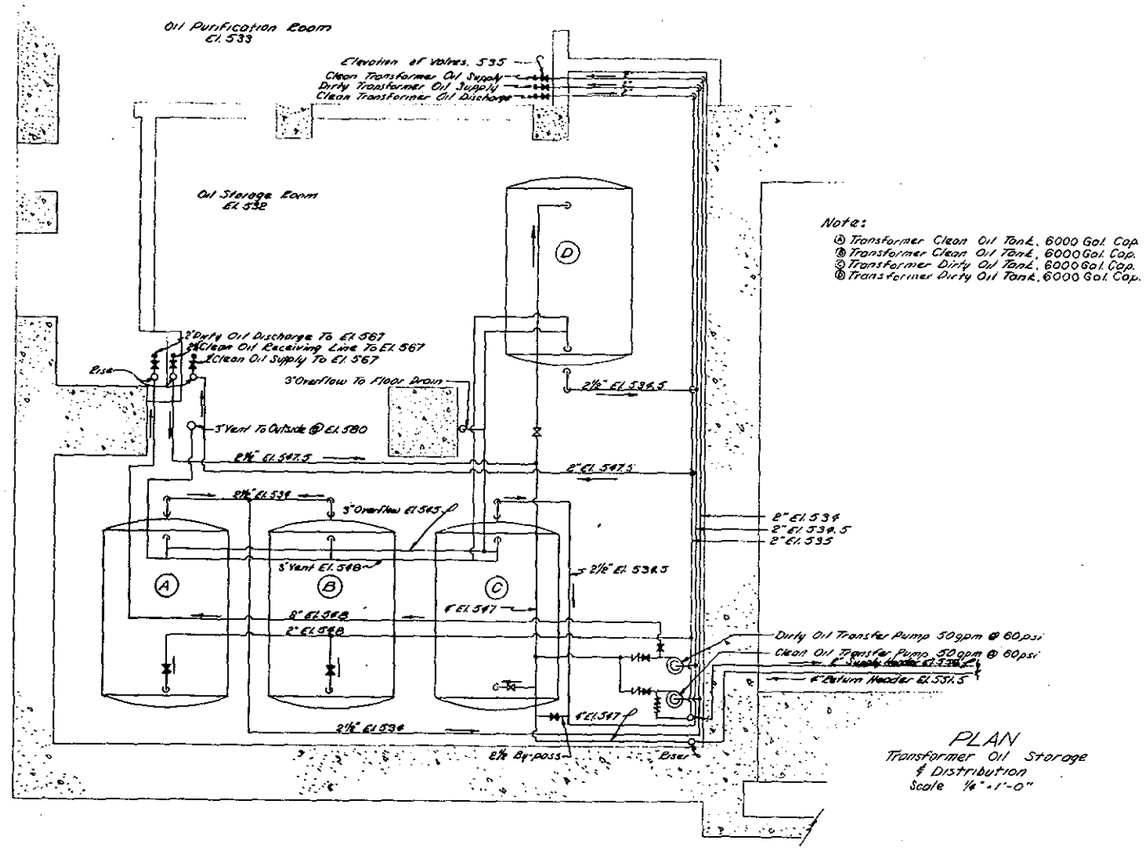
RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

