PretiFlaherty

Andrew Landry
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SENT ELECTRONICALLY

July 18, 2012

Ms Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 202846

Re: Project No. 13884-000 - ME
Pennamaquan Tidal Power Plant Project
Pennamaquan Tidal Power LLC

Dear Ms. Bose,

Pursuant to 18 CFR §5.6, please find the Notice of Intent to File an Application for an Original License in connection with Project No. 13884, together with a Pre-Application Document filed pursuant to 18 CFR §5.6 and a certificate of service. Applicant Pennamaquan Tidal Power LLC intends to use the integrated licensing process. Coincident with this filing, Applicant Pennamaquan Tidal Power LLC has placed a Legal Notice in the Quoddy Tides, a newspaper of general circulation in the county in which the project is located, informing the public of the filing of the Notice of Intent and the Pre-Application Document.

Thank you for your assistance in this matter. We look forward to working with the Commission and interested parties in the development of this project. If you have any questions regarding this matter, please feel free to contact me at 207.791.3191 or alandry@preti.com.

Very truly yours,

/s/ Andrew Landry

Andrew Landry

Enc.

Cc: Distribution List

CERTIFICATE OF SERVICE

I hereby certify that I have this day caused the foregoing document to be served upon each person listed below:

Washington County Commission
c/o Christopher M. Gardner, Chair
85 Court Street
Machias, ME 04654

Maine State Planning Office
38 State House Station
Augusta, ME 04260

Maine Dept. of Environmental Protection
17 State House Station
Augusta, ME 04333

Maine Historic Preservation Commission
65 State House Station
Augusta, ME 04333

Maine Dept. of Inland Fisheries and Wildlife
PO Box 220
Jonesboro, Maine 04648

Maine Dept. of Inland Fisheries and Wildlife
41 State House Station
Augusta, ME 04333-0041

Maine Department of Marine Resources
21 State House Station
Augusta, ME 04333-0021

Selectman Milan Jamieson
535 US Route 1
Pembroke, ME 04666

Selectman Joyce Johnson
17 Johnson Lane
Pembroke, ME 04666-4643

Selectman Allan Pulk
East River Road
Pembroke, ME 04666

City of Eastport
c/o Jon Southern, City Manager
78 High Street
Eastport, Maine 04631

Town of Perry
c/o David B. Turner, Chairman of Board of Selectmen
898 U.S. Route 1, P.O. Box 430
Perry, ME 04667

Passamaquoddy Tribe at Pleasant Point
c/o Governor Rick Doyle
PO Box 343
Perry, ME 04667-0343

Town of Dennysville
RR1 Box 70
Dennysville, Maine 04628

Town of Pembroke
PO Box 247
Pembroke, ME 04666

Capt. Robert Peacock
99 Tollbridge Rd.
Eastport, Maine 04631

National Oceanic and Atmospheric Admin.
National Marine Fisheries Service
55 Great Republic Drive
Gloucester MA 01930-2276

Northeast Regional Office
U.S. Fish and Wildlife Service
300 Westgate Center Drive
Hadley, MA 01035-9589

US Department of the Interior
Office of Environmental Policy and Compliance
408 Atlantic Ave., Room 142
Boston MA 02110-3334

Dept. of the Army
New England District, Corps of Engineers
696 Virginia Road
Concord MA 01742-2751

Planning Board
Town of Pembroke
c/o Albion Goodwin, Chair
PO Box 247
Pembroke, ME 04666

US Environmental Protection Agency
5 Post Office Square - Suite 100
Boston, MA 02109-3912

Donald Soctomah
Tribal Historic Preservation Officer
Passamaquoddy Tribe
PO Box 102
Princeton, ME 04668

National Park Service
Hydropower Assistance Program
1849 C Street, NW
Org. Code 2220*
Washington, D.C. 20240

Dated this 18th day of July, 2012.

/s/ Andrew Landry

_____

Andrew Landry, Esq.
Preti Flaherty Beliveau & Pachios
45 Memorial Circle, PO Box 1058
Augusta, ME 04332-1058
Tel: (207) 623-5300
Fax: 207-623-2914

NOTICE OF INTENT TO FILE AN APPLICATION FOR

AN ORIGINAL LICENSE FOR A TIDAL ENERGY PROJECT

FERC Project No. 13884

Pennamaquan Tidal Power LLC hereby notifies the Federal Energy Regulatory Commission (FERC) of its intent to file a license application for a tidal energy project to be located at the entrance to Cobscook Bay from the Pennamaquan River in the Town of Pembroke, Washington County, Maine. This Notice of Intent is prepared according to 18 CFR §5.5.

(1) Applicant Name and Address

Pennamaquan Tidal Power LLC
45 Memorial Circle
Augusta, Maine 04330

(2) Project Number

Project No. 13884.

(3) License Expiration Date

N/A

(4) Statement of Applicant's Intention to File

Pennamaquan Tidal Power LLC hereby states its intention to file an application for license for a tidal energy project to be located at the entrance to Cobscook Bay from the Pennamaquan River in the Town of Pembroke, Washington County, Maine.

(5) Type of Principal Project Works

The Pennamaquan tidal project will be a 20 MW tidal range project consisting of a tidal barrage, powerhouse, and generator lead transmission facilities.

(6) Location of the Project

The project is located on the Pennamaquan River at its entrance to Cobscook Bay in the Town of Pembroke, Washington County, Maine.

(7) Installed Plant Capacity

The project would have a maximum installed capacity of approximately 20 MW.

(8) Contact Information for:

(i) Every county in which any part of the project is located, and in which any Federal facility that is used or to be used by the project is located;

The project is located Washington County, Maine. The project does not make use of any federal facilities. Washington County's contact information is as follows:

Washington County Commission
85 Court Street
Machias, ME 04654

(ii) Every city, town, or similar political subdivision

(A) In which any part of the project is or is to be located and any Federal facility that is or is to be used in the project is located:

The project is located in the Town of Pembroke, Maine. The project does not make use of any federal facilities. The Town of Pembroke's contact information is as follows:

Town of Pembroke
PO Box 247
Pembroke, ME 04666

(B) That has a population of 5,000 or more people and is located within 15 miles of the existing or proposed project dam;

There are no towns with a population greater than 5,000 people within a 15 mile radius of the project. The project includes a tidal barrage, which differs in material respects from a traditional dam. As Pennamaquan Tidal Power LLC explains in more detail in various filings with the commission, the tidal barrage will allow flow of water in both directions and will maintain high and low tide elevations at approximately existing levels.

(iii) Every irrigation district, drainage district, or similar special purpose political subdivision:

The project is not located in any irrigation district, drainage district or similar political subdivision.

(iv) Every other political subdivision in the general area of the project or proposed project that there is reason to believe would be likely to be interested in, or affected by, the notification:

Town of Perry
PO Box 430
Perry, Maine 04667

City of Eastport
78 High Street
Eastport, Maine 04631

Town of Dennysville
RR1 Box 70
Dennysville, Maine 04628

(v) Affected Indian tribes:

Pennamaquan Tidal Power LLC does not believe that any Indian tribes are affected by the project. However, the Passamaquoddy Tribe at Pleasant Point is located within a 15 mile radius of the project. In recognition of the Tribe's potential interest in the project, we have included the Tribe on the distribution list for all documents filed with the commission regarding the project to date, including this Notice of Intent and the accompanying Pre-Application Document. The following is the contact information for the Tribe:

Passamaquoddy Tribe at Pleasant Point
c/o Governor Rick Doyle
PO Box 343
Perry, ME 04667-0343

BEFORE THE FEDERAL ENERGY REGULATORY COMMISSION

PRE-APPLICATION DOCUMENT
18 CFR § 5.6

For

PENNAMAQUAN TIDAL POWER PLANT
Project No. 13884-000 – ME

Pennamaquan Tidal Power, LLC
c/o Andrew Landry, Esq.
45 Memorial Cir., PO Box 1058
Augusta, Maine 04332
207-623-5300
alandry@preti.com

July 18, 2012

§ 5.6 (d)(1) Process Plan and Schedule

Pre-filing Activities

July, 2012 File Notice of Intent to file a license application (NOI) and pre-application document (PAD).
September , 2012 Pennamaquan Tidal Power submits Proposed Study Plan pending date of Scoping.
October 9, 2012 Scoping Meeting and Site Visit.
January, 2013 First season Studies commence.
January, 2014 Studies Complete.

Post-Filing Activities
January 2014, Post-filing activities as ordered by FERC.
February 28, 2014 End of 36 month term of preliminary permit.

Pennamaquan Tidal Power LLC proposes that a scoping meeting be held on Tuesday, October 9, 2012 at the Pembroke Elementary School, US Route 1, Pembroke, Maine and that a site visit be scheduled for this same date**.**

§ 5.6 (d)(2) Project Location, facilities, and Operation

Project Location: Pembroke, Washington County, Maine
Tidal Range Power Plant

§ 5.6 (d)(2)(i) The exact name and business address, and telephone number of each person authorized to act as agent for the applicant.

Andrew Landry
45 Memorial Cir., PO Box 1058
Augusta, Maine 04332
207-623-5300
alandry@preti.com

Ramez Atiya
1320 East 700 South
Salt Lake City, UT 84102
801-583-1054
atiya@xplornet.com

§ 5.6 (d)(2)(ii) Detailed maps showing lands and waters within the project boundary by township, range and section, as well as by state, county, river, river mile, and closest town, and also showing the specific location of any Federal and tribal, and the location of proposed project facilities, including roads, transmission lines, and any other appurtenant facilities;

Figure 1 shows the location of the project by State (Maine) and County (Washington)
Figure 2 shows the boundaries of the project including the closest towns (Pembroke and Eastport**)**

The project is entirely within the boundaries of the town of Pembroke.

Figure 3 shows the boundary of the project together with transmission line from the power plant boundary to substation 164.

The power line travels along the existing Bangor hydro transmission line along Garnet Head Road.

There are no Federal or Tribal lands within or abutting the project boundary.

§ 5.6 (d) (2) (iii) A detailed description of all existing and proposed project facilities and components, including:
(A) The physical composition, dimensions, and general configuration of any dams, spillways, penstocks, canals, powerhouses, tailraces, and other structures proposed to be included as part of the project or connected directly to it;

The general layout of the Pennamaquan Tidal Power Plant is shown in Figure 4. The Pennamaquan Tidal Power Plant has the layout of a power plant although it differs significantly in its operation from any power plant currently in operation. The Power Plant consists (see figure 4) of (1) Four Powerhouse Caissons each housing four bulb turbine generators, (2) An Interior Wall section consisting of six Wall Panels (four on the Leighton Neck side and two on the Hersey Neck side). Each Wall panel is secured by (3) Support Columns which are anchored to the bedrock. Two sections of (4) Intertidal Wall ties the central portion the shore, on to the Hersey side and the second to the Leighton side. As indicated by its name this section is in the intertidal zone. (5) A gantry crane is used for lift turbine generator units out for servicing. A utility road, (5), over the powerhouse caissons continues over the support columns to a service building on Hersey. (6) One of the spillways in the powerhouse is modified to serve as a lock to accommodate small fishing and recreational boats. This is achieved by installing an additional gate to the powerhouse together with required hydraulic equipment.

The dimensions and physical composition of each of the five components are listed below:

(1) Powerhouse Caisson – There are four powerhouse caissons. Each caisson rests in a fitted pre-excavated bed projected to be a 2.5 m below lowest point of rockhead. Three sectional views are shown in figures 5.1 through 5.3.

Composition: (Reinforced) Concrete
Dimensions of Each Powerhouse Caisson: 22.5m (depth) x 33.4 m (width) x 27.7 m (height)
Total Length of Powerhouse Caisson Row: 4 powerhouses at 33.4 m = 133.6 m

(2) Wall Panel - (See figures 6 a and b). Six Wall Panels each resting in a pre-trenched bed 2.5 m below lowest point of rockhead along the line of the Wall Panel. Each Wall Panel rises 6.8 m above MLLW. This is the design maximum of 1.23 x average tidal range (5.5 m) = 6.8 m above MLLW. For tides above this height (about 20 % of tides), the Wall Panel becomes entirely submerged. It is not economic to install additional capacity to utilize tides above this range.

Composition: (Reinforced) Concrete
Dimensions of Each Panel: 3 m (depth) x 25 m (length) x height dependent of depth of water.

(3) Support Column – (See figures 7 a and b) - The body of the support column consists of a rectangular upper part whose length depends on water depth and a cylindrical lower part, 4 to 6 m long which fits into a pre-drilled socket. The body of the support column is further supported by two inclined piles. The apex of each inclined pile is secured to the top of the support columns by a pin connection. The base of each support column fits into a pre-drilled socket 7m to 10 m in depth.

Composition: (Reinforced) concrete
Body of Support Column
Dimensions - upper rectangular section – 1 m x 3 m x length dependent on water depth
- lower cylindrical section – 2 m diameter x 4m/5m length
Inclined Piles
Dimensions - 0.8 m diameter x length dependent on water depth.

(4) Intertidal Wall - (See figure 8) The Intertidal Wall is located in the intertidal zone at either end of the structure. It is keyed into a trench of minimum depth 2.5 m (see fig.8) and rises to the design maximum of 1.23 x average tidal range (5.5 m) = 6.8 m above MLLW. The wall is submerged for tides above 6.8 m.
Composition – (Reinforced) Concrete
Dimensions.
Distance - Central Section to Leighton Neck = 166 m
Central Section to Hersey Neck = 41 m
Wall Thickness = 1.5 m
Height of wall above rockhead at interface of intertidal wall and central section wall.
Leighton Neck side = H = 6.5 m
Hersey Neck side = H = 7.7 m

The height of the wall adjacent to central wall section = H + 2.5 m

(5) Utility Road (see figure 7b – marked Roadway). The Utility Road is built from the Powerhouse row to the Hersey Neck side only.

Composition- Pre-cast (reinforced) concrete

Dimensions – Length = 25 m per section x 4 sections = 100 m
Width = 11 m

(6) Boat Lock – One of the spillways in the powerhouse acts as a lock. An additional gate is installed in one of the spillways in addition to the gate which controls the flow over spillway. The distance between the gates is 20 m (65 feet), sufficient to safely accommodate the 30 to 40 foot boats typical of the fishing fleet operating in Cobscook Bay. A width is 6.7 m (22 feet) is provided with an option to double that width to 13.4 m (44 feet).

Composition – Steel gates
Dimension – Distance between lock gates = 20 m. Width of lock = 13.4 m.

(B) The normal maximum water surface area and normal maximum water elevation (mean sea level), gross storage capacity of impoundment.

§ 5.6 (d) (2) (iii)(B) is meant to characterize a conventional river hydroelectric dam. The Pennamaquan Tidal Power Plant operates so as to maintain the naturally occurring tidal cycle within Pennamaquan basin. The surface areas are best characterized in terms of the naturally occurring tidal levels. The area is given for an average tide of y_{AV} = 5.5 m and for the design maximum of 1.23 y_{AV} = 6.8 m. 20 % of tides fall in a range above 1.23 y_{AV}. For tides above that level the water level submerges the wall section of the power plant.

Table.1 Area of Pennamaquan Basin

Tidal Range	**Maximum Area**	**Minimum Area**
y_{AV} = 5.5 m	**3.43 km^2**	**2.14 km^2**
1.23 y_{AV} = 6.8 m	**3.49 km^2**	m^2

(C) The number, type, and minimum and maximum hydraulic capacity and installed rated capacity of any proposed turbines or generator to be included in the project;

Type	Fixed blade bulb turbine generator
Mode of Operation	Two way generation with pumping
Generator Rating	1.5 MW
Runner Diameter	3.2 m
Number Turbine Generators	16
Total Installed Capacity	24 MW

(D) The number length and voltage, and interconnections of any primary transmission lines proposed to be included as part of the project, including single-line diagram showing the transfer of electricity from the project to the transmission grid or point of use

Figure 9 shows the existing transmission layout together with the location of the Pennamaquan Tidal Power Plant. An onshore transformer adjacent to the Pennamaquan TPP will be required to step up the voltage to 35 kV. A line will be required to tie into the existing line (shown in black)

running along Garnet Hill Road to transformer 164. The line along Garnet Hill is a 12.5 kV distribution line. An additional 35 kV line will be required to connect to the 35 kV line at transformer 164.

(E) An estimate of the dependable capacity, average annual, and average monthly energy production in kilowatt hours or (mechanical equivalent):

The energy output is a function of the tidal range. Since the tidal range is predictable on a daily basis, the output is predictable. However, the tidal range has a 14 day cycle from minimum, neap tide to a maximum spring tide. The average tidal range at the Pennamaquan TPP is projected to be $y_{AV} = 5.5$ m. The Pennamaquan tidal power plant is designed to employ a range of tides from a minimum 0.69 $y_{AV} = 3.8$ m to a maximum of 1.23 $y_{AV} = 6.8$ m. The tidal period is 6.2 hours per cycle with 704 cycles per year. The daily output will vary in a predictable way from a maximum to a minimum. For the installed capacity of 24 MW, the daily output will vary from

Tidal Range	Output over 6.2 hour cycle
0.69 $y_{AV} = 3.8$ m	46,000 kWh
$y_{AV} = 5.5$ m	114,000 kWh
1.23 $y_{AV} = 6.8$ m	146,000 kWh

Projected Annual Output = 80 million kWh.
Projected Monthly Output = 6.7 million kWh

§ 5.6 (d)(2)(iv) A description of the current (if applicable) and proposed operation of the project, including any daily or seasonal ramping rates, flushing flows, reservoir operations, and flood control operation

The Parallel Cycle

Figures 10.1 a through c and 10.2.a-j show the operation of the Parallel Cycle. The Parallel Cycle shown in 10.2j is meant to illustrate the cycle for any site and is not specific to the configuration of the Pennamaquan Tidal Power Plant. Figures 10.1a-c graph the water level of the sea and the basin over a 24 hour period. As figures 10.1a-c show, the rise and fall in the water level in the basin (shown as a violet line) closely resembles the rise and fall of the water level in the sea (shown as a blue line). The Cycle derives its name from the fact that the rise and fall of the water level in the basin parallels the rise and fall in the water level in the ocean to a considerable degree. The rise and fall of the water in the basin closely follows the natural rise and fall of the tides but is shifted about two hours later. Figures 10.2 a-j are the companion to figure 10.1 a. Figures 10.2 a-j show the phases of the Parallel Cycle at a generic site. The start of each new phase of the Cycle is labeled A through L and each is shown in figures 10.1a and 10.2a-j.

A to B: (figure 10.2.a) Resting Phase. The powerhouse gates (42) and sluice gates (52) are closed. No water passes between the sea and basin. Over the period from A to B (figure 10.1a) the water level in the ocean is rising with the incoming (flooding) tide while the water in basin

remains at constant level. The differential head between sea and basin increases throughout interval AB. At B there is sufficient head to generate power.

B to C: (figure 10.2.b) Flood (rising tide) generation phase. At B the powerhouse gates (42) open. Water flows (flow direction represented by blue arrow) from sea to basin (20) through the turbine thereby generating power. The water level in the sea and the basin both rise as the tide floods and the basin fills (figure 10.1 a). Power generation continues to point C. At point C the spillway gate opens in order to fill the basin more quickly. C occurs just after the sea level high tide.

C to D: (figure 10.2.c) Flood generation - sluicing phase. Water is flowing through turbine generating power and flowing through the sluices (50) filling the basin. The water level in the basin is rising while the water level in the sea is falling with the ebbing tide (figure 10.1 a).

D to E: (figure 10.2.d) Pumping - sluicing phase. At D there is insufficient head to generate power. The turbine begins to operate as a pump (direction of pumping shown as red arrow), discharging water from the sea into the basin (20) to fill the basin more quickly. Water continues to flow from the sea into the basin through the sluices (50). The water level in the basin continues to rise while the water level in the sea continues to fall with the ebbing tide (figure 10.1 a). At E, the water levels in the basin and in the sea become equal.

E to F: (figure 10.2.e) Pumping phase. At E water level in sea and basin are equal. The sluice gates (52) close. The turbine/generators continue to pump water from sea to basin until F when water in the basin has been raised to the desired level at F (figure 10.1 a). At F the turbine gate is closed.

F to G: (figure 10.2.f) Waiting phase two. Powerhouse gates (42) and sluice gates (52) are closed. No water flows between sea and basin. During the period F to G, the water level in the basin remains constant. The level in the sea continues to drop. At G sufficient head has to develop to generate power (figure 10.1a).

G to H: (figure 10.2.g) Ebb generation phase. At G the powerhouse gates (42) open. Water flows from basin to sea through turbine/generators producing power. Throughout the period G to H, the water level in the basin continues to drop as it empties. At the same time the water level in the sea continues to drop with the ebbing tide (figure 10.1a).

H to I: (figure 10.2.h) Ebb generation-sluicing phase. At H, the spillway gate opens allowing water to flow from basin to sea. This brings the level in basin down more quickly. Power generation continues until point I (figure 10.1a) when there is insufficient head.

I to J: (figure 10.2.i) Pumping-sluicing phase. At I there is insufficient head to generate power. The turbine/generators begins to act as a pumps, pumping water from basin to sea to increase the rate at which the water level in the basin falls. Water continues to pass from basin to sea through the sluices (50). Pumping-sluicing continues until water levels in the sea and the basin become equal (point J on figure 10.1 a).

J to K: (figure 10.2.j) At J, the water level in the sea and in the basin are equal. The sluice gates (52) close. The turbine continues in pump mode, further lowering the level of the basin. When the level has been reduced to the desired level at K (figure 10.1a), the turbine gate shuts.

K to L: (figure 10.2 a-j No corresponding figure 10.1a) Waiting phase. During interval K to L, all gates are closed. There is no flow between sea and basin. During this time interval the water level in the basin stays constant. The water level in the sea rises until there is sufficient head to start flood generation.

An examination of figure 10.1a through c shows a major beneficial consequence of the Parallel Cycle: pumping preserves the intertidal zone. The intertidal zone is that region between the shore line at low tide and high tide bounded in figures 10.2a-j by the blue and green lines. The intertidal zone is submerged at high tide and exposed at low tide. The tidal range (difference between high water level and low water level on a given day) passes through a 28 day cycle (Figure 11). The tidal range differs on successive days, increasing from a minimum (neap tide) to a maximum (spring tide) in approximately 7 days (figure 11). The 28 day (more precisely 27.3 day) cycle consists of four 7 day cycles. Because there is some variation from one 28 day cycle to the next, the Parallel Cycle is defined in terms of average neap tides and average spring tides. The intertidal zone (figure 10.2 a-j) is that area between the shore line at high tide and at low tide for the highest tide (spring tide). For lesser tides, the area between high and low water will be smaller, reaching a minimum at minimum neap tide.

The pumping phases E to F (figure 10.1a) raises the level in the basin, flooding the intertidal zone (figure 10.2.e). Without pumping, the basin would only rise to its level at E ((figure 10.1a). In the absence of the power plant, the basin would rise to the same maximum as the sea (the apex on the blue curve representing water level in the sea), a point higher than the basin level at E. Without pumping, land normally submerged at high tide would remain exposed. The effect holds true for all tidal cycles from neap to spring tides. In the absence of pumping, the intertidal zone that is normally submerged at high tide, would become permanently exposed, turning intertidal zone into permanent dry land (littoral). Pumping restores water levels to their natural levels. An examination of figure 10.1a shows that there would be a loss of intertidal zone at low water as well. The pumping phase J to K (figure 10.2.j) lowers the level of the basin (figure 10.1a). Without pumping, the level of the basin would never drop below its value at J (figure 101.a). In the absence of the tidal power plant, the water level in the basin would drop to the minimum attained by the sea (the lowest point along the blue curve) exposing the intertidal zone. Without pumping down, intertidal zone that is normally exposed at low tide would remain permanently submerged. Therefore, without pumping there is loss of intertidal zone at both low tide and high tide.

The parallel cycle is proprietary and was developed by Halcyon Marine Hydroelectric. Detailed computer modeling was carried out by Alstom Power & Transport for the Pennamaquan Project. The parallel cycle was shown to be technically feasible. It was specifically developed to maintain the integrity of the intertidal zone. Ebb generation, flood generation, and two-way generation without pumping all result in a loss of more than half of the intertidal habitat either. The ebb generation cycle, the most widely proposed cycle, permanently submerges the lower half of the intertidal zone. The flood generation cycle permanently exposes the upper half of the intertidal

zone, turning it into permanently dry shore land. Two way generation without pumping permanently flood lower sections of the intertidal zone and permanently exposes upper sections. Although not widely appreciated, hydrokinetic projects also result in loss of intertidal zone. By removing energy from the tidal wave, the tidal range is diminished. The result is that intertidal zones that are normally submerged at high tide become permanently exposed and turned into permanently dry shore land. Perhaps this has not been widely appreciated because hydrokinetic projects have been so small that their effect on tidal range has not been significant. The parallel cycle make it possible to simultaneously generate utility scale power and to protect the intertidal habitat.

The Parallel Cycle was designed to address the problem of loss of intertidal habitat. Conventional cycles fail to preserve the natural tidal range. The Severn Barrage had a projected loss of 14,800 to 18,000 hectares of intertidal habitat. A proposal in Half Moon Cove, Cobscook Bay, ME (FERC Project No. 12704) suffered the same shortcoming as noted in Maine DEP Comment (July 23, 2009). Maintenance of natural tidal boundaries is clearly an important issue. Because of its importance, a detailed numerical model was developed. The detailed numerical model analyzed water levels on both sides of the tidal power plant in 137 second intervals. Thirty simulations were carried out. Simulations investigated energy output, maximum basin level, and percent of natural tidal level reached as functions of the number of turbines (3.2 m , 1.5 MW), starting head at which gates to turbines are opened (points B & G figure 10.1 a), and differential head at which spillway gates are opened (points D & I figure 10.1 a), discharge through turbine, over spillway and total discharge. Analysis was carried out for three tidal ranges: (1) Average tidal range= y_{AV} = 5.5 m, (2) Neap tide = 0.69 x y_{AV} = 0.69 x 5.5 m = 3.9 m, and (3) Spring tide = 1.23 x y_{AV} = 1.23 x 5.5 m = 6.8 m. The results of three of these simulations are shown in figure 10.1 a-c. Figures 10.1 a through c shows the tidal cycle for an average tide (10.1a), for a neap tide (10.1b) and for a high tide (10.1c). The table below summarize the result of six simulations including those in figures 10.1 a through c.

Table 2

	Simulation	No. Units	Output Annual	Turbine Gate Starting Head	Spillway Gate Starting Head	Natural Tidal Level +/- (m)	Max/Min Basin Level	Basin/tide Level
Average Tide 5.5 m	Simulation 34	16	79561 MWh	3 m	2.00	2.750	2.933/ -2.910	106.23%
"	Simulation_35 (fig 10.1a)	16	79662	3	1.90	2.750	2.890/ -2.871	104.75%
Neap Tide 0.69x5.5 m	Simulation 35_low (fig. 10.1.b)	16	39934	3	1.90	1.898	2.459/ -2.423	128.64%
Spring Tide 1.23x5.5m	Simulation35_ high (fig. 10.1c)	16	103,554		1.90	3.383	3.130/ -3.219	93.85%
"	Simulation 35_high_b	17	107,770	3	2.00	3.383	3.317/ -3.407	99.39%
"	Simulation 35_high_c	18	111,102	3	2.00	3.83	3.442/ -3.543	103.26%

Total annual output is based on an average tide. Note that the basin is pumped to 128.64 % of its natural high water at neap tide (0.69 x average tide), the basin rises to 2.890 m and falls to -2.871 m. This is well within spring tide ranges of +/- 3.4 m. Thus pumping maintains water levels well within their natural high and low levels.

Figure 11.b shows the statistical distribution of tides. An examination of figure 11.b shows that 70 % of tides fall within 1.23 y_{AV} and 0.69 y_{AV}. It can be shown that the additional installed

capacity to utilize tides higher than 1.23 y_{AV} is not economically justified. Therefore, for water levels above 1.23 y_{AV} = 6.9 m, the wall is overtopped. The wall therefore becomes submerged for tides above 6.9 m. For very high tides, the tides rise to their normal levels without the use of pumping. Overtopping provides additional access for biological interchange between Pennamaquan and Cobscook.

A fundamental aspect of the operating system is its flexibility. The operating cycle maintains the natural highs at spring tide and natural lows at low tide. For intermediate tides, the operating cycle can raise water level to values above the normal water levels and below normal levels for that tide (figure 11.b). Raising water levels during lower tides may have beneficial effects (such as the suppression of certain invasive species such as moon snails). It has been noted that 98 species that normally live subtidally only, live also intertidally in Cobscook Bay. One explanation is that extreme spring low tides in this region of the world occur only in the morning and late afternoon with the result that the lowest intertidal levels are not exposed to the noon day sun thus not causing desiccation of these organisms. (Larsen, Peter Foster, Notes on the Environmental Setting and Biodiversity of Cobscook Bay, Maine: A Boreal, Macrotidal Estuary, in Ecosystem Modeling in Cobscook Bay, Marine, Northeastern Naturalist 11 Special issue, 2004). By adjusting water levels, exposure to desiccation could be reduced, enhancing the productivity of the intertidal zone. In addition to power production, the Pennamaquan Tidal Power Plant is intended to be a research facility. It may therefore be possible to adjust the operating cycle to enhance biological productivity.

The parallel cycle has an additional advantage. By preserving the tidal range, the parallel cycle preserves the energy content of the water. Maintaining the energy content of the water prevents sedimentation. The parallel cycle therefore preserves the natural sediment balance. The net energy which is transformed into electric energy is withdrawn from the Moon rather than the water. Other cycles, including hydrokinetic devices withdraw energy from the water and lead to sedimentation. Maintaining the natural density of suspended solids is additionally important, since it controls the amount of light reaching various levels of the water column.

§ 5.6 (d)(2)(v) In case of an existing licensed project: …:

Not applicable.

§ 5.6 (d)(2)(vi) A description of any new facilities or components to be constructed, plans for future development or rehabilitation of the project and changes in project operation.

Not applicable.

§ 5.6 (d)(3) *Description of existing environment and resource impacts* – (i) General requirements. A potential applicant must, based on the existing, relevant, and reasonably available information, include a discussion with respect to each resources that includes:

§ 5.6 (d)(3)(i)(A) A description of existing environment as required by paragraphs (d)(3)(ii-xiii) of this section.

See paragraphs (d)(3)(ii-xiii), below.

§ 5.6 (d)(3)(i)(B) Summaries (with reference to sources of information or studies) of existing data regarding the water resources;

We are not aware of studies of Pennamaquan River (the Bay) as such, except for those of Maine DEP classifying Pennamaquan Water as class SB. However a major summary of information as of 2004 is contained in Larsen, Peter Foster, *Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary,* Northeastern naturalist, Volume II, Special issue 2, 2004. The findings regarding Cobscook Bay as a whole are inferred to apply to the Pennamaquan. Specifics would need confirmation through site specific studies.

The discharge of water through Cobscook Bay at half tide is approximately equal to that of the Mississippi River (Brooks et al., Tidal circulation and residence time in a macrotidal estuary: Cobscook Bay, Maine, Estuarine, coastal, and Shelf Science 49:647-665, 1999) It is a macrotidal estuary with a mean tidal range at Eastport of 18.35 ft (5.59) m (NOAA Station 8410149). The nearest station to the proposed Pennamaquan Tidal Power plant is at Garnet Point at the tip of Hersey Neck (see figure 2). The tidal range at Garnet Point Station 8410715 is 19.17 ft (5.84 m) (NOAA). We have used the lower figure of 5.5 m at the Eastport Tidal Station ID: 8410140 which reports mean range of 18.35 ft or 5.59 m.
http://tidesandcurrents.noaa.gov/station_info.shtml?stn=8410715%20GARNET%20POINT,%20PENNAMQUAN%20RIVER,ME

Tidal flow and the shape of Cobscook Bay produce a central dipole pattern on each flood (Figure 18). The easterly dipole feeds Pennamaquan. (Brooks, David Modeling Tidal Circulation and Exchange in Cobscook Bay, Maine, in *Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary,* Northeastern naturalist, Volume II, Special issue 2:2, 2004. pp. 31-33). The Pennamaquan is fed through the north-west dipole.

There is a high degree of vertical homogeneity within much of the Bay due large tidal flows. These induce strong vertical mixing. The temperature gradient is small, showing a temperature difference of less than one 1°C between bottom and surface temperatures (Brook, 2004, p.34). Strong currents create mixing between layers. Since the input discharge is well mixed, the waters entering Pennamaquan can therefore be expected to be well mixed and to exhibit a small vertical temperature gradient.

The Pennamaquan exhibits its own particular characteristic. Flows are significantly smaller than in the main channel producing variations in residence time. Variation in residence time is shown in figure 19, with residence times ranging from five to eight days (Brooks 2004, p. 42). The longer residence time may create a temperature gradient which is greater than that in the central channel. The presence of turbines should not alter residence time or the temperature gradient since the operating cycle maintains the natural discharge. In addition, water temperatures at the top of the water column feeding the spillway will be very close to those at the base of the water column feeding the turbines. If there is a significant temperature gradient it will be due to factors affecting water temperature *after* they enter the Pennamaquan.

Tidal flows are the main determinant of nutrients in the Bay. Salinity versus nitrates show that nutrients and nitrates in particular are brought in from the Gulf of Maine. Plant biomass vs. nitrate levels suggest heavy grazing. (Garside, Chris and Garside, Jean C., Nutrient Sources and Distribution in Cobscook Bay, *Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary,* Northeastern naturalist, Volume II Special issue 2:2, 2004, , pp.75-86). The distribution of nitrates is not uniform throughout the Bay. The Central Bay shows mean nitrate levels to be 4.5 µg/L. Nitrates levels in the Pennamaquan are significantly lower. Levels are lowest in the center of Pennamaquan with value 3.3 µg. These are the lowest levels in Cobscook Bay. The levels rise towards the entrance of the Pennamaquan to about 3.8 µg/L. The levels in the upper Pennamaquan rise again to about 3.8 µg/L. (Garside & Garside, 2004, p. 80). A likely explanation for this "dipole distribution" is that plants in the central Pennamaquan act as a nitrate sink. It is reasonable to surmise that the rise in nitrate levels in the upper Pennamaquan is anthropogenic. These inferences are supported by studies of spatial distribution of phytoplankton of subtidal microphytobenthic producers. These studies show a correlation elevated standing stocks in areas with longer residence. Increased residence time allows growth to limit export due to tidal flushing (Phinney, Yentsch, and Phinney, Primary Productivity of Phytoplankton and Subtidal Microphytobenthos in Cobscook Bay, Maine, *Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary,* Northeastern naturalist, Volume II Special issue 2:2, 2004, , pp.100-122). This is supported by the data showing chlorophyll level of 1.20 µg/L in Pennamaquan compared to 0.80 µg/L at Garnet Point. (Yentsch, et al. 2004, p.109).

The presence of turbines should not alter the nitrate or nutrient distribution since the operating cycle maintains the natural flow into the Pennamaquan. Strong vertical mixing should not be affected by passage through the turbines or over the spillway.

§ 5.6 (d)(3)(i)(C) A description of any known or potential adverse impacts and issues associated with the construction, operation or maintenance of the proposed project, including continuing and cumulative impacts;

The plant will have an impact during construction and afterwards during operation.

<u>Construction Impact</u>

Construction impact has been discussed above. There will be certain unavoidable impacts.

In particular, there will be some production of noise. This will be almost exclusively associated with trenching and drilling. Under water noise levels have not been quantified. However, they will be relatively brief and extend intermittently over the six month construction period.

There will be some sediment which will become water borne. As discussed above, trenching produces large chips that do not contribute to a sediment plume. The production of fine material during drilling will have to be examined. However, the volume of material to drilled be drilled is very limited being less than 115 m^3. This is an extremely small amount of material. It is a small

fraction of 1% of sediment in the sediment plumes entering the water column from dragging for scallops and urchins.

The installation of wall elements, powerhouse caissons and support columns should have very little impact. These elements are simply inserted into the trenched foundation into which they are keyed . The process is rapid and noise levels are low.

The R.H. Foster oil storage tanks on Pembroke parcel 34 (figure 31) were connected to a pipeline (figures 3 & 27) through which the tanks were filled from tankers. The tanks and the pipeline are now decommissioned. There may be pollutant remaining on the seafloor. Construction would necessarily disturb the seafloor and contained pollutants. It may be that the strong currents have removed all traces of these pollutants. An examination of samples will inform the project on the presence of pollutants. The results will inform the project of the risk of reintroduction of pollutants into the water through trenching and drilling.

The removal of the R.H. Foster oil storage tanks and deteriorating buildings and their replacement by landscaped arboretum would have a positive environmental and aesthetic impact.

Operation impact

Five potential impacts are examined: (1) Turbine fish kill, (2) Access to basin, (3) Retiming of the tidal cycle, (4) Loss of habitat (due to the foot print) and (5) potential positive effect on intertidal habitat.

The maintenance of tidal range and tidal power at their natural levels is intended to minimize impact on the ecology of Pennamaquan River. The issue of fish kill through turbine passage is addressed systematically .

Turbine fish kill

Fish mortality due to passage through turbine is an issue which must be addressed by all hydropower projects.

In 1985-1986 Stokesbury and Dadswell examined the morality of juvenile clupeids during passage through the Straflo turbine of the Annapolis Royal tidal power station in Nova Scotia (Stokesbury, K, & Dadswell, J, *Mortality of Juvenile Clupeids during passage through a Tidal, Low-Head Hydroelectric Turbine at Annapolis Royal, Nova Scotia* North American Journal of Fisheries Management, Vol. 11(2), Spring 1991, pp149-154). The proximity of Annapolis makes the assemblage quite similar with anadromous species including American shad *Alosa spidissima*, Atlantic salmon *Salmo salar*, striped bass *Morone saxatilis*, alewife *Alosa pseuoharengus*, American eel *Anguilla rostrata*, and Atlantic herring *Clupea harengus*
They estimated the mortality rates to be 46.3 % for both years combined, or about 23 % for a given season. From an examination of their injuries, Stokesbury and Dadswell found 64.5 % of injuries to be consistent with high pressure gradients, 33.9 % to be consistent with mechanical strikes, and 1.7 % to be consistent with hydraulic shearing. Stokesbury and Dadswell speculate that small clupeid swimming at the surface of the water may be forced to the bottom of the water

column by the intense turbulence encountered during passage through the turbine. They report a potential change in pressure of 175 kPa or more in 0.25 s. .

The turbines proposed for the Pennamaquan Tidal Power project are different both in type and in size. The turbine deployed in Annapolis Royal is a 7.2 m Straflo operating at 55 rpm. The turbines proposed for the Pennamaquan are 3.2 m fixed blade horizontal bulb turbines operating at 92 rpm. While the results from Annapolis are suggestive, they cannot be taken as definitive. A horizontal bulb turbine for instance has a much longer draft tube and changes in pressure are more gradual. Abernathy, Amidan and Čada carried out a study for the DOE specifically addressing the effect of pressure changes on fish passing through horizontal bulb turbines (Abernathy C.S., Amidan, B.G., Čada, G.F., *Fish Passage Through a Simulated Horizontal Bulb Turbine Pressure Regime: A Supplement to "Laboratory Studies of the Effect of Pressure and Dissolved Gas Supersaturation on Turbine-Passed Fish",* Prepared for the US Department of Energy by, the Pacific Northwest National Laboratory, 2003). Pressure regime in the study was representative of extremes found in horizontal bulb turbines.

> No fall chinook salmon died during or after exposure to the horizontal bulb turbine-passage pressures, and no injuries were observed during the 48-hour post-exposure observation period. ... For bluegill sunfish exposed to the horizontal bulb turbine passage pressures, only one fished died [out of 240] and injuries were less severe and less common than for bluegills subjected to either the "worst case" pressure or modified Kaplan turbine [pressure conditions ... . Injury rates for blue gills were higher at 0.7 atm nadir than for the 0.95 atm nadir. However, injuries were limited to minor internal hemorrhaging. Bluegills did not suffer swim bladder rupture in any test scenarios (Abernathy et al, 2003).

Even though these findings seem inconsistent with those at Annapolis, a closer examination of the data may explain the results. In the simulation of passage through a bulb turbine, pressure was gradually increased to 2 atm (202 kPa) followed by a decrease in pressure to either 0.7 or 0.95 atm (70 kPa or 100 kPa) in 0.4 s followed by a gradual return to 1 atm or surface pressure. (Abernethy et al, 2003). The rate of change in pressure for bulb turbines for the worst case scenario simulation was 101 kPa in 0.4s or 250 kPa/s. The rate of change in pressure cited for Annapolis is 175 kPa in 0.25 s or 700 kPa/s (Stokesbury and Dadswell, 1991). The rate of change in pressure in the Annapolis unit is nearly three times that which a fish would experience in a bulb turbine. There is significant variation between types of turbines.

Our discussion of fish passage in outline is to (1) consider data from existing turbines that more closely resemble those proposed for Pennamaquan to set a baseline, (2) identify design issues associated with passage through turbines, (3) identify improvements that can be made and have been made, (4) make an assessment of likely impact, (5) identify the relationship between gaps in our knowledge about the resident community of fish and fish passage through turbines.

The Pacific Northwest Laboratory has been conducting a major research effort to identify issues associated fish passage through turbines leading to increasingly fish friendly turbines. The research has been funded by the Department of Energy's Energy Efficiency and Renewable Energy. A much clearer picture has emerged as a consequence of that research.

Mechanisms Causing Fish Morality During Turbine Passage

Pressure gradients are one of several important factors causing fish mortality in turbines. The Idaho National Laboratory has been carrying out research funded by the Department of Energy to establish the causes for fish mortality in passage through turbines (Cada, G. F., Rinehart, B. N., *Hydropower R&D: Recent Advances in Turbine Passage Technology*, Idaho National Engineering and Environmental Laboratory, April 2000). The study summarizes the primary mechanisms causing of fish mortality.

1. Rapid pressure fluctuation
2. Shears due to velocity gradients
3. Blade impact
4. Entrapment within tip and hub gaps

The first two causes are hydraulic. The second two are due to contact. The DOE has funded systematic study of each these issues. The conclusions below are informed by those studies.

Hydraulic Impacts on Fish Mortality

Rapid Pressure Fluctuations - Results of the Modeling of pressure fluctuations during fish passage through a horizontal bulb turbine carried out by Abernathy, Amidan and Čada (2000) suggests that rapid pressure fluctuations do not cause mortality. The study notes "minimal injury to bluegill" (Abernathy et al 2000, Executive Summary). The difference in susceptibility is due to anatomical differences between physostomous fish such as salmon and trout and physoclistous fish such as perch and bass. The conclusion is supported by the different survival rates between Annapolis (77 %) and Rock Island (95%). According to the Annapolis study (Stokesbury and Dadswell, 1991) 65 % of mortality was due to rapid pressure variations, variations that greatly exceed those encountered in passage through a horizontal bulb turbine.

Cavitation, the formation and collapse of bubbles in regions the hydraulic pressure falls below the vapor pressure can be damaging to fish. Cavitation can be avoided by operating the turbine at high efficiency and by providing adequate submergence. The choice of small diameter turbines, 3.2 m, was partially motivated by the greater depth to which they can be submerged.