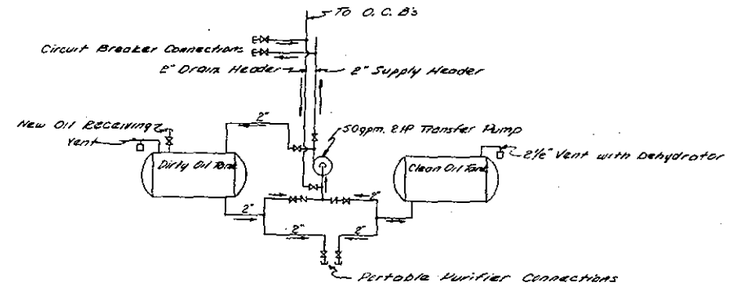
RAW WATER SYSTEM - SHEET 2

International Passamaquoddy Engineering Board

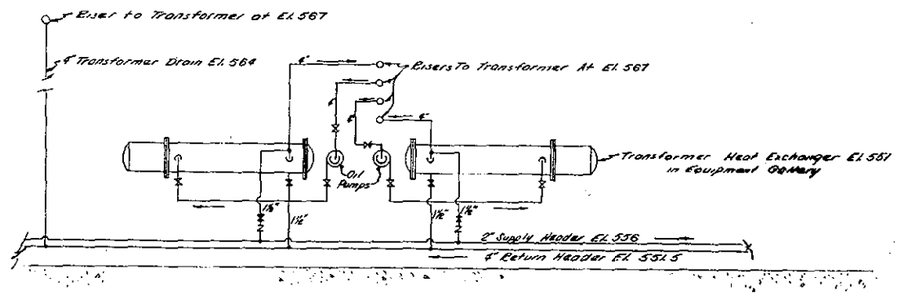
SEPTEMBER 1959 Dwg. No. AG7-101

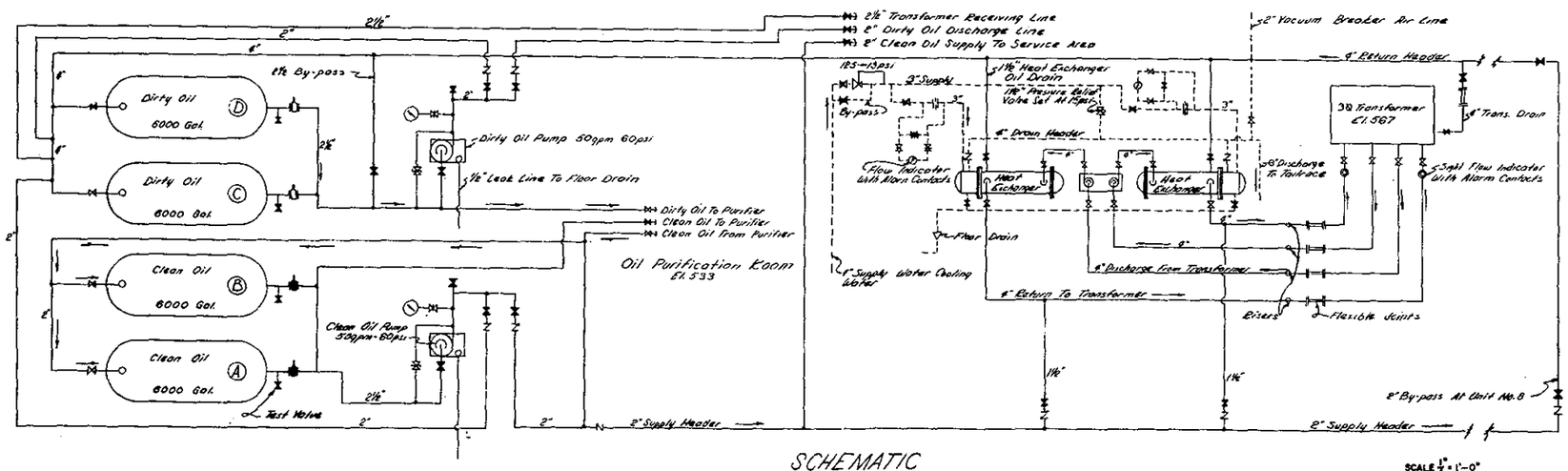


PLAN
Transformer Oil Storage & Distribution
Scale 1/4" = 1'-0"



SCHEMATIC
Switchyard Circuit Breaker Oil System





SCHEMATIC
Transformer Oil Piping System
No Scale

Elevations are in feet, m.s.l.

SCALE 1/4" = 1'-0"

LEGEND

- Gate Valve (Normally Closed)
- Gate Valve (Normally Opened)
- Pressure Relief Valve Set at 35 psi
- Plug Valve
- Globe Valve
- Needle Valve
- Check Valve
- Orifice
- Oil Piping
- Water Piping

Note

All clean oil lines are copper.
All dirty oil lines are black steel.
Valving in oil storage room shown for purification of oil from dirty oil tanks & pumping oil from purifier to clean oil tanks.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