Hydraulic Shear

The effect of shears on fish due to velocity gradients (differences in fluid velocity between nearby points) have been studied over a wide range of values. Tests have been carried on a range of species and size of fish. Tests with salmonids found no mortality at submerged water jet velocities of 30 ft/s (Groves, AG, *Effects of Hydraulic Shearing Actions on Juvenile Salmon. Summary Report*, NOAA Northwest Fisheries Center, NMFS, Seattle, 1972). Alewives and smelts showed no signs of injury when subjected to jets of 30 ft/s to 40 ft/2 (Stone and Webster Engineering Corp., Studies to alleviate potential fish entrapment problems – summary report 1973 – 1974, Nine Mile Point Nuclear Power Station – Unit 2. Prepared for Niagara Mohawk Power Corp. 1972).

Further studies were carried out by the USAC (US Army Corps of Engineers, *Proceedings: 1995 turbine Passage Survival Workshop*. Portland District, Portland, Oregon, 1995). Determination of high shear stress zones aids in the design and operation of turbines and in maximizing fish survivability. Gaps near wicket gates and runner can result in flow separation, creating vortices with high shear stress zones. Vortices in the draft tube may also develop. Although these studies are almost exclusively applied to Kaplan mixed flow turbines, the recommendations will be applied in the final design and operation of the bulb turbines proposed for the Pennamaquan Project.

Cited Potential Mechanical Contact Factors Influencing Fish Survivability

(For example, Cada, Glenn F, *The Development of Advanced Hydroelectric Turbines to Improve Fish Passage Survival*, Fisheries, Vol. 26 no. 0 & Cada, G. F., Rinehart, B. N., *Hydropower R&D: Recent Advances in Turbine Passage Technology*, Idaho National Engineering and Environmental Laboratory, April 2000) . The impacts cited above (blade impact and entrapment between gaps) have been attributed various factors:

1. Number of blades.
2. Gaps between fixed and moving parts.
3. Blade impact factors (shape of leading edge, number of blades, flow velocities)
4. Runner Speed

For the Annapolis Project, Stokesbury and Dadswell found 33.9 % of the 23 % to be consistent with mechanical strikes or about an 8 % mortality rate due to mechanical injuries.

1. Reducing the number of blades on a turbine can have a major beneficial effect on survival of fish. Walleye (17.7 in, 450 mm) and northern pike (24 in, 600mm) were introduced into the turbines of the Manitoba Hydro's Kelsey Generation Station. Survival rate for the 6 bladed and 5 bladed units were 80.4 % and 87.8 % 48-h survival. The Kelsey Station, the French Hydro stations report a 48 h survival rate of 92.4 % for 4 blade unit as compared to 78.6 % survival rate for 5 blade units. This Annapolis unit has 4 blades. The Pennamaquan turbines reduce the number of blades to 3. It is therefore expected to raise 48 hour survival rate above 92.4 %. (Heisey, PG, and Avalos, C, Normandeau Associates, Assessment of Fish Conditional Passed through Conventional and Environmentally Enhanced Hydro Turbines with HI-Z Tag Recapture Technique)

2. There are two spaces between blades which are thought to be problematic (Figure 20). The first is the gap between the runner and discharge ring. The second is the space between the runner and the hub. Fish caught in these gaps would be injured or killed. Test to determine the effect of closing the gaps were carried out at the Bonneville Dam Fish Powerhouse on the Lower Columbia to compare performance of a conventional and minimum gap runner. (Normandeau Associates Inc., J.R. Sasaki and R.L. Townsend, Performance and evaluation of the new advanced Hydro Turbine at Wanapum Dam, Columbia River, Washington. Report for Grant County Public Utility District No. 2, Phrata, WA). Interestingly, the minimum gap runner (MGR) resulted in a slightly higher injury rate than the modified unit (3 % higher). It may be

that flow patterns are altered, directing fish into areas of the machinery more likely to cause injury. These test were carried out for Kaplan turbines. No tests were carried out for horizontal bulb turbines, the units proposed for the Pennamaquan. Computer Fluid Dynamics (CFD) which would be carried out in the final design of the turbines for the Pennamaquan would be examined for the effects of reducing gaps.

3. Direct blade impact is a third factor. Blade impact mortality can be reduced by rounding the leading edge of the blade. Mortality is a function of L/t, the length of fish to thickness of leading edge ratios and the blade strike speed (Alden, EPRI-sponsored Computer Modeling and Laboratory Evaluation of the Effects of Leading Geometry and Blade Speed on Fish Strike). Unfortunately, only direct strikes and considered. Direct strikes are low probability events. The study should have determined mortality rate as a function of the angle of strike.

4. Runner speed - The horizontal bulb turbines proposed for the Pennamaquan Project operate at 92 rpm and are therefore relatively low. Because the 3.2 m runners are relatively small, the linear speed is relatively small. Maximum velocity at blade tip is 15 m/s.

Quantitative approach to fish mortality during passage through Pennamaquan turbines

A quantitative approach to fish mortality rates in passage through the Pennamaquan turbines is developed. The measured mortality rates through existing horizontal bulb turbines is reviewed. The results are then compared with mathematical formulas developed for DOE predicting mortality rates. The degree of agreement between the mathematical models and actual measurements is then examined. The mathematical models are then used to reach an informed prediction of mortality.

In 1997, EPRI publish a database of studies measuring fish survival after passage through Kaplan and Francis turbines (Electric Power Research Institute, (EPRI). 1997. Turbine entrainment and survival database-field test. Prepared by Alden Research Laboratory, Inc. EPRI Report No. TR-108630, Paolo Alto, CA). Since the EPRI study, additional data has been generated. An expanded data was assembled by Normandeau Associates (Normandeau Associates, Inc. & Gomez and Sullivan Engineers, P.C., Downstream Fish Passage Effectiveness Assessment RSP 3.2, Conowingo Hydroelectric Project, FERC Project Number 405, prepared for Exelon, March 2011). The database includes fish mortality through Francis, and Kaplan turbines. Among the stations employing Kaplan turbines two were bulb types such as those proposed for the Pennamaquan Tidal Power Plant. These were the Rock Island in Washington State and the Townsend Dam in Pennsylvania. The results are provided in the table below where

L = Average Fish length
Q = Turbine flow
N = Number of blades
H = Head
f = runner speed in revolutions per minute (rpm)
D = Runner diameter

Table 11 Experimentally determined fish survival rate from projects equipped with horizontal bulb turbines – Rock Island Station, WA, and Townsend Dam, PA

Station	Species Tested	L (cm)	Q (m^3/s)	N	f (rpm)	H (m)	D (m)	Peripheral Velocity (m/s)	% Survival (1 h)
Rock Island	Chinook Salmon	18	481	4	85.7	12.1	7.0	31.5	96.1
1. Townsend	Largemouth Bass	22	22	3	152	4.9	2.9	22.9	86.0
2. Townsend	Rainbow Trout	34	22	3	152	4.9	2.9	22.9	86.5
3. Townsend	Rainbow Trout	14	22	3	152	4.9	2.9	22.9	94.4
4. Townsend	Largemouth Bass	22	42	3	152	4.9	2.9	22.9	96.8
5. Townsend	Largemouth Bass	10	22	3	152	4.9	2.9	22.9	100.0
6. Townsend	Rainbow Trout	14	42	3	152	4.9	2.9	22.9	100.0
Essex	Atlantic Salmon	29	43	3	128.6	7.9	4.0	26.9	96.1
Pennamaquan			52	3	92	2.75 to 3.1	3.2	15.4	

Sampling method was HI-Z Turb'N Tag for all studies. The parameters for the Pennamaquan are given for comparison. It is seen that the Pennamaquan Project is similar to the Townsend. The main differences are the lower rpm (92 vs. 152 rpm), the operating head is higher at Townsend (4.9 m vs. 2.75 to 3.1 m).

Predictive mathematical model

The predictive model uses a formula developed by Franke et al. (Franke, G.F., D.R. Webb, R.K. Fisher, Jr., D. Mathur, P.N. Hopping, P.A. March, M.R. Headrick, I.T. Laczo, Y. Ventikos, and F. Sotiropoulous. 1997). Development of environmentally advanced hydropower turbine system design concepts. Prepared for U.S. Dept. Energy, Idaho Operations Office. Contract DE-AC07-94ID13223). Franke et al. based their work on previous theoretical work and on their own analysis of previous work. The works was validated using existing empirical data from studies carried out at existing hydro facilities. An extensive discuss of can be found in Frank et al (1997). Formulas were developed for Kaplan, the group to which the horizontal bulb turbines proposed for Pennamaquan belong (as well as Francis turbines which is irrelevant here). The probability of a lethal strike during passage through a Kaplan turbine given Franke's formula:

$$P = \lambda\,(N_{*}L/D)\{[\cos \alpha_a / 8Q_{\omega a}] + [\sin \alpha_a / (\pi\, r / R)]\}$$

The probability of survival is then given by

$$S = 1 - P \textit{ where}$$

P = probability of a lethal strike,
λ = strike mortality correlation factor where Franke et al set $0.1 < \lambda < 0.2$
N = number of turbine runner blades,
L = fish length,
D = runner diameter
α_a = angle to axial of absolute flow upstream of turbine runner,
$Q_{\omega a} = Q/\omega D^3$ is the discharge coefficient and Q is the flow or discharge and
ω = rotational speed converted from f (rpm) by $2\pi f / 60$,
R = turbine runner radius
r = turbine runner radius at point fish enters turbine, and
S = survival probability

For a horizontal bulb turbine the angle to axial of absolute flow upstream of turbine runner is zero ($\alpha_a = 0$) and Franke's formula reduces to Franke's formula for a horizontal bulb turbine:

$$P = \lambda N_* L / 8Q_{\omega a} D \qquad \text{(Equation 1)}$$

and

$$S = 1 - P \qquad \text{(Equation 2)}$$

Franke's formula does not take into account if the leading edge is rounded or sharp. Nor does it take into account species difference. The justification for this assumption is to be found in their extensive discussion. Some additional support is found in the analysis below.

Table 11 – Comparison of mortality rates predicted by Franke's formula and experimental data for projects equipped with ***horizontal bulb turbines*** at Rock Island Station, WA, Townsend Dam, PA and at Essex Station, MA (Expanded EPRI Database – Normandeau Assoc.

Station	Species	Flow Q (m^3/s)	Fish Length L (cm)	Measured %Survival (1 h) M	Predicted % Survival (Franke, et al)	
					$\lambda_1 = 0.1$	$\lambda_2 = 0.2$
					S_1	S_2
Rock Island	Chinook Salmon	481	18	96.1	91.8	83.5
1. Townsend	Largermouth Bass	22	22	86.0	95.1	90.3
2. Townsend	Rainbow Trout	22	34	86.5	92.5	85.0
3. Townsend	Rainbow Trout	22	14	94.4	96.9	93.8
4. Townsend	Largermouth Bass	42	22	96.8	97.4	94.8
5. Townsend	Largermouth Bass	22	10	100.0	97.8	95.6
6. Townsend	Rainbow Trout	42	14	100.0	98.3	96.7
Essex MA	Atlantic Salmon	125	29	98.0	96.7	93.4

With the exception of Station 1 Townsend (table 11 above), the predicted survival rate using

Franke formulas with $\lambda_2 = 0.2$ underestimate survival rate. In six of the 8 cases, $\lambda_1 = 0.1$ underestimate survival rate. Franke's formula therefore provides conservative estimates.

Certain general feature emerge from Tables 10 and 11. Survival rate increase significantly when the flow rate, Q is increased. The reason is that water velocity through the turbine increases with increasing flow rate. The result is that the fish passes through the turbine more quickly and is therefore less likely to be struck by the blade. This is experimentally supported by the data. The difference between conditions in 1.Townsend and 4.Townsend is an increase in flow rate from 22 m^3/s to 42 m^3/s. The measured survival rate, M, for 22 cm largemouth bass increases from 86.0 % to 96.8 % when the flow rate in increased. Similarly when flow increased from 22 m^3/s to 42 m^3/s the survival rate of 14 cm rainbow trout increases from 94.4 % to 100 % (Townsend 3 and 6). The experimentally measured result is given a clear theoretical interpretation when we convert Franke's equation 1 into the equivalent but more transparent from

$$P = \lambda N_* Lf / 2\pi v \quad \textit{where} \qquad \text{(Equation 3)}$$

f is the rotational speed in revolutions per minute (rpm) and v is the velocity of the water. As v increases with flow rate, the time for fish passage is reduced and the probability of impact is reduced. The probability of impact is also reduced by reducing the rotational speed.

Table 12 Comparison of hydraulic characteristics of the Townsend and Pennamaquan projects

Station	Flow Q (m^3/s)	N	f (rpm)	Head H (m)	Diameter D (m)	Peripheral Velocity (m/s)
5. Townsend	22	3	152	4.9	2.9	23.1
6. Townsend	42	3	152	4.9	2.9	23.1
Pennamaquan	52	3	92	2.75 to 3.1	3.2	15.4

We now apply Franke's formula to the Pennamaquan turbines. The Townsend cases 5 and 6 closely resemble the Pennamaquan. Both employ horizontal bulb turbines. The number of blades is 3 on both. Pennamaquan 3.2 meter diameter turbines are somewhat larger than the 2.9 meter Townsend turbines. Pennamaquan flow rate of 52 m^3/s is comparable to the discharge rate of 42 m^3/s through the Townsend turbines when they are operated at the higher flow rate. Only the operating frequency is significantly different with the Pennamaquan turbines operating at 92 rpm compared with 152 rpm for the Townsend turbines. These parameters should result in lower fish mortality rates in Pennamaquan than in Townsend. Application of Franke's formula is justified by the similarity of the projects in addition to previous justification provided in the DOE studies. This evidence based approach provides confidence in the validity of Franke's predictive model as applied to the Project.

<u>Pennamaquan Project: Mortality rate for species of concern</u>

We use two values of λ: $\lambda_1 = 0.1$ and $\lambda_2 = 0.15$. An examination of Table 11 the shows that observed survival rates for Townsend (4. And 6. operated at 42 m^3/s) are lower than those predicted Franke's formula with $\lambda_1 = 0.1$. The choice of $\lambda_1 = 0.1$ should provide reasonable rates

of mortality. $\lambda_2 = 0.15$ should provide conservative estimate.

Table 13. Survival Rate of fish listed as Species of Interest (Alewives and Blueback herring are grouped as River Herring)

Project	Flow Q (m^3/s)	Fish Species		Fish Length L (cm)	% Predicted Survival (Franke, et al)	
					$\lambda_1 = 0.1$	$\lambda_2 = 0.15$
Pennamaquan	52	Rainbow smelt		15 - 20 cm	98.9 - 98.6 %	98.4 - 97.9 %
Pennamaquan	52	River Herring (Spawning Alewives)		28 - 30 cm	98.0 - 97.8 %	97.0 -96.8 %
Pennamaquan	52	Eel	Elver	10 cm	99.3 %	98.9 %
			Silver - male	25 - 38 cm	98.2-97.3 %	97.3-96.0 %
			Silver - female	38-100 cm	97.3-92.9 %	96.0-89.4 %

Further data is provided relating to eel and blueback herring mortality is provided in Table 14. No data is available from horizontal bulb units. The closest related data is from Kaplan units. Table 14 includes data on blueback herring. The study reports a survival rate of 96 %., a rate consistent with mortality rates caused by mechanical injury and not pressure related factors. The figure is consistent with the results of the Pacific Northwest Laboratory study on pressure (Abernathy C.S., Amidan, B.G., Čada, G.F., *Fish Passage Through a Simulated Horizontal Bulb Turbine Pressure Regime: A Supplement to "Laboratory Studies of the Effect of Pressure and Dissolved Gas Supersaturation on Turbine-Passed Fish",* Prepared for the US Department of Energy by, the Pacific Northwest National Laboratory, 2003). Abernathy et al studied the effect on bluegill. Bluegill and river herring share a high susceptibility of swim bladder damage and therefore to pressure fluctuation. These figures support the figures calculated in table 13. While the herring in table 14 are smaller (10 cm vs. 28-30 cm), the number of blades is higher (4 vs 3), the rotational speed is higher (144 rpm vs. 92), the peripheral velocity is greater (20.7 vs 15.4) and the water velocity and therefore time spent in passage is longer. The operational factors would result in a lower survivability rate for passage through the Crescent turbines than for the Pennamaquan. If the Crescent turbines were horizontal bulb turbines, the mortality rate due to strikes would be about 2 % or equivalently the survival rate would be 98 %. This is somewhat higher than the 96 % observed. The consistency of these result support the conclusion that fish mortality in Kaplan turbines and in horizontal bulb turbines in particular are due to mechanical strikes. This in turn supports the validity of predictions made on the basis of Franke's formula.

Table 14 lists eel mortality at Robert Moses Station. Application of Franke's formula (equation 1) to Robert Moses Station gives a theoretical predicted mortality probability of $P = 0.723\lambda L$. The same calculation for Pennamaquan gives $P = 0.711\ \lambda L$. The survival rate should be slightly lower at Robert Moses than at Pennamaquan. The predicted value at Pennamaquan 85.6 % for $\lambda_3 = 0.2$ predict agrees with the prediction. It must be kept in mind that while both turbines are Kaplans, the Pennamaquan is a horizontal bulb so that the turbines are not exactly of the same type. However, the general agreement between observation between theoretical predictions and the observed values at Robert Moses provides support for a prediction of a minimum survival probability of 85 % of sexually mature female eels passing through the turbines at Pennamaquan.

Table. 14 Measured survival rate of eels and blueback herring through Kaplan (not horizontal bulb) turbines at Robert Moses Station, NY, Crescent NY (Normandeau Associates, Inc. Downstream Fish Passage Effectiveness Assessment, RSP 3.2, Conowingo Hydroelectric Project, FERC Project Number 404, Prepared for Exelon, March 2011, pp. 67-71)

Station	Flow Q (m^3/s)	N	f (rpm)	Head H (m)	Diameter D (m)	Peripheral Velocity (m/s)	Eel Length (cm)	Observed % Survival (1h)
Robert Moses	255	6	94.7	25	6.1	30.2	100	84%
Station	Flow Q (m^3/s)	N	f (rpm)	Head H (m)	Diameter D (m)	Peripheral Velocity (m/s)	Blueback Herring (cm)	Observed % Survival (1h)
Crescent, NY	43	5	144	8.2	2.7	20.7	10	96.0 %
Pennamaquan	52	3	92	2.75 to 3.1	3.2	15.4		

Pennamaquan Project: Mortality rate for species identified by Maine Department of Inland Fisheries and Wildlife

Brown trout are typically 13" to 20" in length. Brook trout are 6" to 14 " in length. Projections of mortality rate passage through the turbines based on the formula developed by Franke et al is given in table 15 for three values of the correlation parameter λ (0.1, 0.15, and 0.2). A correlation factor of 0.15 is most consistent with the data.

Table 15 Predicted mortality rate of brook trout and brown trout.

Fish Species	Fish Length L (cm)	% Predicted Survival (Franke, et al)		
		$\lambda_1 = 0.1$	$\boldsymbol{\lambda_2 = 0.15}$	$\lambda_3 = 0.2$
Brook Trout	15 - 35cm	98.9 - 97.5%	**98.4 - 96.3 %**	97.9 - 95.0 %
Brown Trout	33 - 50 cm	97.6 - 96.4%	**96.5 – 94.6 %**	95.3 - 92.9 %

Fish Passage Options

Female silver eels have the lowest survivability rate of any of "species of concern" on the federal register or species of interest listed by MDIFW. Mortality would become negligible if eels were captured in the fishway, transported below the tidal power plant and released. Outward migration of silver eels occurs later than the spawning migration of rainbow smelt or river herring. Activities in the fishways associated with the capture of eels for transport and release below the tidal power plant should not interfere with the spawning runs of rainbow smelt or river herring. Table 16 suggests that no conflict would exist with rainbow smelt or river herring migration.

There is insufficient knowledge to determine if eel capture and release program would interfere with required freedom of movement for brown or brook trout. It may be for instance that eel passage is obstructed at night when eels are active. Eels would be captured early in the morning and fishway reopened.

Feasibility of Eel Capture, Transport and Release Study: The study would determine feasibility of capture, transport and release of silver eels below Project alignment in order to bypass turbines. The study would include the possible conflict with the movement of other species.

Table 16 Spawning Migrations

Species	Spring	Summer	fall	winter
Rainbow smelt Spawning run	March			
River Herring Spawning run	May	June , July		
Silver Eel Migration to sea		August		

There are two dams on Pennamaquan river (the river). Each is equipped with a Denil fish passage. Both fishways are currently in poor conditions. There is a considerable amount of debris in the fishways. The concrete wall on the upper fishway is in danger of collapse (private communication with Milan Jamieson, chairman, Pembroke Selectmen). There are two beaver dams on the river. One older beaver dam is on the upper river. There is a new beaver dam on the lower river. Once in operation, the Pennamaquan Project would assume the maintenance of fishways. The maintenance of the fishways should improve the productivity of the watershed, helping to offset mortality due the turbines.

Access to basin

Boat Lock – One of the spillways in the powerhouse acts as a lock. Two gates instead of one are installed at each end of one of the spillways. The double gate acts as a lock. The distance between the gates is 20 m (65 feet), sufficient to safely accommodate the 30 to 40 foot boats typical of the fishing fleet operating in Cobscook Bay as well as most recreational boats. A width is 6.7 m (22 feet) is provided with an option to double that width to 13.4 m (44 feet).

Access through the lock will be restricted when sluicing and pumping is in progress. The interval is C through F and H through K in figure 10.1 a. Access would be unavailable during that period lasting about two hours out of each 6.2 hour cycle.

Operating Cycle

On an average tide the natural tidal cycle in the basin is moved forward about 1 hour 45 minutes. (figure 10.1 a) The forward retiming introduces a differential between the tidal cycle inside and outside of the bay. We are not aware of any effect on organisms. From the prespective of an

organism on the ocean side of the tidal power plant, the tide is rising at the same rate as it normally does. The flow through the turbines is essentially the same as the natural flow. The main difference occurs in actual passage through the turbine.

A second difference introduced on all cycles (figure 10.1) is the waiting periods FG and KL. These can be modified by allowing the turbines to restart one at a time starting midway during the waiting period. The cycle FG and KL would then become more rounded (sinusoidal) and would follow more closely the natural cycle.

A third difference is seen on figure 10.1 b. On lower tides, pumping raises the level of the basin above its normal (and below its normal) for that tide. The result is to make lower tides more like the average. The results are projected to be positive for the productivity of the intertidal habitat. Extreme tides during the summer result in drying out of the intertidal zones. It has been noted that this places stress on the habitat (Vadas, R.L., Beal, B.F, Wright, W.A., Nickl, S, and Emerson, S, Growth and Productivity of Sublittoral Fringe Kelps (*Laminaria longicruris*) Bach.Pyl. in Cobscook Bay Maine, in Northeastern Naturalist, 11, Special Issue 2_ 143-161; Larsen, PF., Notes on Environmental Setting and Biodiversity of Cobscook Bay Maine; a Boreal Macrotidal Estuary, in Northeastern Naturalist, 11, Special Issue 2_ 13-20). Preventing the drying out of the intertidal zone should result in higher productivity. In discussion with MDIFW bird biologist, it was suggested that higher productivity in microinvertebrates would improve the bird habitat in the intertidal zone. Should negative environmental consequences emerge, the tidal power plant could be operated to raise and lower water levels to their normal range for neap tides.

Microinvertebrate Study The microinvertebrate study would determine species and abundance and establish baselines. The purpose of the study is to establish a baseline that would provide the data required to compare with species and abundance once the plant is in operation. The study would inform us of productivity as a result of modifying neap cycle to more closely resemble average tides.

Bird Study In consultation with MDIFW, a shore bird study was proposed. The shore bird study would complement the invertebrate study. The purpose of the study is to establish a baseline from which to determine if the altered neap tide cycle increases bird species and/ or numbers.

It has additionally been suggested by local fisherman that Moon snails may be the result of algal growth during summer months when the intertidal flats are exposed to sunlight for extended periods. Algal growth may suffocate invertebrates who come up out of the mud and become prey to moon snails. Raising water levels during neap tides to levels more closely resembling average tides may suppress algal growth and reduce predation by moon snails.

Moon Snail Study The purpose of the study is to establish a baseline for the moon snail. The study would also establish a baseline on microinvertebrates on which the moon snail preys. Finally the study would establish a baseline on algal growth during the summer months. The data would then be used to determine if raising water levels to more closely resembles levels at average tides reduces moon snail predation.

Habitat Loss Due to Tidal Power Plant Footprint

The tidal power plant has a footprint of less than one acre. The small footprint is one of the advantage of the construction method.

Impact on shellfish

The tidal power plant may sit over seafloor having shellfish. The footprint of the tidal power plant is less than 1 acre.

The tidal flow and range is maintained by the operating cycle so that intertidal areas are exposed and submerged to their natural levels. The effect of bringing neap tides by pumping to more closely resemble average tides has been discussed above.

Impact on marine mammals

There is insufficient information on marine mammals in Pennamaquan River to determine the impact of the tidal power plant. A study is required to determine baselines and to assess impact.

Impact on marine plants

Maintenance of the intertidal zones is vital to the preservation of marine plant ecology.

The project may have an impact on marine plants in the immediate vicinity of the project. Eel grass beds near the project may be affected by the alteration of the flow in the immediate vicinity. It is not clear if this will increase, decrease, or leave unchanged the extent eelgrass beds. The presence of barrier will greatly reduce wave action and tidal flows in the immediate vicinity of the project.

Eelgrass beds and other aquatic plants away from the immediate vicinity of the tidal power plant (figure 24) should remain unaffected. Small turbines arranged across the channel more closely reproduces natural flow patterns and therefore maintain the natural conditions. 2-D/3-D modeling will inform us on how closely natural flow pattern is maintained.

§ 5.6 (d) (3) (D) A description of any existing or proposed project facilities or operations, and management activities undertaken for the purpose of protecting, mitigating impacts to, or enhancing resources affected by the project, including a statement of whether such measures are required by the project license, or were undertaken for other reasons. The type and amount of the information included in the discussion must be commensurate with the scope and level of resources impacts caused or potentially caused by the proposed project. Potential license applicants are encouraged to provide photographs and other visual aids, as appropriate to supplement text, charts, and graphs included in the discussion.

Mitigations

The Pennamaquan Tidal Power Plant is intended to be both a full scale power and a research facility. It incorporates features which address issues which have been historically problematic for tidal power plants. We have attempted to resolve the major environmental issues in the design of the plant. Research into best practices for tidal range power would continue as part its operation. These efforts would be conducted with State and Federal Agencies as well as academic institutions. From the outset, measures were taken in the design of the plant to minimize its environmental impact.

The operating cycle employs two way generation with pumping to simulate the natural flow and ebb of the tides. Pumping is designed to preserve the intertidal zones. The footprint is reduced to a minimum.

At water depth of 10 meters, an embankment would typically have a base of width of 40 meters. This has been replaced by a wall, 3 meters in width. Small 3.2 m diameter turbines are proposed. The use of small turbines has environmental benefits. The use of small turbines reduces the length of the powerhouse caissons. The result is that the footprint of the powerhouse is smaller. The use of small turbines extends width of the power along the width of the channel. The result is that the flow is distributed along the width of the channel, more closely resembling the natural flow pattern. It is anticipated that the flow patterns will be altered only in the vicinity of the power plant.

Preservation of the intertidal zones and the flow patterns should protect the ecological integrity of Pennamaquan River. We are not aware of any negative environmental impacts resulting from the introduction of a phase difference in the tidal cycle between ocean and basin.

The preservation of the tidal range within the basin through pumping preserves the energy content of the water. A careful analysis of the energy flow shows that the net effect of the proposed cycle is to reduce the energy of the Moon and not the water. This is very important since the rate of sedimentation is very sensitive to the energy content in the water. The preservation of the energy content is unique to this operating cycle. Hydrokinetic projects for example withdraw energy from the water and if installed in large scale will result in sedimentation downstream. The use of pumping to preserve the energy content of the water and to prevent sedimentation is a major benefit of the cycle.

Spillways were designed over the powerhouse thus eliminating the need for separate sluice caissons. The result is a smaller footprint.

Horizontal bulb turbines are proposed. These have a low mortality rate for fish passage. Small turbines were selected rather than a smaller number of large ones to reduce fish mortality. The number of blades were reduced to three. Additional mitigations are proposed to further reduce fish mortality. These include rounding the leading edge of the runner. The gaps between moving parts in which fish could be trapped would also be closed.

An optimum combination of mitigating measures would be deployed. The Pennamaquan Tidal

Power is envisioned as both a power plant and a research facility. It would operate in conjunction with State and Federal agencies to determine optimum solutions. Tidal range power is an immense public resource. A research facility to inform best practices would be an important contribution towards its development.

Mortality rates have been discussed. Highest anticipated mortality rates are for silver eels on their outward migration. It is proposed that the eels be captured in the fishways bypassing the dams on the Pennamaquan river and then transported and released below the power plant. The strategy would eliminate the need for eels to go through the turbines.

Currently, the fishways on the Pennamaquan are in a state of disrepair. The Project would repair and maintain the fishways. Currently, Maine Department of Inland Fisheries and Wildlife (MDIFW) has a program to improve the condition of fishways. The improvement and maintenance of the fishways would have a beneficial impact on the brown trout and brook trout management program of MDIWF.

§ 5.6 (d)(3)(i)(D) A description of or proposed project facilities or operations, and management activities undertaken for the purpose of protecting, mitigating impacts to, or enhancing resources affected by the project, including a statement of weather such measures are required by the project license, or were undertaken for other reasons. The type and amount of information included in the discussion must be commensurate with the scope and level of resource impacts caused or potentially caused by the proposed project. Potential license applicants are encouraged to provide photographs and other visual aids as appropriate, to supplement text, charts, and graphs included in the discussion.

Pre-Construction

Pre-Construction activities require geotechnical investigation. The geotechnical investigation requires 15 borings along the alignment of the power plant. Each borehole has a diameter of 10 cm and is to a depth of 20 m. The total volume of material removed is 0.24 cubic meters or 8.3 cubic feet of rock. The geotechnical investigation will determine what surficial material overlies the rock.

Construction of the tidal power plant requires drilling and trenching and possible dredging. The power plant consists of (see figure 4):

(1) Powerhouse caissons	134 m x 23 m
(2) Interior Wall Section	150 m x 3 m
(3) Support Columns	
(4) Intertidal Wall Sections	220 m x 3 m

Construction Impact

(1) Powerhouse caissons - The powerhouse caissons are fitted into pre-excavated trenched beds. The minimum depth of each bed is 3 m. It is estimated that a removal of rock to a depth of 4 m is required to provide a horizontal surface for the caissons. A total of 12,300 m^3 or 15,000 cubic

yards of rock will need to be removed. Trenching is to be carried out using a MIAH 7000 trencher which produces quarter to half inch rock chips. The rock chips will be largely removed (vacuumed) using a Toyo, Marco-Dynajet or Pneuma Pump. A plan for disposal of material will be worked out with US Army Corps of Engineers. It is known that there are surficial muds in overlaying the rock. The depth of these muds is however unknown. An investigation will be required. It may be possible to trench through the surficial material or it may have to be dredged. The impact of dredging will depend on the depth of the surficial material. A plan will then need to be developed in cooperation with the USACE. A permit is required from the USACE.

(2) Interior Wall Section – (see figure 6) Wall sections are fitted into pre-excavated trenched beds. The minimum depth of each bed is 2.5 m. It is estimated that a removal of rock to a depth of 4m is required to provide a horizontal surface for each wall element. The trenching process is the same as that employed for the powerhouse caissons. A volume of 1350 m^3 or 1700 cubic yards of rock will need to be removed.

Trenching and dredging requires a permit from the US Army Corps of Engineers (USACE). Trenching is to be carried out using a MIAH 7000 trencher which produces quarter to half inch rock chips. The rock chips will be largely removed (vacuumed) using a Toyo, Marco-Dynajet or Pneuma Pump. A plan for disposal of material will be worked out with USACE. It is known that there are surficial muds in overlaying the rock. The depth of these muds is however unknown. An investigation will be required. It may be possible to trench through the surficial material or it may have to be dredged. The impact will depend on the depth of the surficial material. Once the information is available, a plan will then need to be developed in cooperation with the USACE.

(3) Support Columns – (see figure 7) A cylindrical socket 2 m in diameter and 4 m to 6 m in depth. The base of the support column is then fitted into the socket. Two inclined (batter) piles are secured to the support column. The batter piles are inserted into pre-drilled socket 0.8 m in diameter and 7.5 to 15 meters in depth. The required depth will depend on quality of the rock as determined during the geotechnical investigation. Six to eight such columns will be required. The total volume of all three sockets for each of support is between 20 and 34 m^3. This is a small volume. Drilling may produce some fine enough material to form a plume. Total volume of drilled material is between 140 m^3 and 200 m^3.

Drilling activities will require a permit from the USACE. A plan will be developed in conjunction with USACE to determine if the material removed during drilling can be discharged directly into the water or if it must be removed.

(4) Intertidal Wall - The intertidal wall is set in a trench 3 m in depth and 2 to 3 m in width. Trenching is carried out at low tide in the dry. The same MIAH trencher is modified for trenching in the dry.

A plan will be developed with USACE to manage trenched material.

Minor road access is required. There is a road to the boat launch belonging to the town of Pembroke. No additional access is required. The power house caissons, wall elements and

support columns are fabricated on shore and either floated out to the site and sunk in place or are barged to the site. A shore based construction yard is currently in the planning stage by Perry Marine and Construction. It is to be located on Deep Cove near the Port of the City of Eastport. Construction in the intertidal zone is carried using equipment stored on barges and offload onto the site.

The R.H. Foster oil storage tanks on Pembroke parcel 34 (figure 31) were connected to a pipeline (figures 3 & 27) through which the tanks were filled from tankers. The tanks and the pipeline are now decommissioned. There may be pollutant remaining on the seafloor. Construction would necessarily disturb the seafloor and contained pollutants. It may be that the strong currents have removed all traces of these pollutants. An examination of samples will inform the project on the presence of pollutants. The results will inform the project of the risk of reintroduction of pollutants into the water through trenching and drilling.

Construction will impede access into the upper Pennamaquan. There appears to be very little activity in the bay. The power plant is above the boat ramp and will interfere with its operation on an intermittent basis. Frequency and use of the Pennamaquan will have to be investigated fully.

Cumulative Impact

Operation of Tidal Power Plant

There will be no effluents or toxic substances discharged. The bulb turbines proposed are propeller type and have water lubrication. The plant should therefore have no adverse effect on water quality.

The major impact of tidal range power has traditionally been its alteration of the intertidal zones. Ebb generation cycles permanently submerge the lower half of the intertidal zone. Two way generation cycles *without* pumping (1) permanently submerge a portion of the intertidal zone which is normally exposed at low tide and (2) permanently expose a portion of the intertidal zones that is normally submerged at high tide. The Parallel Cycle maintains the natural high and low tidal levels. Figure 10.1 a-c show the operating cycle for an average tide (fig. 10.1a), low tidal cycle (fig.10.1b) and a high tidal cycle (fig.10.1c). Figure 10.1a corresponds to 0.69 y_{av} or a neap tide 69% of average tide of 5.5 m. Figure 10.1c corresponds to 1.23 y_{av} or a spring tide 123% of average. 10 % of tides fall below 0.69 y_{av} and 20 % of tides rise above 1.23 $y_{av.}$ The limits 0.69 to 1.23 y_{av} represent 70 % of tides. Figures 10.1a-c are based on utilizing 16 turbines. Calculations have been carried out for more turbines. Water levels for high (1.23), low (0.69) and average are listed in the table below:

Table 4 – Maximum and Minimum Water Levels for high, low and average tide

Tide	Simulation	Number of Turbines	Tidal level (+/-)	Minimum Basin Level	Maximum Basin Level	Basin/Tide Level (%)
Average	35	16	2.750 m	2.890 m	-2.8718 m	104.75 %
Low (0.69 y_{av})	35_low	16	1.898 m	2.459 m	-2.423 m	128.64 %

High (1.23 y_{av})	35_high	16	3.383 m	3.130 m	-3.219 m	93.85 %
High (1.23 y_{av})	35_high_b	17	3.383 m	3.317	-3.047 m	99.39 %
HAT*				4.229	-4.229	

*HAT = Highest Astronomical Tide

Table 4 shows that the tidal levels achieved by pumping are higher than their normal levels for tides at or below average. However, water levels remain within the high and low of high tidal level, 1.23 $y_{av.}$ The tidal cycle tends to even out the tides. The minimum is raised to within 29 cm or 11 inches (2.459 m) of average (2.750 m). The result is to reduce the difference between neap and spring tides. The biological consequences are not clear. It is projected that the reducing tidal extremes will increase biological productivity and will therefore have a positive impact. This is particularly true in the summer months when the intertidal flats tend to dry out in the heat. Discussions with MDIFW suggest that the anticipated resulting increase in micro-invertebrates would have a beneficial impact on shore birds. It must be borne in mind the Pennamaquan Tidal Power Plant is a research facility in addition to its role as a power generating facility. The consequences of the evened out tidal regime would be studied. Should the consequences be negative the plant would be operated to bring water levels to their natural values. Clearly, this can be achieved. The operating cycle will be adjusted to maximize environmental benefits

For high tides (1.23 y_{av}), the level is brought to 94% (93.85 %) of normal or 16 cm (6 inches) of normal range when 16 turbines are installed. With 17 turbines water levels are brought to their normal values (99.39 %).

The height of the wall section of the power plant is designed to a height equal to maximum water level for a 1.23 y_{av} tide. For tides above that level, the wall becomes submerged and the water and water rises to its level in the absence of the power plant.

The operation of the plant will alter flow velocities near the power plant. Three water velocities are compared: (1) the velocity of the water in the channel calculated at mid-tide when velocities are maximum. No data is publicly available. The calculations are based on the geometry of the channel and on estimated live water volumes; (2) the velocity of water at the exit of the draft tube; (3) the velocity of the water over the spillway.

Figure 10.1a shows the parallel cycle and provides a qualitative interpretation for the numbers. The slope of the basin line (purple) is a measure of the discharge through the power plant. The slope of the basin line and line for the sea (blue) closely parallel each other. Therefore the discharge, Q (m^3/s) through the tidal power plant is very close to the natural discharge through the channel. Since the power plant restricts the flow through a narrower cross sectional area, the velocities through the tidal power plant will be higher than natural velocities. At B (figure 10.1a) the gates to the turbines open. The gates to the spillway remain closed. At C, the gates to the spillway open so that water flows through both the spillway and the turbines.. Water velocities over the spillway attain a maximum at the moment the spillway gates open at C on the flood cycle. The ebb cycle is the reverse of the flood. At G the gates to the turbines open. The spillway gates remain closed. At H the gates to the spillway are opened. The maximum water velocity over the spillway is maximum H on the ebb cycle.

Table 5 – Flow velocities

Channel		Head – H (m)	Discharge Q (m^3/s)	Velocity v (m/s)
Pennamaquan	Average Tide (y_{av})		1950 m^3/s	0.9 m/s
	High tide (1.23 y_{av})		2250	1.1 m/s
Draft Tube Exit			Discharge/Unit 52 m^3/s	1.2 m/s
Spillway	Just as the spillway opens at D	2 m	2054 m^3/s	5.1 m/s
		1.4 m	1901 m^3/s	4.3 m/s
		1 m	1736 m^3/s	3.6 m/s
		0.4 m	1098 m^3/s	2.3 m/s

The shore on the Hersey Neck side is covered by boulders. There are no sediments. The higher velocities should therefore produce little scouring. No scouring is expected on the Leighton Neck side which is over 200 m from the flow. By way of reference, surface velocities in the Mississippi at 18 ft gage height are 3.6 m/s. www.mvn.usace.army.mil/eng/edhd/velo_no.asp . Velocity profiles are expected to quickly reach their normal value away from the tidal power plant. The velocity profiles will be determined by the 2-D modeling study.

Flow is restricted through the powerhouse (turbines and spillways). This will alter flow patterns near the power plant. When designing the project, larger turbines were considered (up to 6.5 m). The smaller 3.2 m turbines were chosen in order to increase the width through which turbines would flow. Three 6.5 m would have been required. The width of the powerhouse would have been about 48 m. By comparison the width of the powerhouse for the 3.2 m turbines proposed for the project is 137 m. Flow through the more extended powerhouse more closely resembles natural flow. The 3.2 m turbines were chosen in part for this reason. It is proposed to determine flow profiles through 2-D modeling study. 3-D modeling is possible if 2-D does not provide the information required.

2-D/3-D modeling study is one the proposed studies.

Sedimentation patterns before and after construction of the power plant will also be modeled. The prevention of net sedimentation was one of the motivations behind the parallel cycle. Sedimentation is very sensitive to changes in the energy content of the water. The use of pumping maintains the energy content of the water and therefore prevents sedimentation. It might seem counter intuitive that a power plant that withdraws energy would preserve the energy content of the water. However, an analysis of energy flow shows that when pumping is employed, the energy pathway removes energy from the moon rather than the water. The main reason is that power is generated at a higher head (point G – fig.10.1a) than the average head against which pumping takes place (between E and F – fig. 10.1a). This is a major of advantage of the parallel cycle over other cycles and methods of generating power from the tides. Hydrokinetic turbines for examples will inevitably lead to sedimentation as they withdraw energy from the water. Sedimentation will be negligible only to the extent that the energy withdrawn is small. For the parallel cycle, large amounts of power can be generated without

leading to sedimentation.

2-D modeling is initially planned. The results will be assessed with NOAA, MDMR and other regulatory agencies. 3-D modeling would be carried out should 2-D be insufficient.

§ 5.6 (d)(3)(ii) *Geology and soils.* Descriptions and maps showing the existing geology, topography, and surrounding area. Components must include:

§ 5.6 (d)(3)(ii)(A) A description of geological features including bedrock lithology, stratigraphy, structural feature, glacial features, unconsolidated deposits, and mineral resources at the project site.

Pennamaquan River Site

The rock type expected to be encountered during trench and socket excavation belongs to the Hersey Formation. It is an Upper Silurian sedimentary rock formation composed of maroon and green siltstone, mudstone, and shale, locally calcareous. The rock mass is likely weathered, fractured and faulted.

The strength of the intact rock is estimated to potentially range from 5 MPa – 25 MPa with an average UCS estimated to be around 7.5 MPa. The rock strength could vary further pending on extent of weathering and carbonate content. In reality, the rock mass strength could be within a much larger range. It is critical to perform borings at this site to adequately characterize the rock and the parameters required for the pile socket design.

For the given range of expected rock strengths, the socket length of the piles could vary from about 7.5 m to 15 m. For the stated rock socket lengths, a 2 m allowance has been added to the socket allowance to account for the near-surface fractured/weathered condition of the in situ rock.

For the given range of expected rock strengths, the socket length for the support columns could vary from about 4 m to 6 m. For the stated rock socket lengths, 2 m of length has been included to account for the upper 2 m of rock which is expected to be highly weathered.

No calculations were performed to determine the depth of trench for the wall section. A nominal trench depth of 2.5 m should suffice based on a 2 m deep weathered/fractured zone with 0.5 m keyed into better quality rock.

The hardness of the rock is estimated to be about 4 to 5.

The following figures show geological features:

Figure 12 a through c shows bedrock, including bedrock lithology, and stratigraphy.

Figure 13 shows surficial material including material of glacial origin and unconsolidated deposits and mineral resources.

§ 5.6 (d)(3)(ii)(B) A description of soils, including the types, occurrence, physical and chemical characteristics, erodability and potential for mass soil movement.

Figure 14 a, b, and c (Soil Types) and figure 15. Coastal Marine Geologic Environment together with interpretation of maps given with the figures provide the description required by § 5.6 (d)

(3) (A) (ii) (B)

§ 5.6 (d)(3)(ii)(C) A description of reservoir shorelines and streambanks, including: (1) Steepness, composition (bedrock and unconsolidated deposits), and vegetative cover; and (2) Existing erosion, mass soil movement, slumping, or other forms of instability, including identification of projection facilities and operation are known or may cause these conditions.

(2) The boundary of the reservoir and the steepness of the shoreline is shown in Figure 3. Figure 13 shows surficial material including bedrock and unconsolidated deposits. A more detailed account of the composition and vegetative cover along the shoreline is given in Figure 15 which divides the shoreline into three environments: (1) Supratidal environment just above the highest water datum, but under the partial influence of marine processes, (2) the Intertidal environment between the highest high water datum and the lowest low water datum subject to twice daily tidal flooding and all other marine forces and (3) the Subtidal environment just below lowest low water. The vegetation in these environments is given on the map together with the companion text beneath the map.

No erosion, mass soil movement, slumping or other form of instability is indicated. A site visit in June, 2011 by Ramez Atiya of Pennamaquan Tidal Power, LLC and Milan Jamieson, Selectman (chairman) of Pembroke identified no areas of risk. A detailed examination of the site for potential issues will be carried out during the study phase.
The operating cycle described in § 5.6 (d)(2)(iv) preserves natural tidal levels. Therefore the shoreline will not be affected by the presence of the power plant except possibly very near the power plant itself. The flow rate through the power plant is very close to the natural flow rate. No significant changes in flow pattern are anticipated at appreciable distance from the power plant. Near the power plant, where the flow is directed through the turbines during the power, there will be a potentially significant change in the flow pattern. Detailed computer generated flow patterns with and without the power plant will be generated as one of the studies. The results will inform us of changes in flow patterns and of issues that may arise.

§ 5.6 (d)(3)(iii) *Water Resources.* A description of the water resources of the proposed project and surrounding area. This must address the quantity and quality (Chemical/physical parameters) of all waters affected by the project, including but not limited to the project reservoir(s) and tributaries thereto, bypassed reached, and tailrace. Components must include (A through I below):

Because tidal hydro operates on different principles than river hydro, items A through C are not strictly applicable. An explanation is given for each item.

§ 5.6 (d)(3)(iii)(A) Drainage area

Not applicable.

The numbers requested are relevant to river hydro whose output is fed by runoff from a drainage area. The values requested here do not have clear meaning with respect to a tidal range power.

For the parallel cycle, water flows into Pennamaquan River from Cobscook Bay during the flood cycle and from Pennamaquan River into Cobscook Bay on the ebb cycle. (The names in the area are misleading. Pennamaquan River is not a river at all but a fjord. Its name is a matter of tradition and is not a descriptor). The drainage area on the flood cycle is therefore the drainage area of the Atlantic ocean which feeds Cobscook Bay. Certain related numbers can be provided. The drainage area of Pennamaquan Lake which empties out into Pennamaquan River (MIDAS 1402, Maine Department of Environmental Protection) has a drainage area of 22.6 square miles. (There is another point of confusion. There is an actual Pennamaquan River, an actual river, which empties into Pennamaquan River, the fjord.)

§ 5.6 (d)(3)(iii)(B) The monthly minimum, mean, and maximum recorded flows in cubic feet per second of the stream or other body of water at the power plant intake or point of diversion, specifying any adjustments made for evaporation, leakage, minimum flow releases, or other reduction in available flow.

Not applicable. See discussion in paragraph (d)(3)(iii)(C), below.

§ 5.6 (d)(3)(iii)(C) A monthly flow duration curve indicating the period of record and location of gauging station(s), including identification number(s), used in deriving the curve; and a specification of the critical streamflow used to determine the project's dependable capacity

Tidal hydropower generation is significantly different from river hydropower and requires a somewhat different treatment. Information requested is provided within the context of tidal hydropower generation.

Two major cycles govern tidal flow. The first is the daily sinusoidal variation represented by the blue curve in figure 10.1a-c (semidiurnal) and having a period of about 12.8 hours. The second is the intra-monthly variation shown in figure 11.a. The time of the new moon and full moon produces high (*spring*) tides. When the moon is in its quarter, it produces low (*neap*) tides. These relationships are illustrated in figure 11.a. The time from new moon to new moon is known as the *synodic* month and has an average length of 29.53 days. The intra-monthly variation has an approximate period of 14.2 days. The variation however is not entirely regular. The statistical distribution of tides is illustrated in figure 11.b. The volume of water flowing into and out of the basin is the live *water volume* and provides a natural measure of variation. The live water volume for an average tide, a spring tide (1.23 times the average), and neap tide (0.69 times the average) behind the power plant are given in the table below along with the average flow into the basin.

The average tidal range is that reported at Eastport gauging station (Station ID 8410140). Further studies will be conducted to determine precise values at the Pennamaquan Tidal Power Plant site.

Table 3

Tide	Range	Live Water Volume	Average Flow
Average tide (y_{AV})	5.6 m = 18.35 ft	15.4 million m^3	693 m^3/s = 24500 cfs

Spring tide (1.23 y_{AV})	6.9 m = 22.3 ft	18.0 million m^3	1070 m^3/s = 37800 cfs
Neap tide (0.68 y_{AV})	0.69 m = 12.7 ft	12.7 million m^3	478 m^3/s = 16880 cfs

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These figures represent the monthly minimum and to the extent possible, monthly maximum flow. The minimum flow is of course zero at high and low tide.

The live water volume for a tidal power plant is the equivalent to the critical streamflow for river hydro. It can be used determine the firm capacity of the plant.

The highest recorded tide at Eastport tidal station is 29.02 feet on Nov. 10, 1997.

§ 5.6 (d)(3)(iii)(D) Existing and proposed uses of project waters for irrigation, domestic water supply, industrial and other purposes including any upstream or downstream requirements or constrains to accommodate those purposes;

None.

§ 5.6 (d)(3)(iii)(E) Existing instream flow uses of streams in the project area that would be affected by the project construction and operation; information on existing water rights and water rights applications potentially affecting or affected by the project;

Not applicable.

§ 5.6 (d)(3)(iii)(F) Any federally-approved water quality standards applicable to project waters;

A majority of Maine Water quality standards are part of the water quality "docket" of standards that is maintained with the U.S. Environmental Protection Agency (USEPA). Changes to docket standards require the approval of the USEPA for purposes of implementation of the federal Clean Water Act. See the Docket Page for more information on docket standards. See also Water Quality Standards, 40 CFR Part 131 (federal rules) (off-site).

§ 5.6 (d)(3)(iii)(G) Seasonal variation of existing water quality data for any stream, lake, or reservoir that would be affected by the proposed project, including information on:
(1) Water temperature and dissolved oxygen, including seasonal profiles in the reservoir;
(2) Other physical and chemical parameters to include, as appropriate for the project; total dissolved gas, pH, total hardness, specific conductance, chlorophyll, suspended sediment concentrations, total nitrogen (mg/L as N), total phosphorus (mg/L as P), and fecal coliform (E.coli) concentration.

The standards for Pennamaquan River (the fjord) are classified as SB. Class SB water are defined under Maine Title 38: Water and Navigation, Chapter 3: Protection and Improvement of Waters. Subchapter 4-A: Water Classification Program, Article 4-A:Water Classification Program, Standard §465-B 2:

<u>§465-B. Standards for classification of estuarine and marine waters</u>

2. Class SB waters. Class SB waters shall be the 2nd highest classification.

A. Class SB waters must be of such quality that they are suitable for the designated uses of recreation in and on the water, fishing, aquaculture, propagation and harvesting of shellfish, industrial process and cooling water supply, **hydroelectric power generation**, navigation and as habitat for fish and other estuarine and marine life. The habitat must be characterized as unimpaired. [2003, c. 227, §7 (AMD).]

B. The dissolved oxygen content of Class SB waters must be not less than 85% of saturation. Between May 15th and September 30th, the numbers of enterococcus bacteria of human and domestic animal origin in these waters may not exceed a geometric mean of 8 per 100 milliliters or an instantaneous level of 54 per 100 milliliters. In determining human and domestic animal origin, the department shall assess licensed and unlicensed sources using available diagnostic procedures. The numbers of total coliform bacteria or other specified indicator organisms in samples representative of the waters in shellfish harvesting areas may not exceed the criteria recommended under the National Shellfish Sanitation Program, United States Food and Drug Administration. [2005, c. 409, §3 (AMD).]

C. Discharges to Class SB waters may not cause adverse impact to estuarine and marine life in that the receiving waters must be of sufficient quality to support all estuarine and marine species indigenous to the receiving water without detrimental changes in the resident biological community. There may be no new discharge to Class SB waters that would cause closure of open shellfish areas by the Department of Marine Resources. For the purpose of allowing the discharge of aquatic pesticides approved by the department for the control of mosquito-borne diseases in the interest of public health and safety, the department may find that the discharged effluent will not cause adverse impact to estuarine and marine life as long as the materials and methods used provide protection for nontarget species. When the department issues a license for the discharge of aquatic pesticides authorized under this paragraph, the department shall notify the municipality in which the application is licensed to occur and post the notice on the department's publicly accessible website. [2007, c. 291, §7 (AMD).]

Because the Parallel Cycle closely follows the natural cycle, we anticipate no change in temperature profile including season(item G(1)).

(1) Water temperature and dissolved oxygen.

Water temperature

Monthly water temperatures at Garnet Points are provided in figure 16.b Garnet Point is located 1.5 km SE of the proposed plant site (shown at the tip of Hersey Neck on figure 3). Since turbines draw water from the lower 7 meters of the water column, the resulting mixing with waters of the upper section of the water column might affect vertical stratification of the temperature. However, extreme mixing caused by tidal flows virtually eliminates the temperature gradient, creating a uniform vertical temperature profile. Brooks measured the temperature gradient along an eastward transect from Birch Point (which can be seen at the tip of

Seward Neck on figure 2). A maximum temperature difference of 0.8 ^{o}C was recorded between surface water and water a depth of 24 m (Brooks, DA Modeling Tidal Circulation and Exchange in Cobscook Bay, Maine, 2004, Northeastern Naturalist, 11, Special Issue 2_23-50). At the site of the tidal power plant, strong currents through the narrows should produce even stronger mixing. At a maximum depth of 14 m where the turbines are located, the temperature gradient should be smaller than the 0.03 ^{o}C/m observed by Brooks. Induced mixing by the turbines is not expected to have a significant effect on the temperature gradient.

A potential effect of the operating cycle is a slight increase in temperature when the basin (Pennamaquan) is maintained a constant level between points A-B and F-G (figure 10.1a). The choice of 16 smaller turbines rather fewer larger ones was partly motivated to address this issue. Opening the sluice gates on one or more turbines early will result in rounding the straight line A-B and F-G resulting in a profile closer the natural cycle. Temperature effects can therefore adjusted as needed by opening the gate to the turbines one at a time rather than opening all 16 at once.

Dissolved Oxygen

Water quality standards for Class SB waters assignment requires a 6 mg/l at 85 % saturation. Pennamaquan waters are listed as Class SB water by MDEP (Town of Pembroke, Maine, Comprehensive Plan, Section D, 2009). Dissolved oxygen (DO) is essential. The presence of the turbines is likely to increase DO and therefore to have a beneficial effect. However, no quantitative data is available.

Salinity (conductance)

Salinity is an important environmental factor in the marine environment. Salinity at Garnet Point 1.5 km from the proposed tidal power plant site varies over the year from about 31 ppt in December to 34 ppt in Feb-April (Vadas, Beal, Wright, Nickl, and Emerson, Growth and Productivity of Sublittoral Fringe Kelp (*Laminaria longiruris*) Bach.Pyl. in Cobscook Bay, Maine, in Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary, Northeastern Naturalist, Volume 11, Special Issue 2, 2004).

Runoff from Pennamaquan river (the river) brings fresh water into Pennamaquan River (the bay). The runoff has a primary maximum in April of about 3.6 m^3/s and a secondary maximum of 2.5 m^3/s in January (Brooks, David A., Modeling Tidal circulation and Exchange in Cobscook Bay, Northeastern Naturalist, Volume 11, Special Issue 2, 2004). The flow is therefore small when compared to 690 m^3/s, the low tidal inflow for typical neap tides. It is therefore unlikely to affect salinity except in the upper reaches of the Pennamaquan. The Parallel Cycle follows the natural tidal cycle

Total nitrogen (mg/L as N), nitrates and total phosphorus (mg/L as P)

Concentrations of nitrogen, nitrates and soluble phosphorous over the course of the year are shown in figure 16.b. These are not expected to be affected by the presence of the plant in Pennamaquan. There are no aquaculture pens to act as sources of nitrates within Pennamaquan.

The nearest pens are in the waters adjacent to the city of Eastport.

Fecal coliform (E. Coli)

There are no point sources or licensed Overboard Discharge Permits within the boundaries of Pembroke which include the Pennamaquan. Pembroke has no municipal sewage treatment plant. (Town of Pembroke, Maine, Comprehensive Plan, November 2009). The Comprehensive Plan states: "Mpm-point source pollution poses the greatest threat to water quality in Maine communities and Pembroke and Perry are no exception. The most significant contributing source comes from erosion and sedimentation as well as excessive run-off of nutrients. Additional contributing factors include animal wastes, fertilizers, sand and salt storage, waste lagoons, faulty septic systems, roadside erosion, leaking underground storage tanks, and hazardous substances. Identification and regulation of these sites is important in safeguarding both surface and ground waters.

Since the flow in and out of Pennamaquan is undiminished, it is not expected that fecal coliform concentrations can increase. In fact the turbines have the capability of flushing out Pennamaquan River (the fjord). Conversely the presence of the power plant would make it possible to contain hazardous substance within the Pennamaquan or keep hazardous substances out in the event of an emergency.

Chlorophyll,

The main reservoirs of chlorophyll in Cobscook Bay are phytoplankton, benthic diatoms, eelgrass, fucoid algae, green algae, kelp, and red algae (Ecosystem Modeling in Cobscook Bay, Maine: A Boreal Macrotidal Estuary, Northeastern Naturalist, 11 (Special Issue 2):355-424, 2004). Phytoplankton density in Pennamaquan River was measured to be 1.20 µg/L (Phinney et al. Primary Productivity of Phytoplankton and Subtidal Microphytobenthos in Cobscook Bay, Maine, Ecosystem Modeling in Cobscook Bay, Maine: A Boreal Macrotidal Estuary, Northeastern Naturalist, 11 (Special Issue 2):101-122, 2004). The distribution of attached algae and plants in Pennamaquan will be provided in § 5.6 (d) (3) (A) (v)*Wildlife and Botanical Resources.*

Turbidity and suspended sediment

Relative turbidity levels are shown in figure 17. The entrance to Pennamaquan has relatively low turbidity. The turbidity is class 4 along the alignment of the power plant. Class 3 waters marked in green marks relatively clear water. A quantitative measure is provided by measurements carried out by Quoddy Bay LNG. Measurements carried out in the Western Passage in 2006 showed readings of 25 mg/l total suspended solids at high tide and 15 mg/l at low tide corresponding to class 3. Turbidity readings were found to be uniform from the surface to the bottom as would be expected given tidal mixing (Quoddy Bay LNG, Docket No PF06-11-00, Resource Report 2, 2-12, 2006).

§ 5.6 (d)(3)(iii)(H) The following data with respect to any existing or proposed lake or reservoir associated with the proposed project; surface area, volume, maximum depth,

mean depth, flushing rate, shoreline length, substrate composition.

Pennamaquan lake empties out into Pennamaquan River (the bay) through Pennamaquan river (the river). (see Salinity part (G) above. The presence of the Tidal Power Plant is not projected to have any effect on *water* in Pennamaquan Lake. The effects of the plant on migrating fish is discussed below in **(iv)** ***Fish and aquatic resources***.
www.lakesofmaine.org/search-results.html?DoWhat=&l=pennamaquan&t=&z=&m=&=Search

Area (acres): 1193
Perimeter (miles): 8.2
Mean Depth (feet): 13
Max Depth (feet): 24
Invasive Aquatic Infestation: none known
Water Quality: n/a
Maximum flushing rate is approximately 4 m^3/s.

§ 5.6 (d)(3)(iii)(I) Gradient for downstream reaches directly affected by the proposed project.

Not applicable.

§ 5.6 (d)(3)(iv) ***Fish and aquatic resources.*** **A description of the fish and other aquatic resources, including invasive species, in the project vicinity. This section must discuss the existing fish and macroinvertebrate communities including the presence or absence of anadromous, catadromous, or migratory fish, and any know potential upstream or downstream impacts of the project on the aquatic community. Components of the description must include:**

§ 5.6 (d)(3)(iv)(A) Identification of existing fish and aquatic communities;

Aquatic resources are classed into two groups: (A) Marine Animals: (1) fish and invertebrates – including those listed as (a) endangered or threatened, and those listed as (b) species of concern. (2) Marine Mammals, (3) Marine Reptiles and (B) Marine Plants.

Marine Animals

The species list below is from Steven H Jury, John D. Field, Steven L. Stone, David M. Nelson, and Mark E. Monaco, Distribution and Abundance of Fishes and Invertebrates in North Atlantic Estuaries, ELMR Rep. No. 13. NOAA/NOS Strategic Environmental Assessments Division Silver Spring, MD, May 1994. The data below is for Passamaquoddy Bay. The abundance of various species has changed significantly since the study was carried out. Four species have seen significant decline. Three have placed on the listed as "Species of Concern". These are rainbow smelt – *Osemerus mordax* (2004), River Herring- *Alosa pseudoharengus and A. aestivalis* (2006).

(B) Identification of any essential fish habitat as defined under the Magnuson-Stevens Fishery Conservation and Management Act and established by the National Marine Fisheries Service;

THREATENED, ENDANGERED AND CANDIDATE SPECIES IN MAINE – Endangered Species Act

The following marine resources are listed as threatened, endangered, and candidate species in Maine
(Source: US Department of the Interior US Fish and Wildlife Service)

Table 7
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COMMON NAME		SCIENTIFIC NAME	DISBRIBUTION (counties)	STATUS
Fishes	Atlantic Salmon	*Salmo salar*	Aroostook, Franklin, Hancock, Kennebeck, Lincoln, Sagadahoc, Piscataquis, Waldo, Somerset, Cumberland, Androscoggin, Knox, Penobscot, Hancock, Washington	E
	Shortnose Sturgeon	*Acipenser brevirostrum*	Kennbec, Lincoln, Sagadahoc, Waldo, Penobscot, Hancock, Adroscoggin	E
Reptiles	Atlantic ridley turtle	*Lepidochelys kempii*	Pelagic, Summer resident	E
	Leatherneck turtle	*Dermochelys ccoriacea*	Pelagic, Summer resident	E
	Loggerhead turtle	*Caretta caretta*	Pelagic, Summer resident	T
Mammals	Blue whale	*Balaenopetera musculus*	Pelagic	E
	Finback whale	*Baleanopeter physalus*	Pelagic	E
	Humpback whatle	*Megaptera novaeangliae*	Pelagic	E
	Sei whale	*Blaenoptera borealis*	Pelagic	E
	Sperm whale	*Physeter catodon*	Pelagic	E

NMFS, the US Fish and Wildlife Service (USFWS) list the Gulf of Maine Distinct Population Segment of Atlantic salmon (GOM DPS) as endangered under the ESA. The GOM DPS occurs in watersheds from the Adroscoggin River northward to the Dennys River. The Pennamaquan Tidal Power Plant would fall within the general area. On June 19, 2009, NMSF (74 FR 29344) (www.nmfs.noaa.gov/pr/species/fish/atlanticsalmon.htm) designated critical habitat Atlantic salmon and specifically 45 specific areas The Pennamaquan project sited not located within designated critical habitat for Atlantic salmon.

Atlantic ridley turtles are distributed throughout the Gulf of Mexico and U.S. Atlantic seaboard, from Florida to New England. www.nmfs.noaa.gov/pr/species/turtles/kempsridley.htm. The project area is not listed as critical habitat (63FR466693).

Leatherbacks are commonly known as pelagic (open ocean) animals, but they also forage in coastal waters. In fact, leatherbacks are the most migratory and wide ranging of sea turtle

species.. In the Atlantic, the loggerhead turtle's range extends from Newfoundland to as far south as Argentina. The critical habitat does not include the project site.

It is highly unlikely that any of the listed whales is in the vicinity of the project.

SPECIES OF CONCERN

The following with potential to found in Pennamaquan River are listed as species of concern by NOAA http://www.nmfs.noaa.gov/pr/species/concern/. The table below also lists if the specie is a candidate for Endangered Species Act listing.

Table 8

Species	Candidate for ESA
Alewife (*Alosa pseudoharengus)*	Candidate for ESA
Blueback herring (*Alosa aestivalis*)	Candidate for ESA
Rainbow smelt (*Osmerus mordax*)	

Anadromous Species

River Herring

The Alewife and Blueback herring are collectively referred to as "river herring". A river herring fishery has historically operated on the Pennamaquan river with licenses being issued by the town of Pembroke. The fishery operated annually starting on May 15 and ending on Memorial Day. The fish were harvested in small holding ponds built into the denil fishways designed to allow migration past the two dams along the Pennamaquan river. The river herring fishery was suspended in 2011 and remains in force pursuant to listing as a Species of Concern. Adult alewives are preferred bait for the spring lobster fishery in Maine (www.maine.gov/dmr/searunfish/alewife/index.htm). The status of river herring is found on www.nmfs.noaa.gov/pr/pdfs/species/riverherring_detailed.pdf. The Pennamaquan Tidal Power Plant is in the alewife migratory route. A projection of fish mortality during passage through the turbines is given below.

River herring are an anadromous species that ascend coastal rivers in the spring to spawn. In the spring, they migrate up the Pennamaquan Estuary, then up the Pennamaquan river and into Pennamaquan Lake and watershed. The seaward migration of young generally occurs from mid July through early November at a size range of 3.2 to 15.2 cm. Common length of spawning females is 30 cm. (http://www.maine.gov/dmr/searunfish/alewife/index.htm). NOAA identifies factors of decline as dams and other impediments, habitat degradation, fishing, bycatch and striped bass predation.

Alewife and river herring populations have seen significant decline in the North East. It was listed as abundant by Jury et al (1994). The Jury study is for Passamaquoddy and is not restricted to Cobscook Bay. A fin fish study (2011) conducted by James McCleave and Gayle Zydlewski of the University of Maine at Orono is included below as table 10 reports catching a significant number of Atlantic herring, *Clupea harengus* but a much smaller number of Blueback herring, *Alosa aestivalis* No interpretation was available. No previous baseline exists

as a basis of comparison.

River Herring Study. A study is proposed to determine the abundance of alewives and blueback herring and to gather date on fish length. The study would be conducted during river herring migration in the spring and during the return migration to salt water. An accurate count can be made by blocking the fishway in appropriate time intervals in order to obtain a statistical sample and yet not hinder the migration. Fish length would then allow us to project mortality rates in passage through the turbines.

Preliminary projections of river herring mortality rates as a result of passage through the turbines are given in table 13.

Rainbow Smelt

During the past two decades the population of smelt has been in decline. NOAA lists four factors for the decline: acid precipitation, fishing, dams and blocked culverts, and spawning habitat degradation.

Rainbow smelt are small fish with an average adult length of 15 cm to 20 cm (6 to 8 inches). They are anadromous, migrating to spawn in fresh water. Some populations are found entirely in fresh water. Rainbow smelt usually remain close to shore and in shallow water. Some spend the entire year in the estuaries. Little is known about the life history of the smelt http://www.nmfs.noaa.gov/pr/pdfs/species/rainbowsmelt_detailed.pdf. Table 10 reports significant numbers of rainbow smelt in the main channel in May and September with falling numbers in June and August. The likely explanation is that significant numbers of rainbow smelt make a spawning run in May, spend May through August in fresh water and return to salt water in September.

There are considerable gaps in our knowledge regarding the habits of smelt. In particular, it is thought that during spawning season rainbow smelt move into salt water during the day and back into freshwater at night. It is not known how far down the channel they swim. (Private communication, Gail Wippelhauser, Maine Department of Marine Resources). We propose:

Rainbow Smelt Study The first of the study would determine the number of smelt migrating up through the fishways. The study would in addition determine the distribution of fish length. Rainbow smelt tend to spawn near salt water. They may therefore not ascend up the fishways. The study would give a more precise account of their location and movement.

The second study would determine the movement of rainbow smelt during the spawning period in May through August. In particular, the study would determine where they spawn. Apparently, rainbow smelt move from fresh to salt water to make feeding runs. The study would determine how far they swim into salt water on their feeding runs and if they swim far enough down the channel to be entrained into the turbines.

Fish size would provide data on which to base mortality projections through the turbines. Preliminary projections of rainbow smelt mortality rates as a result of passage through the turbines are given in table 13.

Catadromous Species

American Eel (*Anguilla Rostrata*)

The American Eel is currently under consideration for protection under the Endangered Species Act (http://www.fws.gov/northeast/newsroom/eels.html). The American Eel is known to inhabit the Pennamaquan River, the river.

The American eel is catadromous. Spawning takes place in the Sargasso Sea. After fertilization, the larvae are carried by the Gulf Stream, taking a year reach the Atlantic coast. By the time they reach the coast, the larvae have developed into glass eels, small transparent eels 3 to 4 inches in length. These mature into elvers. Elvers are pigmented juvenile eels, typically less than 10 cm (4 in.) in length. Elvers migrate into brackish water, moving into inland habitats through tidal rivers. There they become yellow eels, sexually immature adults. After a period of 3 to 40 years of living in freshwater, brackish waters, or marine waters, the yellow eels sexually mature into silver eels. Silver eels complete sexual maturation on their return migration to the Sargasso Sea. (Fishery Management Report No. 36 of the Atlantic State Marine Fisheries Commission, Interstate Fishery Management Plan for American Eel (*Anguilla rostrata)*, April 2000).

During the course of one lifetime, an eel in Pennamaquan would pass twice through the alignment of the tidal power plant. The first time, it would pass through as a small elver. The second time it would pass through as a large sexually mature adult. If no alternate route or other mitigation were provided, it would pass mainly through the turbines. Mortality rate projections for elvers and for adult silver eels are given in table 13.

Harvest pressure and habitat losses are listed as primary causes of decline in abundance. It has been estimated that access to Atlantic coastal watersheds may have been reduced by up to 84% (Fishery Management Report No. 36 of the Atlantic State Marine Fisheries Commission, Interstate Fishery Management Plan for American Eel (*Anguilla rostrata)*, April 2000, p.v). In this respect a tidal power plant employing the Parallel Cycle is fundamentally different from a hydroelectric dam (this is not true for most power cycles proposed for tidal range power developments). Elvers would enter the Pennamaquan Estuary through the turbines on the flood generation phase. Because of their small size and limited swimming speed, elvers and young eels depend on tides to aid upstream migration. Their small size would ensure a high survival rate. A tidal power plant operated on the Parallel Cycle therefore represents a far less serious obstacle to migrating elvers than a hydroelectric dam.

Projected mortality rates for large adults passing through turbines are given in table 13. Mitigating strategies to reduce or eliminate silver eel mortality are proposed. Silver eels begin their migration to the Sargasso from August to September. Because low flows during the summer, virtually all migrating eels pass through the fishways that bypass the two dams on the

Pennamaquan River. The eels could be captured and transported directly past the tidal power plant. The fishways are equipped with small containment ponds used for the river herring fishery. It may be possible to install screens that selectively let fish through but prevent large eels from passing.

Eel study The study would determine the number of elvers migrating into the watershed. It would determine the number and size distribution of adult silver eels on their return migration. The count can be carried out by capture in the fishways on the Pennamaquan River (the river). The size distribution of silver eels would provide data on which to base projection of eel mortality during passage through the turbines.

§ 5.6 (d)(3)(iv)(B) Identification of any essential fish habitat as defined under the Magnuson-Stevens Fishery Conservation and Management Act and established by the National Marine Fisheries Service;

Estuarine and riverine ecosystems in Cobscook Bay are part of the larger Passamaquoddy Bay that has been identified as essential fish habitat (EFH) for the species listed below.

www.nero.noaa.gov/hcd/me9.html
www.sharpfin.nmfs.noaa.gov/website/EFH_Mapper/map.asp

Summary of Essential Fish Habitat (EFH) Designations Passamaquody Bay, Maine

Table 9

Species	Eggs	Larvae	Juveniles	Adults	Spawning Adults
Atlantic salmon *(Salmo salar)*			F,M,S	F,M,S	
Atlantic cod *(Gadus morhua)*		S	S	S	
haddock *(Melanogrammus aeglefinus)*					
pollock *(Pollachius virens)*		S	M,S	S	
whiting *(Merluccius bilinearis)*			M,S	M,S	
offshore hake *(Merluccius albidus)*					
red hake *(Urophycis chuss)*			M,S	M,S	
white hake *(Urophycis tenuis)*			M,S	M,S	
redfish *(Sebastes fasciatus)*	n/a				

witch flounder *(Glyptocephalus cynoglossus)*					
winter flounder *(Pleuronectes americanus)*	M,S	M,S	M,S	M,S	M,S
yellowtail flounder *(Pleuronectes ferruginea)*	S	S			
windowpane flounder *(Scopthalmus aquosus)*	M,S	M,S	M,S	M,S	M,S
American plaice *(Hippoglossoides platessoides)*	S	S	M,S	S	S
ocean pout *(Macrozoarces americanus)*	S	S	S	S	S
Atlantic halibut *(Hippoglossus hippoglossus)*	S	S	S	S	S
Atlantic sea scallop *(Placopecten magellanicus)*	S	S	S	S	S
Atlantic sea herring *(Clupea harengus)*		M,S	M,S	M,S	
monkfish *(Lophius americanus)*					
bluefish *(Pomatomus saltatrix)*					
long finned squid *(Loligo pealei)*	n/a	n/a			
short finned squid *(Illex illecebrosus)*	n/a	n/a			
Atlantic butterfish *(Peprilus triacanthus)*					
Atlantic mackerel *(Scomber scombrus)*			M,S	M,S	
summer flounder *(Paralicthys dentatus)*					
scup *(Stenotomus chrysops)*					
black sea bass *(Centropristus striata)*					
surf clam *(Spisula solidissima)*	n/a	n/a			
ocean quahog *(Artica islandica)*	n/a	n/a			
spiny dogfish *(Squalus acanthias)*	n/a	n/a			
tilefish *(Lopholatilus chamaeleonticeps)*					

Estuaries Tables

S = The EFH designation for this species includes the seawater salinity zone of this bay or estuary (salinity > or = 25.0%).

M = The EFH designation for this species includes the mixing water/ brackish salinity zone of this bay or estuary (0.5% < salinity < 25.0%).

F = The EFH designation for this species includes the tidal freshwater salinity zone of this bay or estuary (0.0% < or = salinity < or = 0.5%).

n/a = The species does not have this lifestage in its life history (dogfish/ redfish), or has no EFH designation for this lifestage (squids, surf clam, ocean quahog). With regard to the squids, the surf clam, and the ocean quahog, juvenile corresponds with pre-recruits, and adult corresponds with recruits in these species' life histories.

These EFH designations of estuaries and embayments are based on the NOAA Estuarine Living Marine Resources (ELMR) program (Jury et al. 1994; Stone et al. 1994).

No Habitat of Particular of Concern (HAPC) is listed.

There is no definitive fin fish survey in Cobscook Bay and in Pennamaquan River in particular. A baseline study will be required.

University of Maine at Orono Finfish Study

A fin fish study has been undertaken for Cobscook bay by James McCleave and Gayle Zydlewski of the University of Maine at Orono. Their findings are summarized in the table below (from the presentation made by authors in Eastport, January 20, 2012)

Table 10 – University of Orono Finish Study – Data of the number of individuals listed by species captured May through June of 2011.

Month	**May**	**June**	**August**	**September**	**Total**
Species	**Number of individuals**				
Atlantic herring, *Clupea harengus*	351	1,090	545	24	2,010
Threespine stickleback, *Gasterosteus aculeatus*	259	428	437	308	1,432
Winter flounder, *Pseudopleuronectes americanus*	156	251	461	286	1,154
Rainbow smelt, *Osmerus mordax*	238	14	12	33	297
Mummichog, *Fundulus heteroclitus*	29	25	148	70	272
Black spotted stickleback, *Gasterosteus wheatlandi*	43	109	68	11	231
Atlantic tomcod, *Microgradus tomcod*	0	17	24	28	69
Longhorn sculpin, *Myoxocephalus octodecemspinosus*	27	13	21	1	62

Grubby, *Myoxocephalus aeneus*	47	10	1	3	61
Atlantic silverside, *Menidia menidia*	3	10	18	25	56
Fourspine stickleback, *Apeltes quadracus*	0	1	21	33	55
White Hake, *Urophycis tennuis*	0	2	20	28	50
Haddock, *Malanogrammus aegelfinus*	0	0	40	8	48
Pollock, *Pollachius virens*	0	10	12	3	25
Sea Raven, *Hemitripterus americanus*	12	1	6	3	22
Atlantic cod, *Gadus morhua*	4	9	2	3	18
Butterfish, *Peprilus tricanthius*	0	0	7	10	17
Alewife, *Alosa pseudoharengus*	0	1	1	14	16
Silver hake, *Merluccius bilinearis*	1	7	8	0	16
Shorthorn sculpin, *Myoxocephalus scorpius*	3	6	1	1	11
Atlantic mackerel, *Scomber Scombrus*	0	0	10	0	10
Red hake, *Urophycis chuss*	0	2	2	4	8
Snakeblenny, *Lumpenus lampretaformis*	0	4	3	0	7
Lumpfish, *Cyclopterus lumpus*	0	2	1	1	4
Winter skate, *Raja ocellatus*	2	0	2	0	4
Radiated shanny, *Ulvaria subbifurcata*	0	1	1	0	2
Rock gunnel, *Pholis gunnelus*	0	1	1	0	2
Ninespine stickleback, *Pungitius pungitius*	0	1	0	0	1
American sand lance, *Ammodytes americanus*	0	1	0	0	1
Little skate, *Raja erinacea*	0	0	0	1	1
Atlantic halibut, *Hippologlossus hippoglossus*	0	0	0	1	1
Blueback herring, *Alosa aestivalis*	0	1	0	0	1
Total	1,175	2,017	1,874	899	5,965

Shellfish

Figure 22 shows the marine resources within the boundaries of the towns of Pembroke and Perry in Washington County, Maine and in Pennamaquan River in particular. The map indicates shellfish habitat in the intertidal zone. Surprisingly, no eelgrass is indicated.

Scallops are an important resource in Cobscook Bay and therefore a summary of the resources in Pennamaquan River is provided. Scallop harvestable biomass is monitored. Figure 23 shows that Pennamaquan River is a minor but significant part of the scallop fishery in Cobscook Bay. Figure 23.a shows that about half the scallop harvest in Pennamaquan River would be carried out outside the project boundary.

Marine plants

Figure 21 shows identified marine plants in the Pennamaquan River. F5 Algal Flats (identified in green) are high, coarse and fine-grained intertidal flats covered with the green algae,

Enteromorpha erecta. M1, high salt-marsh. are organic-rich sediments densely vegetated primarily with Algal Flats - High, coarse and fine-grained intertidal flats covered with the green algae, Enteromorpha erecta the salt-marsh grass Spartina patens. F3 marked in yellow are mussel bars, low mounds of living mussels, Mytilis Edulis , and/or disarticulated and broken mussel shells accumulated by wave shoaling. Algal flats (F5), high salt marsh (M1), and mussel bars (F3) are part of the intertidal environment, defined as lying between the highest high water datum and the lowest low water datum subject to twice daily tidal flooding. The location and distribution of algal flats and salt marshes indicates that they should not be affected by the tidal power plant. Since the tidal flow rates are preserved by the tidal power and the cross section over which the turbines discharge water spans a considerable width of the channel, it is projected that flow patterns will be disrupted only near the plant. 2-D modeling will informs as to the accuracy of this projection.

Eel grass flats, Fe, are fine-grained and coarse-grained, shallow subtidal (low intertidal) flats which support dense stands of eel-grass, Zostera marina. Eel grass plays many important roles. Eel grass has rhizome/root mats which stabilize soils and prevent erosion. Eel grass supports an array of species including crustaceans, worms, mollusks, and fishes. They are habitat for commercially valuable scallops. By supporting oxygen producing micro and macroalgae on its blades, eelgrass indirectly contributes to the oxygen content. Eel grass slows down currents, causing particulates to precipitate. These are then held in place by the root mat which aids in preventing resuspention of fine material. The removal of particulates reduces turbidity. (Cornell University www.seagrassli.org/ecology/why_is_eelgrass_important.html). Although eel grass can exist in moderately high energy environments, moderate currents provide optimum growth conditions. As wave and tidal currents increased in energy, coarse sediments accumulate leading to reduction in eel grass. (Larkum, A.W.D., Orth, R.J., Duarte. C.M. (Editors), 2006. Seagrasses: Biology, Ecology and Conservation. Springer). There are eel grass beds in the neighborhood of the tidal power plant. It is not clear if the presence of the tidal power plant would increase, decrease, or leave unchanged the eel grass beds. Figure 24 shows eel grass in Pennamaquan River in context of Cobscook Bay.

Salt-marsh grass, Spartina is listed as rare in Maine (State Rarity Rank S3), but globally secure (Global Rarity Rank G5)
www.maine.gov/doc/nrimc/mnap/focusarea/cobscook_bay_focus_area.pdf

Rockweed, *Ascophyllum nodosum* (F3 Algal flats , figure 21) is harvested in Pennamaquan River. There has been controversy over its removal (see for example www.maine.gov/doc/nrimc/mnap/focusarea/cobscook_bay_focus_area.pdf) However Maine DMR does not appear to concur on the negative effects of the harvest. Rockweed harvest carried out under the Cobscook Bay Rockweed Management Area and is managed by Maine DMR. www.maine.gov/dmr/rm/rockweed/symposium2010/fegley.pdf

Rockweed harvesting is significant in Washington County where unemployment is high. Rockweed is hand harvested using small boats. About 10 % of total rockweed proposed for harvesting in Cobscook Bay was from Pennamaquan River (435 tons out of a total of 4267 tons www.maine.gov/dmr/rm/rockweed/cobsbay/index.htm) .

Other aquatic plants are green algae (Cladophora, Enteromorpha, Rhizoclonium, Spongomorpha and Ulva), brown (Ascophyllum, Fucus, Pylaeilla and Scytosiphon) and red algae (Devalerea, Demontia, Palmeria, Polysiphonia, Porphyra). The species grow in differing abundance in low intertidal and mi-intertidal zones. Figure 24 shows their distribution.

There may in addition be kelp beds although these tend to be in high energy wave and current. For example, high kelp densities are given at Garnet Point, Mahar Point, and Bar island ((Vadas, et al Growth and Productivity of Sublittoral Fringe Kelps in Cobscook Bay, Maine, 2004, Northeastern Naturalist, 11, Special Issue 2: 143-160)

§ 5.6 (d)(3)(iv)(C) Temporal and spatial distribution of fish and aquatic communities and any associated trends with respect to:

(1) Species and life stage composition
(2) Age and growth data;
(3) Standing crop
(4) Spawning run timing; and
(5) The extent and location and location of spawning, rearing, feeding, and wintering habitat.