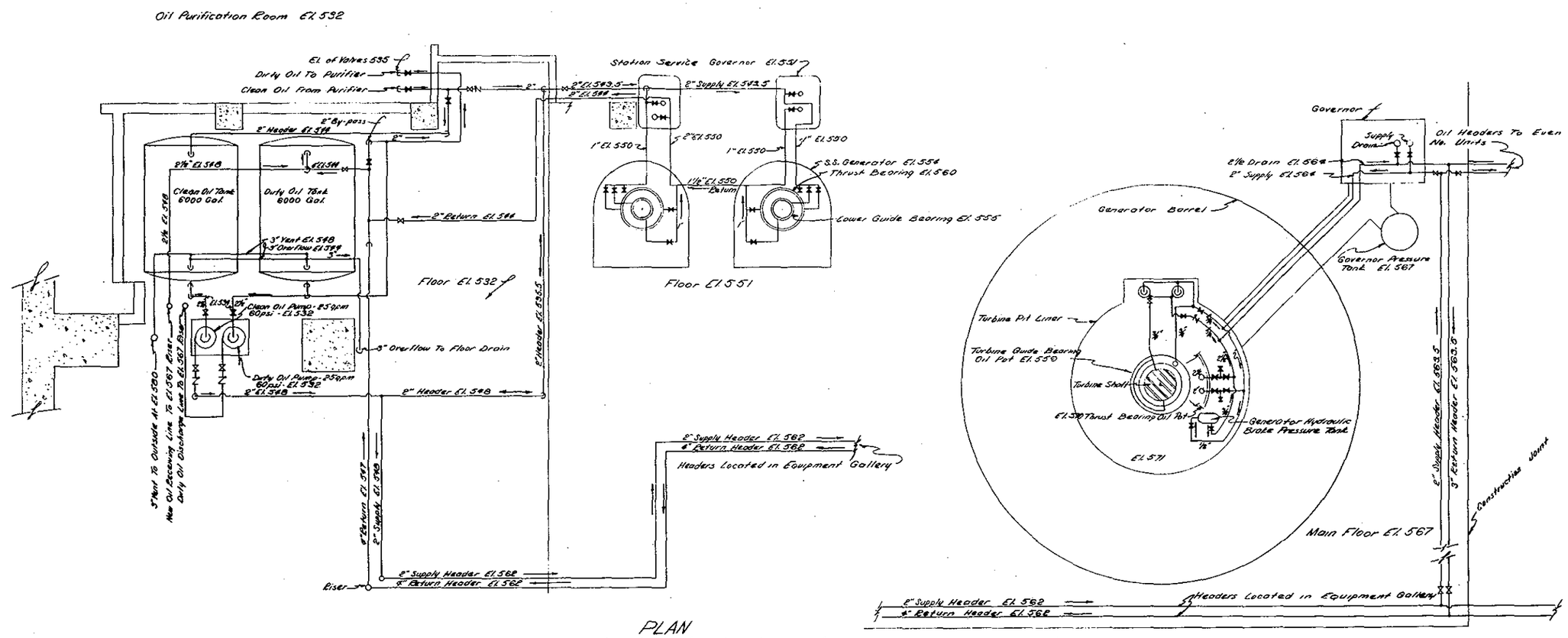
POWERHOUSE

INSULATING OIL SYSTEM

International Passamaquoddy Engineering Board

SEPTEMBER 1959

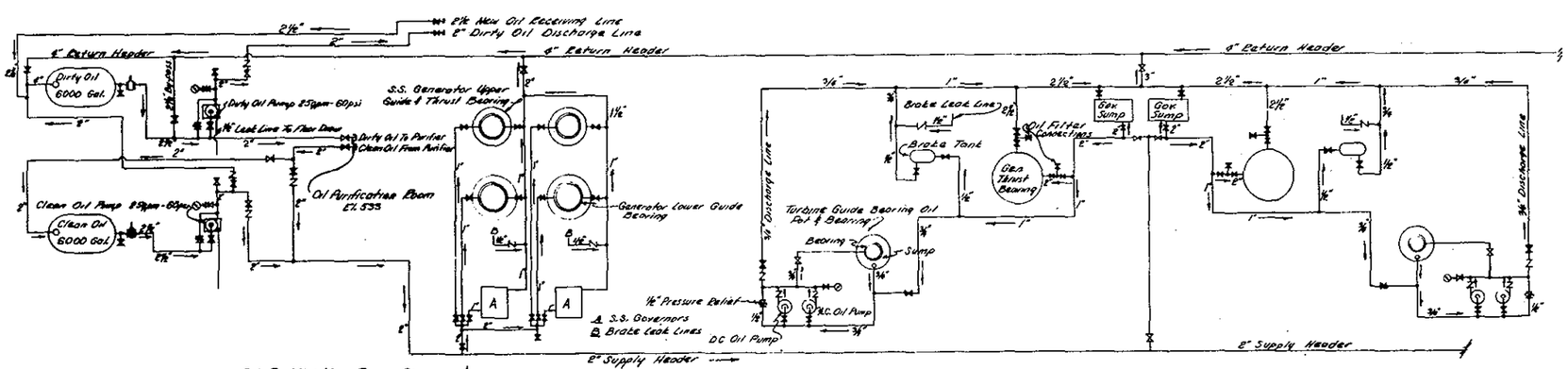
Dwg. No. AG7-102



PLAN

Lubricating Oil Storage & Distribution System

Scale 1/8" = 1'-0"



Oil Purification Room Equipment
1- 1200 gph (Transformer Oil) - 900 gph (Lubricating Oil) Stationary Filter With Centrifuge & Heater
1- 900 gph (Transformer Oil) - 450 gph (Lubricating Oil) Portable Filter With Centrifuge & Heater
1- Oven For Drying of Filter Papers
1- Dielectric Tester

SCHEMATIC

Lubricating Oil Piping System

No Scale