<u>List of symbols</u>

Salinity Zone: T = Tidal Fresh , M = Mixing , S = Seawater
Life Stage: A = Adults, S = Spawning Adults, J = Juveniles, L = Larvae, E = Eggs, M = Mating, P = Parturition
Temporal Distribution – J through D = January through December
Abundance, h = highly abundant, a = abundant, c = common, r = rare, blank = not present, na = no data available

Table 6

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Blue Mussel	A		a	h		h	h	h	h	h	h	h	h	h	h	h	h
	S		a	h					c	h	h	h	h	h	h	h	
Mytilis Edulis	J		a	h		a	a	a	a	a	a	a	a	a	a	a	a
	L		a	h					c	a	a	a	a	a	a	a	r
	E		a	h					c	a	a	a	a	a	a	a	

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D

Sea Scallop	A		r	h	a	a	a	a	a	a	a	a	a	a	a	a	a
	S			h							a	a	a	a	a		
Placopecten magellanicus	J		r	h	a	a	a	a	a	a	a	a	a	a	a	a	a
	L		r	h							a	a	a	a	a	c	r
	E		r	h							a	a	a	a	a		

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
American Oyster	A		r	r		r	r	r	r	r	r	r	r	r	r	r	r
	S			na								na					
Crassotrea virginica	J		r	r		r	r	r	r	r	r	r	r	r	r	r	r
	L		r	na								na					
	E		r	na								na					

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Northern quahog	A			c		c	c	c	c	c	c	c	c	c	c	c	c
	S			na													
Mercenaria mercinaria	J			c		c	c	c	c	c	c	c	c	c	c	c	c
	L			na													
	E			na													

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Softshell Clam	A		h	a		h	h	h	h	h	h	h	h	h	h	h	h
	S		h	a						a	h	h	h	a			
Mya arenaria	J		h	a		h	h	h	h	h	h	h	h	h	h	h	
	L		h	a						a	h	h	h	a			
	E		h	a						a	h	h	h	a			

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Northern shrimp	A			a		c	a	a	r								

Pandalus borealis	S			a		c	a	a	r								
	J			c		r	r	r	c	c	r	r	r	r	r	r	r
	L			a		r	a	a	r	r	r	r	r	r	r	r	r
	E			a		c	a	a	r								

Species		Spatial Distribution				Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Sevenspine bay shrimp	A		h	h		h	h	h	h	h	h	h	h	h	h	h	h
	S		h	h		a	a	h	c	c	c	c	c	r	r	r	r
	J		h	h		h	h	h	h	h	h	h	h	h	h	h	h
Crangon septemspinosa	L		h	h		a	a	h	h	c	c	c	c	c	r	r	r
	E		h	h		a	a	h	h	c	c	c	c	r	r	r	r

Species		Spatial Distribution				Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
American Lobster	A		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S			c							r	c	c	c	c	r	
Homarus americanus	J		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	L		na	c							r	c	c	c	c		
	E			c		c	c	c	c	c	c	c	c	c	c	c	c

Species		Spatial Distribution				Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Jonah Crab	A		na	r		r	r	r	r	r	r	r	r	r	r	r	r
	S			na								na					
Cancer borealis	J		na	r		r	r	r	r	r	r	r	r	r	r	r	r
	L			na								na					
	E			na								na					

Species		Spatial Distribution				Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic Rock Crab	A		c	c		c	c	c	c	c	c	c	c	c	c	c	c

Cancer irroratus	S		c	c										c	c	c	c
	J		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	L		c	c							c	c	c	c	c	c	c
	E		c	c		c	c	c	c	c	c	c	c	c	c	c	c

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Green Crab	A		a	a		c	c	c	c	h	h	h	h	h	h	h	c
	S		c	c							c	c	c	c	c		
Carcinus maenas	J		a	a		c	c	c	c	h	h	h	h	h	h	h	c
	L		c	c						c	c	c	c	c	r	r	
	E		c	c						c	c	c	c				

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Green Sea Urchin	A		r	h		h	h	h	h	h	h	h	h	h	h	h	h
	S			h		c	h	h	c								
Strongylocentrotus droebachiensis	J		r	h		h	h	h	h	h	h	h	h	h	h	h	h
	L			h			c	h	h	h	r						
	E			h	c	h	h	c	c								

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Spiny dogfish	A		c	a							c	c	c	h	h		
	M			na								na					
Squalus acanthius	J		c	a							c	c	c	h	h		
	L																
	E			na								na					

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Skates	A			a		c	c	c	c	c	c	c	c	c	c	c	c

Raja species	S		r	na		c	c	c	c	c	c	c	c	c	c	c	c
	J		c	a		c	c	c	c	c	c	c	c	c	c	c	c
	P			na		c	c	c	c	c	c	c	c	c	c	c	c

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic sturgeon	A	na	r	r					r	r	r	r	r	r	r	r	
	S	na											na				
Acipenser oxyrhynchus	J	na	r	r					r	r	r	r	r	r	r	r	
	L	na											na				
	E	na											na				

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
American eel	A	na	r	r									r	c	c	r	
	S	na															
Anguilla rostrata	J	na	r	r		c	c	c	c	h	h	c	c	c	c	c	c
	L	na					r	c	h	h	c						
	E	na															

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Blueback herring	A	c	c	a		a	r	r	c	c	c	c	c	c	c	a	a
	S	r								r	r	r					
Alosa aestivalis	J	c	a	a		a	r	r	r	r	r	c	c	c	c	a	a
	L	r								r	r						
	E	r								r	r						

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D

Alewife	A	a	a	a		a	r	r	c	a	a	c	c	c	r	a	a
	S	r								r	r						
Alosa pseudoharengus	J	a	a	a		a	r	r	r	r	r	c	a	a	c	a	a
	L	r								r	r						
	E	r								r	r						

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
American shad	A	r	r	a					r	r	r	r	a	a			
	S																
Alosa sapidissima	J	r	r	r						r	r	r	r	r			
	L																
	E																

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic menhaden	A		c	c					r	c	c	c	c	c	r	r	
	S																
Brevoortia tyranus	J		r	r					r	r	r	r	r	r	r	r	
	L																
	E																

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic herring	A		a	h		a	a	a	a	h	h	h	h	h	h	a	a
	S																
Clupea harengus	J		a	h		a	a	a	a	h	h	h	h	h	h	a	a
	L		c	a		c	c	c	c	c			r	c	a	a	a
	E																

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D

Rainbow smelt	A	a	a	a		a	a	a	c	a	c	c	c	c	c	c	a
	S	c					r	c	r								
Osmerus mordax	J	c	a	a		c	c	c	c	c	a	a	a	c	c	c	c
	L	a	c						r	a	a	c	r				
	E	c															

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic salmon	A	c	c	c					r	c	c	c	c	c	c	r	
	S																
Salmo salar	J	c	c	c		r	r	r	c	c	c	r	r	r	r	r	r
	L																
	E																

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic cod	A		r	c		r	r	r	c	c	c	c	c	c	c	r	r
	S																
Gadus morhua	J		r	c		r	r	r	c	c	c	c	c	c	c	r	r
	L			c					c	c	c						
	E																

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Haddock	A			r		r	r	r	r	r	r	r	r	r	r	r	r
	S																
Melanogrammus aeglefinus	J			r		r	r	r	r	r	r	r	r	r	r	r	r
	L																
	E																

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Silver hake	A			r				r	c	a	a	a	a	a	a	r	r

Melanogrammus aeglefinus	S								r	r	r	r	r	r			
	J			r				r	c	a	a	a	a	a	a	r	r
	L								r	r	r	r	r	r			
	E								r	r	r	r	r	r			

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic tomcod	A		c	a		a	a	c	a	a	a	a	a	a	a	a	a
	S			r		a	c	c	r								r
Meluccius bilinearis	J		c	a		a	a	c	a	a	a	a	a	a	a	a	a
	L			r		r	a	a	a	c	r						
	E			r		a	c	c	r								

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Pollock	A			c		r	r	r	r	r	r	r	r	c	c	r	r
	S																
Pollachius virens	J		c	a		c	c	c	c	a	a	a	a	a	a	a	c
	L			c				c	c								
	E																

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Red hake	A		c	c							c	c	c	c	r		
	S																
Urophycis chuss	J		c	c							c	c	c	c	r		
	L																
	E																

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
White hake	A		a	a		r	r				c	a	a	a	a	c	r

Urophycis tenuis	S			na													
	J		a	a		r	r				c	a	a	a	a	c	r
	L			na													
	E			na													

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Mummichog	A	a	a	c		a	a	a	a	a	a	a	a	a	a	a	a
	S	a	a	c							c	a	a				
Fundulus heteroclitus	J	a	a	c		a	a	a	a	a	a	a	a	a	a	a	a
	L	a	a	c							c	a	a	c			
	E	a	a	c							c	a	a				

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Silversides	A		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S		c	c						c	c	c	c				
Menidia species	J		c	c		r	r	r		c	c	c	c	c	c	r	r
	L		c	c						c	c	c	c				
	E		c	c						c	c	c	c				

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Fourspine stickleback	A	r	c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S	r	c							c	c	c	c				
	J	r	c	c		c	c	c	c	c	c	c	c	c	c	c	c
Appeltes quadracus	L	r	c							c	c	c	c	r			
	E	r	c							c	c	c	c				

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D

Threespine stickleback	A	c	c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S	c	c							c	c	c	c				
	J	c	c	c		c	c	c	c	c	c	c	c	c	c	c	c
Gasterusteous aculeatus	L	c	c							c	c	c	c	r			
	E	c	c							c	c	c	c				

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Ninespine stickleback	A	c	c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S	c	c							c	c	c	c				
	J	c	c	c		c	c	c	c	c	c	c	c	c	c	c	c
Pungitius pungilitus	L	c	c							c	c	c	c	r			
	E	c	c							c	c	c	c				

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Northern pipefish	A		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S		c	c					r	c	c	c	c				
Syngnathus fuscus	J		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	L		c	c						r	c	c	c	c	r		

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Grubby	A		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S		c	c		c	c	c	c	r							
Myoxocephalus aeneaus	J		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	L		c	c			c	c	c	c	r						
	E		c	c		c	c	c	c	r							

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Longhorn sculpin	A		r	a		h	h	h	h	h	h	h	h	h	h	h	h

Myoxocephalus octodecemspinosus	S		r	a		f	c										
	J		r	a		h	h	h	h	h	h	h	h	h	h	h	h
	L		r	a		h	h	h	a	c	r						
	E		r	a		h	h	c	r								

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Shorthorn sculpin *Myoxocephalus scorpius*	A		r	c		c	c	c	c	c	c	c	c	c	c	c	c
	S		r	c		c	r									r	c
	J		r	c		c	c	c	c	c	c	c	c	c	c	c	c
	L		r	c		c	c	c	c	c	r						r
	E		r	c		c	c	c	c	r						r	c

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
White perch *Morone americana*	A	c	c	a		c	c	c	c	c	c	c	c	c	c	c	c
	S	c	r	a					r	c	c	r					
	J	c	c	a		c	c	c	c	c	c	c	c	c	c	c	c
	L	c	r	a					r	c	c	c	r				
	E	c	r	a					r	c	c	r					

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Striped bass *Morone saxatilis*	A	r	r	r						r	r	r	r	r	r		
	S																
	J	r	r	r													
	L									r	r	r	r	r	r		
	E																

Species		Spatial Distribution			Temporal Distribution											
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Bluefish	A		r	r							r	r	r	r	r		
	S																

Pomatomus saltatrix	J		r	r							r	r	r	r	r		
	L																
	E																

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Cunner	A		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S			c							c	c	c				
Tautogolabrus adspersus	J		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	L		r	a							c	a	a	R			
	E		r	a							c	a	a				

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Ocean pout	A		r	a		a	a	a	a	a	a	a	a	a	a	a	a
	S			a										a	a	r	
Macrozoarces americanus	J		r	a		a	a	a	a	a	a	a	a	a	a	a	a
	L			a		a	a	a	c	r						c	a
	E			a		a	r							a	a	a	a

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Rock gunnel	A		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	S		c	c		c	c	c	c								
Pholis gunnelus	J		c	c		c	c	c	c	c	c	c	c	c	c	c	c
	L		c	h		c	c	h	h	c							
	E		c	a		c	a	a	a	r							

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic sand lance	A		r	c		c	c	c	c	c	c	c	c	c	c	c	c

Ammodytes americanus	S			c		c	c	c	c								
	J		r	c		c	c	c	c	c	c	c	c	c	c	c	c
	L		r	a		r	a	a	a	c							
	E			c		c	c	c	c								

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Atlantic mackerel	A		c	c							c	c	c	c	r		
	S																
Scomber scombrus	J		c	c							c	c	c	c	r		
	L			na													
	E			na													

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Butterfish	A		r	r							r	r	r	r			
	S																
Peprilus tricanthus	J		r	r							r	r	r	r			
	L		na	na													
	E		na	na													

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Windowpane	A	c	c			c	c	c	c	c	c	c	c	c	c	c	c
	S	c	c								c	c					
Scopthalmus aquosus	J	c	c			c	c	c	c	c	c	c	c	c	c	c	c
	L	c	c								c	c	c	c	r		
	E	c	c								c	c	c	r			

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
American plaice	A			c		r	r	c	c	c	c	c	c	c	c	c	r
	S			c				c	c	c	r						
Hippoglossoides platesoides	J		c	c		r	r	c	c	c	c	c	c	c	c	c	r
	L			c				r	c	c	c	r					
	E			c				c	c	c	r						

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Winter flounder	A		a	a		c	c	h	h	h	h	h	h	h	h	h	c
	S		a	a				c	a	h	r						
Pleuronectes americanus	J		a	a		h	h	h	h	h	h	h	h	h	h	h	h
	L		a	a				r	a	h	r						
	E		a	a			c	a	h	C							

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Yellowtail flounder	A			r		r	r	r	r	r	r	r	r	r	r	r	r
	S			r					r	r	r	r	r				
Pleuronectes ferrugenius	J			r		r	r	r	r	r	r	r	r	r	r	r	r
	L			r					r	r	r	r	r				
	E			r					r	r	r	r	r				

Species		Spatial Distribution			Temporal Distribution												
	Life Stage	T	M	S		J	F	M	A	M	J	J	A	S	O	N	D
Smooth flounder	A	r	c	r		c	c	c	c	c	c	c	c	c	c	c	c
	S	r	c	r		c	c	c									c
Pleuronectes americanus	J	r	c	r		c	c	c	a	a	a	a	a	a	a	c	c
	L	r	c	r		c	c	c	c	r							
	E	r	c	r		c	c	c									c

<u>Maine Department of Inland Fisheries and Wild: Species of Interest</u>

Maine Department of Inland Fisheries and Wildlife has identified the following as fisheries concerns that use Pennamaquan River and Estuary (Communication with Gregory Burr, Regional Fisheries Biologist, MIF&W):

Wild Brook Trout (*Salvelinus fontinalist)*

The Wild Brook Trout, also known as the Eastern Brook Trout is a native species. Adult size "varies greatly, depending on water temperature, productivity, and food sources. The statewide average length of 3 year-old brook trout in Maine lakes is 13.3 inches. However, same age trout from different lakes range from 7.5 to 17.5 inches in length. Stream populations are typically slower growing than lake populations. Some high elevation trout populations mature and reproduce at lengths smaller than 6 inches." Typical length is 6 in to 14 in. http://www.maine.gov/ifw/fishing/species/identification/brooktrout.htm

Although we know little about their estuary habits, we do know that they are produced in many of the tributaries to Pennamaquan River and Estuary. These wild brook trout migrate from the estuary and ocean back into the tributaries in the spring and early summer and possibly in the fall to feed and spawn. (electronic communication - Gregory Burr, Regional Fisheries Biologist, Grand Lakes Region, Maine Dept. of Inland Fisheries & Wildlife). MDIFW has a brook trout management plan. http://www.maine.gov/ifw/fishing/species/management_plans/brooktrout.pdf

Brown Trout (*Salmo Trutta*)

Brown trout are introduced annually into Pennamaquan and Round Lakes by MDIFW. They move down the river on high water events in the spring and fall and feed in the estuary and move back up into the river in the spring and possibly in the fall. (electronic communication - Gregory Burr, Regional Fisheries Biologist, Grand Lakes Region, Maine Dept. of Inland Fisheries & Wildlife).

"Growth is dependent on the available food source. In Maine, age 1 wild browns are approximately 4-6 inches long, and 6-8 inches at age 2. Brown trout can grow to large sizes; the largest on record in Maine was caught in 1997 at Square Pond in Acton and weighed over 23 pounds. Growth to 4 pounds is not uncommon on many lakes and ponds. Brown trout have the ability to survive to an old age, but in Maine lakes browns typically don't survive beyond 6-8 years of age." Typical length if 13in to 20 in. http://www.maine.gov/ifw/fishing/species/management_plans/browntrout.pdf

Brown trout are generally found in freshwater systems, but can adapt to the marine environment and become sea-run. A few waters in Maine are currently being managed for sea-run brown trout.

Brown trout are stocked by MDIWF.

Brook Trout Brown Trout Study A study will be required to determine the number and movement of wild brook and brown trout. The presence of two fishways along the Pennamaquan makes it possible to carry out detailed studies. There are two dams on the river, each equipped with a denil fish passage. Except during high water events, the water flows through the fishway. The fish way have small containment ponds which can be closed off. These were placed for the river herring fishery. The study would carry out a count of brook/brown trout passing through the fishways. The distribution of length would be determined. Fish would be radio tagged and their subsequent movement monitored. The study would determine if the fish pass through the proposed alignment of the tidal power plant. If they do not, then no mitigation would be required. If they do, then projected mortality rate based on the determined length of the fish

would inform the project of the need and extent of mitigation.

The fishways also offer the possibility of capture and direct transport of fish across the alignment of the plant if needed.

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As we discussed I have several fisheries concerns. First, we have anadromous brook trout that use the Pennamaquan River Estuary. Although we know little about their estuary habits, we do know that they are produced in many of the tributaries to Pennamaquan River and Estuary. These wild brook trout migrate from the estuary and ocean back into the tributaries in the spring and early summer and possibly in the fall to feed and spawn. Second, we also have stocked brown trout that are introduced annually into Pennamaquan and Round Lakes that move down the river on high water events in the spring and fall and feed in the estuary and move back up into the river in the spring and possibly in the fall. There are also important anadromous rainbow smelt migrations that occur in the tributaries to the Pennamaquan River and its estuary that you should be made aware of. The studies that we will likely suggest for the PAD will involve identifying population estimates of wild brook trout and movements within the estuary of wild brook trout and stocked brown trout.

Cobscook Bay Marine Invertebrate Checklist

A more complete list of invertebrates is found in Thomas, J. Trott, Cobscook Bay Inventory: *A Historical Checklist of Marine Invertebrates Spanning 162 years*, Northeastern naturalist, Volume II Special issue 2:2, 2004 (pp. 261- 324). Prior to 1900 dredging was the primary source of sampling. It was found however that most species that occurred subtidally were also found intertidally. The list below is almost entirely based on collection made intertidally (Trott 2004).

PHYLUM PORIFERA

Class Calcaerea
Order Clathrinidae
Family Clathrinidae
Cathrina coriacea
Order Leucosolenia
Family Leucosolenida
Leucosoleanis botryoides
Family Sycettidae
Sycon ciliatum

Class Demospongiae
Order Halisarcida
Family Halisarcidae
Halisarca dujardini
Order Poecilosclerida
Family Acarnidae
Iophon nigricans
Family Microcinonidae
Microciona prolifera
Family Myxillidae
Myxilla fimbriata
Myxilla incrustans
Family Tedaniidae
Tedania suctoria

Family Mycalidae
Mycale lingua
Mycale ovulum
Family Isodictyidae
Isodictya deichmannae
Isodictya palmate
Order Halichondria
Family Halichrondriidae
Halichrondiria bowerbanki
Halichondria panicea
Halichondria sitiens
Hymeniacidon heliophila
Order Haploscelerida
Family Chalinidea
Haliclona canaliculata
Haliclona oculata
Order Hadromerida
Family Chalinidae
Cliona celata
Pionevastificia
Family Plymastiidae
Polymastia robusta
Family Suberitidae
Subrertites ficus

PHYLUM CNIDARIA

Class Schyphozoa
Order Stauromedusae
Suborder Elutherocarpida
Family Eleutherocarpida
Haliclystus auricular
Haliclystus salpinx
Halmocyathus lagena
Lucernaria quadricornis
Suborder Cleistocarpida
Family Dpastridae
Craterolophus convolvulus
Order Semaeostomeae
Family Cyaneida
Cyanea capillata
Family Ulmaridae
Aurelia auriata
Phacellophora camtscheatica

Class Hydrozoa
Order Anthoathecatae – athecate hydroids
Family Clavidae
Clava multicornis
Family Hydractiniidae
Hydractinia Americana
Hydractinia echniata
Family Bouainvilliidae
Bougainvillia supercilliaris
Family Pandeidae
Leukartiara octona
Family Eudendriidae
Eudenrium capillare
Eudendrium cochleatum
Eudendrium dispar
Eudendrium ramosum
Family Zancleidae
Zanclea costata
Family Acaulidae
Acaulis primaries
Candelabrum phrygium
Family Corymorphidae
Corymorpha nutans
Corymorpha pendula
Family Tubulariidae
Ectopleura crocea
Ectopleura larynx
Tubularia indivisa
Family Corynidae
Sarsia tubulosa
Order Anthoathecatae-hydromedusea
Family Hydractiniidae
Hydractinia Americana
Hydractinia borealis
Family Bougainvilliidae
Bougainillia superciliaris
Family Pandeidae
Catablema veiscarium
Leuckartiara octona
Family Zancleidae
Zanclea costata
Family Corynidae
Sarsia tubulosa
Order Limnomedusae
Family Olindiidae
Gonionemus vertens
Order Leptothecatae-Thecate hydroids
Family Melicertidae

Melicertum octocostatum
Family Calycellidae
Calycella syringa
Family Haleciidae
Halecium articulosum
Halecium beanie
Halecium halecinum
Halecium muricatum
Halecium sessile
Family Plumulariidae
Nemertesia American
Plumularis gracillima
Family Aglaopheniidae
Lytocarpia myriophyllum
Family Lafoeidae
Lafoea dumosa
Family Campanulariidae
Campanularia groelandica
Campanularis volubilis
Clytia hemisphaerica
Laomedea flexuiosa
Obelia dichotoma
Obelia geniculata
Obelia longissima
Orthopysxis integra
Rhizocaulus verticillatus
Family Sertulariidae
Abiertinaria ablietina
Diphasisa fallax
Diphasia pinastrum
Dynmena pumila
Hydrallmania falcate
Sertularia argentea
Sertularia cupressina
Sterularia latiusculua
Sertularella polyzonias
Sertularella regosa
Sertularia similis
Sympletoscyphys Tricuspidatus
Tamarisca tamarisca
Thuiaria articulate
Order Leptothecatae-hydromedusae
Family Melicertidae
Melicertum octocostatum
Family Aequoreidae
Aequorea albida
Rhacostoma atlanticum
Family Laodiceidae
Staurophora mertensi
Family Tiaropsidae
Tiaropsis multicirrata
Order Trachumedusae
Family Rhopalonematidae
Aglantha digiltalis
Subclass Siphonophorae
Order Cystonectae
Family Physaliidae
Physalia physalis
Order Physonectae
Family Agalmatidea
Agalma elegans
Nanomia cara
Class Anthozoa
Sublass Ceriantipatharia
Order Ceriantharia
Family Cerianthidae
Cerianthus borealis
Subclass Alcyonaria
Order Alcyonacea
Suborder Alcyoniina
Family Alcyoniidae
Drifa glomerata
Gersemia rubiformis
Subclass Zoantharia (=Hexacorallia)
Order Actiniaria
Family Actiniidae
Aulactinia stella
Bolocera tuedia
Urticiana feline
Family Actinostolidae
Actinostola callosa
Stomphia carneola
Stomphia coccinea
Family Diadumenidae
Diadumene lineate Edwardsia elegans
Family Edwardsiidae
Edwardsia sipunculoides
Family Halcampidae
Halcampa duodecimcrirrata
Family Haloclavidae
Iyanthus laevis
Preachia parasitica

Family Metridiidae	Metridium senile

Invasive Species

The Northern Moon Snail, *Euspira heros*, is a large predatory sea snail in the family Naticidae. This large snail occurs subtidally but is sometimes found intertidally. The moon snail feeds voraciously on clams and other snails. The moon snail has had a devastating effect on clam flats. An AP report reports "that he clam harvest in bay-area towns has fallen about 85 percent in the past five years." (By Clarke Canfield, Associated Press Writer / June 23, 2010). William Wilson, an area fisherman, noted that during neap tides, algae growth accelerates, growing into a thick mat. Mr. Wilson notes that clams emerge during period of dense algal growth. He surmises that the algal growth begins to suffocate the clams, causing them to come up. When they come up through the mud, they become vulnerable to moon snails predation (private communication). The presence of a tidal power plant operated on the Alstom-Halcyon operating could have a protective value. Pumping during neap tide could control algal growth to a desired level. The Pennamaquan Tidal Power Plant is partly intended to be a research facility. The operation of the plant to protect clams would be conducted in collaboration with agency biologists.

§ 5.6 (d)(3)(v) *Wildlife and botanical resources.* A description of the wildlife and botanical resources including invasive species in the project vicinity. Components of the description must include: (A) Upland habitat(s) in the project vicinity including the project's transmission line corridor or right-of-way and a listing of plant and animal species that use the habitat(s); (B) Temporal and spatial distribution of species considered important because of their commercial, recreational or cultural value.

The Pennamaquan tidal power project will not establish a new reservoir. Rather, it will employ the existing one, Pennamaquan River. The operating cycle will preserve the natural boundaries governed by the tides. The project is therefore not expected to have any impact on upland habitat. In particular it is not expected to have impact on wildlife resources other than possibly birds. A discussion on botanical resources within the intertidal zone were listed and discussed in the previous sections. Since no reservoir is proposed, no impact on upland botanical resources is anticipated.

Figure 25 shows considerable forested area. A preliminary examination shows this to be mainly spruce and fir.

A series of maps prepared by the state of Maine provided by the Department of Conservation of the State of Maine give a description of upland habitats for the various incorporated towns. The maps are too large to provide in this document. The links are to the maps for the municipality of Pembroke which includes the entire Pennamaquan. The full set of maps is available on www.beginningwithhabitat.org/the_maps/status-p.html .

Map 1 Water Resources and Riparian Habitats, shows the town lines of Pembroke enclosing

Pennamaquan River. (http://beginningwithhabitat.org/the_maps/pdfs/Pembroke/Map1.pdf). Developed Land, indicated in black does not full show the extent of development. This is more clearly seen on the aerial view in figure 26. Town of Pembroke Property Map indicates that virtually all land abutting Pennamaquan River is privately owned. No resource protection areas are indicated.

Map 2 (http://beginningwithhabitat.org/the_maps/pdfs/Pembroke/Map2.pdf) High Value Plants & Animal Habitats, labeled as pertaining to the Town of Perry, nevertheless includes Pennamaquan River in its entirety. (1) No Rare or Exemplary Plants and natural Communities are indicated. No "known rare, threatened or endangered species and/or the associated habitats based on species sightings" are indicated (yellow lines). No "Rare Plant Locations" or "Rare or Exemplary Natural Community Locations" are indicated (blue lines). (2) Map 2 shows the presence of Essential Wildlife Habitat: Several eagle nesting sites are shown (violet circles). One nesting site is shown at Hersey Cove near the Project sites. No part of project however actually falls within the designated exclusion area. (3) Map 2 indicates the presence of Significant Wildlife Habitats. No Deer Wintering Areas are indicated. Several Inland Waterfowl/Wading Bird habitats are indicated (vertical violet line). None are in the vicinity of the project. No Seabird Nesting Islands are indicated (heavy crossed violet lines). No Shorebird Areas are indicated (left slanting violet lines).

(4) Map 2 shows the presence of Tidal Waterfowl/Wading Birds over a considerable area of the basin. These would be within the project boundary as shown in figure 3. Maine's Natural Resources Protection Act (NRPA, 1988) is intended to prevent further degradation and loss of natural resources including Significant Wildlife Habitat. The degradation of intertidal zones has been a major negative impact of all tidal power when operated on conventional cycles. It can be shown that two way tidal range power (without pumping) and hydrokinetic tidal power both have a maximum capacity factor of 34%. Both result in the permanent exposure of intertidal zones that are flooded at high tide and permanent submerging of intertidal zones that are exposed at low tide. An aim of this project is to demonstrate that tidal range power can be developed in an environmentally responsible way. To that end Alstom Power and Halcyon Marine Hydroelectric conducted an extensive research program to demonstrate that pumping can be used to avoid the loss of intertidal zones. The proposed project uses pumping to raise the water levels to their natural high tidal levels. Pumping is also used to lower water levels to their natural tidal lows. The cycle parallels the natural tidal cycle. In so doing, it preserves the intertidal zones. Therefore, while there are extensive intertidal zones within the project boundary, these will be exposed and submerged to their natural levels. In addition, the rate of discharge through the turbines is very nearly equal to the natural rate of flow in and out of the basin as indicated by the slopes of the basin and sea level lines in figure 10.1a-c. The waiting phase F-G and K-L in figure 10.1 a-c represent the largest deviation from the natural tidal cycle. These can be made to more closely follow the shape of the natural cycle by starting turbines sequentially starting at F until all 16 are in operation. The result would be to "round" the lines F-G and K-L. The Pennamaquan Tidal Power Plant is envisioned in part as a research facility. The consequences of various modes of operation would be investigated in collaboration with State and Federal Agencies and academic institutions. Further, small turbines (3.2 m) diameter turbines are proposed. Part of the motivation is that the turbine row will extend over a significant part of the part of the channel. The result is that the discharge from the turbines will extend across much of

the channel, closely following natural flow. This is intended to preserve the natural flow pattern as closely as possible. Preservation of the intertidal zones and the natural flow pattern should protect waterfowl and wading bird habitat. The 2-D modeling study which we intend to perform should corroborate these claims. We therefore expect that the mitigations described above will therefore be protective of waterfowl and wading birds that depend on the ebb and flood of the tides.

Map 2 indicates no Atlantic Salmon Rearing Habitat, Spawning Habitat, or Limited Spawning Habitat. Map 2 shows High Value Habitat for Priority Trust Species. Two small areas in Hersey cove and two islands designated as High Value Habitat lie within the project boundary. The preservation of tidal range and flow pattern should provide considerable protection to these areas. There significant areas of High Value Habitat for Priority Trust Species outside the boundaries of the project. We are unaware of any mechanism by which the project would affect these areas.

Environmental Review of Site

The transmission corridor is maintained by Bangor Hydro and runs along the Garnet Point Road on Hersey Neck. The road and the immediate area around it are shown in black on map 2 (see Figure 3) classifying it as developed area. Although showing boundaries of the town of Parsonfield, Map 3 is listed under Pembroke on Maine's Beginning with Habitat's Map website (http://www.beginningwithhabitat.org/the_maps/status-p.html). Map 3 identifies Undeveloped Habitat Blocks. Map 3 suggests that that there are no significant Undeveloped Habitat Blocks within the boundaries of Pembroke, the closest such Blocks being in Parsonfield. This confirms our impression in our inspection of the area. With the exception of conserved areas, Hersey and Leighton Necks appeared to us to be developed.

Map 8 shows USFWS Priority Trust Species Habitat. It identified four categories of habitats: (1) Saltmarsh /saltwater (shown in violet), (2) Freshwater wetlands (blue), (3) Grassland/shrub/bare ground (yellow to brown), and (4) Forested habitat (green). Each of these Habitats as falls into one of three levels of importance: 1-49 %, 50-74 %, and Top 25 % (most important). Map 8 lists the 91 USFSS Gulf of Maine Priority Trust species, including animals and plants that regularly occur in the Gulf of Maine watershed. These species are either (A) Federally endangered, threatened, or candidate species, or (B) Migratory birds, sea-run fish and marine that (i) show significant and persistent declining population trends OR have been identified as endangered or threatened by 2 or 3 states in the Gulf of Maine watershed or (ii) Species of concern as identified in the US Shorebird Conservation Plan, Colonial Waterbird Plan or Partners in Flight.

Species are further identified with an *, indicating high value habitat within the boundaries of Pembroke with the potential to support that species. The * does not signify the presence of a species but rather that the habitat is *potentially* significant to that species.

Table (Map 8) Birds species marked

Bird Species marked with * indicating local high value habitat with the potential to support that species

American bitter	Field sparrow	Prairie warbler
American black duck	Grasshopper sparrow	Red crossbill
American woodcock	Killdeer	Red-shouldered hawk
Bald eagle	Little blue heron	Scaup (greater and lesser)
Baltimore Oriole	Louisiana waterthrush	Sedge wren
Bay-breasted warbler	Marsh wren	Short-eared owl
Blackpoll warbler	Northern flicker	Solitary sandpiper
Blue-winged warbler	Northern goshawk	Upland sandpiper
Buff-breasted warbler	Northern harrier	Veery
Buff-breasted sandpiper	Olive-sided flycatcher	Whimbrel
Canada warbler	Osprey	Whip-poor-will
Cape May warbler	Eastern meadowlark	Wood duck
Chestnut-sided warbler	Peregrine falcon	Wood thrush
Common snipe	Field sparrow	Scaup (greater and lesser)
Eastern meadowlark	Pied-billed grebe	

Bird Species not marked with *		
Arctic tern	Purple sandpiper	Short-billed dowitcher
Bicknell's thrush	Razorbill	Snowy egret
Black Scoter	Red-headed woodpecker	Surf scoter
Black tern	Red knot	Tricolored heron
Black-bellied plover	Roseate tern	White-winged scoter
Common loon	Ruddy turnstone	Yellow rail
Common tern	Saltmarsh sharp-tailed sparrow	
Least sandpiper	Sanderling	
Least tern	Seaside sparrow	
Little gull	Semipalmated sandpiper	

Fisheries * indicating local high value habitat with the potential to support that species	
Alewife	American eel

Fisheries not marked *	
American shad	Bluefish
Atlantic salmon	Horseshoe crab
Atlantic sturgeon	Shortnose sturgeon
Blueback herring	Winter flounder

Pennamaquan River (the bay) is significant to both fish and some of the listed birds. It is ranked in the 50-74 % category. It is not ranked 25 % (most important). Maintaining the natural cycle of the tides within Pennamaquan River (the bay) is an important mitigation, providing protection of the habitat for water and shore birds as well as fish

Since no reservoir is required, birds upland of the project boundary should not be affected. Maintaining the integrity of the intertidal zone preserves the mudflats on which shore birds depend.

Two related issues arise for fish. The first is fish mortality rate through the turbine. The second is access both for migrating and resident fish. The net effect needs to be assessed for both resident and migrating fish. A study will inform us on the presence of species. The specifics will then inform us as to appropriate steps. Turbine fish kill from horizontal bulb turbines will depend on the particular species and the size of the fish affected. Considerable access is provided through the spillways designed over the turbines.

In addition to Birds and Fisheries, Map 8 lists Plants and Mammals. Of these species listed, only one, the Small Whorled Pogonia (Isotria medoloides) is marked * indicating that Pembroke is potentially high value habitat for this species. The plant is listed as a threatened species by USFWF having been downlisted from endangered status in 1994.

The other species listed are

Plants	
Eastern prairies fringed orchid	Robbin's cinquefoil
Furbish's lousewort	

Mammal	Canada lynx

Reptile	Plymouth redbelly turtle

Environmental Review of Botanical Resources – Maine Department of Conservation

A request was submitted to the Maine Department of Conservation conduct a Review of Records search for rare and exemplary botanical resources within 10 miles of the proposed Pennamaquan Tidal Power Plant boundary. No rare or endangered species were reported. The Review notes that exemplary saltmarshes are within the project boundaries. Since the boundaries of intertidal zone is preserved by the operating cycle, the saltmarshes should not be affected by the project.

STATE OF MAINE
DEPARTMENT OF CONSERVATION
93 STATE HOUSE STATION
AUGUSTA, MAINE
04333-0093

PAUL R. LEPAGE
GOVERNOR

WILLIAM H. BEARDSLEY
COMMISSIONER

October 31, 2011

Ramez Atiya
Halcyon Marine Hydroelectric
1320 East 700 South
Salt Lake City, UT 84102

Re: Rare and exemplary botanical features in proximity to: Proposed Tidal Power Project, mouth of the Pennamaquan River, Pembroke, Maine

Dear Mr. Atiya:

I have searched the Natural Areas Program's Biological and Conservation Data System files in response to your request of September 29, 2011 for information on the presence of rare or unique botanical features documented from the vicinity of the project site in Pembroke, Maine. Rare and unique botanical features include the habitat of rare, threatened, or endangered plant species and unique or exemplary natural communities. Our review involves examining maps, manual and computerized records, other sources of information such as scientific articles or published references, and the personal knowledge of staff or cooperating experts.

Our official response covers only botanical features. For authoritative information and official response for zoological features you must make a similar request to the Maine Department of Inland Fisheries and Wildlife, 284 State Street, Augusta, Maine 04333.

According to the information currently in our Biological and Conservation Data System files, there are no rare botanical features documented specifically within the project area, but note there is a 10 acre saltmarsh at the northwest end of Hersey Cove. We haven't yet visited this area. Given that your tidal project will not expose significant intertidal zones, this saltmarsh should not be impacted by your project. This lack of data in the project area may indicate minimal survey efforts rather than confirm the absence of rare botanical features. You may want to have the site inventoried by a qualified field biologist to ensure that no undocumented rare features are inadvertently harmed.

If a field survey of the project area is conducted, please refer to the enclosed supplemental information regarding rare and exemplary botanical features documented to occur in the vicinity of the project site. The list may include information on features that have been known to occur historically in the area as well as recently field-verified information. While historic records have not been documented in several years, they may persist in the area if suitable habitat exists. The enclosed list identifies features with potential to occur in the area, and it should be considered if you choose to conduct field surveys.

MAINE NATURAL AREAS PROGRAM
MOLLY DOCHERTY, DIRECTOR

PHONE: (207) 287-8044
FAX: (207) 287-8040
TTY: (207) 287-2213

This finding is available and appropriate for preparation and review of environmental assessments, but it is not a substitute for on-site surveys. Comprehensive field surveys do not exist for all natural areas in Maine, and in the absence of a specific field investigation, the Maine Natural Areas Program cannot provide a definitive statement on the presence or absence of unusual natural features at this site.

The Natural Areas Program is continuously working to achieve a more comprehensive database of exemplary natural features in Maine. We would appreciate the contribution of any information obtained should you decide to do field work. The Natural Areas Program welcomes coordination with individuals or organizations proposing environmental alteration, or conducting environmental assessments. If, however, data provided by the Natural Areas Program are to be published in any form, the Program should be informed at the outset and credited as the source.

The Natural Areas Program has instituted a fee structure of $75.00 an hour to recover the actual cost of processing your request for information. You will receive an invoice for $150.00 for our services.

Thank you for using the Natural Areas Program in the environmental review process. Please do not hesitate to contact me if you have further questions about the Natural Areas Program or about rare or unique botanical features on this site.

Sincerely,

Don Cameron
Ecologist
Maine Natural Areas Program
207-287-8041
don.s.cameron@maine.gov

Rare and Exemplary Botanical Features in the Project Vicinity

Documented within a four-mile radius of the Proposed Pennamaquan Tidal Power Plant, Pembroke, Maine.

Feature Name	Global Rank	State Rank	State Status	EO Number	Last Seen	Habitat
Triglochin gaspensis	G3G4	S2	SC	5	2000-07-13	Tidal wetland (non-forested, wetland)
Triglochin gaspensis	G3G4	S2	SC	6	2006-09-07	Tidal wetland (non-forested, wetland)
Spartina saltmarsh	G5	S3		31	2009	Tidal wetland (non-forested, wetland)
Carex recta	G4	SH	PE	12	1909-07-06	Tidal wetland (non-forested, wetland)

Print Date 9/29/2011 For more information visit our website http://www.maine.gov/doc/nrimc/mnap Page 1

§ 5.6 (d)(3)(vi) *Wetland, riparian, and littoral habitat.* A description of the floodplain, wetlands, riparian habitats, and littoral in the project vicinity. Components of this description must include: (A) a list of plant and animal species, including invasive species, that use the wetland, littoral, and riparian habitat; (B) A map delineating the wetlands, riparian, and littoral habitat; and (C) Estimates of acreage for each type of wetland, riparian, or littoral habitat, including variability in such availability as a function of storage at that project that is not operated in run-of-river mode.

The Maine Department of Inland Fisheries **Map 7** Wetlands Characterization, classifies the intertidal zone as tidal floodplain. Map 7 is the Wetlands Characterization map for the Municipality of Pembroke prepared by MDIFW. Because of its size and the size of the file only the link is provided: http://beginningwithhabitat.org/the_maps/pdfs/Pembroke/Map7.pdf . RUNOFF/FLOODLOW ALTERATION is indicated on the map in small squares. The intertidal zone is so marked with additional coloration Green to indicate Aquatic Beds, (floating or submerged aquatic vegetation) or Open Water. The distribution of the marine vegetation has already been provided.

Table

Water Level	Area of Basin	Exposed Intertidal Area
Mean Lower Low Water	2.2 km^2	1.9 km^2
Mean Water Level (Mid-tide)	2.8 km^2	1.3 km^2
Maximum High Water Level	4.1 km^2	0 km^2

Because the tidal range is maintained, wetlands outside the project boundary will not be affected.

§ 5.6 (d)(3)(vii) *Rare, threatened and endangered species.* A description of any listed rare, threatened and endangered, candidate, or special status species that may present in the project vicinity. Components of this description must include:
(A) A list of Federal- and state-listed or proposed to be listed, threatened, and endangered species know to present in the project vicinity;
(B) Identification of habitat requirements;
(C) References to any known biological opinion, status reports, or recovery plan pertaining to a listed species;
(D) Extent and location of any federally-designated critical habitat, or either habitat for listed species in the project area; and
(E) Temporal and spatial distribution of the listed species within the project vicinity.

The following link provides a list of endangered and threatened species both as listed by the State of Maine and the Federal Government as provided by the Maine Department of Inland Fisheries and Wildlife:
www.maine.gov/ifw/wildlife/species/endangered_species/state_federal_list.htm. Those in the vicinity of the project are specifically identified.

In addition, the bald eagle is given specific protection in the State of Maine.

Maine Endangered Species Program/State and Federal List of Endangered and Threatened Species

The following species are listed as endangered or threatened in Maine:

F = Federally Endangered under the U.S. Endangered Species Act
f = federally threatened under the U.S. Endangered Species Act
S= State Endangered under the Maine Endangered Species Act
s = state threatened under the Maine Endangered Species Act

P = Potentially high value habitat in Pembroke as indicated by * on Map 8 of MDIFW
K = Known to be in Washington County either through direct sighting or because its range is in part falls within Washington County based on MDIFW website www.maine.gov/ifw/wildlife/species/endangered_species/american_piipit/index.htm
N = No report

Table – Endangered

Name	**F**	**f**	**S**	**s**	**P**	**K**
Beetles						
American Burying Beetle (*Nicrophorus americanus*)	**F**					
Birds						
American Pipit (*Anthus rubescens*) (Breeding population only)			**S**	**s**		
Arctic Tern (*Sterna paradisaea*)				**s**		**K**
Atlantic Puffin (*Fratercula arctica*)				**s**	**P**	**K**
Barrow's Goldeneye (*Buchephala islandica*)				**s**		**N**
Black-crowned Night Heron (*Nycticorax nycticorax*)				**s**		**N**
Black Tern (*Chlidonias niger*)			**S**			**K**
Common Moorhen (*Gallinula chloropus*)				**s**		**N**
Eskimo Curlew (*Numenius borealis*)	**F**					**N**
Golden Eagle (*Aquila chrysaetos*)			**S**			
Great Cormorant (*Phalacrocorax carbo*) (Breeding population only)				**s**		**N**
Grass Hopper Sparrow (*Ammodramus savannarum)*			**S**			**N**
Harlequin Duck (*Histrionicus histrionicus*)				**s**		**K**
Least Bittern (*Lxobrychus exilis*)			**S**			**N**
Least Tern (*Sterna antillarum)*			**S**			
Peregrine Falcon (*Falco peregrinus*) (Breeding population only)			**S**			**K**
Piping Plover (*Charadrius melodus*)		**f**	**S**			
Razorbill (*Alca torda*)				**s**	**P**	**K**
Roseate Tern (*Sterna dougallii*)	**F**		**S**			**K**
Sedge Wren (*Cistothorus platensis*)			**S**		**P**	**K**
Short-eared Owl (*Asio flammeus*) (Breeding population only)				**s**		**N**
Upland Sandpiper (*Bartramia longicauda*)				**s**		**K**

Fish						
Atlantic Salmon (*Salmo salar*)	**F**				**P**	**K**
Redfin Pickerel (*Esox americanus americanus*)			**S**		**P**	**N**
Shortnose Sturgeon (*Acipenser brevirostrum*)	**F**					
Swamp Darter (*Etheostoma fusiforme*)				**s**		
Invertebrates						
Butterflies and Skippers						
Clayton's Copper (*Lycaena dorcas claytoni*)			**S**			
Edwards' Hairstreak (*Satyrium edwardsii*)			**S**			
Hessel's Hairstreak (*Callophrys hesseli*)			**S**			
Juniper Hairstreak (*Callophrys gryneus*)			**S**			**?**
Karner Blue (*Lycaeides melissa samuelis*)	**F**					
Katahdin Arctic (*Oeneis polixenes katahdin*)			**S**			
Purple Lesser Fritillary (*Boloria chariclea grandis*)				**s**		**?**
Sleepy Duskywing (*Erynnis brizo*)				**s**		**?**
Dragonflies and Damselflies						
Boreal Snaketail (*Ophiogomphus colubrinus*)				**s**		**?**
Rapids Clubtail (*Gomphus quadricolor*)			**S**			**?**
Ringed Boghaunter (*Williamsonia lintneri*)				**s**		
Freshwater Mussels						
Brook Floater (*Alasmidonta varicosa*)				**s**		**?**
Tidewater Mucket (*Leptodea ochracea*)				**s**		
Yellow Lampmussel (*Lampsilis cariosa*)				**s**		**K**
Mayflies						
Flat-headed Mayfly (Roaring Brook Mayfly) (*Epeorus frisoni*)			**S**			
Tomah Mayfly (*Siphlonisca aerodromia*)				**s**		**K**
Moths						
Pine Barrens Zanclognatha (*Zanclognatha martha*)				**s**		
Twilight Moth (*Lycia rachelae*)				**s**		
Mammals						
Canada Lynx (*Lynx canadensis*)		**f**			**P**	
Eastern Cougar (*Felis concolor couguar*)	**F**					
Finback Whale (*Balaenoptera physalus*)	**F**					**K**
Gray Wolf (*Canis lupus*)	**F**					
Humpback Whale (*Megaptera novaeangliae*)	**F**					**K**
New England Cottontail (*Sylvilagus transitionalis*)			**S**			**?**
Northern Right Whale (*Eubalaena glacialis*)	**F**					
Northern Bog Lemming (*Synaptomys borealis*)				**s**		

Sei Whale (*Balaenoptera borealis*)	**F**					**K**
Sperm Whale (*Physeter catodon*)	**F**					**K**
Reptiles						
Snakes						
Black Racer (*Coluber constrictor*)			**S**			
Turtles						
Atlantic Ridley (*Lepidochelys kempi*)	**F**					**K**
Blanding's Turtle (*Emys blandingii*)			**S**			
Box Turtle (*Terrapene carolina*)			**S**			
Leatherback (*Dermochelys coriacea*)	**F**					**K**
Loggerhead (*Caretta caretta*)		**f**				**K**
Spotted Turtle (*Clemmys guttata*)				**s**		

Maine Department of Inland Fisheries and Wildlife maintains status reports and recovery plans pertaining to the listed species above. References from the MDIFW for species that are known to be in Washington County or are included on Map 8 are listed below together with the website address.