SCALE 1/4" = 1'-0"

LEGEND

- Pressure Gage.
- Relief Valve Set at 35 psi
- Normally Closed Gate Valve
- Normally Open Gate Valve
- Plug Valve
- Hose Connection
- Check Valve
- Needle Valve

NOTE

All Clean Oil Piping To Be Copper
All Dirty Oil Piping To Be Black Steel
Valving Shown In Oil Storage Room For Supplying Oil Filter With Dirty Oil From Dirty Tank & Pumping Clean Oil Into Clean Storage Tank.

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

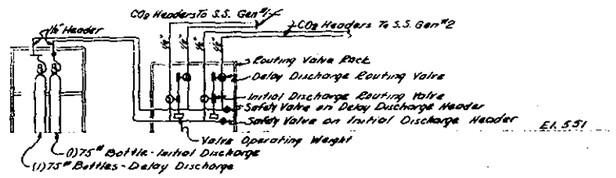
POWERHOUSE

LUBRICATING OIL SYSTEM

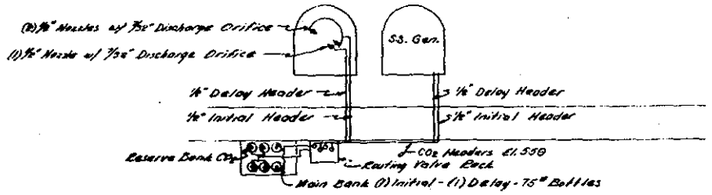
International Passamaquoddy Engineering Board