General Website for Birds: www.maine.gov/ifw/wildlife/species/plans/birds/index.htm#razorbill
For convenience both web address and reference are given. All the Following are authoritative reports from the Maine Department of Inland Fisheries and Wildlife, Resources Assessment Section, Bird Group

Atlantic puffin and Razorbill

Atlantic Puffin and Razorbill Management System, Dec. 11, 2007
www.maine.gov/ifw/wildlife/species/pdfs/ATPU-RAZOManagementSystem_FINAL_12-11-2007.pdf

Atlantic Puffin Management Goals and Objectives, 2000-2015, August 28,2001

Wickett, MaryEllen, Feasibility Statement for Atlantic Puffin Goals and Objectives, July 11, 2001,
www.maine.gov/ifw/wildlife/species/plans/birds/atlanticpuffinrazorbill/puffinfeasibility.pdf

Wickett, MaryEllen, Problems and Strategies for Atlantic Puffin Management in Maine, July 11,2011
www.maine.gov/ifw/wildlife/species/plans/birds/atlanticpuffinrazorbill/puffinproblems.pdf
Atlantic Puffin/Razorbill Assessment, 4 November 1999
www.maine.gov/ifw/wildlife/species/plans/birds/atlanticpuffinrazorbill/puffinrazorbillassesment.pdf

Harlequin duck

Harlequin Duck Management Goals and Objectives, 2001-2016, Adopted MDIW, Aug. 28, 2001
www.maine.gov/ifw/wildlife/species/plans/birds/harlequinduck/go.pdf
Wickett, MaryEllen, Feasibility Statement for Harlequin Duck, 2001-2016, July 16, 2001
www.maine.gov/ifw/wildlife/species/plans/birds/harlequinduck/feasibilitystatement.pdf
Wickett, MaryEllen, Problems and Startegies for Herlequin Duck Management in Maine, July 18, 2001
www.maine.gov/ifw/wildlife/species/plans/birds/harlequinduck/problemsandstrategies.pdf
Harlequin Duck Assessment, Final – 29 December 1999
www.maine.gov/ifw/wildlife/species/plans/birds/harlequinduck/speciesassessment.pdf
Tudor, Lindsay, Harlequin Duck Management System, October 19, 2004
www.maine.gov/ifw/wildlife/species/plans/birds/harlequinduck/managementsystem.pdf

Island Nesting Terns
Island-Nesting Management System and Data Base, Revised May 1, 2009
www.maine.gov/ifw/wildlife/species/pdfs/Island-nesting Terns MS 2009-update_FINAL_5-1-2009.pdf
McCollough, Mark & Tudor, Lindsay, Island-Nesting Terns Assessment, Sept. 20, 2006
www.maine.gov/ifw/wildlife/species/plans/birds/islandnestingterns/ternassessment06.pdf
Problems and Strategies for Island-Nesting Terns Management in Maine, Jan. 8, 2007
www.maine.gov/ifw/wildlife/species/plans/birds/islandnestingterns/problems06.pdf
Bradford, Allen, Feasibility Statements for Island-Nesting Terns 2006, Goals and Objectives, Jan. 8, 2007 www.maine.gov/ifw/wildlife/species/plans/birds/islandnestingterns/feasibility06.pdf
Island-Nesting Management Issues and Concerns, Nov. 8, 2006

Peregrine Falcon
Peregrine Falcon Goals and Objectives, Feb. 13, 1992
www.maine.gov/ifw/wildlife/species/plans/birds/islandnestingterns/feasibility06.pdf
Todd, Charles S., Feasibility Statements for Peregrine Falcom Goal and Objectives, June 28, 1993 www.maine.gov/ifw/wildlife/species/plans/birds/peregrinefalcon/feasibilitystatement.pdf
Todd, Charles S., Problems and Strategies for Peregrine Falcon in Maine, June 28, 1993
www.maine.gov/ifw/wildlife/species/plans/birds/peregrinefalcon/problemsandstrategies.pdf
Todd, Charles S., Peregrine Falcon Assessment, Aug. 29, 1985

Sedge Wren
The sedge wren is a small brownish bird. It range extend through most of Main including almost all of Washington County.
www.maine.gov/ifw/wildlife/species/endangered_species/sedge_wren/index.htm
Upland Sandpiper
Weik, Andrew P., & Hodgman, Thomas P., Upland Sandpiper Assessment, Oct. 27, 2006
www.maine.gov/ifw/wildlife/species/plans/birds/uplandsandpiper/speciesssessment_2006.pdf
Hodgman, Thomas P., Problems and Strategies for Uplandland Sandpiper and Grasshopper Sparrow Management in Maine, March 3, 2010.
www.maine.gov/ifw/wildlife/pdfs/UPSAandGRSP_Problems_and_Strategies_2009-

2024_FINAL.pdf
Hodgman, Thomas P., Feasibility Statements for Upland Sandiper and Grasshopper Sparrow Goals and Objectives, Dec. 2009.
www.maine.gov/ifw/wildlife/pdfs/UPSAandGRSP_FeasibilityStatements_2009-2024_FINAL.pdf
Upland Sandpiper and Grasshopper Sparrow Management Goal and Objectives 2009-2024
www.maine.gov/ifw/wildlife/pdfs/UPSAandGRSP_FeasibilityStatements_2009-2024_FINAL.pdf

Bald Eagle

In 2007 the Federal Government removed the Bald Eagle from its list of Endangered and Threatened Species. In January 2009, MDIFW recommended the removal of the Bald Eagle from Maine's list of Endangered and Threatened species. The State currently has a management program. www.maine.gov/ifw/wildlife/species/endangered_species/baldeagle_delisting.htm

Management goals and objectives for Bald Eagles include Population Goals and Habitat Goals. Part of the Habitat Goals is the preservation of known nesting site.

Map 2 (http://beginningwithhabitat.org/the_maps/pdfs/Pembroke/Map2.pdf) shows one nesting site on Pennamaquan River. The Project is outside the exclusion zone.

Bald Eagle Management Goals and Objectives 2004-2019
www.maine.gov/ifw/wildlife/species/plans/birds/baldeagle/baldeagle.pdf
Todd, Charles S., Feasibility Statements for Bald Eagle Goals & Objectives
www.maine.gov/ifw/wildlife/species/plans/birds/baldeagle/feasibilitystatement.pdf
Todd, Charles S., Bald Eagle Assessment, Jan. 30. 2004
www.maine.gov/ifw/wildlife/species/plans/birds/baldeagle/speciesassessment.pdf
Bald Eagle Management Issues and Concerns, April 14, 2004
www.maine.gov/ifw/wildlife/species/plans/birds/baldeagle/issuesandconcerns.pdf

Fish

Atlantic Salmon
www.maine.gov/ifw/wildlife/species/endangered_species/atlantic_salmon/index.htm

Freshwater Mussels

Yellow Lampmussel

The Yellow Lampmussel is a freshwater species. It range stretches across the from the Southern coast, through the middle interior of Maine. It range dips into the Northwest corner of Washington County. It was included in the list only because it is technically found in Washington County. However the project almost surely will have no effect on this species.

www.maine.gov/ifw/wildlife/species/endangered_species/yellow_lampmussel/index.htm

Mayflies

Tomah Mayfly
The Tomah Mayfly ranges through the Northern half of Maine including all of Washington County. It is however rare. The Tomah mayfly inhabits small river and streams bordered by extensive areas that are seasonally flooded. It is improbable that the project will adversely affect it.
www.maine.gov/ifw/wildlife/species/endangered_species/tomah_mayfly/index.htm

Moths

Pine Barrens Zanclognatha

www.maine.gov/ifw/wildlife/species/endangered_species/pine_barrens_zanclognatha/index.htm

Mammals

Canada Lynx

Pembroke is listed on MDIFW's Map 8 as potential habitat. MDIFW's website www.maine.gov/ifw/wildlife/species/endangered_species/canada_lynx/index.htm does not show Washington County as part of the Lynx's range. It is particularly unlikely to found within the vicinity of the project since there is considerable development in the area.

Marine Mammals Whales

The following Marine Mammals are listed by James McCleave, Gayle Zydlewski, Huiie Xue, and Michael Peterson, Physical Habitats and Natural Resources – Coastal Maine

Common name	Scientific name
Minkewhale	*Balaenopteraacutorostrata*
Fin whale	*Balaenopteraphysalus*
N. right whale	*Balaenaglacialis*
Humpback	*Megapteranovaeangliae*
Harbor seal	*Phocavitulina*
Harbor porpoise	*Phocoenaphocoena*

http://depts.washington.edu/nnmrec/workshop/docs/McCleave_Maine.pdf

The MDIFW Map 8 does not list any marine mammal within Pennamaquan River.

Marine Mammal Study The purpose of the study is to determine the presence and abundance of marine mammals with Pennamaquan River (the estuary) and in the vicinity of the plant. The study would inform the Project of the need for trashracks. It would also inform the Project of the

need for access should that be required.

The links to the MDIFW for each of the whales is listed below.

Finback Whale
www.maine.gov/ifw/wildlife/species/endangered_species/finback_whale/index.htm

Humpback Whale
www.maine.gov/ifw/wildlife/species/endangered_species/humpback_whale/index.htm

Northern Right Whale
www.maine.gov/ifw/wildlife/species/endangered_species/northern_right_whale/index.htm

Sei Whale
www.maine.gov/ifw/wildlife/species/endangered_species/sei_whale/index.htm

Sperm Whale
www.maine.gov/ifw/wildlife/species/endangered_species/sperm_whale/index.htm

Reptiles

Turtles

Atlantic Ridley
The Atlantic Ridley turtle are rarely reported in the Gulf of Maine. The MDIFW website shows Cobscook Bay at the northernmost end of the its range. It seems improbable that it would be found in Pennamaquan river. Atlantic Ridleys next mainly in the Gulf of Mexico.
www.maine.gov/ifw/wildlife/species/endangered_species/atlantic_ridley/index.htm

Leatherback
Leatherbacks are unique among reptiles in that they can regulate their body temperature. In addition, they have body insulation and heat exchange that enables them to migrate as far north Labrador. www.maine.gov/ifw/wildlife/species/endangered_species/leatherback/index.htm

§ 5.6 (d)(3)(viii) *Recreation and land use.* A description of existing recreational and land uses and opportunities within the project boundary. The components of this description include:

§ 5.6 (d)(3)(viii)(A) Text description illustrated by maps of existing recreational facilities, type and activity supported, location, capacity, ownership and management;

Pennamaquan River, the bay, is a recreational resource. The town of Pembroke maintains a boat ramp. There appears to be very little current recreational activity in Pembroke. The November *2009 Town of Pembroke, Maine – Comprehensive plan* section N-9 contains a section (page 9) dealing with Recreation, Scenic Resources and Open Space. It consists of the table shown below:

RECREATION, SCENIC RESOURCES AND OPEN SPACE			
Goal: Pembroke and Perry will maintain and improve access to recreational opportunities particularly water access			
Policy	**Implementation Strategy**	**Responsibility**	**Timeframe**
Civic Organization			
Promote and develop social, cultural and recreational activities in Pembroke and Perry	Create a Civic Improvement Committee to identify projects, assist with fundraising (including donations and grants) and events.	Selectmen	Immediate
Public Access			
Encourage recreational opportunities and increase access to surface water	Inventory access (public and non-public) points including recommendations for research, acquisition and improvements.	Selectmen	Immediate
	Provide facilities on lakes to allow public access, including landing facilities, as described in the Capital Improvement Plan.	Selectmen; Planning Board	On-going and as funding allows
Secure public access to the water for recreational and commercial users	Pursue the wide variety of available measure to secure such accesses. These could include: Landowner negotiations, Cooperation with local land trusts, Accepting donations of land or easements, Purchase of easements or land, Use of Land for Maine's Future funds	Selectmen; Planning Board	On-going and as funding allows
Open Space			
Encourage the preservation of open space	A revised land use ordinance will consider including provisions to require that major new residential developments reviewed by the planning board present recreational and open space areas in their plans.	Selectmen; Planning Board	Short-term (within 2 years)

§ 5.6 (d)(3)(viii)(B) Current recreational use of project lands and water compared to facility or resource capacity;

There is currently very little recreational use of Pennamaquan River. There are tour boats that operate from nearby Eastport. However, many of these tours are whale watching tours outside Cobscook Bay proper.

§ 5.6 (d)(3)(viii)(C) Existing Buffer Zones within Project Boundary

The buffer zone is to be determined. The project will seek to purchase land adjacent to the project.

§ 5.6 (d)(3)(viii)(D) Current and future recreational use of project lands and waters compared to facility or resource capacity.

Future recreational uses are listed in part (A) above. It is unclear what the recreational capacity is for Pembroke. The land surrounding Pennamaquan River is largely privately owned. State law does allow for access to the intertidal zone. The State Comprehensive Outdoor Recreation Plan www.maine.gov/doc/parks/programs/SCORP/documents/MESCORPChapIV.pdf lists combined trails in Hancock Washington, as well as snowmobile and ATV trails in Washington County. It does give the total number of public boat launches in Washington County as being 57. One of these is on Pennamaquan River. The State Comprehensive Outdoor Recreation Plant website is www.maine.gov/doc/parks/programs/SCORP/index.html . No plans specific to Washington County or the Pennamaquan River in particular are referenced.

Current & Potential Uses of Pennamaquan River Study: The first purpose of the study is to determine in greater detail current use of the Pennamaquan River. The study would monitor traffic in and out of the Pennamaquan River. The second purpose of the study is to identify potential use of Pennamaquan River. The tidal power plants at La Rance (France) and at Annapolis Royal (Nova Scotia) are both major tourist attractions. Annapolis Royal draws 35000 visitors annually. It is anticipated that the Pennamaquan Tidal Power Plant would draw significant number of tourists. Tourism would bring significant income into Washington County and have a major positive impact to this economically depressed area. The study would be carried out in consultation with local municipalities and residents.

§ 5.6 (d)(3)(viii)(E) If the potential applicant is an existing licensee, its current shoreline management plan or policy, if any with regard to permitting development of piers, boat docks and landings, bulkhead and other shoreline facilities on project lands and water;

Not applicable.

§ 5.6 (d)(3)(viii)(F) A discussion of whether the project is located within or adjacent to a:

(1) River segment that is designated as part of, or under study for inclusion in the National Wild and Scenic River System;

The water of the Pennamaquan river (the freshwater river) flow into Pennamaquan River, the saltwater Bay. The Pennamaquan river (the river) is not designated as part of, or under study for inclusion in the national Wild and Scenic River system. The Pennamaquan river has an average discharge of 4 m^3/s. It is not a free flowing river. There is a dam at its upper end its upper end controlling Pennamaquan Lake. There is also a second small dam at its lower end which once was used as a small hydroelectric facility by Bangor Hydro.

(2) State protected river system

The Pennamaquan river is not part of a State of Maine protected river system.

§ 5.6 (d)(3)(viii)(G) Whether any project lands are under study for inclusion in the National Trails System or designated as, or under study for inclusion as a Wilderness Area;

No land within the project boundary is under study for inclusion in the National Trails System or designed as, or under study for inclusion as a Wilderness Area.

§ 5.6 (d)(3)(viii)(H) Any regionally or nationally important recreation areas in the project vicinity;

Reversing Falls is a listed recreation area (Figure 27). The powerful currents of the tidal waters filling and draining in Cobscook Bay create a phenomenon the locals know as Reversing Falls. It is located at the end of Leighton Point Road, at Mahar Point, Reversing Falls Park Reversing Falls is listed on the National Register of Historic Places.

§ 5.6 (d)(3)(viii)(I) Non-recreational land use and management within the project boundary;

A boat ramp operated by the Town of Pembroke is within the project boundary.

§ 5.6 (d)(3)(viii)(J) Recreational and non-recreational land use and management adjacent to the project boundary.

The parcels of land on the Hersey Neck and on Leighton Neck in the immediate vicinity of the project are shown on figure 31.

The land adjacent to the project boundary is privately owned with the exception of a strip of land from Garnet Head Road to the boat ramp (Pembroke Parcel number 33). Two other parcels in the vicinity are conserved land. These are part of Maine's Land Trust Network. One parcel (Pembroke parcel 36) is owned by the Nature Conservancy. The other, parcel is parcel 19. Both are shown in figure 26.

§ 5.6 (d)(3)(ix) *Aesthetic resources.* A description of the visual characteristics of the lands and waters affected by the project. Components of this description include a description of the dam, natural water features, and other scenic attraction of the project and surrounding vicinity. Potential applicants are encouraged to supplement the text description with visual aids.

Pennamaquan River is a salt water fjord (its mouth narrower than its body). It is part of Cobscook Bay. Cobscook Bay is a highly indented and very picturesque landscape created by the Laurentide ice sheet. The area is sparsely populated. Population in the area has been falling over the past hundred years. The result is that there are no extensive developments. Property around Pennamaquan River consists of large parcels. Only at the upper end of the Pennamaquan is the density of housing significant. The area around the Pennamaquan consists of cleared meadows or woods.

Figure 25 shows an aerial view from Google Maps. Figures 28a & b show two photographs. Figure 28a shows a typical view from Leighton Neck Road. Figure 28.b is a photograph of the projected plant site from the Leighton Neck side. The boat launch maintained by the town of Pembroke is visible across the Pennamaquan.

Various options have been considered for the Pennamaquan Tidal Power Plant. One option is to build the plant to look like a traditional tidal mill many of which once dotted the Maine coast. Such a design would blend in with existing architectural styles in the area. Since concrete can be cast to look like stone, the wall and powerhouse caisson would be cast to resemble stone. A building running the length of the power house can be built with a frame construction exterior. It would of course be up to modern structural standards. Its interior would house a fully up to date generating facility. A second option is that of a narrow bridge. In fact, if access and safety make it possible, the project could serve as a bridge. There are many possible configurations of this options ranging from a fully operational to a narrow footbridge from the Leighton Neck side to the location of the plant. The bridge would rise to a minimum height above high water level.

The project would be designed to have architectural merit in order to complement the scenic value of the Pennamaquan. Choices would be made in collaboration with the community of Pembroke.

It may be possible to purchase the RH Foster property (parcel 34) on which site large decommissioned oil tanks and the deteriorating administrative buildings once used when RH Foster delivered oil to the area. Parcel 34 is in the immediate vicinity or could serve as landfall for the tidal power plant. The oil tanks and the deteriorating building would be removed. A new building housing the electrical controls would be constructed in their place. The parcel is 26 acres. Removal of the oil tanks and deteriorating buildings would add to the aesthetics of Garnet Head Road. The mature trees on the property would be preserved and the remainder of the area landscaped.

In addition to visual impact, there is the potential of noise impact. Horizontal bulb turbines produce little noise. They look and operate very much like submarines. The noise level will need to be quantified both above and below the water.

§ 5.6 (d)(3)(x) *Cultural resources.* A description of the known cultural or historical resources of the proposed project and surrounding area. Components of this description includes:

The information from this section is drawn from Town of Pembroke, *Maine Comprehensive Plan*, Nov. 2009.

Native Americans have long resided in the area. According to the Historic Preservation Commission, there is evidence of shell middens. Their location is undisclosed in order to protect the sites. The original townships of eastern Maine were established in 1793. The town of Pembroke was formed in 1832. Lumber exports were the principal business after the Revolutions. The availability of lumber led to thriving shipbuilding through the 1870's.

Commercial fishing dates to the 1800's. Seven canneries operated in the area in the early 1900's. Pembroke's first school was built in 1812.

§ 5.6 (d)(3)(x)(A) Identification of any historic or archeological site in the proposed project vicinity, with particular emphasis on sites or properties either listed in, or recommended by the State Historic Preservation Officer or Tribal Historic Preservation Officer for inclusion in, the National Register of Historic Places;

No professional historical archeological survey of Pembroke has been carried out. Archeological studies have been conducted at reversing falls which is on the National Register of Historic Places (figure 27). The Maine Historic Preservation Committee has recommended that comprehensive surveys be carried out to determine those properties that would qualify for listing in the National Register. The Charles Best house, a Greek revival style house on County Road in West Pembroke is the only residence in the National Register. Charles Best was co-discoverer of insulin. The George Hatch, the Bridges, the Farnsworth and the Pattangall house are other houses of note.

The St. John's Roman Catholic Church is considered to be clearly eligible for listing in the National Register of Historic Places. Another, the People's Church is unique for its small size.

The town of Pembroke has 5 large public cemeteries and many private family plots.

There are two prehistoric sites that have been reported along the shoreline within the project area, sites 80.32 and 80.48. They were recorded by the R. S. Peabody Museum in Andover, MA, probably during the 1950s, when an RSPM archaeologist was working with vocational archaeologists in Washington County. We do not have any further information, other than site locations. It is likely that these were the find sites of stone tools eroded along the shoreline, but may also represent significant sites. They are shown Figure 27.
Reversing Falls is listed in the National Register of Historic Places. It is in the vicinity, but not within the boundaries of the project (Figure 28).
The shores of the Pennamaquan River estuary (tidal project potential impact areas) have not been surveyed for prehistoric (pre-Columbian Native American) archaeological sites. A Phase I level archaeological survey (at least) will be necessary. Orange highlighted shoreline on the graphic attached is considered “sensitive” for the presence of undiscovered prehistoric sites – in other words, this is the shoreline upon which Phase I archaeological survey must concentrate.

The alignment of the Tidal Power Plant does intersect sensitive area identified by the orange band in figure 28. The R.H.Foster oil storage tanks and the Pembroke boat ramp are on the Hersey Neck side of the project. The area there is likely highly disturbed. The Leighton Neck side is only slightly developed with one abandoned house and one small cabin on the property. It is not clear to what extent its archeological resources have been disturbed.

A Phase I reconnaissance survey would be necessary within the estuary to identify the potential presence of shipwrecks, fish weirs or industrial remains associated with historic maritime activities. NOAA carried out a bathymetric and seafloor survey which should inform us on the presence of submerged historical resources.

The transmission line is shown in yellow in figure 27. The project would replace the existing line with a higher capacity. The poles would likely have to be replaced by taller poles. The transmission line follows Garnet Point Road. It is likely that the modifications to the existing line would be carried out from the road. The extent to which this might disturb archeological resources would need examination.

Archeological Sites

According to the Maine Historic Preservation Commission (MHPC), there are thirteen prehistoric archeological sites in Pembroke. Twelve are shell middens or eroded shell middens along the shore of Cobscook Bay. A reconnaissance survey of shoreland zone in Pembroke is complete except for Hersey Neck and the east side of Leighton Neck.

There are four know *historic archeological* sites in Pembroke. These are

Site Name	**Type**	**Site Number**	Era
Pembroke Iron Works	Works American ironworks	ME342-001	1832 to at least 1882
"John Dexter"	American wreck, Schooner	ME342-002	1904
E. Cushing Homestead	America domestic	ME342-003	Mainly latter half of 19th Century
Ayer Jct. Siding House	American railroad, house	ME342-004	1898-1978

§ 5.6 (d)(3)(x)(B) Existing discovery measures, such as surveys, inventories, and limited subsurface testing work, for the purpose of locating, identifying, and assessing the significance of historic and archeological resources that have been undertaken within or adjacent to the project boundary;

No professional historical archeological survey of Pembroke has been carried out. A reconnaissance survey of shoreland zone in Pembroke is complete except for Hersey Neck and the east side of Leighton Neck.

§ 5.6 (d)(3)(x)(C) Identification of Indian tribes that may attach religious and cultural significance to historic properties within the project boundary or in the project vicinity as well as available information on Indian traditional cultural and religious properties, whether on or off any federally-recognized Indian reservation (A potential applicant must delete from any information made available under this section specific site or property location, the disclosure of which would create a risk of harm, theft, or destruction of archeological or Native American cultural resources or to the site at which resources are located, or would violate any Federal law, including the Archeological Resources Protection Act of 1979, 16 U.S.C. 470w-3, and the National Historic Preservation Act of 1966, U.S.C, 470 hh)

The Pleasant Point Reservation of the Passamaquoddy Indian Tribe is a driving distance of about 15 miles from the project site. There are about 2,000 tribal members on the tribal census and about 1,100 members in Sipayik.

There are no tribal lands directly adjacent to the project boundary.

According to the Historic Preservation Commission, there is evidence of shell middens. There is evidence of 13 middens primarily composed of shell middens along the coast.

§ 5.6 (d)(3)(xi) *Socio-economic resources.* A general description of socio-economic conditions in the vicinity of the project. Components of this description include general land use patterns (e.g. urban, agricultural, forested), population patterns, and sources of employment in the project vicinity.

Information for this section is drawn from Town of Pembroke, Maine, *Comprehensive Plan*, Nov. 2009

Regional Economy

Forestry and fishing have been the traditional and associated industries such as lumber, shipbuilding, and cannon have been the traditional economic drivers in Pembroke. Sardine packing peaked during World War II and has since completely disappeared. Lobstering, clamming, wreath making, paper manufacture aquaculture and small manufacturing are important sources of employment. Two-thirds of Pembroke residents find employment in nearby center of Eastport, Calais and Machias.

There are 26 local employers in the town of Pembroke. Maine Department of Labor lists employers as self-employed and home-based businesses particularly farming, fishing construction and forestry related businesses. The largest single employer in Pembroke is the school.

Washington County has been one of the most depressed counties in New England. Pembroke is part of the Calais Labor Market Area. The Area has lost population over the past 20 years. Population losses have been: - 9.7 % 1980-2000, - 7.3 % 1990-2000. Population loss appears to be accelerating. The decline is most concentrated in school aged and those between 24 and 44 years of age. The declining school enrollment has been particularly severe with a decline of 26.2 % over the last 20 years. Concurrently, there has been an increase in the dependency ratio within households. The dependency ratio adds the net elderly and youth population the divides the sum by the working age. The result is a measure of the fraction of a community's ability to generate income. The dependency ratio for the Calais Labor Market Area has been on the increase. The result is an increase of poverty as the proportion of wage earners decreases. The Calais Labor Market Area has a poverty rate of 16.1 % in 2001, up 1.5% since 1990.

During the 1998-2000 period Restaurants, Educational Services and Food Stores were the sector with greatest growth. These however generated low wage employment with earnings below $378 per week. High wage sectors (defined as those with earnings greater than $492/week) such

as Lumber and Wood Products, Paper and Allied Products and Trucking and Warehouse were either stable or in decline.

Population Projections

	Pembroke		Washington County		Maine	
Year	Number	% Change	Number	% Change	Number	% Change
2020	848	-2.19%	23,796	-13.03%	1,401,406	7.8%
2015	867	1.14%	33,111	2.47%	1,300,000	-2.26%
2010	877	-0.34%	859	0.30%	1,330,117	-2.96%
2005	880	0.11%	32,217	-5.09%	1,371,022	7.7%
2000	879	3.7%	33,941	-3.87%	1,274,923	3.83%

Population projection suggest that the area population will be falling even as the State population generally increases.

Labor Force and Employment Statistics

Labor Force Status 2000	**Pembroke**		**Washington County**	
	Number	**Percent**	**Number**	**Percent**
No of persons 16 years or older	711	100%	27,214	100%
No. of persons in labor force	378	53.2%	15,500	57%
Employed	335	47.1%	14,042	51.6%
Unemployed (% of No. in labor force)	43	6%	1,312	8.5%
Not in Labor Force	335	46.8%	11,714	43%

(from USDA, Pembroke town, Washington County Maine – Fact Sheet)

Unemployment

Year	**Pembroke**	**Washington Co.**	**Maine**
2010		11.1%	7.6 %
2009		11.1 %	7.8 %
2008	10.4 %	8.5%	5.4 %
2007	10.0 %	7.6 %	4.6 %

Source: www.maine.gov/labor/cwri/county-economic-profiles/countyProfiles.html and Town of Pembroke, Maine, *Comprehensive Plan*, Nov. 2009

The table above shows that Pembroke has an unemployment rate that is higher than Washington County as a whole and much higher the general unemployment in Maine.

Employment Characteristic: 2000	**Pembroke**		**Washington County**	
Industry	**Number**	**Percent**	**Number**	**Percent**
Employed persons 16 years and over	335	100%	14,042	100%
Agriculture, forestry, fisheries, and mining	19	5.7%	1,531	10.9%
Construction	35	10.4%	944	6.7%

Manufacturing	68	20.3%	1,968	14.0%
Wholesale trade	2	0.6%	384	2.7%
Retail Trade	35	10.4%	1,521	10.8%
Transportation, warehouse, utilities info	17	5.1%	581	4.1%
Information	15	4.5%	146	1.0%
Finance, insurance and real estate	9	2.7%	433	3.1%
Professional, scientific, management, administrative, and waste management services	12	3.6%	438	3.1%
Education, health and social services	81	24.2%	3,694	26.3%
Arts, entertainment, recreation, accommodation and food services	3	0.9%	779	5.5%%
Other services (except public administration)	14	4.2%	642	4.6%
Public administration	25	7.5%	981	7.0%
Class of Worker	**Pembroke**		**Washington County**	
Private wage and salary workers	223	66.6%	9,225	65.7%
Government workers	76	22.7%	2,882	20.5%
Self-employed workers	36	10.7%	1,886	13.4%
Unpaid family workers	0	0%	49	0.3%

The high percentage of persons over 16 not in the labors force reflects the difficult employment picture in Pembroke and in Washington County generally. Unemployment figure are provided in the table below.

Median Household Income

Year	Washington County	State of Maine	% of State Median HH
2011	$ 31,861	$ 54,134	69.7 %

The poverty rate in Pembroke (1999) was 20.5 %

Land Use

Land Use – See figure 30 (from Town of Pembroke, Maine, *Comprehensive Plan*, Nov. 2009)

Pembroke Land Cover By Area			
Cover Type	**Miles**	**Acres**	**Percent**
Cultivated	0.1	57	0.2%
Developed	3.3	2,253	9.1%
Forest	29.4	20,149	81.7%
Grass/Pasture	0.3	202	0.8%
Open Land	0.1	55	0.2 %
Wetlands	2.9	1,982	8.0 %
Total Land Area	35.9	24.658	100 %

§ 5.6 (d)(3)(xii) *Tribal resources.* A description of Indian tribes, tribal lands, and interests that may be affected by the project.

The Passamaquoddy Tribe is the closest Indian community to the project. The Pleasant Point Passamaquoddy Reservation is located at Pleasant Point, at an approximate distance of 15 miles from the project. No part of the Pleasant Point Reservation occupies any shoreland along the boundary of the project.

§ 5.6 (d)(3)(xii)(A) Identification of information on the resources specified in paragraphs (d)(2)(ii-xi) of this section to the extent that existing project construction and operation affecting those resources may impact tribal cultural, or economic interests. E.g. impacts of project-induced soil erosion on tribal culture sites;

As reported in section (x), according to the Maine Historic Preservation Commission (MHPC), there are thirteen prehistoric archeological sites in Pembroke. Twelve are shell middens or eroded shell middens along the shore of Cobscook Bay. The project should not impact these resources. In particular, since the natural tidal range is preserved, any as yet undiscovered archeological resources would not be affected by the operation of the project.

§ 5.6 (d)(3)(xii)(B) Identification of impacts on Indian tribes of existing project construction and operation that may affect tribal interests not necessarily associated with resources specified in paragraphs (d)(3)(ii-xi) of this Sections. Eg., tribal fishing practices or agreements between the Indian tribe and other entities other than the potential applicant that have a connection to project construction and operation.

In their deliberations with the State of Maine and the Federal Government, the Passamaquoddy Tribe has invoked aboriginal fishing rights. These deliberations have specifically targeted the fishing Atlantic Salmon and the harvesting of porpoises. Resolution of these issues is not affected by the construction or operation of the project.

Access to Pennamaquan River is an issue that would affect the Tribe and will need to be studied. Fishing and recreational interests and will need to be studied for potential impact.

§ 5.6 (d)(3)(xiii) *River Basin Description*

N/A

§ 5.6 (d)(4) *Preliminary issues and studies list.* Based on the resource description and impacts discussion required by paragraph (d)(3) of this section; the pre-application document must include with respect to each resource area identified above, a list of:

§ 5.6 (d)(4)(i) Issues pertaining to the identified resources;

Tidal range power is a massive resource whose development has been technically feasible for nearly a century. Two major obstacles have stood in the way of its implementation. The first

has been the cost of the civil works. The second has been the negative environmental impact.

The Pennamaquan Tidal Power Plant is intended as a demonstration plant for a low cost construction method based on piling techniques developed over the last 30 years. The second is to demonstrate Alstom-Halcyon's low environmental impact tidal range power generation.

Reduction is in the cost of the civil works is in part due to the use of a pile supported enclosure. Conventional construction of enclosures for tidal power plants consists of traditional dam construction, the use of pre-cast caissons, or embankments. Conventional dam construction in the dry is prohibitively expensive for long structures. Embankments are a low cost option only in very shallow water. Their cost grows exponentially with depth. The caissons required to support tidal loads must necessary be large and massive (50 to 70 m in length). The pile supported wall is a low cost alternative to the three conventional methods. Massive elements of conventional construction are replaced by a narrow pile supported wall. For the Pennamaquan Tidal Power Plant, the wall is 3m wide. Reduction in dimensions yields commensurate reduction in the use of concrete and therefore in cost. The approach is made possible by recent major advances in both piling methods and in new high performance concretes. Wall construction has environmental advantages. The footprint is small. The wall elements are designed so that they can be refloated and removed. The Pennamaquan Tidal Power is fully decommisionable.

The second reduction in cost of the civil works is the result of the powerhouse caissons, whose structure is much simpler and uses far less material than a conventional powerhouse caisson.

The second major obstacle to the widespread development of tidal range power is the negative impact of the operating cycle. Conventional operating cycles lead to the loss of intertidal zones. Intertidal flats that are normally submerged at high tide become permanently exposed. Intertidal flats that are normally exposed at low tide become permanently submerged. For some cycles both result. This is true for hydrokinetic cycles as well. Reduction in the energy content of the water will result in loss of intertidal habitat. For optimum development (34% capacity factor) it can be shown that the results are identical. Only limiting power generation to small scale can the loss of intertidal zone. Since intertidal flats play an important ecological role, their reduction represents a significant. The development of a power cycle that fully preserves the intertidal zone is therefore important. The cycle employs two way generation with pumping at the end of each power cycle to raise or lower level of the basin. The cycle has been named the Parallel Cycle since it parallels the natural rise and fall of the tide. The cycle was developed by Halcyon Marine Hydroelectric. Detailed simulations for the Pennamaquan Tidal Power Plant were carried out by Alstom Power and Transport in collaboration with Halcyon.

A second negative environmental impact of conventional tidal power is sedimentation. Sedimentation is a consequence of both tidal range and hydrokinetic tidal power. Rate of precipitation of sediment is very sensitive energy content of water. By pumping to natural level, the natural energy content of the water is restored. It can be shown the end result of the Parallel Cycle is a net reduction in the kinetic energy of moon rather than the water. The Parallel Cycle therefore eliminates sedimentation. The elimination of sedimentation is important to maintaining water quality. It is also important to maintain the transmission of light through the water column, a factor governing plant and phytoplankton productivity.

The tides pass through a 28 day cycle shown in figure 11.a. The horizontal bulb generators have considerable flexibility in their operation. This leads the possibility of variants of the operating cycle. In the first variant, the turbines can be operated so that the level of the basin reproduces the natural 28 day cycle. Water levels in Pennamaquan River would then look essentially like the 28 day cycle shown in figure 11.1a. The cycle would parallel the natural cycle. Figures 10.1a-c show a second variant where the turbines are allowed to raise the level of the basin to the maximum capacity of the turbines. The effect is most pronounced at neap tide (fig. 10.1b) where the level of the basin is raised considerably above its natural neap tide level. This is not necessary but it is possible. All variants share an important common feature. First, during each 28 day period the basin is raised to its natural high level and lowered to its natural low level just as would occur if there were no tidal power plant present. This preserves the natural boundaries of the intertidal zones. Pumping above normal levels during neap tides has the effect of making the tidal cycle on one day more like the average tidal cycle. The environmental consequences are not known. They may in fact be beneficial, leading to a higher productivity in Pennamaquan River. The Pennamaquan River Tidal Power Plant is in part envisioned as a research facility. The Power Plant would be operated according the various possible cycles over a period of years to determine ecological and energy optimum. There may be some specific environmental benefits. It has been speculated that the too much algal grows tends to suffocate shell fish who come up through the mud, becoming prey to Moon Snails. It may be that by raising the level of basin at neap tides, rate of algal growth can be controlled. This may enhance shellfish productivity. These variants would be investigated as part of the research program of the power plant. It is important to note that the plant can always be returned to the operating cycle that reproduces the natural tidal level on a daily basis. Investigating options would provide much important ecological information. It would also determine the economic optimum.

There are two aspects of the operating cycle that should be noted. The first is the difference in time when high tide (or low tide) is reached in the basin and the corresponding time of high (low) tide in the Pennamaquan. The time difference is about 1.5 hours. The lag is necessary to generate the differential head on which the turbines operate. A study is proposed below to determine its effects.

The second aspect is the "flat" section (A to B and F to G in fig.10.1a-c) of the cycle during the waiting period when the level of the basin is constant. The waiting period is about 1.5 hours. There are potential impacts due to the increased residence time. The residence time can be adjusted by starting discharge through the 16 turbines sequentially soon after point A or F (figure 10.1a). This will "round" sections A-B and F-G making more the natural sinusoidal curve of the tide and decreasing residence time.

Minimization of environmental impact has been an integral part of the design process for the plant from the outset. This applies to the civil works, the operating cycle and the choice of turbines. Horizontal bulb turbines were chosen in part because they result in a lower fish passage mortality rate than other types of turbines. For example, projected mortality rates under 5 % for horizontal bulb turbines are far lower than those the large Straflo unit at Annapolis. 16 small turbines (3.2 m diameter) were chosen instead of say 2 large 7.5 m diameter turbines for environmental as well as cost reasons. Small turbines (3.2 m diameter) have two environmental

advantages. When set side by side, they span a wider section of the mouth of the Pennamaquan. Flow is therefore less concentrated than it would be if two large turbines were used. The flow more closely resembles the natural pattern.

Using small turbines also permits placement of spillways over each turbines. This provides more access for biological exchange between ocean and basin and reduces habitat fragmentation.

Reducing habitat fragmentation has been another goal of the design. The operating range of turbines is limited to tides up to 1.23 times the average tide of y_{AV} = 5.5 m or 6.8 m. 20 % of tides are above 1.23 y_{AV} = 6.8 m. The height of the tidal wall is design so that tides above 6.8 m overtop the wall. The wall is therefore overtopped on 20 % of tides. Overtopping provides additional access in and out of Pennamaquan and reduces habitat fragmentation.

Fish mortality and injury is an issue which will need to be addressed. Horizontal bulb turbines have a lower rate of mortality and injury. Turbine characteristics have been adjusted to reduce fish mortality and injury. The number of blades has been reduced to three. Small turbines have been chosen so that the speed of the blade tip is reduced. Gaps resulting in fish injuries will be eliminated. Nevertheless, since there will be fish mortality and injury during passage, their extent and significance must be studied. The rate of mortality and injury will depend on the length of the fish. This will in turn depend on age and species. A baseline study will be required to determine what species are present in Pennamaquan River. The significance of morality and injury rates depends on the overall size of the population and on the endangered or threatened status of the species. The presence of marine mammals and turtles will also have to be determined. Protection of marine mammals and turtles may require the installation of trash racks. A baseline study to determine what species are present, when they are present and in what number is required.

The alewife population is of special concern since its numbers have been falling throughout New England. Alewives migrate up Pennamaquan River then up Pennamaquan river and into Pennamaquan lake and its watershed to spawn. There has been commercial harvesting of alewives in Pembroke for use as bait. This has been suspended.

In addition to environmental issues, the aesthetic dimension of the project is considered. There are many alternatives to making the tidal power plan aesthetically pleasing. For instance, the plant can be constructed to look like one of the traditional tidal mills that dotted the coast of Maine in the 19th Century. The wall can be made to look like stone resembling enclosure used in the 19th century. The Powerhouse can be topped by a building replicating the building that would have housed the machinery in the 19th Century. Such a design would blend in with the historical buildings of Pembroke. Discussions with the Maine Historical Society have been initiated.

§ 5.6(d)(4)(ii) Potential studies or information gathering requirements associated with the identified issues;

Geotechnical and Submerged Soil Study

The purpose of the study is two-fold. The first is to determine foundation characteristic. 15 borings would be drilled to a depth of 20 m and 3 borings of 2 m into the rock will be required prior to carrying the foundation design for the power plant. In addition presence and depth of sediment and surficial material would be determined. The second is to analyze submerged soils for contamination. The project is near the RH Foster property, Parcel 34 (figure 31) where RH Foster maintains two decommissioned oil storage tanks. A pipeline for filling the tanks has been decommissioned. Submerged soil will need to be analyzed for contamination from the oil operation.

The study would inform a report on the potential effects of trenching and drilling required for construction.

The study would be conducted in consultation with Maine Department of Environmental Protection.

Tidal Range and Flow Volume Study

The purpose of this study is to determine the tidal range and the flow into Pennamaquan River. Determination of these values over a 28 day period (together with historical data) will provide the needed data to determine the live water volume. Determination of live water volume can be obtained from water levels and aerial imagining of Pennamaquan River. Tidal range and live water volume over the tidal cycle will lead to an accurate determination of energy output. There is a tidal station at Garnet Point at the tip of Hersey Neck (Station ID: 8410715). Information from the station may be sufficient.

The study would inform a report on the firm capacity of the tidal power plant.

The study would be carried out in consultation with the Federal Regulatory Energy Commission.

Water quality Study

The purpose of this study is to document water quality in Pennamaquan River. The study would serve as a basis to predict water quality over the operating range of the Pennamaquan Tidal Power Plant.

The study plan would be developed in consultation with the Maine Department of Environmental Protection.

2-D/3-D Modeling

The purpose of the study is the following: (1) To determine the flow patterns within Pennamaquan River. Although there is information about flow patterns in Cobscook Bay, more detailed information may be required to determine far field effects. (2) To develop a 2-D model of flow within Pennamaquan River construction. The far field effects would also be modeled in order to inform the project of alteration in flow patterns outside the Pennamaquan River basin. If 2-D modeling does not provide adequate information 3-D modeling can be carried out. If 2-D

modeling turns out not to be sufficient to determine changes in sedimentation rates, 3-D modeling can be carried out.

The study would inform a report on changes in flow patterns and volume and on alterations in sediment patterns.

Aquatic Vegetation Study (Submerged Aquatic Vegetation and Algae Study)

The purpose of the study is to update the 1976 study carried out by Barrry S. Timson for Maine Geological Survey, Department of Conservation. The results of the study were summarized in the map: *Coastal Marine Geologic Environments of the Pembroke Quadrangle, Maine.* The map is shown in figure 15. The study would characterize the supratidal, intertidal and subtidal environments to characterize the type and distribution of aquatic vegetation as well as the surficial geological in each of the three environments.

The study would inform a report on the potential effects of the operation of the tidal power plant on aquatic life on the surficial geology within the project boundary.

The study would be carried out in consultation with Maine Department of Inland Fisheries and Wildlife and with the U.S. Fish & Wildlife Service.