SEPTEMBER 1959

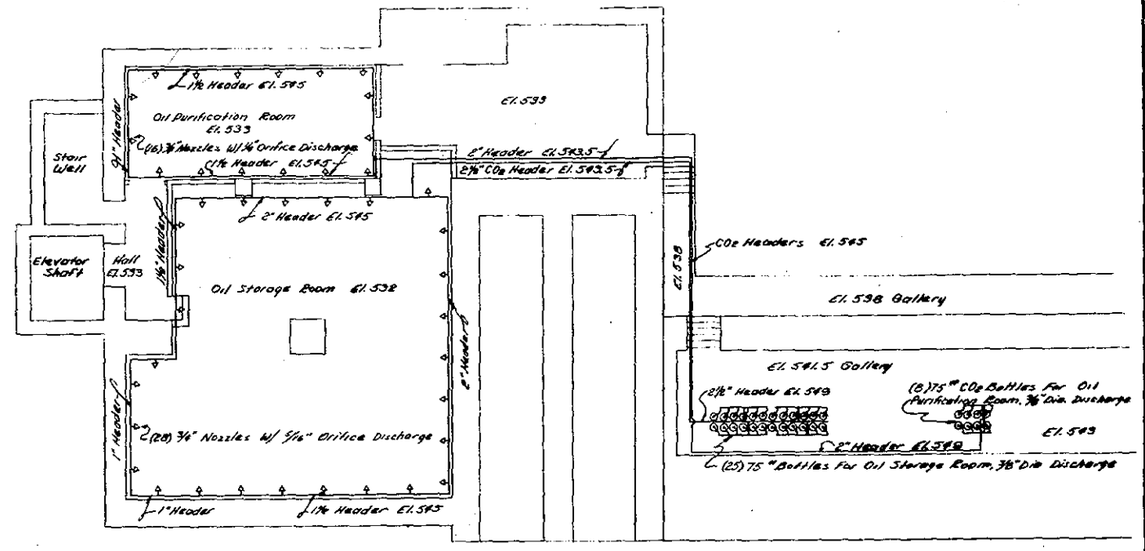
Dwg. No. AG7-103



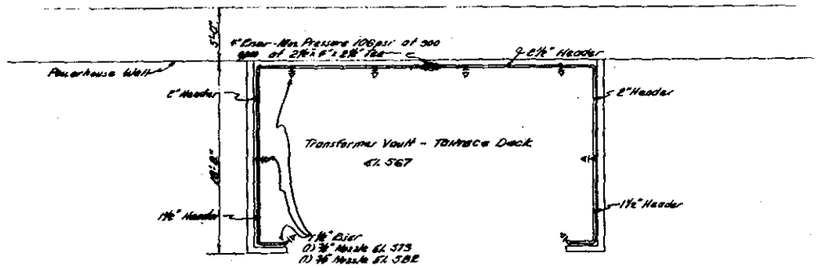
ELEVATION
Station Service Generator CO2 System
Scale ½" = 1'-0"



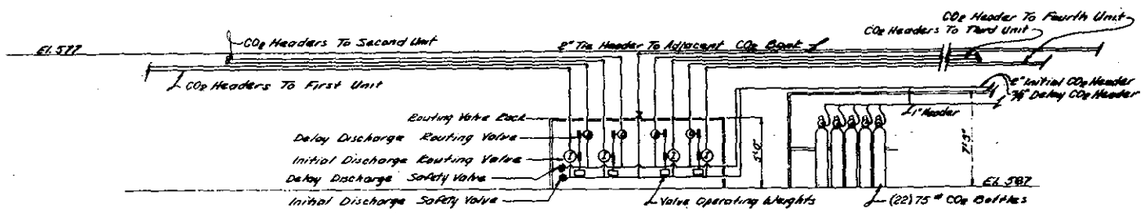
PLAN
Station Service CO2 System
Scale ½" = 1'-0"



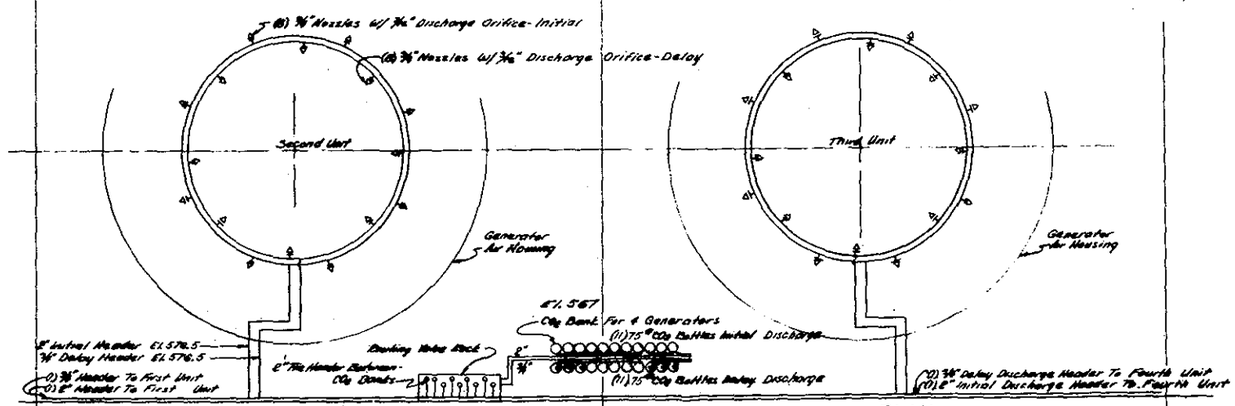
PLAN
CO2 System For Oil Rooms
Scale ½" = 1'-0"