Finfish, Marine Mammal, Reptile, and Invertebrate Study

A study to determine the species of finfish, marine mammal, and reptiles determines baselines. The baseline is then used to determine the impact of the project on the species present and in particular the impact of turbine passage.

Fins Fish Study: The purpose of the study is to extend the University of Maine at Orono to determine the species presence specifically in Pennamaquan River.

Further specific studies would be conducted to determine the presence, distribution, and abundance of finfish, marine mammals, reptiles, and invertebrates in Pennamaquan River. The study would inform the project on the presence and abundance of endangered and threatened marine species, species of concern and species managed by the Maine Department of Inland Fisheries and Wildlife.

River Herring Study: The purpose of the study is to determine the abundance, size of alewives and blueback herring. Data would be gathered during the spawning run in spring and on the run back to the sea. The study would be conducted in the fishways located at the two dams on Pennamaquan river. The distribution of lengths allows us to project mortality rates in passage through the turbines.

Rainbow Smelt Study: The first purpose is to determine the abundance of rainbow smelt. The count would be carried out in the fishways during the spawning run during May through August. The study would also investigate the possibility of spawning sites below the river. The second

purpose of the study is to determine the movement of rainbow smelt during the spawning period. Rainbow smelt may move between fresh and salt water during this period. The study would determine how far they swim into salt water on their feeding runs and if they swim far enough down the channel to be entrained into the turbines.

Wild Brook Trout and Brown Trout Study The purpose of the study is to determine the number and movement of wild brook and brown trout. The study would carry out a count of brook/brown trout passing through the fishways and to gather data on length of fish. The movement of these fish between fresh and salt water is insufficiently known. Fish would be caught in the fishways, radio tagged and their subsequent movement monitored. The study would determine if they swim far enough down the channel to be entrained into the turbines.

Eel Study The purpose of the study is to determine the number, size and migration schedule of eels in Pennamaquan. The first study would gather data on elvers migrating into the watershed. The second study would determine the number and size distribution of adult silver eels on their return migration. The count can be carried out by capture in the fishways on the Pennamaquan River (the river). The size distribution of silver eels would provide data on which to base projection of eel mortality during passage through the turbines.

Silver Eel Transport Study: The purpose of the study is to determine the feasibility of capturing silver eels in the fishways on their spawning run to the Sargasso Sea. The feasibility of transport and release of silver eels below the tidal power would be determined. Compatibility of capture with freedom of movement of other fish would be determined.

Crustacean Study: The purpose of the study is to determine the species of crustacean present in Pennamaquan River. In particular, the study would determine the presence and abundance of lobster.

Microinvertebrate Study The purpose of the microinvertebrate study is to determine species and abundance and establish baselines. The baseline would provide the data required to compare with species and abundance once the plant is in operation. Baselines allow comparison of productivity once the Project is in operation. In particular, the baseline allows comparison when the cycle modifies neap tide cycle to more closely resemble average tides (figure 10.1b). Increased productivity is projected to provide added food sources for birds. The study is linked to the shore bird study below.

The information generated by the studies listed above serve as a basis to determine project impact.

Turbine Entrainment and Passage Survival Study: The purpose of the study is twofold. The first is to determine species which would be entrained into the turbines. The second would determine survival rate after passage through the turbines.

Shore Bird Study The shore bird study would complement the microinvertebrate study. The purpose of the study is to establish a baseline on the number and temporal distribution of shore

birds. The baseline would allow comparison with numbers when pumping is employed to bring neap tide water levels closer to average. Pumping may prove beneficial to shore birds.

Bird Study

The purpose of the study is to determine the presence of any protected, threatened or endangered species. In particular the study would determine the presence of nesting sites.

The study would be carried out in consultation with Maine Department of Inland Fisheries and Wildlife.

Marine Mammal Study The purpose of the study is to determine the presence and abundance of marine mammals with Pennamaquan River (the estuary) and in the vicinity of the plant. The study would inform the Project of the need for trashracks. It would also inform the Project of the need for access should that be required.

Commercial and Recreational Study

The purpose of the study is to determine current levels of commercial and recreational use of Pennamaquan River. In particular it would determine the level of use of Pennamaquan River for fishing, for harvesting shellfish, and for harvesting rockweed.

The study would inform project on the need for boat access in and out of Pennamaquan and on the type and level of access required.

Current & Potential Uses of Pennamaquan River Study: The first purpose of the study is to determine in greater detail current use of the Pennamaquan River. The study would monitor traffic in and out of the Pennamaquan River. The second purpose of the study is to identify potential uses of Pennamaquan River. Potential uses may benefit or conflict with the presence of the Pennamaquan Tidal Power Plant. The tidal power plants at La Rance (France) and at Annapolis Royal (Nova Scotia) are both major tourist attractions. Annapolis Royal draws 35000 visitors annual. It is anticipated that the Pennamaquan Tidal Power Plant would draw significant number of tourists. Tourism would bring significant income into Washington County and have a major positive impact to this economically depressed area. The study would be carried out in consultation with local municipalities and residents. Potential conflicts would be determined in conjunction with local municipalities and residents.

Archeological and Historic Resources study

The purpose of the Archeological and Historic Study is to determine the presence of Archeological and Historic Resources in the vicinity of the tidal power plant and along the transmission corridor.

The study would inform the project of steps required to preserve archeological and historic resources.

Aesthetics Study

The purpose of the Aesthetics Study is to assess the aesthetic effects of the tidal power plant. The Aesthetics Study would consist of two parts. (1) The first would be a Visual Impact Study. (2) The second would be a Noise Impact Study. The study would quantify noise level both above water and underwater.

The study would determine possible designs for the plant. The plant could be made to look like a traditional Maine tidal mill. A New England covered bridge could span the length of the project. These options would be consistent with the traditional architecture seen in Pembroke. The design would be carried out in consultation with the community.

The Visual Impact Study would inform the project on the preferred architectural design for the project. The possibility of acquiring the RH Foster oil tanks parcel would be investigated. The removal of the disused oil tanks and deteriorating buildings would improve the aesthetic environment.

Noise Impact Study: The Noise Impact Study would quantify noise level both above water and underwater. Noise levels would be determine noise levels during construction and during the operation of the tidal power plant.

§ 5.6(d)(4)(iii) Relevant qualifying Federal and state or tribal comprehensive waterway plans;

There are no current Federal, State or tribal comprehensive waterway plans.

§ 5.6(d)(4)(iv) Relevant resource management plans.

The U.S. fishery is managed under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan (FMP). Under this FMP, The following fish are listed under the Multispecies Fishery Management Plan: American Paice, Atlantic Cod, Atlantic Halibut, Haddock, Ocean Pout, Offshore Hake, Pollock, Red Hake, Redfish, Silver Hake, White Hake, Windowpane Flounder, Winter Flounder, Witch Flounder, and Yellowtail flounder (Source: http://www.nero.noaa.gov/nero/fishermen/images/Multispecies/).

Of these the following were identified in Cobscook Bay by University of Orono fin fish study (Table 10): Atlantic Cod, Winter Flounder, White Hake, Silver Hake, Haddock,

§ 5.6(d)(5) *Summary of contacts.* An appendix summarizing contacts with Federal, state, and interstate resource agencies, Indian tribes, non-governmental organizations, or other members of the public made in connection with preparing the pre-application document sufficient to enable the Commission to determine if due diligence has been exercised in obtaining relevant information.

Over the past 18 months, Pennamaquan Tidal Power, LLC has held numerous in person meetings and telephone conferences with various governmental agencies and other interested parties

regarding issues relating to the project, including its potential environmental impact and appropriate studies to investigate such potential impacts. The following is a list of regulators, government representatives and interested persons with whom Pennamaquan Tidal Power, LLC has met.

CONTACT LIST
Pennamaquan Tidal Power Project

Maine Regulators

Name	Position	Organization	Telephone (207)-	e-mail
Jim Beyer Land&Water quality	Division of Land Resources Regulation	ME DEP Easter Regional Office	446-9026	jim.r.beyer@maine.gov
Robin Clukey	Maine DEP		446-1733	Robin.clukey@maine.gov
Richard Bard	Asst. Wildlife Biologist	M DIFW	434-5927	richard.bard@maine.gov
Lindsay Tudor	Bird Biologist	MDIFW	941-4479	lindsay.tudor@maine.gov
Steve Walker	Environmental Review Coordinator	MDIFW	287-5254	steve.walker@maine.gov
Tom Schaeffer		MDIFW	434-5927	
Gregory Burr	Regional Fisheries Biologist	MDEP	434-5925	Gregory.Burr@maine.gov
Todd Burrows		State Planning Office		
Stephen Dickson, PhD	State Marine Geologist	M Geological Survey	287-7174	stephen.m.dickson@Maine.gov
Dan Prichard	Submerged Lands Program	Bureau of Parks & Lands, DOC	287-4919	Dan.Prichard@Maine.gov
JNLeith SmithPhd	Maine Historic Preservation	Historic Preservationist,	287-8304	leith.smith@maine.gov
Arthur Spiess	Maine Historic Preservation	Senior Archaeologist, prehistoric archaeology	287-2789	arthur.spiess@maine.gov
Robin Reed	MHPC		287-2992	
Brian M. Swan	Environmental Coordinator	ME DMR	624-6573 633-9510	brian.swan@maine.gov
Gail Wipplelhauser	Marine Resources Scientist	ME DMR	624-6349	gail.wippelhauser@maine.gov

Federal Regulators

Name	Position	Organization	Telephone (207)-	e-mail
Michael R. Johnson	Fishery Biologist Habitat Conservation Division	NMSF, NOAA	978-281-9130	mike.r.johnson@noaa.gov
Dan Tierney	Fisheries biologist	NOAA, Fisheries	207-866-3755,	dan.tierney@noaa.gov
Jeanine Cody	Office of Protected Resources	NMFS, NOAA	301-713-2289	Jeannine.Cody@noaa.gov
Christine Red Cloud	BIA			

Andrew Raddantz			614-654-6838	

USACE

Name	Position	Organization	Telephone (207)-	e-mail
Jay Clement		USACE	623-8367	Jay.L.Clement@usace.army.mil
Shawn Mahaney		USACE		Shawn.mahaney@usace.army.mil

Maine PUC

Name	Position	Telephone (207)	e-mail
Christine R. Cook	Utility Analyst/Attorney	287-1392	christine.r.cook@maine.gov
Jason Rauch	Utility Analyst	287-1370	jason.rauch@maine.gov
Sarah B. Tracy	Staff Attorney	287-5901	sarah.b.tracy@main.gov
Mitchell Tannenbaum			

Maine Government

Name	Position	Telephone (207)	e-mail
Kenneth C. Fletcher	Director, Office of Energy Independence and Security		Kenneth.C.Fletcher@maine.gov
John Baldacci	Governor		

Finance Authority of Maine (FAME)

Name	Position	Telephone (207)	e-mail
Charles Emmons	Senior Commercial Loan Officer	620-3510	cemmons@famemaine.com
Christopher H. Roney	General Council	620-3520	croney@famemaine.com

Washington County

Name	Position	Organization	Telephone (207)	e-mail
Harold Clossey	Executive Director	Sunrise County Economic Council	255-0983 Cell 214-3600	hclossey@sunrisecounty.org
Betsy Fitzgerald	Washington County Manager		255-3127 Cell 255-3313	manager@washingtoncountymaine.com

Utilities & Transmission

Name	Position	Organization	Telephone (207)	e-mail
Debbie Manning		Bangor Hydro	973-2533	dmanning@bhe.com
Jeff H. Fenn	Director of Electrical Engineering	SGC	866-8501 Cell 478-6522	jfenn@sgceng.com
AndrewJ.Perkins	Senior Project Manager	SGC Engineering	866-6501 Cell 745-4700	aperkins@sgceng.com
Scott Hallowell	Chief Executive Officer	Eastern Maine Electric Cooperativ	454-7555 Ext 128	scotth@emec.com

Pembroke

Name	Position	Telephone (207)	e-mail
Milan Jamieson	Selectman (Chairman)	Cell 263-6867 726-4243	milanjamieson@hotmail.com
Joyce Johnson	Selectman	726-4216	
Alan Pulk	Selectman	726-5848	clerk@pembrokemaine.org
Frederick Gralenski			

Other Contacts

Name	Organization	Telephone	e-mail
Christopher Bartlett	Maine Sea Grant/U of Maine	853-2518 ext 105	cbartlett@maine.edu
Will Hopkins	Cobscook Bay Resource Center	207-853-6607	Cobscook@myfairpoint.net
Jim McCleave	U. Maine Orono	(207) 581-4392	mccleave@maine.edu
Gayle Zydlewski	U. Maine Orono	(207- 581-4365	gayle.zydlewski@maine
Debbie Manning	Bangor Hydro		

Other Contacts

Name	Organization	Telephone	e-mail
Steve Crawford	Environmental Director	Cell 207-214-8366 Tribal Office 853-2600	
Bob Peacock	Chairman, Easport City Council	207-733-5556	
Jonathan Southern	Eastport City Manager	207.853.2300	

Name (retired)	Organization	Telephone	e-mail
Dana Paul Murch	ME DEP	287-7784	dana.p.murch@maine.gov
Steven Timpano	MDIFW		

§ 5.6(e) If applicable, the applicant must also provide a statement of whether or not it will seek benefits under section 210 of the Public Utility Regulatory Policies Act of 1978 (PURPA) by satisfying the requirements for qualifying hydroelectric small power production facilities in §292.203 of this chapter. If benefits under section 210 of PURPA are sought, a statement of whether or not the applicant believes the project is located at a new dam or diversion (as that term is defined in §292.202(p) of this chapter), and a request for the agencies' view on that belief, if any.

Not applicable

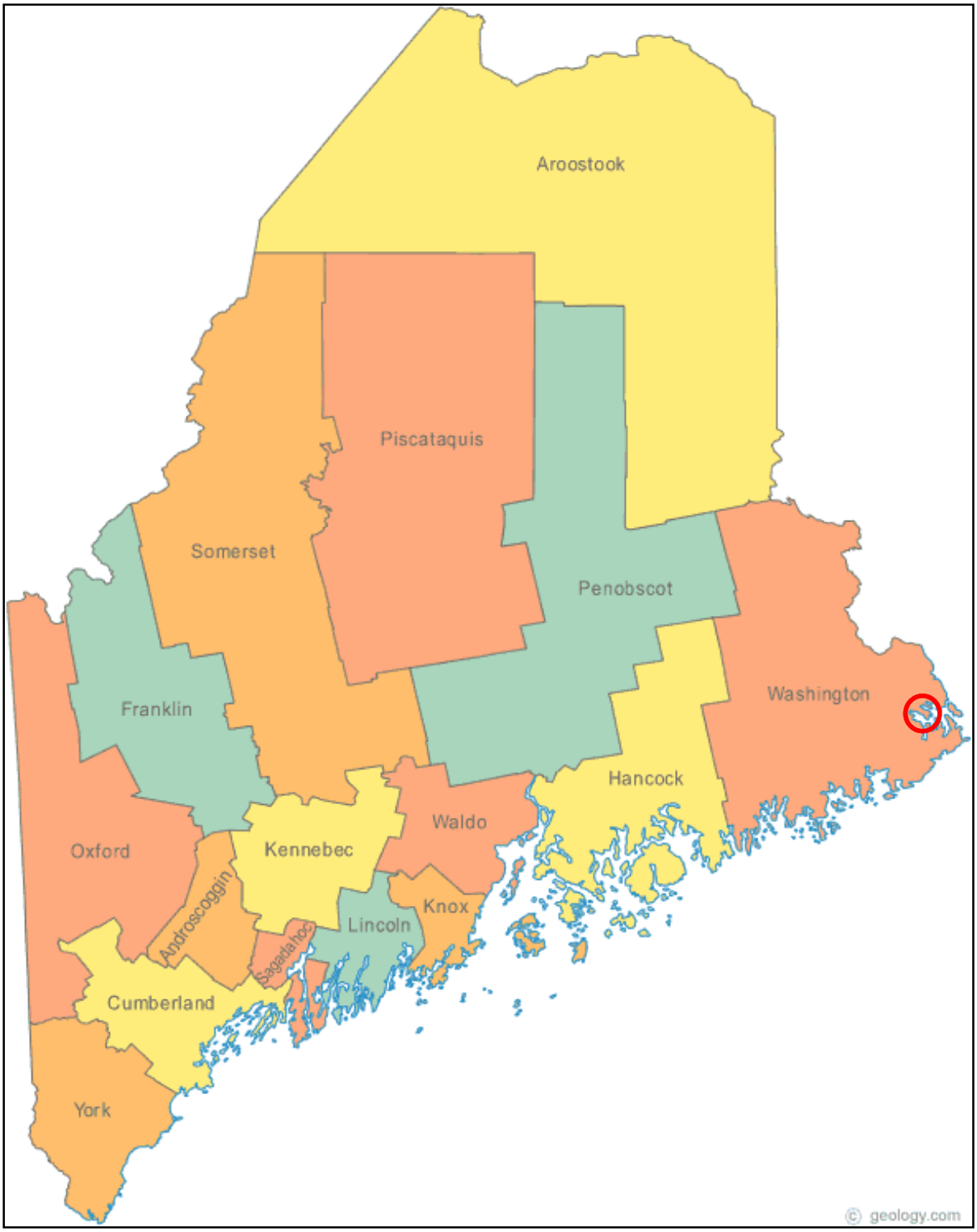

Figure 1. Pennamaquan Tidal Power Plant location - State: Maine, County: Washington. Project location within red circle.

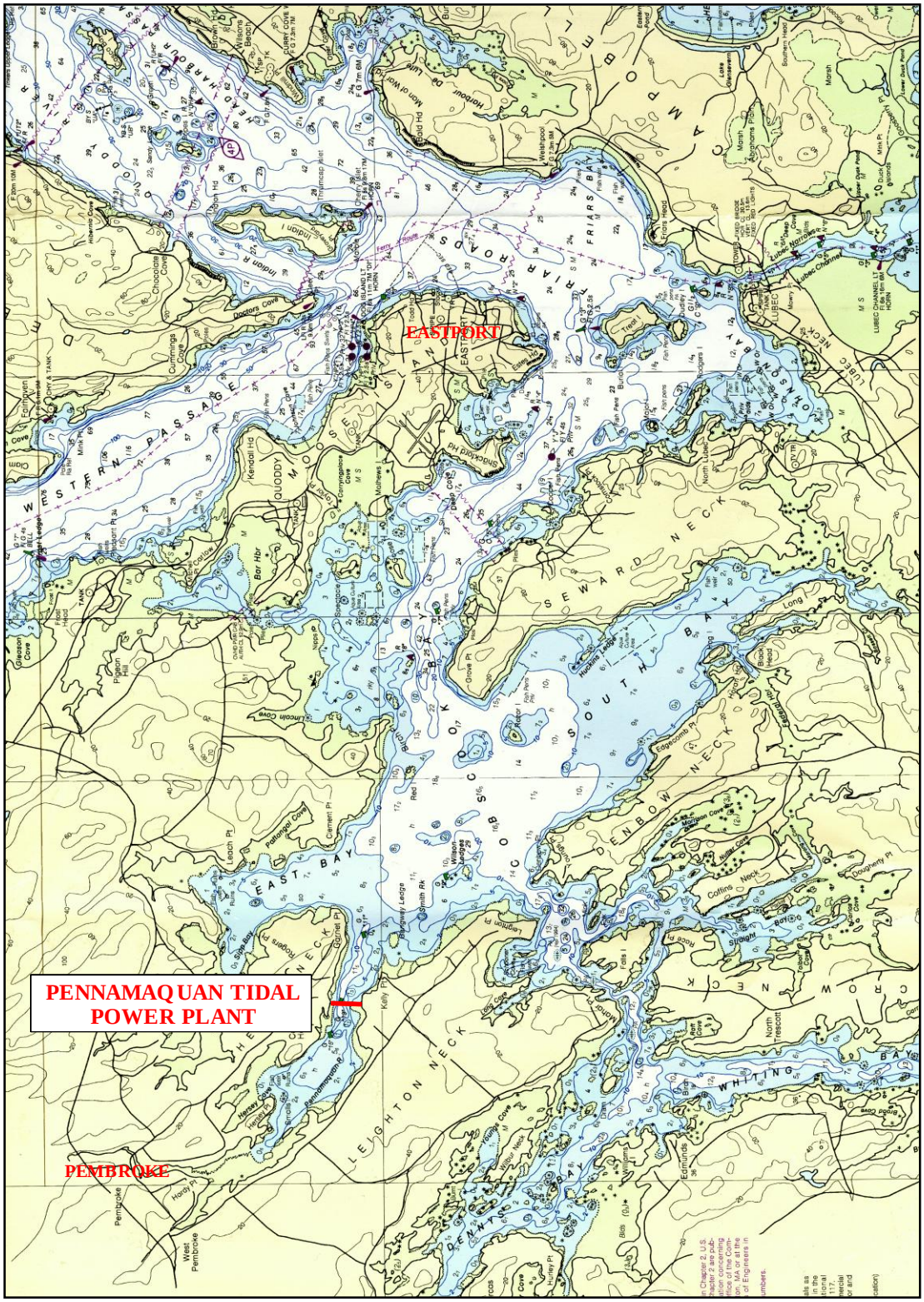

Figure 2. Pennamaquan Tidal Power Plant (shown as red line) in relation to Cobscook Bay and to the nearby town of Pembroke and the City of Eastport.

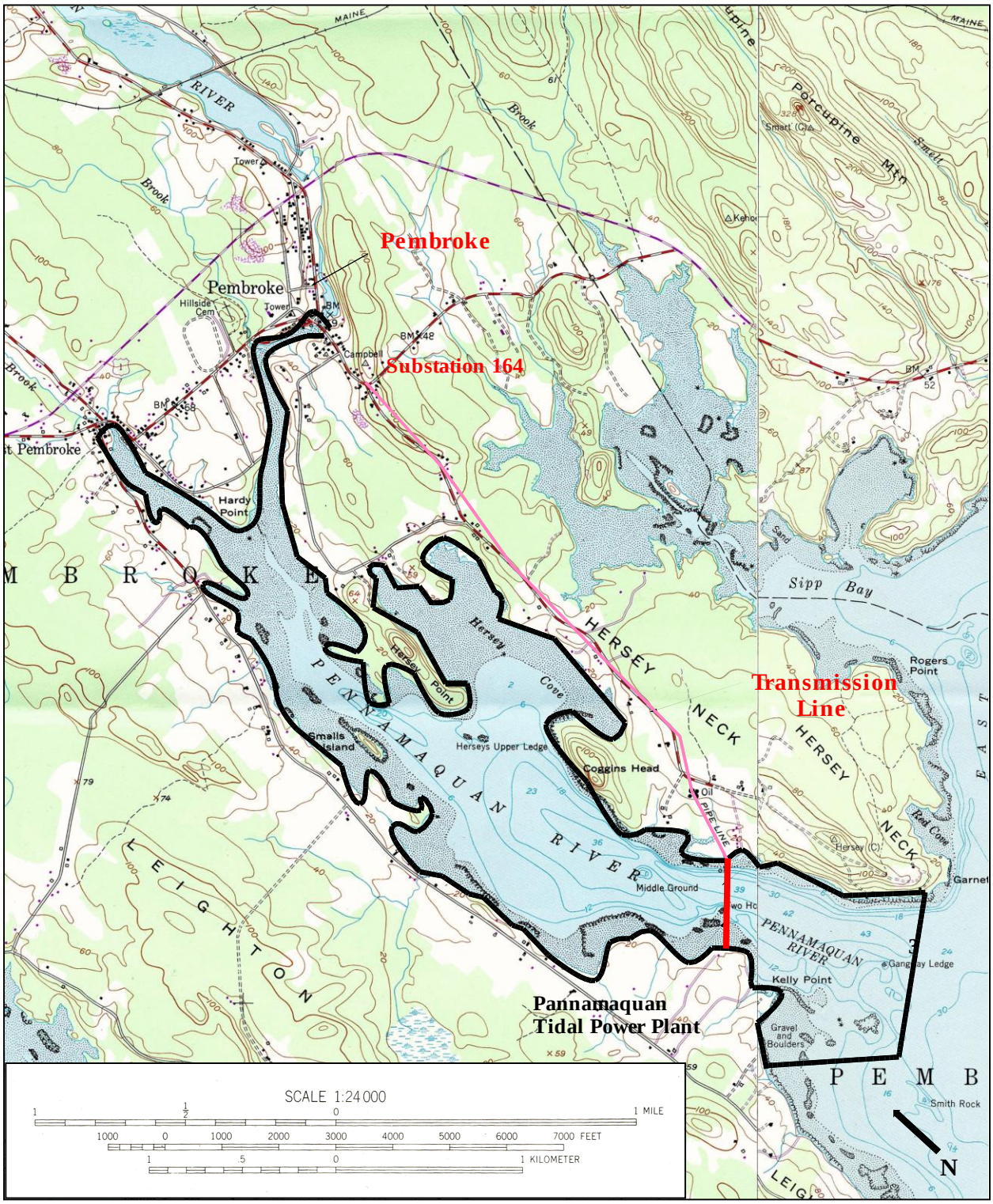

Figure 3. Boundary Pennamaquan Tidal Power Plant Project together with the transmission line to substation 164 in Pembroke.

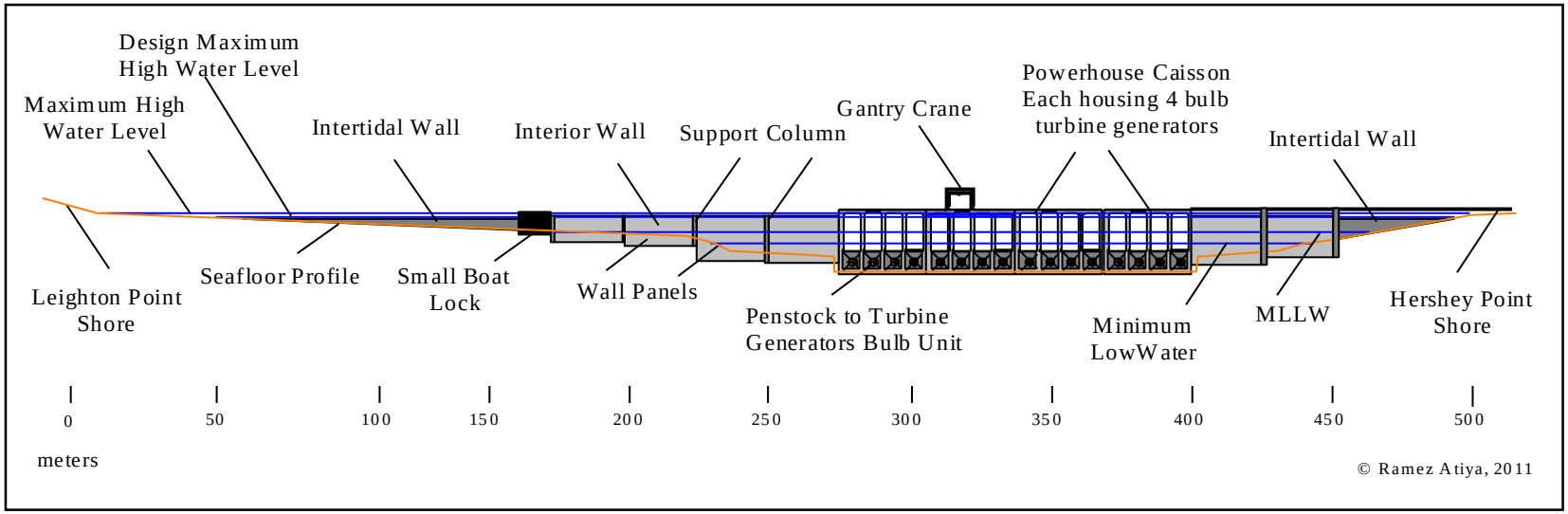

Figure 4. Pennamaquan Tidal Power Plant Layout

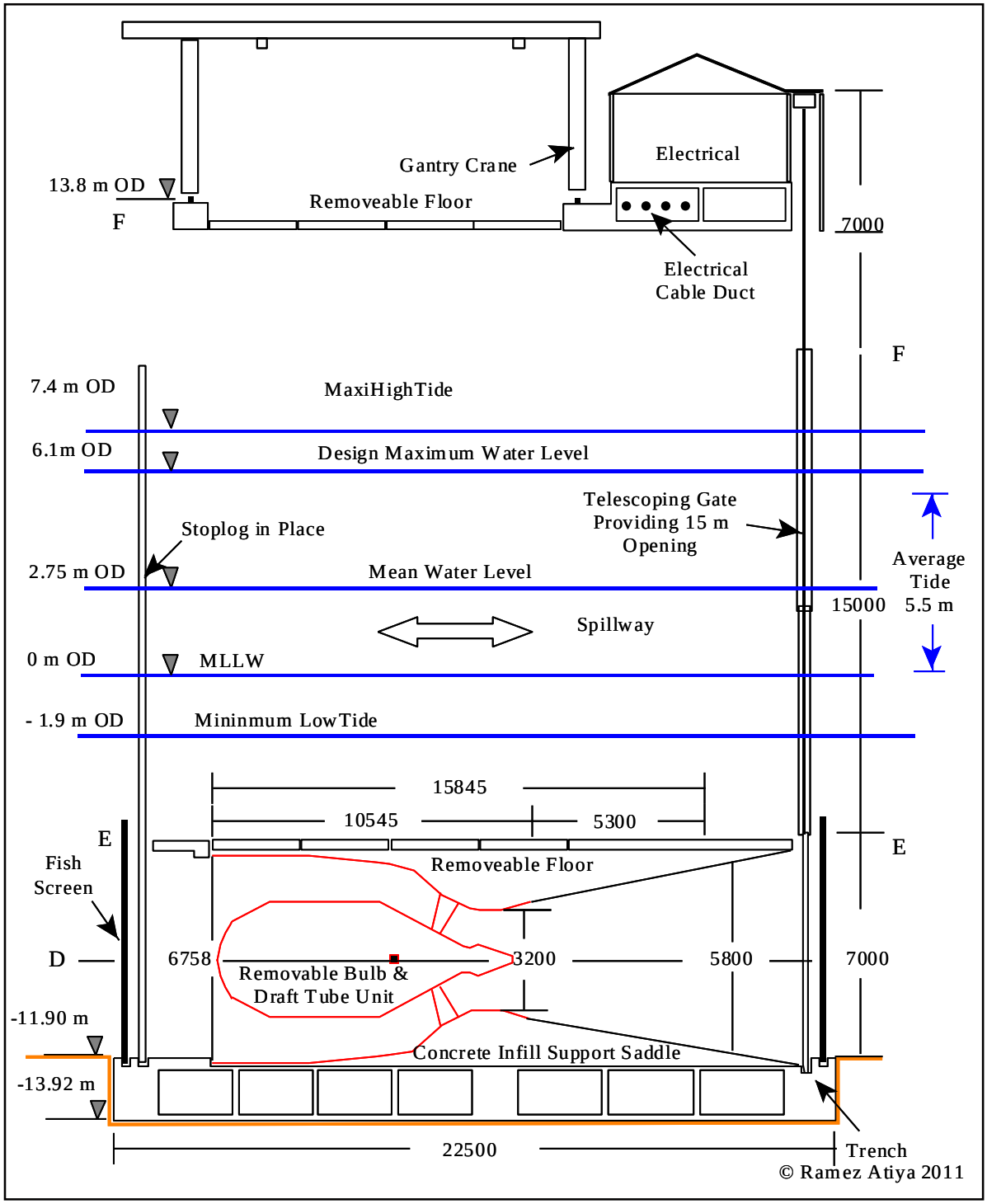

Figure 5.1 Caisson Section - Side View

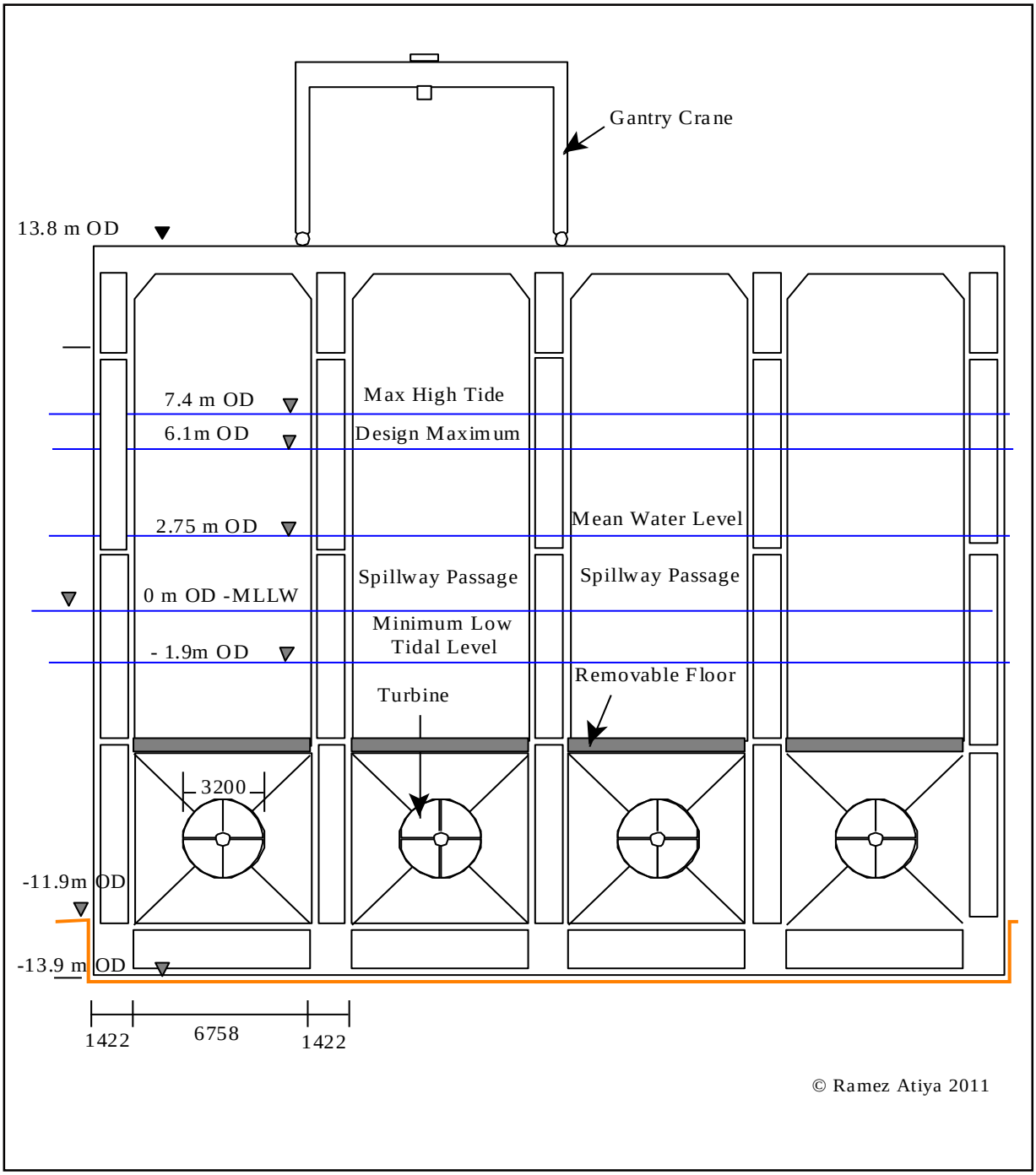

Figure 5.2 Caisson Section - Front View

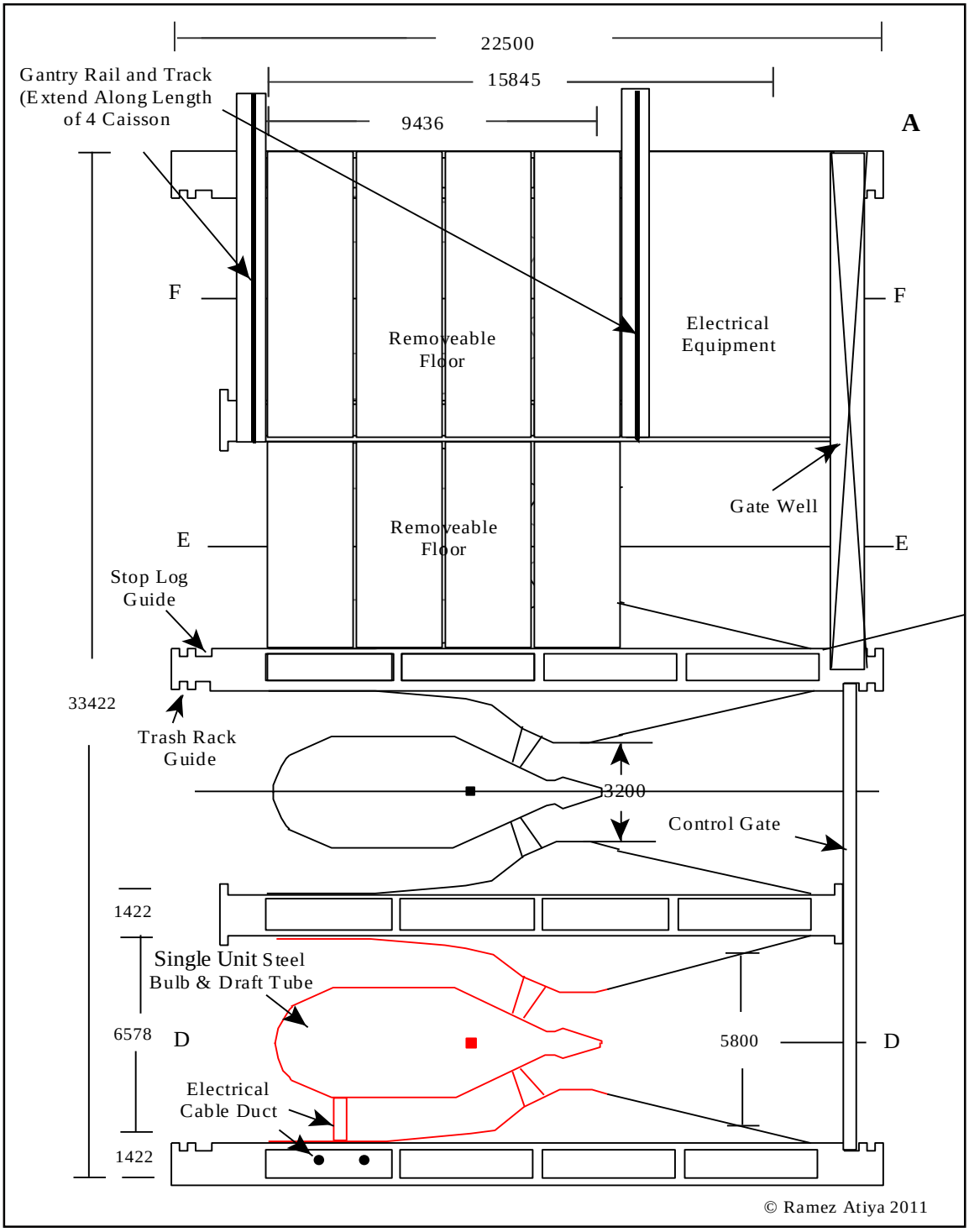

Figure 5.3 Caisson Plan

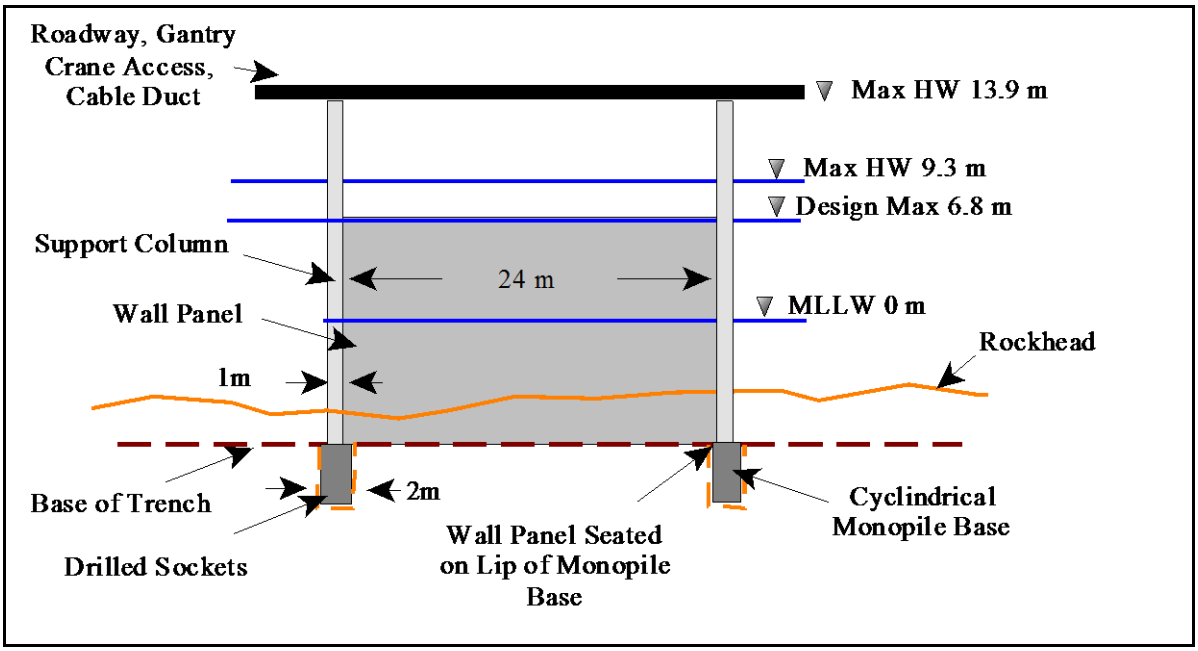

Figure 6.a Wall Section secured between two Support Columns.

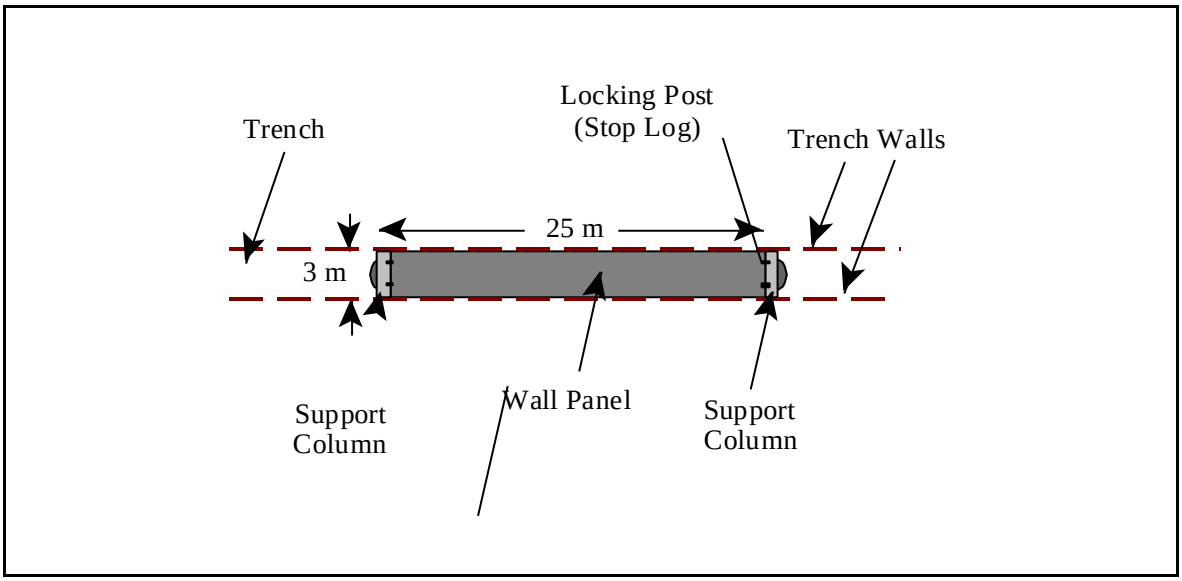

Figure 6.b Wall Section secured between two Support Column – top view.

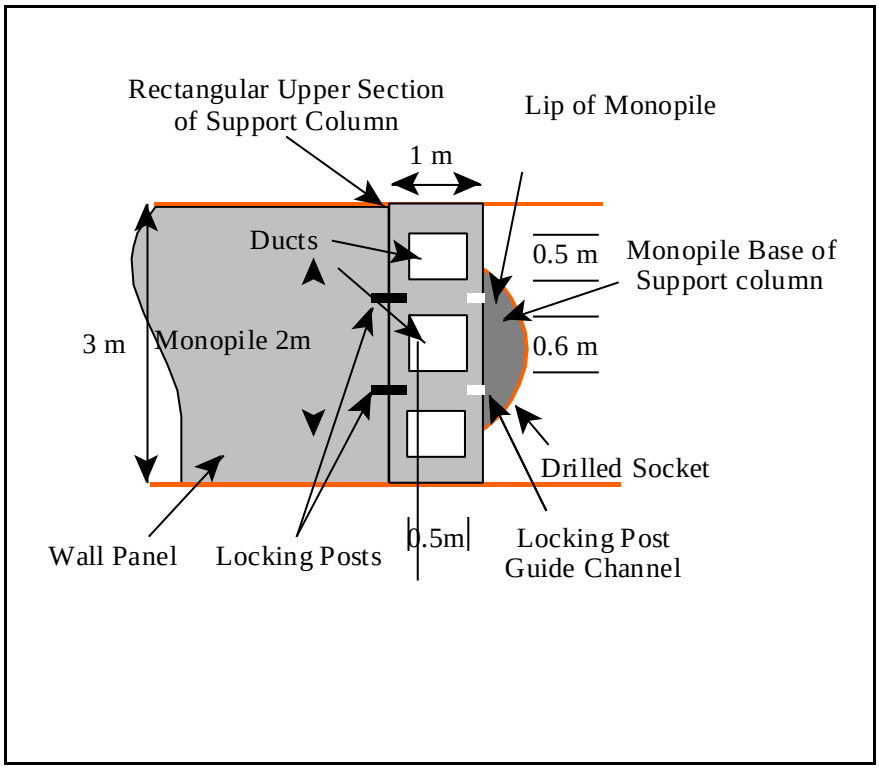

Figure 7 a - Support Column (section top view - Inclined piles not shown)

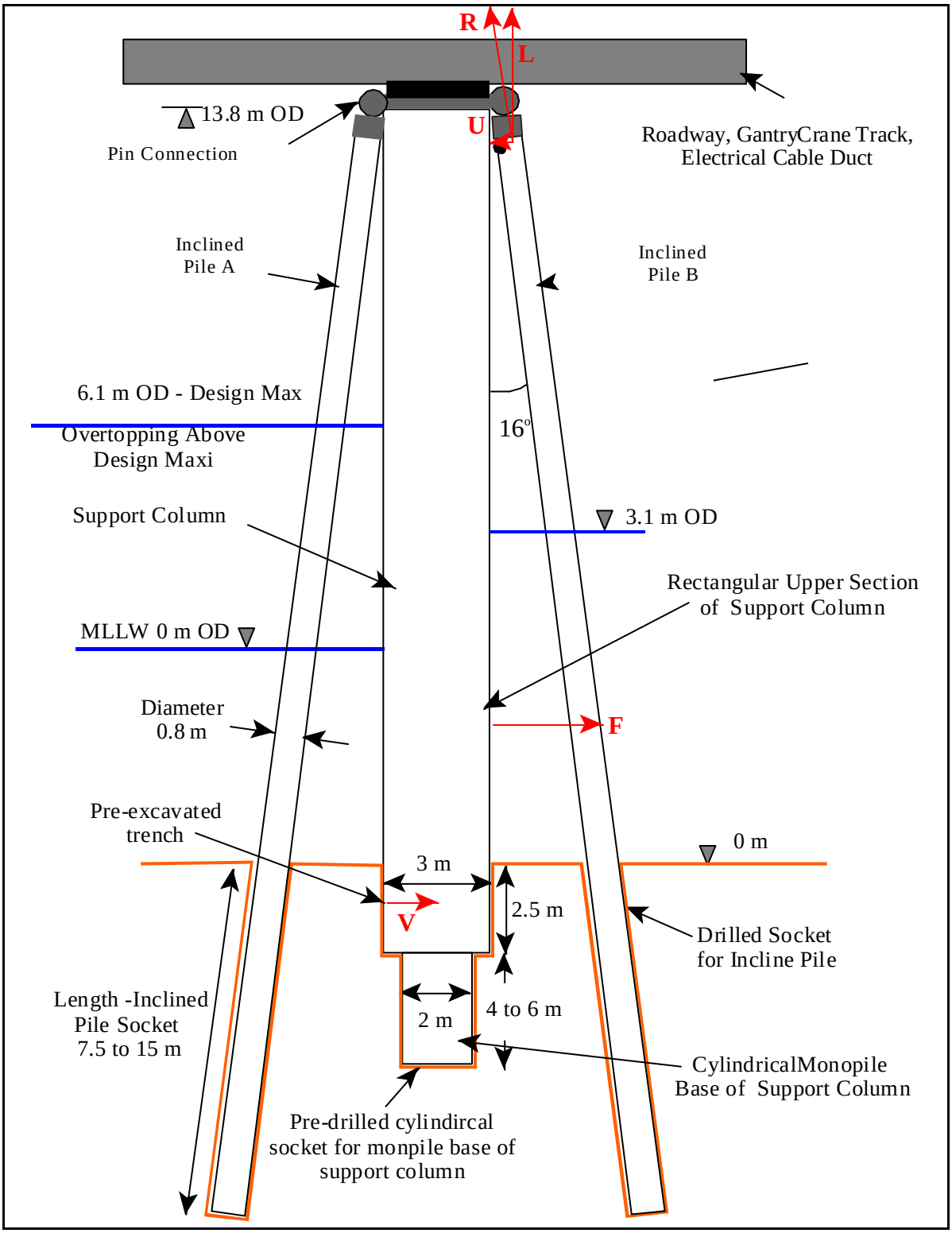

Figure 7 b - Support Column -Side View. Load on column transferred from Wall Panel.

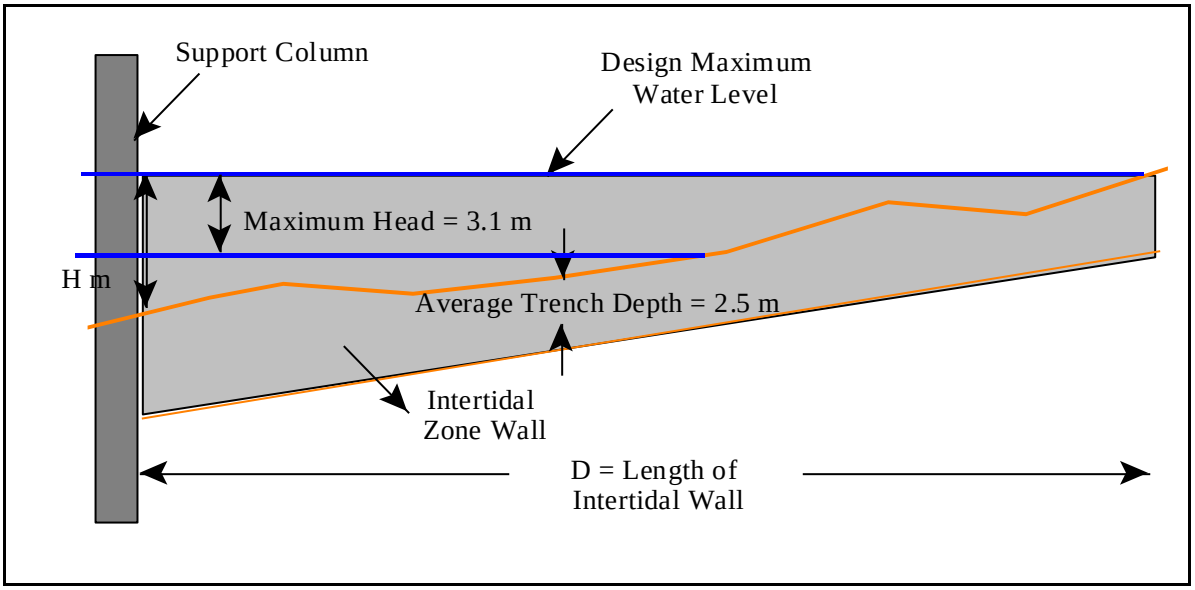

Figure 8 – The Intertidal Wall.

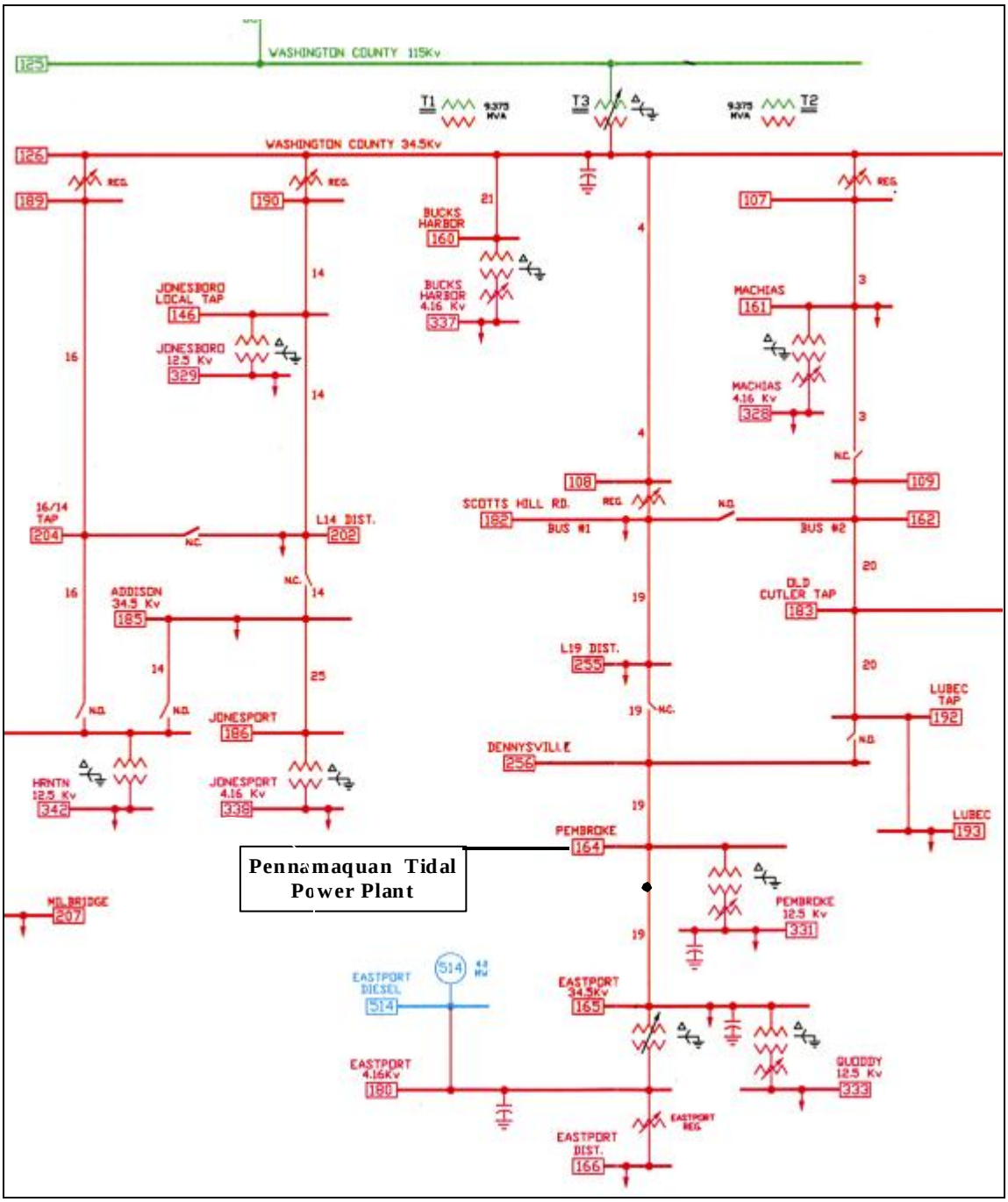

Figure 9 - Transmission grid to the 115 kV line. The line from the Pennamaquan TPP to Pembroke 164 is an existing line running Leighton Point Road.

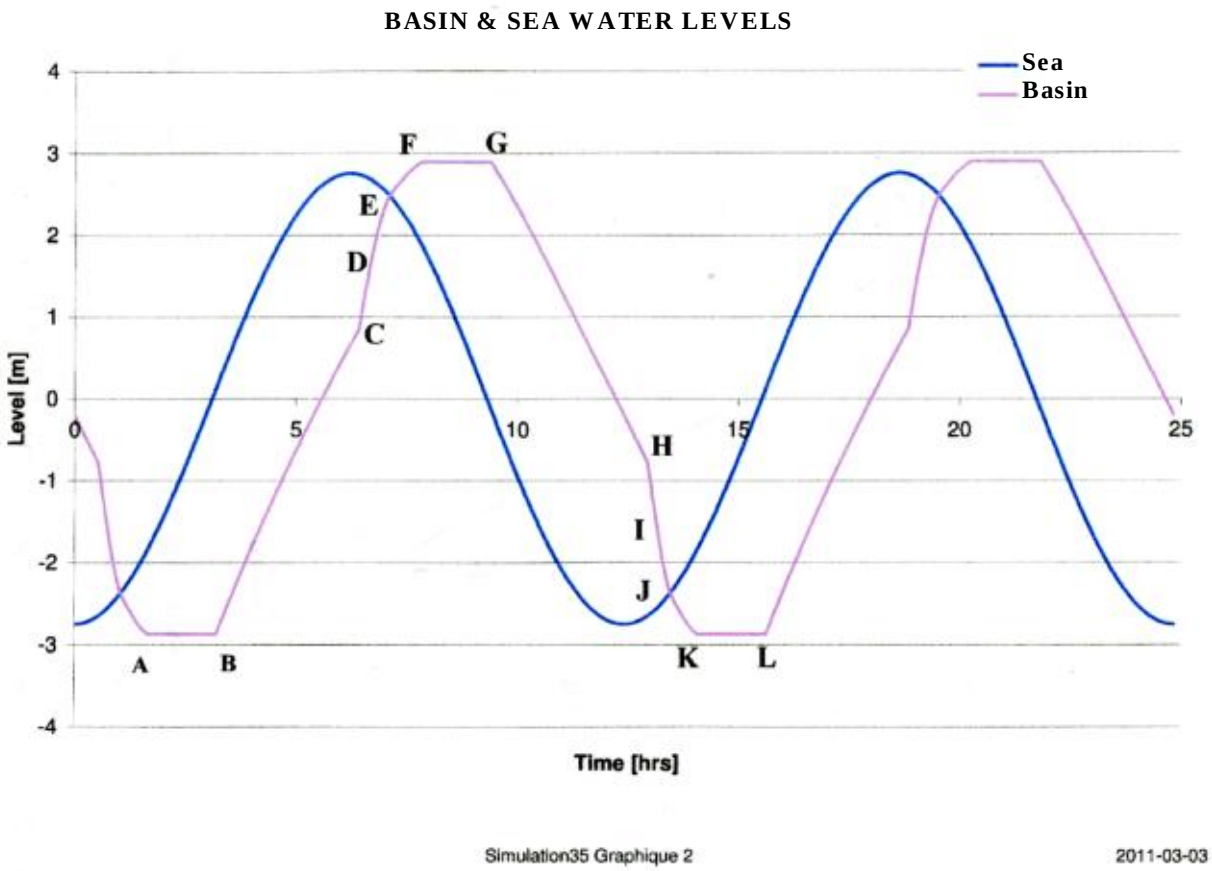

Figure 10.1a (16 turbines – 24 MW installed) The Parallel Cycle for an average tide (tidal range 5.5 m).

Operating Cycle – Time Sequence

Point	Time (hr)	Sea Level (m)	PQ level (m)	Head (m)	Spillway Gate	Turbine Gate	Duration (hours)
A	1.66	- 1.83	-2.78	1.039	Closed	Closed	
B	3.21	0.148	-2.871	3.019	Closed	Open	Δ_{AB} = 1.55
C	6.42	2.73	0.856	1.878	Open	Open	Δ_{BC} = 3.21
D	6.77	2.64	1.89	0.74	Open	Open	Δ_{BD} = 3.56
E	7.11	2.46	2.497	-0.032	Closed	Open	Δ_{CE} = 0.69
F	7.85	1.85	2.980	-1.038	Closed	Closed	
G	9.40	-0.121	2.890	-3.011	Closed	Open	Δ_{FG} = 1.55
H	12.96	-2.4647	-0.788	-1.860	Open	Open	Δ_{GH} = 3.56
I	13.23	-2.521	-1.781	-0.74	Open	Open	Δ_{GI} = 3.83
J	13.50	-2.47	-2.413	0.066	Closed	Open	Δ_{HJ} = 0.54
K	14.10	-1.833	-2.871	1.039	Closed	Closed	
L	15.60	0.148	-0.871	3.019	Closed	Open	Δ_{KL} = 1.50

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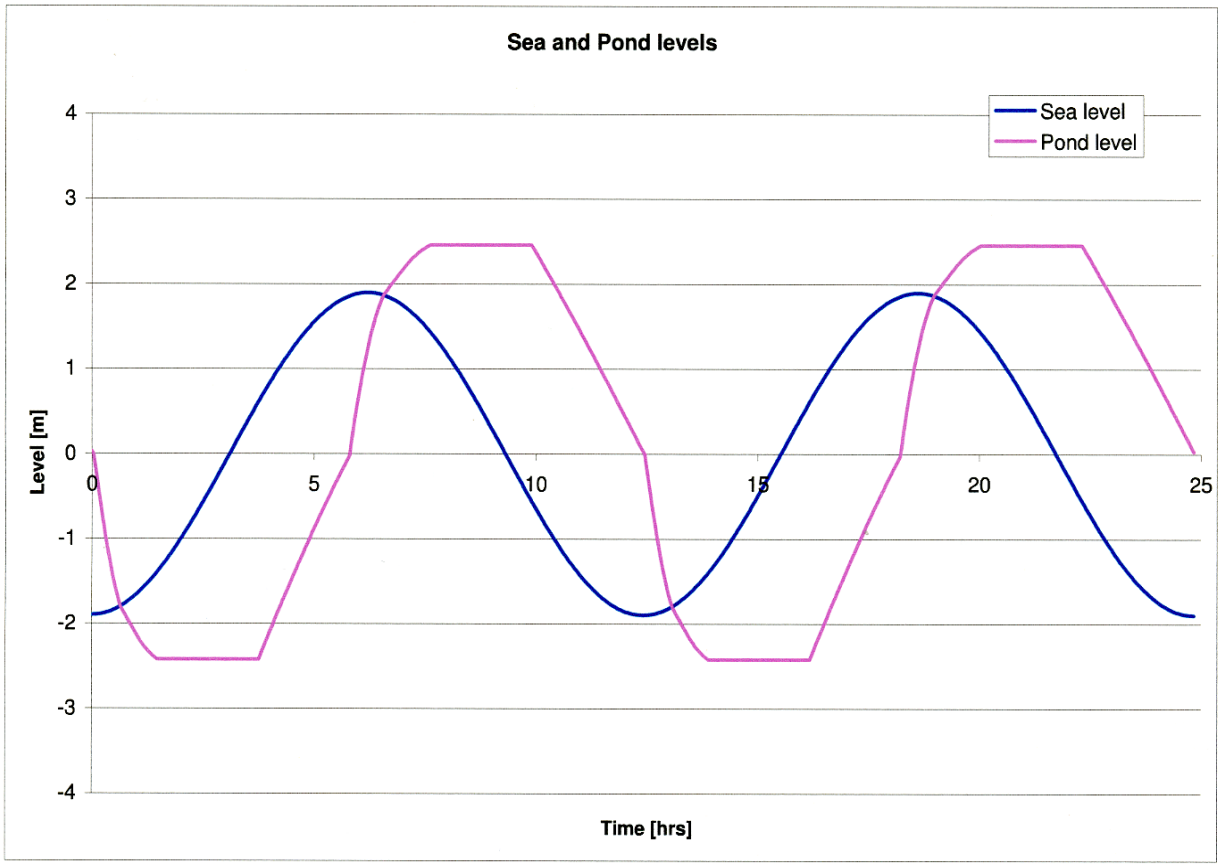

Simulation35_low Graphique 2 2011-03-03

Figure 10.1b (16 turbines – 24 MW installed) The Parallel Cycle at neap tide (tidal range 0.69 average = 3.8 m). Pumping is employed to raise the water levels in order to produce more energy. However, pumping stays within the natural high and low water levels governed by the tides.

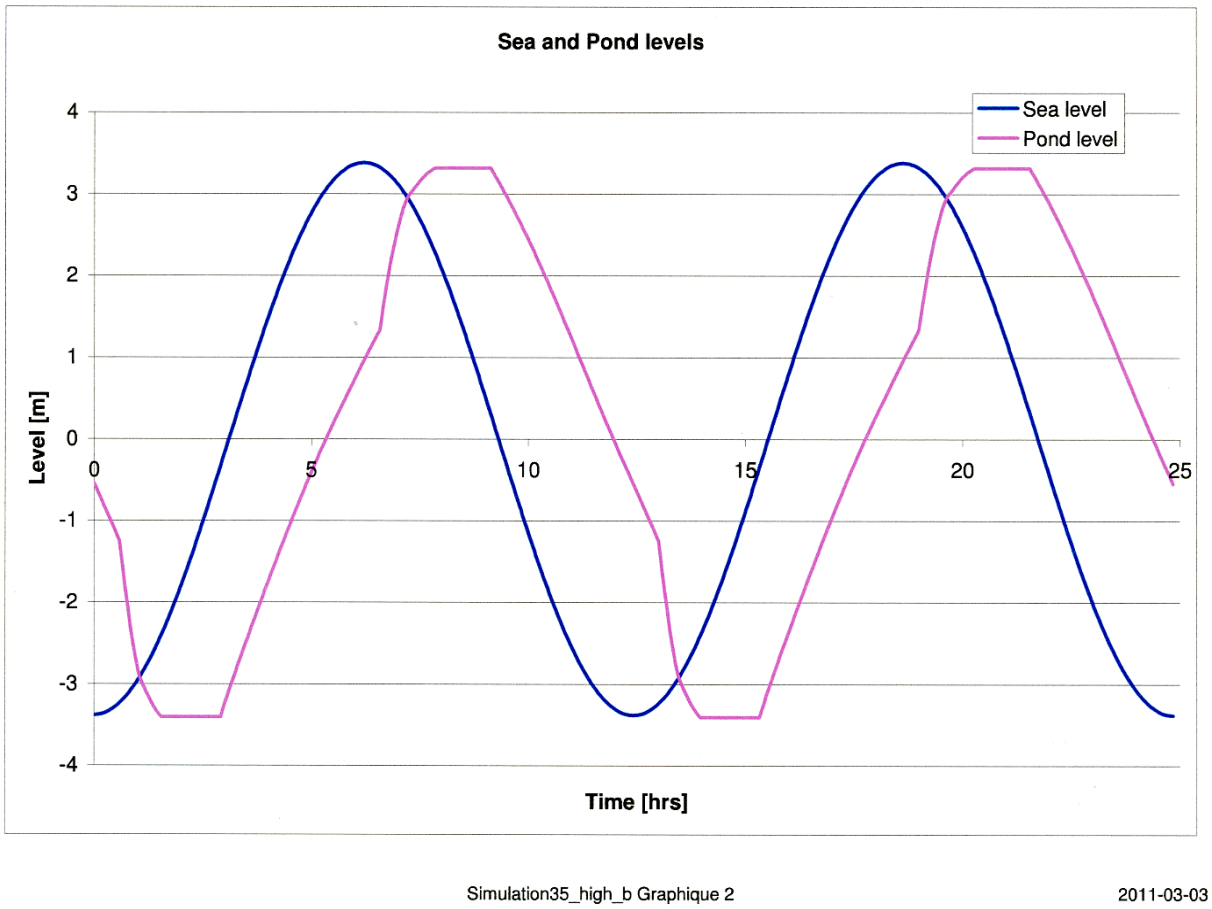

Figure 10.1c (17 turbines – 25.5 MW installed) The Parallel Cycle at spring tide (tidal range 1.23 average = 6.8 m). Pumping is employed to raise the water levels to 99.4 % or to within 3 cm of the natural range.

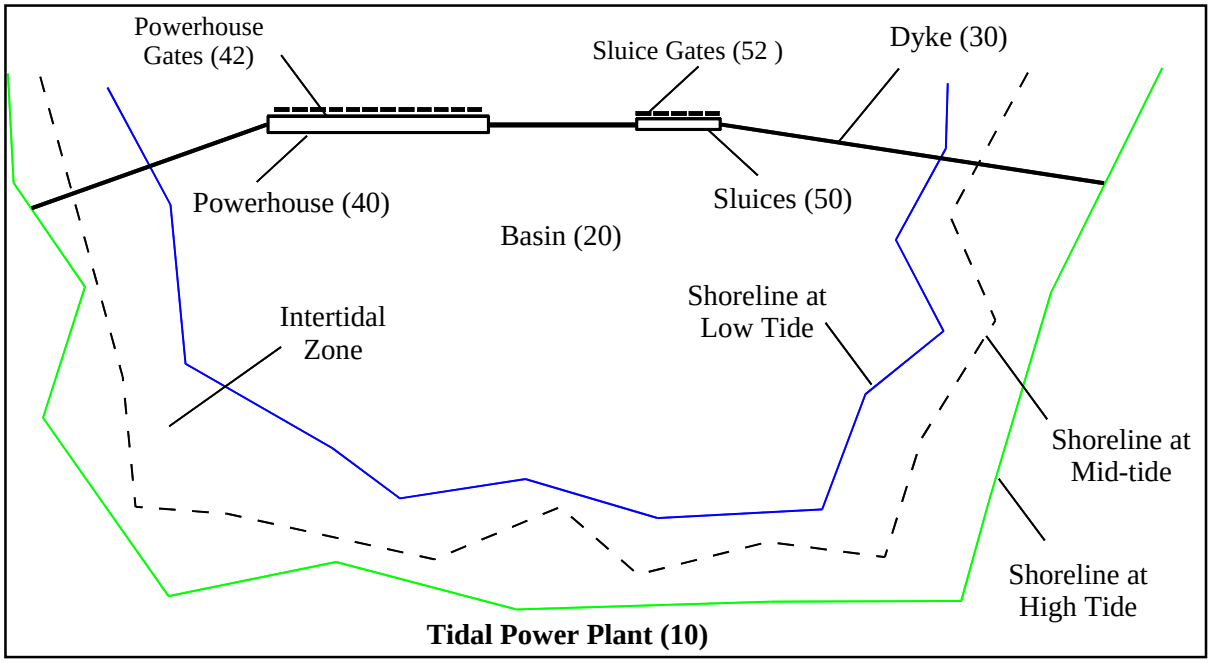

Figure 10.2a - A to B - Resting phase. All gates are closed allowing no flow of water between basin and sea. Water level in the basin is lower than water level in the sea. Water level in the sea is rising with the flooding tide while water level in the basin remains constant.

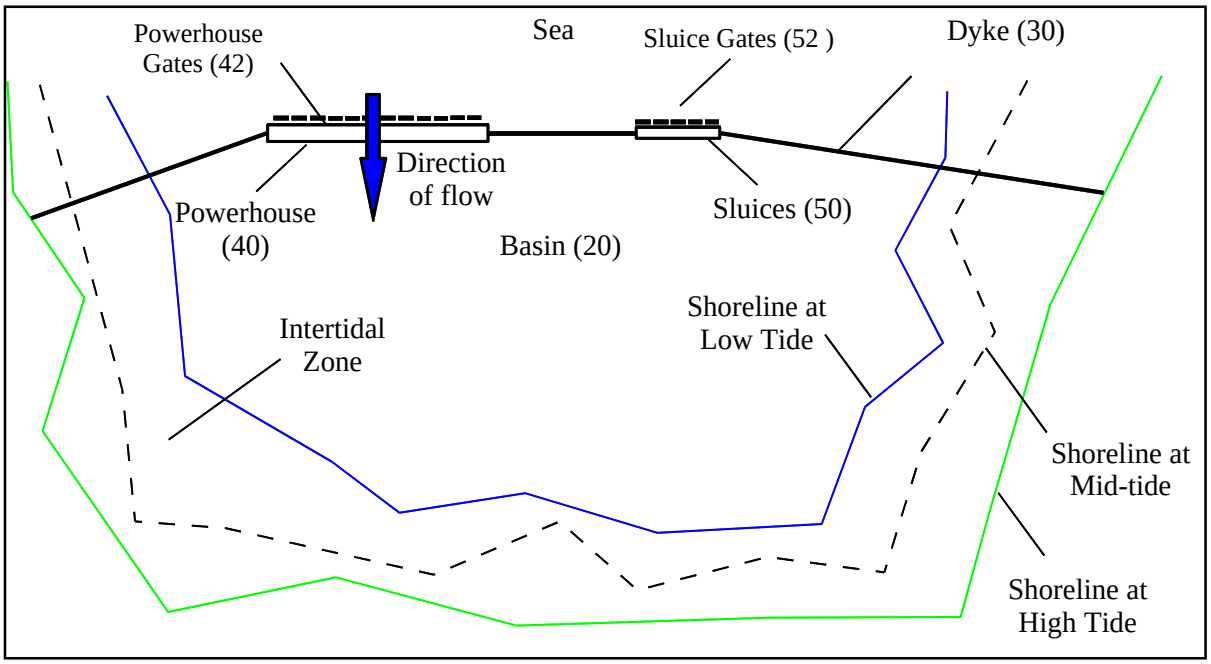

Figure 10.2b - B to C - Flood generation phase. The water level in the sea has risen sufficiently, creating the required differential head to operate the turbine generator. The Powerhouse gates are open, allowing water to pass from sea to basin through the turbine generator power. Water level in sea and basin are both rising.

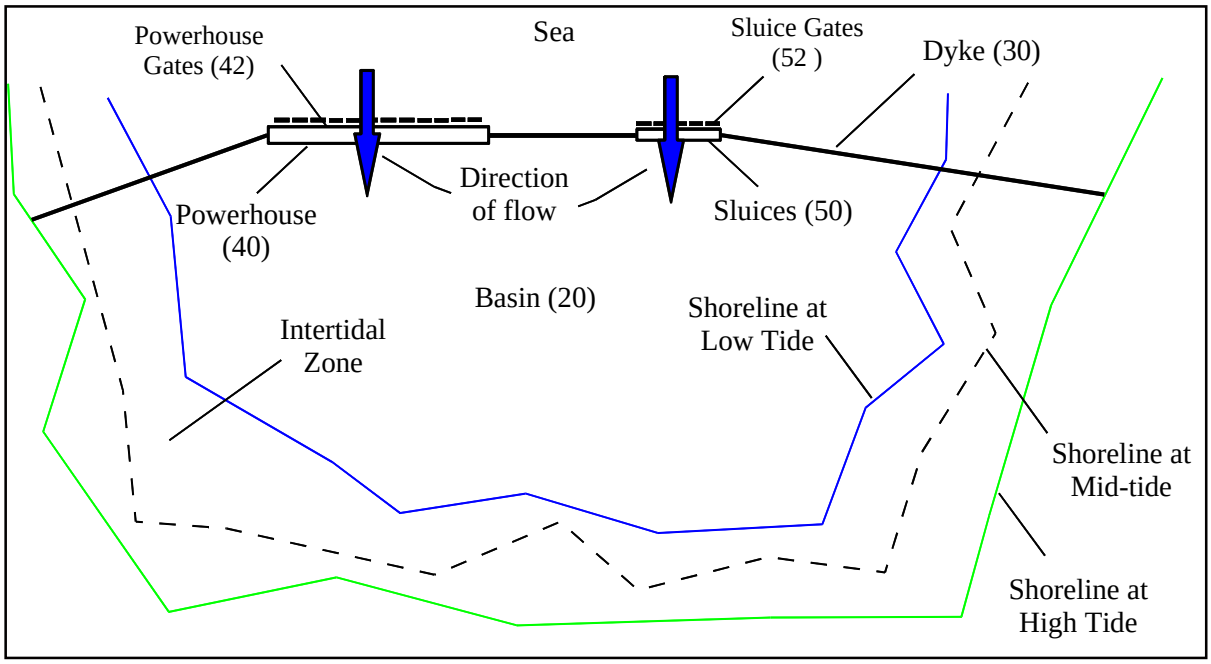

Figure 10.2c - C to D - Sluice gates are opened in order to allow water level in the basin to rise more quickly.

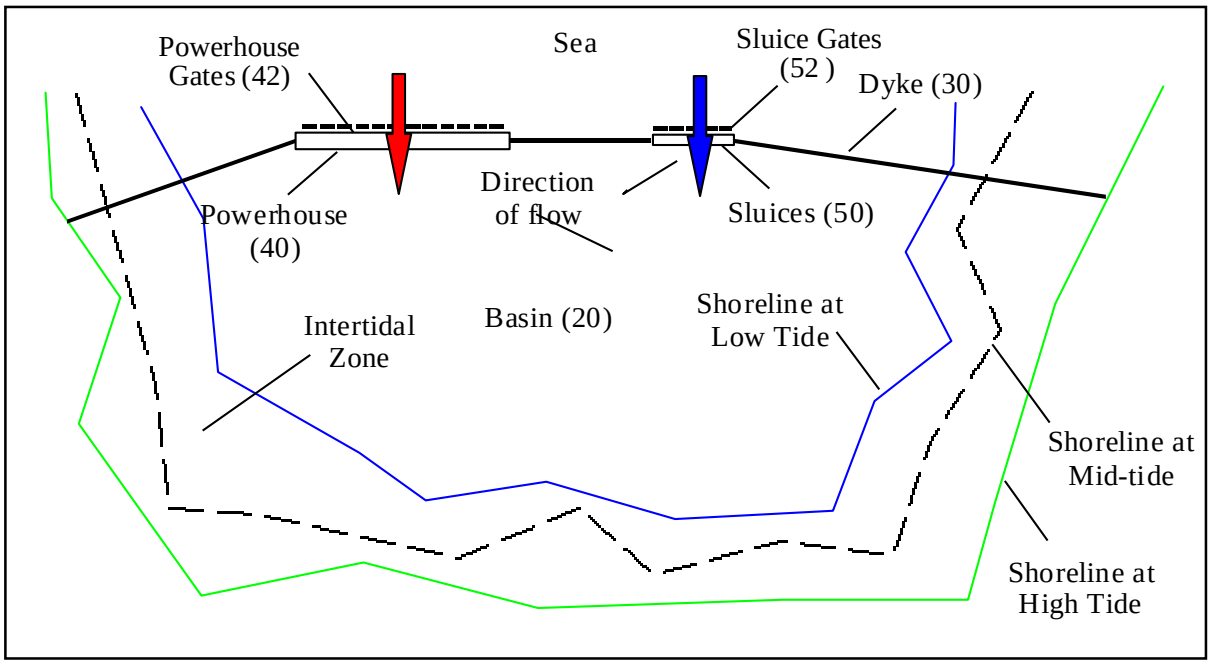

Figure 10.2d - D to E. Differential head between basin and sea is insufficient to operate turbine generator. The turbine generator is operated as a pump to raise water in basin more quickly.

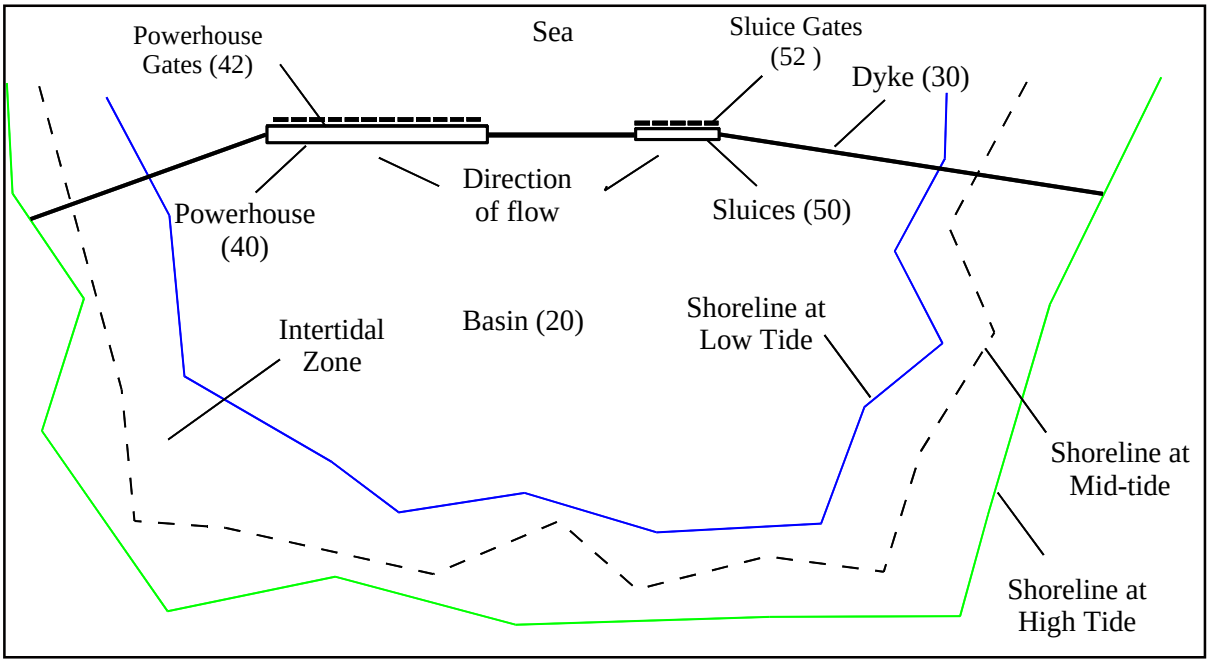

Figure 10.2e - E to F - At E, water levels in basin and sea are equal. The sluice gates are shut. The turbine generators continue to pump, raising the water level in basin to desired level.

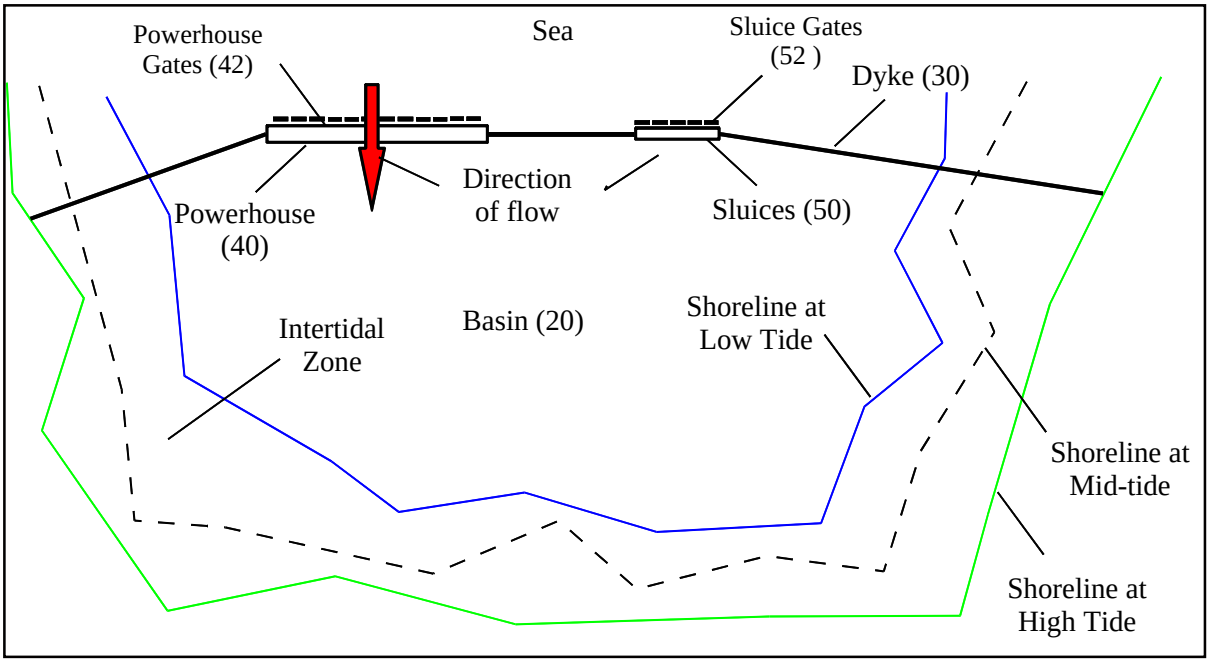

Figure 10.2f - F to G. Resting phase. Water level in basin is kept constant. Water level in sea is falling with ebbing tide.

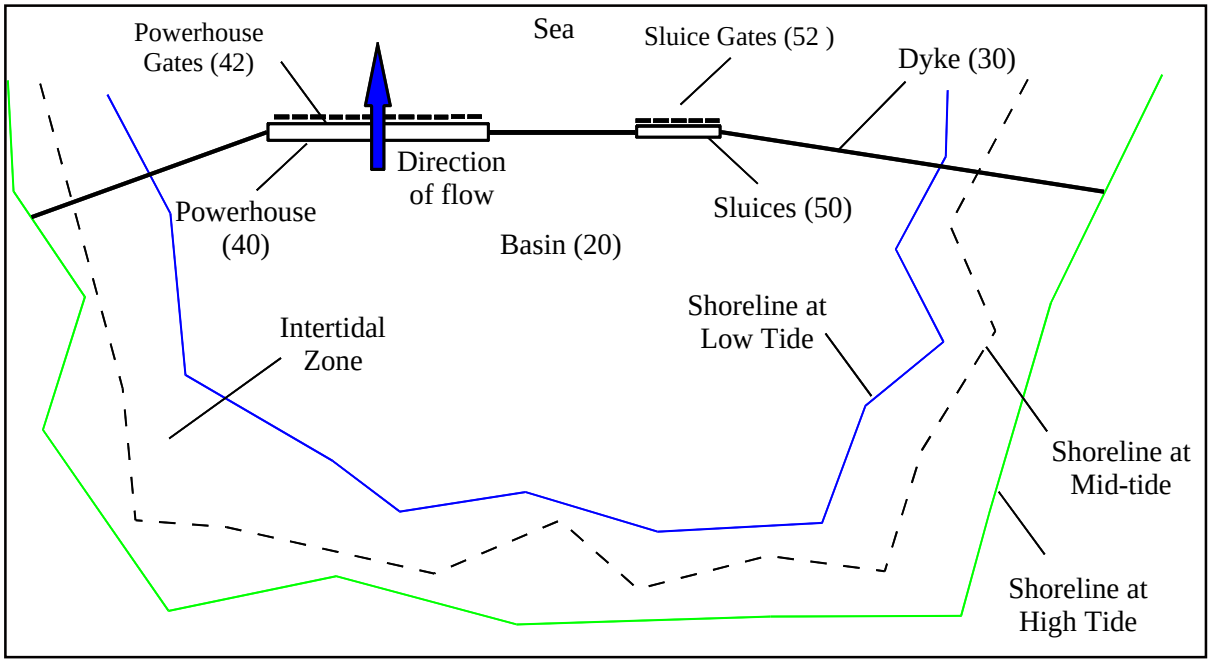

Figure 10.2g - G to H. Ebb generation. Ebbing tide has created sufficient head at E. Powerhouse gates are opened allowing water to flow from basin to sea through turbine generator.