PLAN
Transformer Vault Fog System
Scale ⅜" = 1'-0"



ELEVATION
Typical Main Unit Routing Valve & CO2 Bottle Rack
Scale ½" = 1'-0"



PLAN
Main Unit CO2 System
Scale 3/16" = 1'-0"

Note
1. For main unit CO2 system all piping on initial discharge line will be 2" diameter. All piping on delay discharge unit will be ¾" diameter.

Elevations are in feet, m.s.l.

SCALE ½" = 1'-0"
SCALE ¼" = 1'-0"
SCALE 1/8" = 1'-0"

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

FIRE PROTECTION SYSTEM

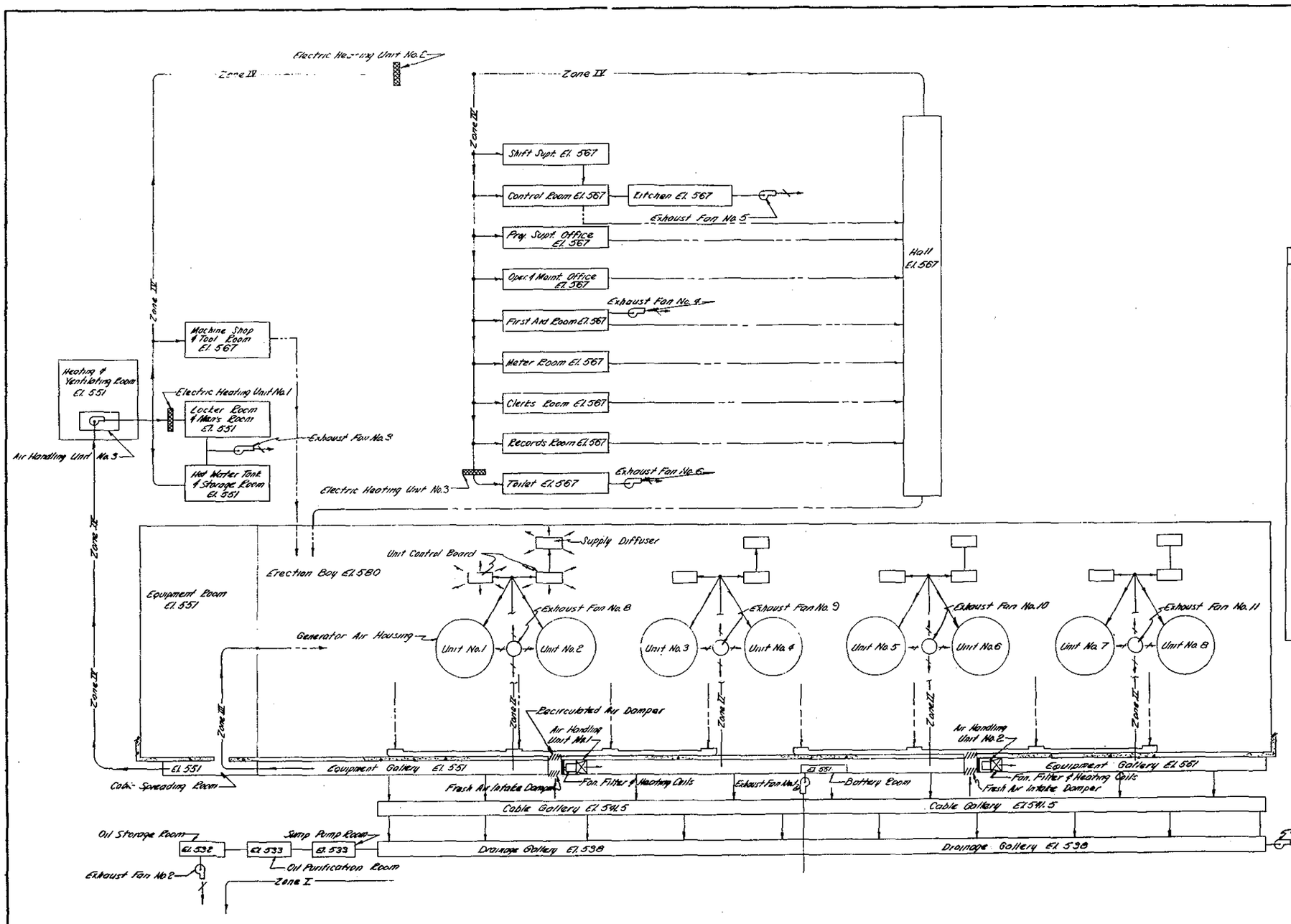
International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. A97-104

12-155

PLATE 12-43



EQUIPMENT SCHEDULE

EXHAUST FANS

NO.	AREA	CAPACITY
1.	Battery Room El. 551	750 cfm
2.	Oil Storage Room El. 532	1200 cfm
3.	Locker & Mens Room El. 551	1800 cfm
4.	First Aid Room El. 567	100 cfm
5.	Kitchen El. 567	100 cfm
6.	Toilet El. 567	150 cfm
7.	Drainage Gallery El. 538	1200 cfm
8-11.	Generator Room El. 567 2 Speed Roof Ventilator	7500/15000 cfm

ELECTRIC HEATERS

NO.	AREA	CAPACITY
1.	Locker & Mens Room El. 551	9 KW
2.	Office Area & Control Room El. 567	18.5 KW
3.	Toilet El. 567	2 KW

AIR HANDLING UNITS

NO.

1 & 2 62,000 cfm at 1¼" Static Pressure
29,350 cfm Recirculated Air at 60°F
32,650 cfm Outside at -10°F
1,500,000 BTU/HR
Water in at 78°F
Water out at 72°F
Air off coil at 70°F
Water Flow = 500 gpm
20 HP Fan Motor

3. 6370 cfm at 1" Static Pressure
2 HP Fan Motor

LEGEND

Supply
Return
Exhaust

Elevations are in feet, m.s.l.

NO SCALE

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

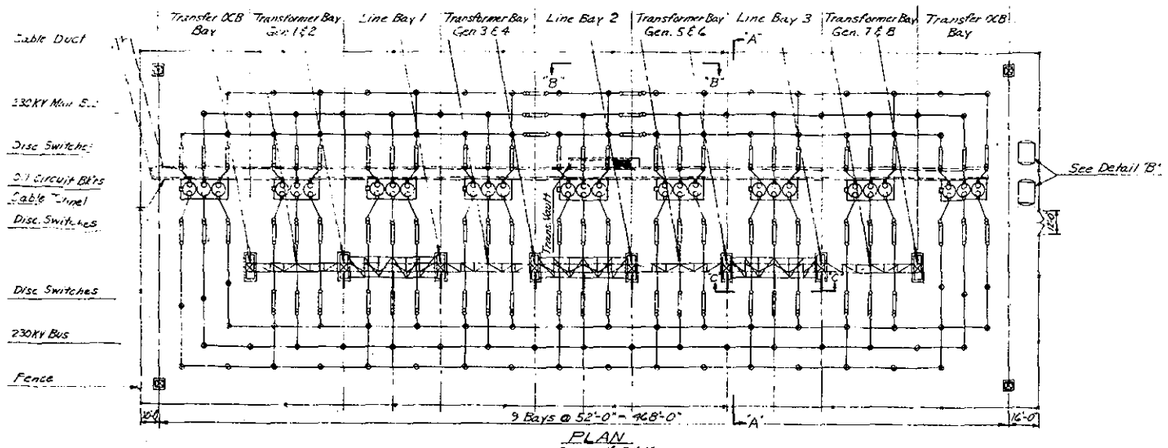
RANKIN RAPIDS DEVELOPMENT

POWERHOUSE

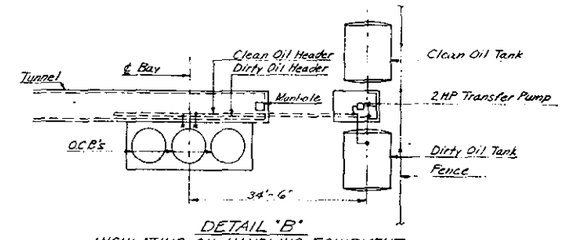
HEATING & VENTILATING SYSTEM

International Passamaquoddy Engineering Board

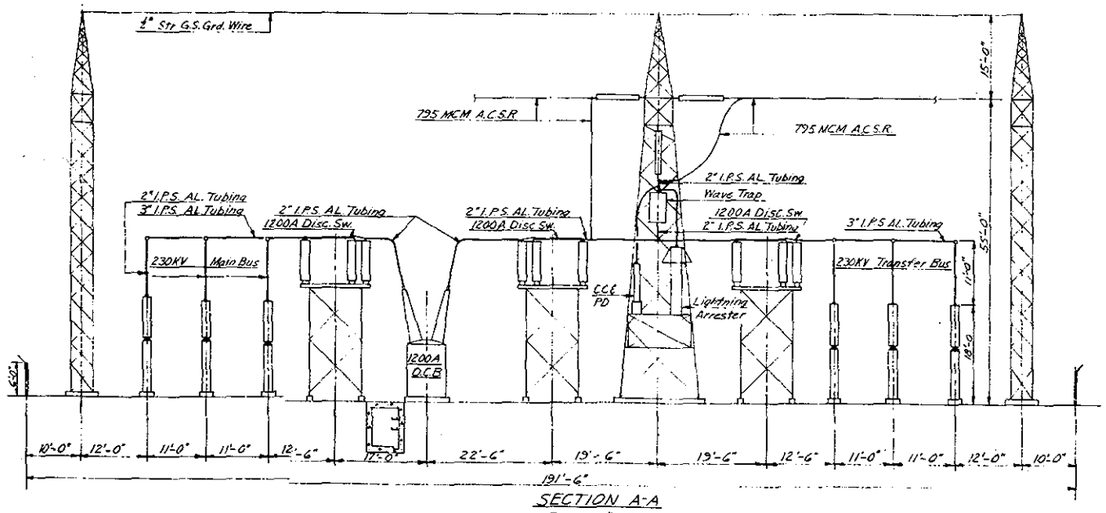
SEPTEMBER 1959 Dwg. No. AG7-105



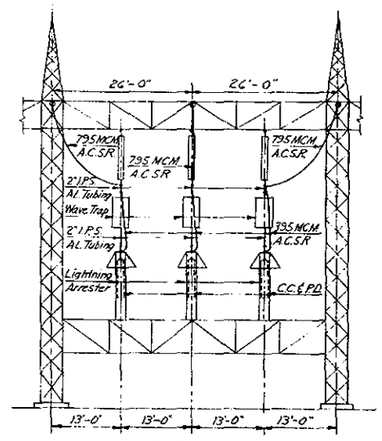
PLAN
Scale: 1" = 30'-0"



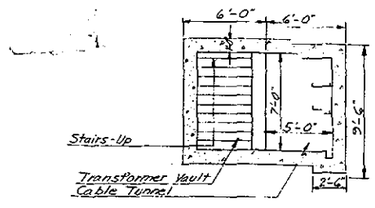
DETAIL "B"
INSULATING OIL HANDLING EQUIPMENT
Scale: 3/32" = 1'-0"



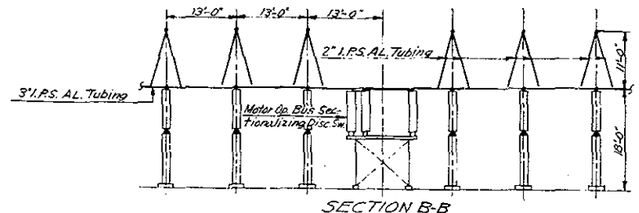
SECTION A-A
Scale: 1" = 10'-0"



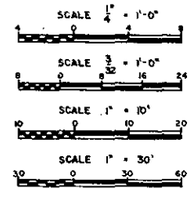
SECTION C-C
Scale: 1" = 10'-0"



DETAIL "A"
Scale: 1/4" = 1'-0"



SECTION B-B
Scale: 1" = 10'-0"



INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

SWITCHYARD

PLAN AND SECTIONS

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. AG7-106