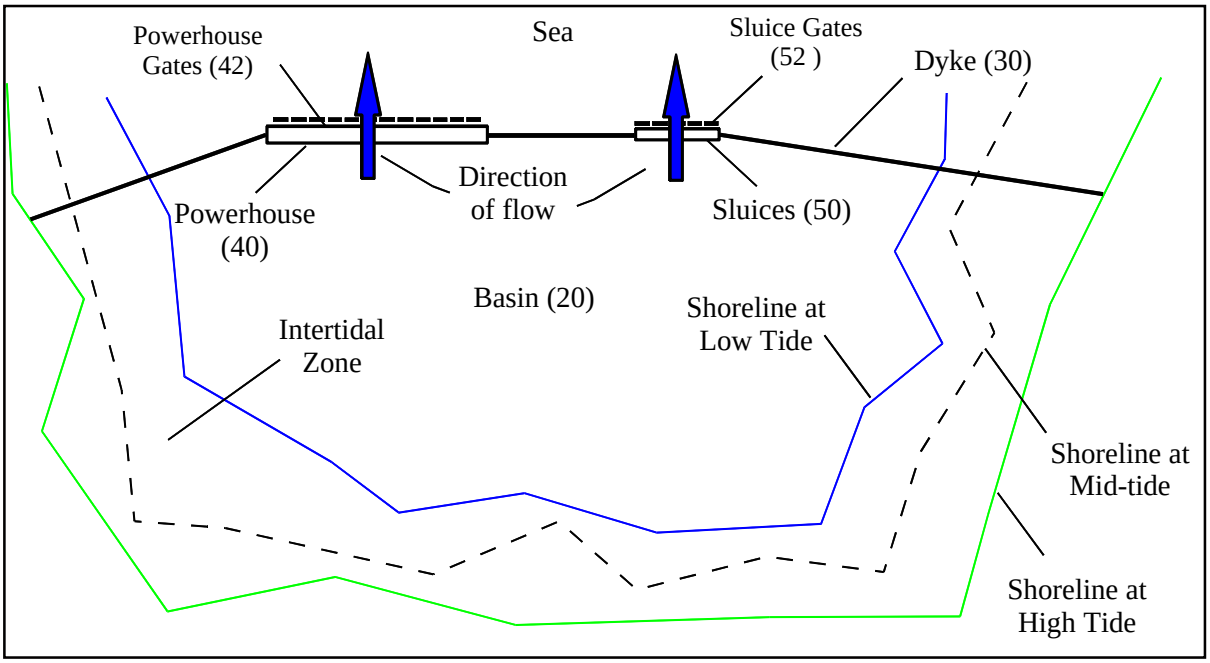

Figure 10.2h - H to I. Sluice gates are opened in order to allow water level in the basin to fall more quickly

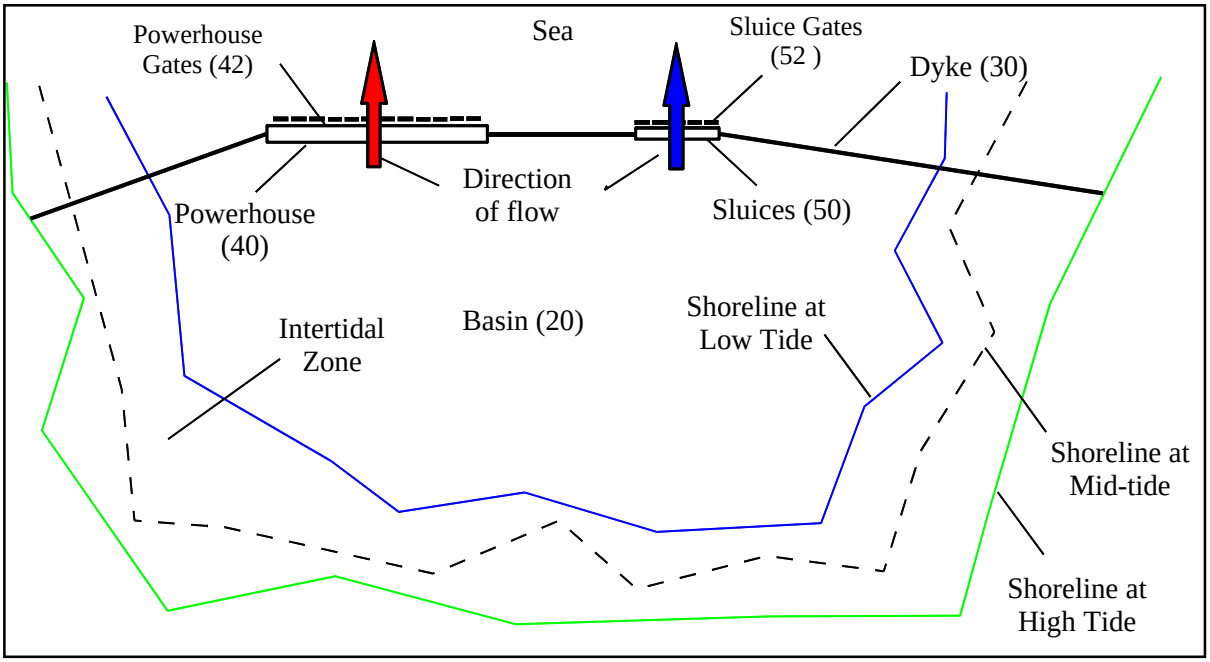

Figure 10.2i - I to J - Sluicing and pumping. Differential head between basin and sea is insufficient to operate turbine generator. The turbine generator is operated as a pump to draw down basin more quickly.

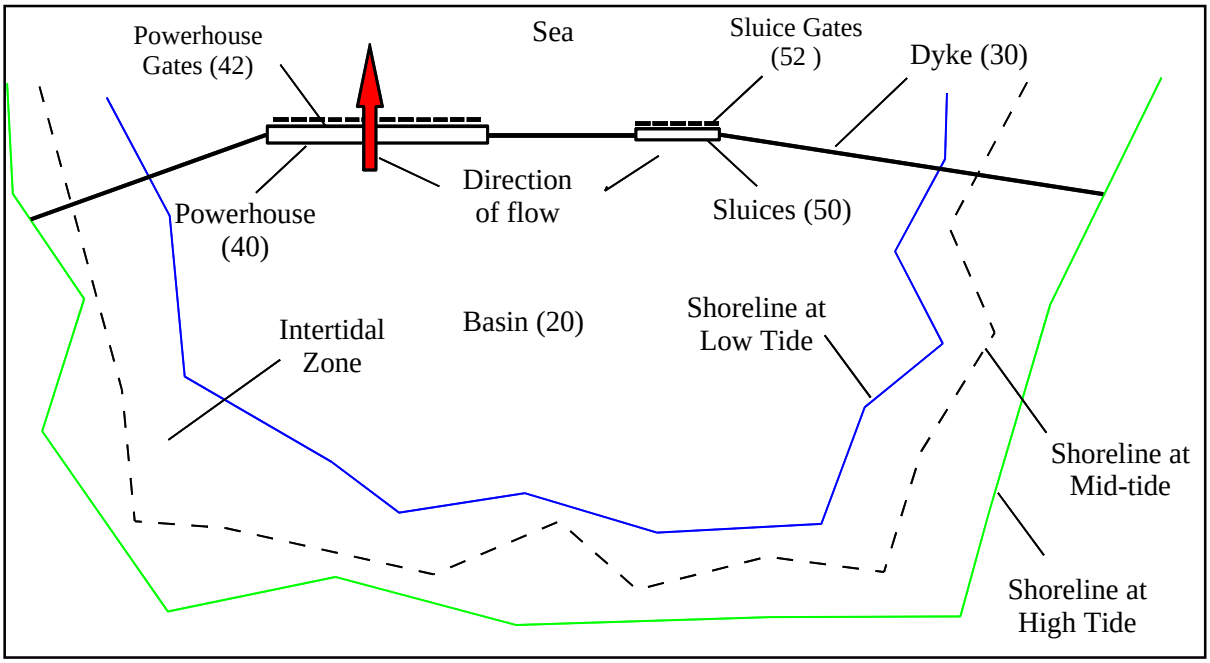

Figure 10.2j - Pumping. At J, water levels in basin and sea are equal. The sluice gates are shut. The turbine generators continue to pump, lowering the water level in basin to desired level.

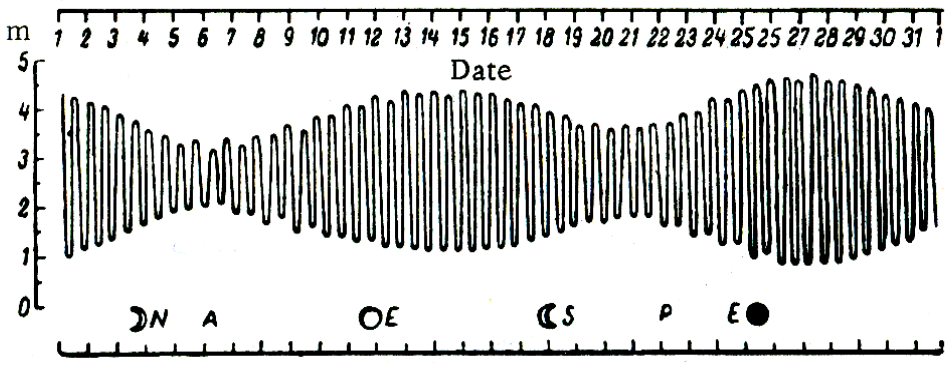

FIGURE 2-4. One-month marigram (curve of tides) for a regular semi-diurnal tide (Sosnovets Island, White Sea)
For the symbols used, cf. Figure 7-5.

Figure 11.a The 29.5 day tidal cycle. [Bernshtein, LB, *Tidal energy for Electric Power Plants*, Translated from Russian by the Israel Program for Scientific Translation, 1965, US Dept. Of Interior and National Science Foundation, p.14)

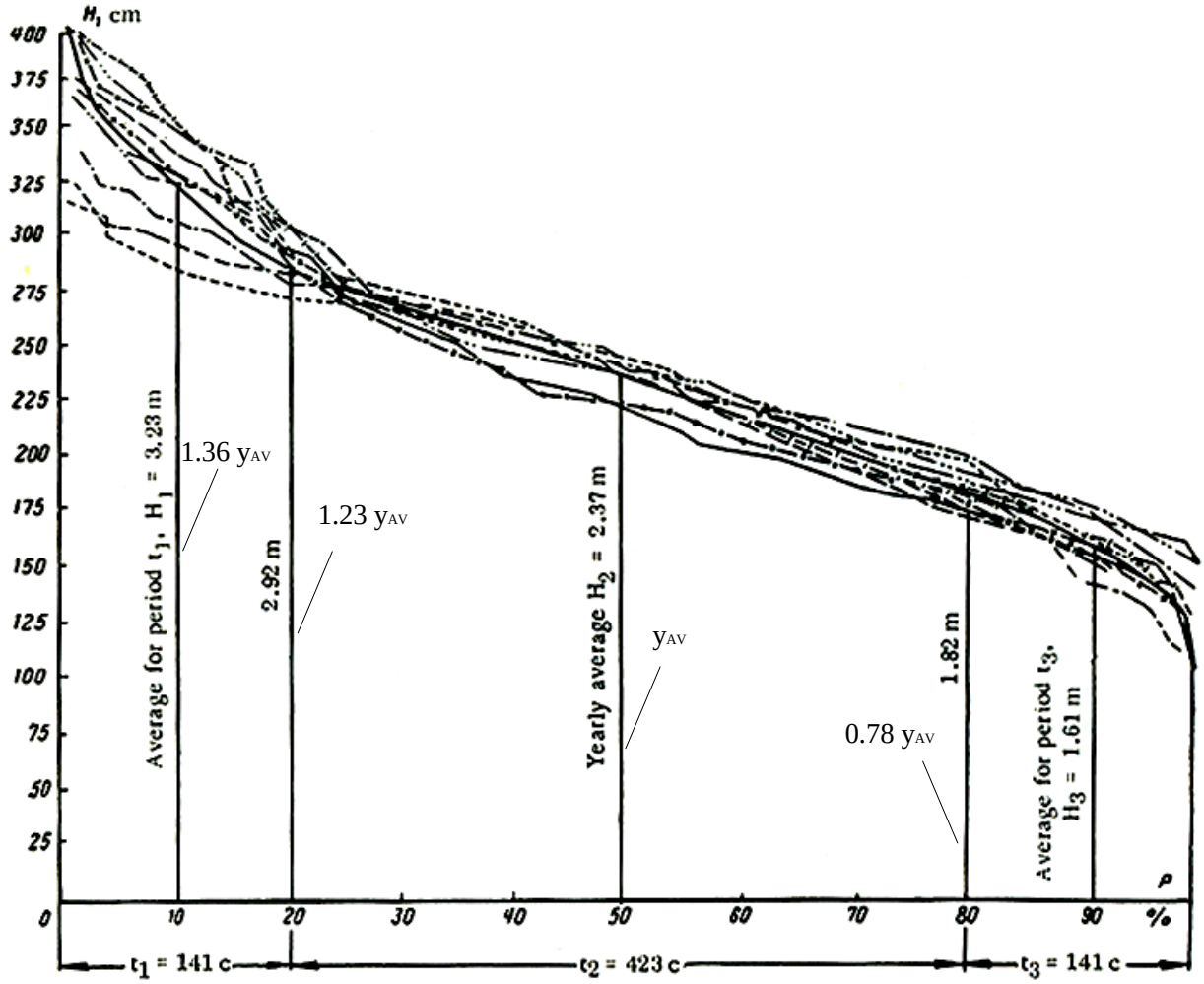

FIGURE 2-3. Probability curves for the frequency of tidal range occurrence in the Kislaya Inlet for each lunar month. The thick line is the annual curve.

Figure 11.b The statistical distribution of tides. y represents an average tide. The figure shows 20 % of tides rising above 1.23 y or falling below 0.78 y. [Bernshtein, LB, *Tidal energy for Electric Power Plants*, Translated from Russian by the Israel Program for Scientific Translation, 1965, US Dept. Of Interior and National Science Foundation, p.14)

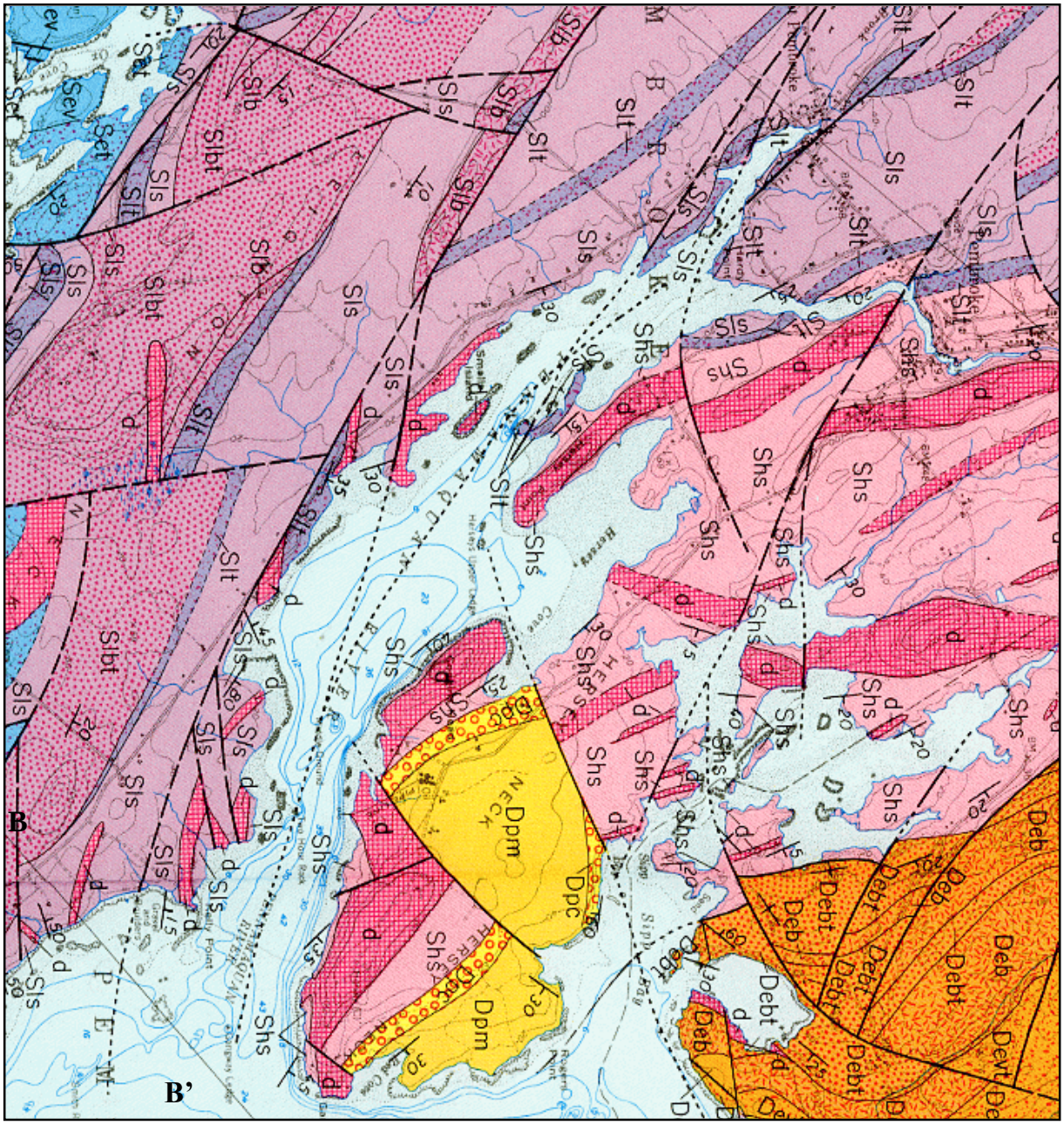

Figure 12.a Geologic Map (From Olcott Gates *Geological Map and Cross Sections of the Eastport Quadrangle*

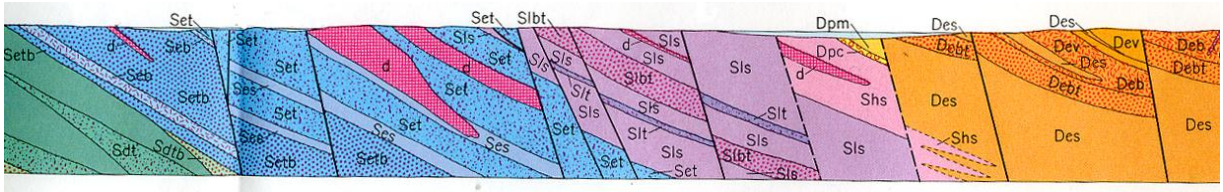

Figure 12.b Cross Section Along B-B' (From Olcott Gates 1975)

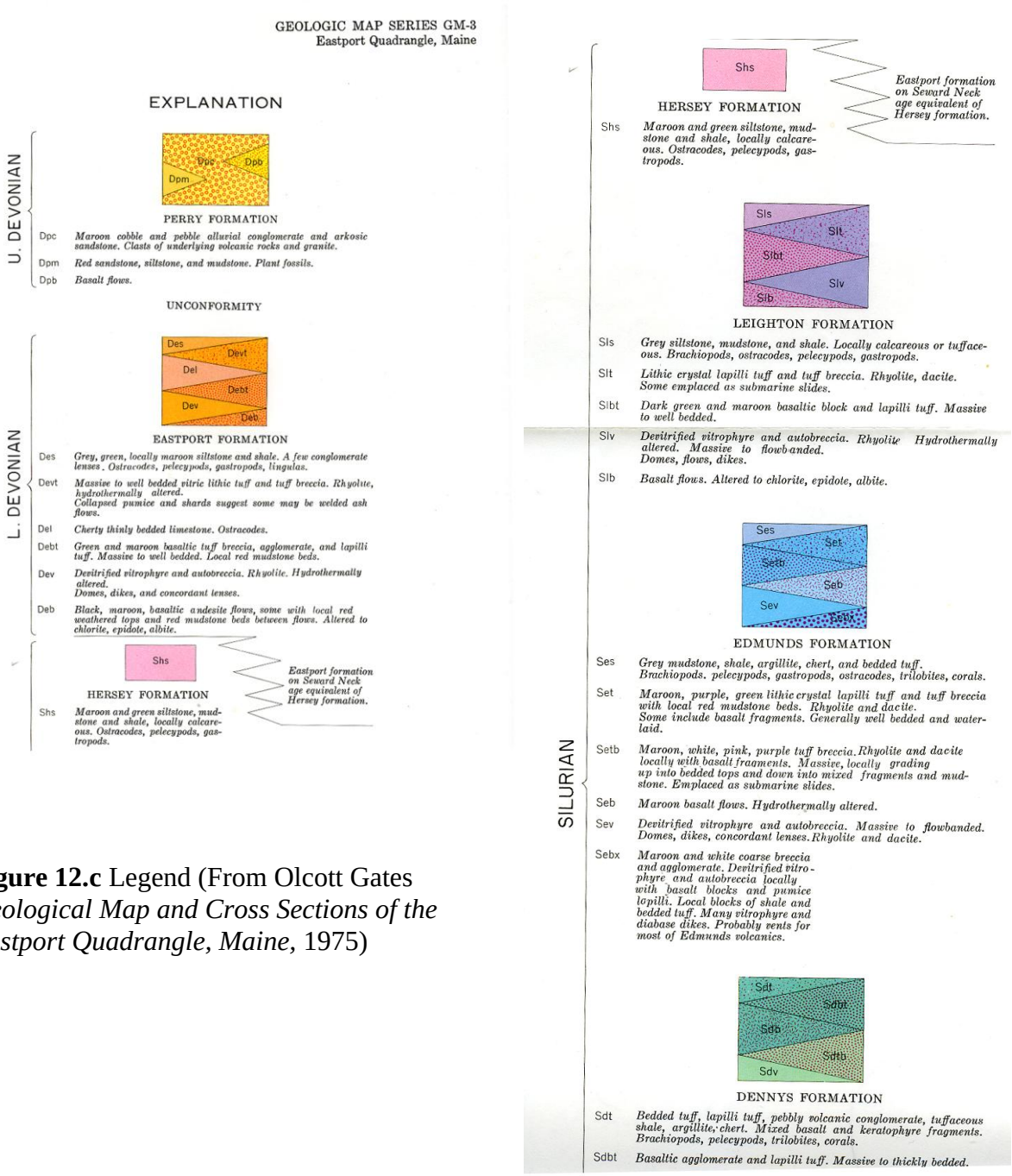

Figure 12.c Legend (From Olcott Gates *Geological Map and Cross Sections of the Eastport Quadrangle, Maine*, 1975)

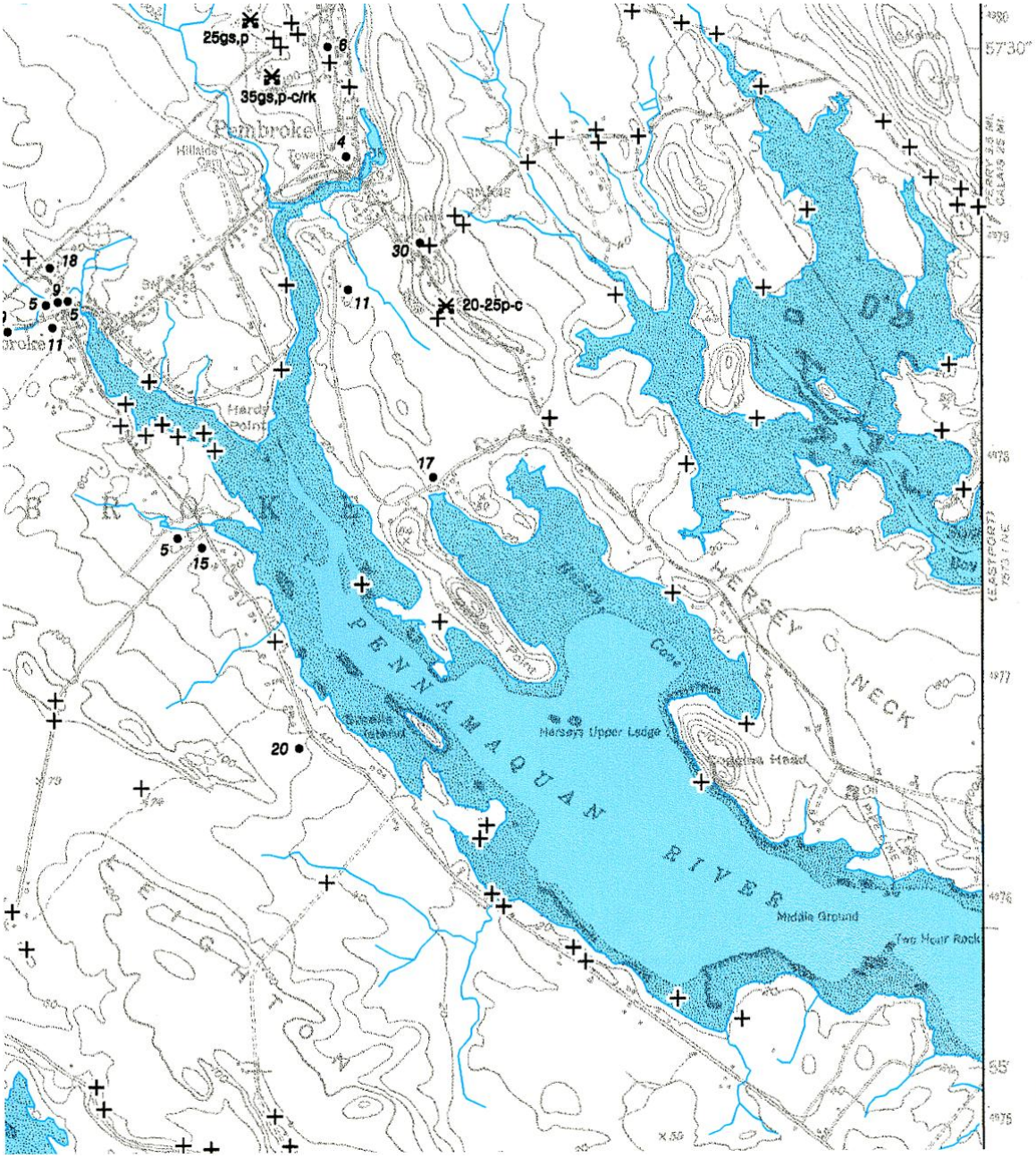

Figure 13. Surficial Material. The map shows surficial sediment independent of interpretation of their origin. Glacial deposits are shown as "diamitcton". (Maine Geological Survey, Daniel B. Lock, Pembroke quadrangle, Maine, Open-file no. 00-111, 2000)

Legend

Gravel g Undifferentiated gravel, used as a general term. Can be subdivided by size as follows
b boulder gravel c cobble gravel p pebble gravel

Mixed Units gs gravelly sand sg sand and gravel

Sand s Undifferentiated sand subdivided as follows
vcs very coarse sand cs coarse sand ms medium sand

Silt st

Clay cy

Diamicton d Undifferentiated diamicton subdivided as follows
ds sandy-matrix diamicton dt silty-matrix diamicton dy clayey-matrix diamicton
t till ta ablation till tl lodgement till tf flowtill
T variably weathered till

Organic Material
af artificial fill bd scattered boulder rk bedrock rs rottenstone
u unidentified R refusal (in test boring or wells) (f) fossiliferous

8a-b Material data from shovel hole.
56 Depth to bedrock
● Bedrock well
■ Dug well
20fs,ft Observation well with materials data
10gs/rk borrow pi
+ Bedrock outcrop

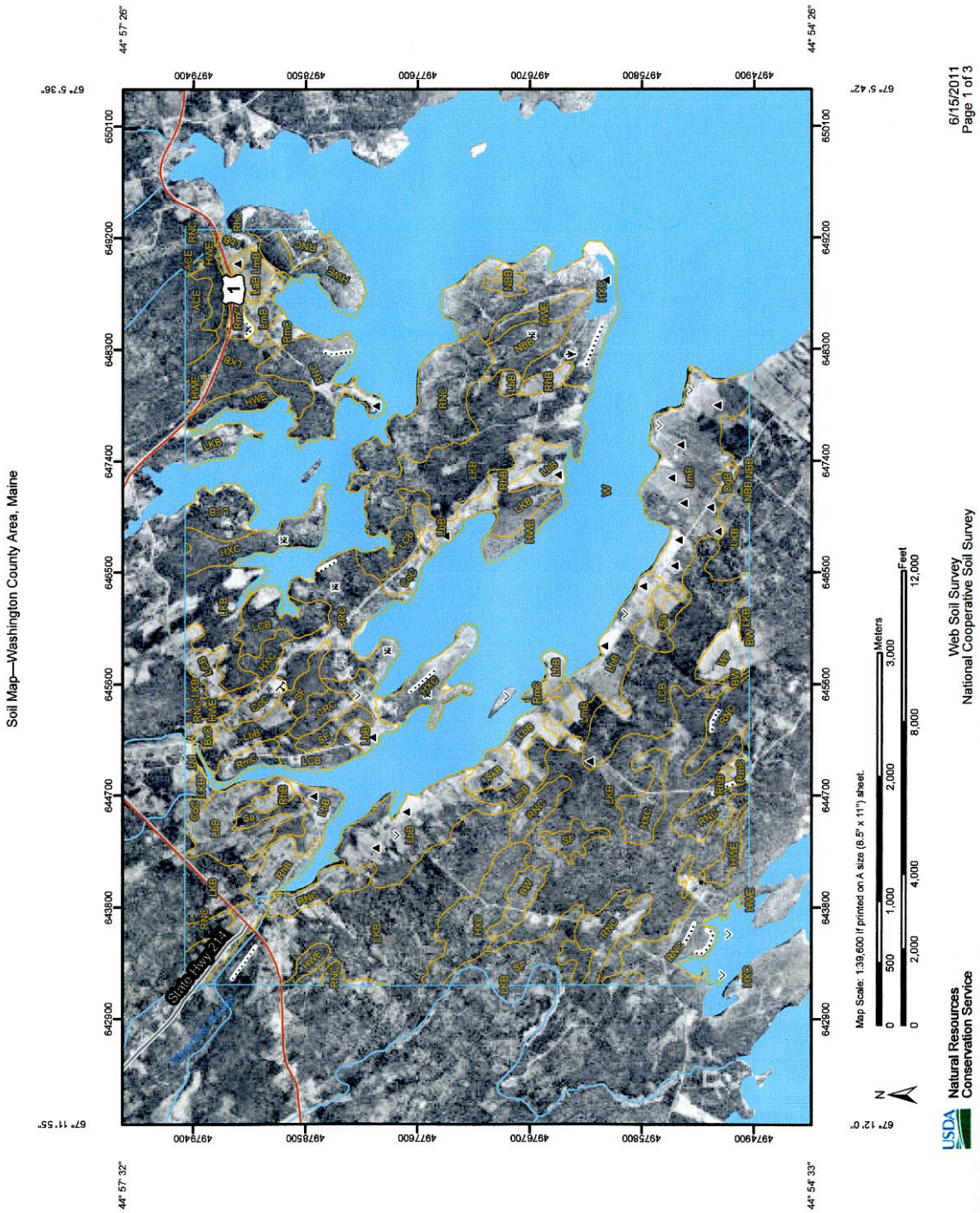

Figure 14.a - Soil Map

Map Unit Legend

Washington County Area, Maine (ME617)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
ACE	Abram-Rock outcrop-Ricker complex, 15 to 80 percent slopes	32.8	0.5%
BW	Bucksport and Wonsqueak soils	30.2	0.4%
BxC	Buxton silt loam, 8 to 15 percent slopes	6.4	0.1%
CoC	Colton gravelly sandy loam, 8 to 15 percent slopes	54.0	0.8%
CRC	Colton-Adams complex, 3 to 15 percent slopes	167.0	2.4%
DgB	Dixfield-Colonel complex, 3 to 8 percent slopes	8.1	0.1%
HWE	Hogback-Abram-Rawsonville complex, 15 to 60 percent slopes, very stony	225.3	3.3%
HXC	Hogback-Rawsonville-Abram complex, 3 to 15 percent slopes, very stony	483.6	7.1%
LaB	Lamoine silt loam, 0 to 6 percent slopes	16.0	0.2%
LbB	Lamoine-Buxton complex, 0 to 8 percent slopes	524.8	7.7%
LCB	Lamoine-Buxton-Scantic complex, 0 to 15 percent slopes	398.0	5.8%
LKB	Lamoine-Rawsonville-Scantic complex, 0 to 8 percent slopes, very stony	1,416.9	20.8%
LmB	Lamoine-Scantic complex, 0 to 5 percent slopes	317.8	4.7%
NBB	Naskeag-Rawsonville-Hogback complex, 0 to 8 percent slopes, very stony	59.7	0.9%
RhB	Rawsonville-Hogback complex, 3 to 8 percent slopes	154.0	2.3%
RhC	Rawsonville-Hogback complex, 8 to 15 percent slopes	0.1	0.0%
RmC	Rawsonville-Hogback-Abram complex, 3 to 15 percent slopes, very stony	67.4	1.0%
RNC	Rawsonville-Lamoine-Hogback complex, 0 to 15 percent slopes, very stony	589.0	8.6%
Sa	Scantic silt loam	37.5	0.5%
SF	Scantic-Biddeford association, 0 to 3 percent slopes	143.5	2.1%
SkB	Skerry fine sandy loam, 3 to 12 percent slopes	24.1	0.4%
Ud	Udorthents-Urban land complex	6.6	0.1%
W	Water	2,029.8	29.7%
WF	Wonsqueak and Bucksport soils, frequently flooded	34.3	0.5%
Totals for Area of Interest		**6,826.9**	**100.0%**

Figure 14.b - Soil map, legend

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads

MAP INFORMATION

Map Scale: 1:39,600 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 19N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Washington County Area, Maine
Survey Area Data: Version 13, Oct 2, 2009

Date(s) aerial images were photographed: 5/15/1996

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Figure 14.c - Soil map, legend

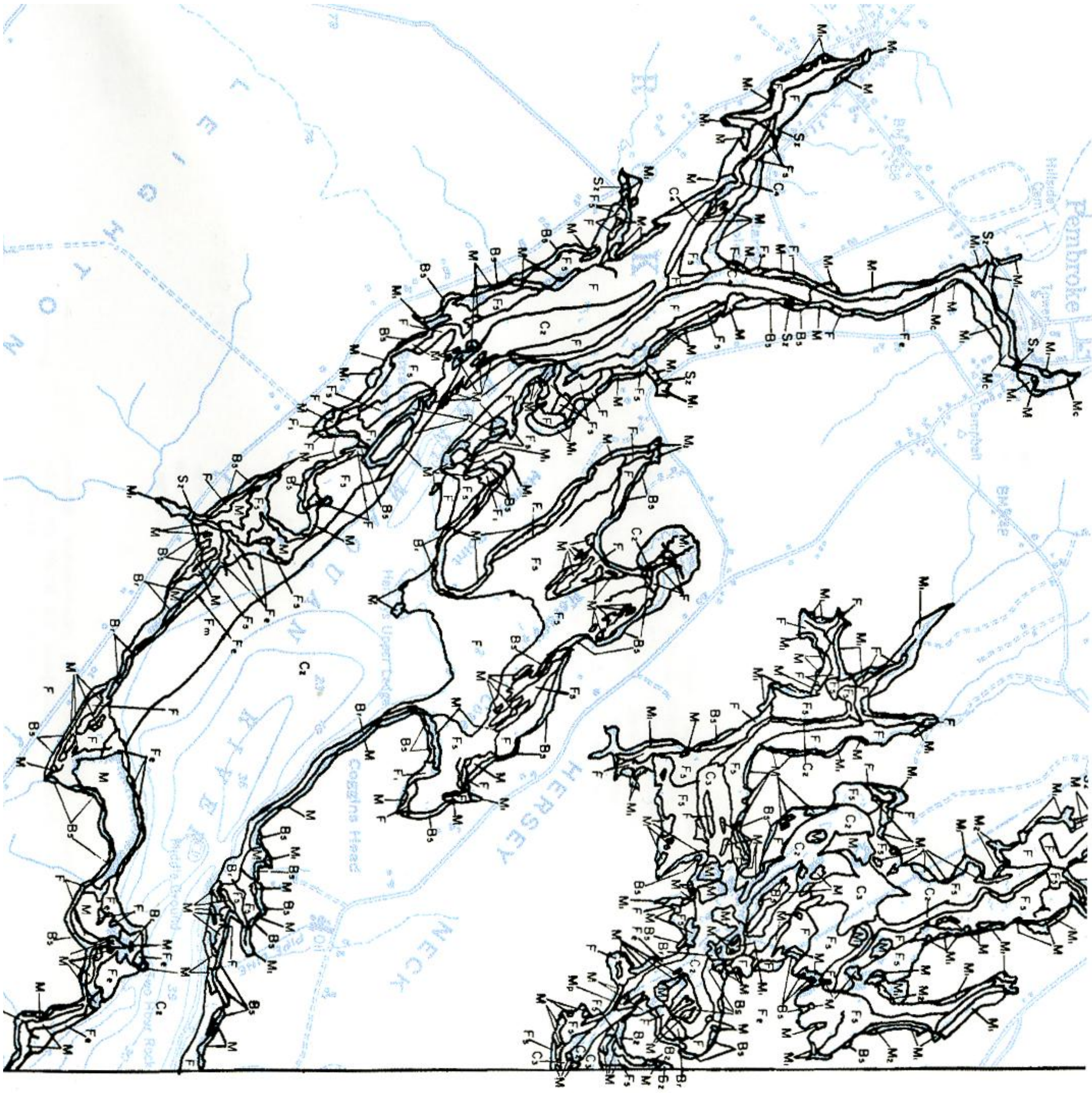

Figure 15. Coastal Marine Geological Environments (from Barry S. Timson, *Coastal Marine Geologic Environments of the Pembroke Quadrangle, Maine*, Marine Geological Survey, Department of Conservation, Augusta, Maine 1976, Open-file No. 76-0118). Interpretation of the environments given below.

SUPRATIDAL ENVIRONMENTS

Environments just above the highest high water datum, but under the partial influence of marine processes and forces.

Sd Dunes and vegetated beach ridges
Unconsolidated sand or gravel deposits capping beach environments. Dunes are subject to storm waves and winds, while gravel beach ridges are subject nly to storm wash. Each may be vegetated with salt-tolerant vegetation.

Sw Fresh-Brackish Water
Ponded water behind beach ridges, man-made constrictions on former tidal embayments, or on marsh surfaces transitional between upland and salt marsh environments. Salinity of the water is less than 5 parts per thousand (ppt).

Sm Fresh-Brackish Marsh
Water-saturated, organic-rich, sediments characterized by broad-leafed vegetation tolerant of constant submergence in fresh water. Salinity of interstitial water is less than 5 ppt.

Sz Man-Made Land
Structures or fill emplaced by man in the nearshore environments.

Sx Landslide Excavation and Deposits
Natural excavation into shoreline upland slopes created by large-scale slumping or sliding of bank material and the resulting deposits at the base of the slopes.

Se Eolian Flat
Partially vegetated sand flats adjacent to dune fields. Subject to generally northwest winds and occasional storm flooding.

Sf Washover Flat
Sand deposits covering salt marshes behind inlet mouths which originate from storm washover or inlet delta deposits on salt marshes. Subject to storm washover and spring tide flooding.

Sr Fluvial Marsh
Vegetated river floodplain and bank environments. Characterized by freshwater pond vegetation such as pond lilies, reeds, and wild rice. Subject to daily tidal flooding as well as inundation during high river discharge periods.

INTERTIDAL ENVIRONMENTS

Environments between the highest high water datum and the lowest low water datum subject to twice daily tidal flooding and all other marine forces.

Marsh Environments Vegetated environments or isolated depressions within vegetated environments located above mean tide level in protected coastal area.

M1 High Salt Marsh
Organic-rich sediments densely vegetated primarily with the salt marsh grass Spartina patens (salt-meadow grass). High salt marshes are at the same level as mean high water.

M2 Low Salt Marsh
Mud or muddy sand embankments sparsely to densely vegetated by the salt marsh grass Spartina alterniflora (salt-cordgrass). Low salt marsh exists between mea tide level and mean high water.

M3 Marsh Levee
Channel-margin sediments vegetated with salt-meadow grass which exists up to several tens of centimeters above the salt marsh surface. The marsh levee consists of sandy silt or silt-size sediment deposited from flood waters rising above channel margins, either from high river discharge into estuarine embayments or from storm-surge influenced flood tides from the ocean.

M4 Salt pannes and Salt ponds
Salt-water fill, non-vegetated depressions on the high salt marsh surface (salt pannes) or salt-water filled depressions anywhere in the intertidal zone (i.e. tidal pools). Salt pannes may be dry and covered with algae during late summer months.

Beach Environments Deposits of unconsolidated sediment which extend shoreward from the lowest tide line to the upland or vegetated dune field or beach ridge. Dominated by wave processes.

B1 Sand Beach
Beaches consisting of sand-sized sediment which are subject to high or moderate wave energy (waves generated in the Gulf of Maine)

B2 Mixed Sand and Gravel Beach
Beaches consisting of sand and gravel-size sediment which are subject to high or moderate wave energy.

B3 Gravel Beach
Beaches consisting of gravel-size sediment which are subject to high or moderate wave energy.

B 4 Boulder Beach

Beaches consisting of boulder-size sediment which are subject to high or moderate wave energy.

B5 Low-Energy Beach

Beaches consisting of a wide variety of sediment sizes which are protected from high wave energy. Sediment characteristics are dependent upon sediment source, which is ususally from pland scarps immediately shoreward of the beach. Low-energy beaches may exhibit growth of salt marsh grass when there is little sediment movement.

Br Boulder Ramp

Sloping surfaces in the lower intertidal zone veneered by large boulders. This environment is seaward of gravel or boulder beaches on high wave energy shorelines. Boulders are remnant lag deposits of eroded glacial tills. Boulder movement is limited to periods of intense storm wave activity.

Bw Washover Fan

Fan-shaped deposits of gravel located behind gravel beach ridges and covering portions of marshes. Few washovers have been recognized as mappable units on sand beaches. Washover fans are deposited by storm waves. Fan sediment is derived from the beach itself.

Bs Spits

Partially submerged beach ridges which extend offshore into open water. This category includes tombolos (spits joining an island with the mainland).

Flat Environment Gently sloping or level environments composed primarily of fine sand, silt, and clay accumulated in relatively quiet water. Flats are depositional areas controlled primarily by tidal currents and sediment settling from the water column. Flat environments may be eroded temporarily by storm waves.

F Mud Flats

Flats comprised of sediment finer than sand.

F1 Coarse-Grained Flat

Intertidal flats where sand or larger-size material comprises most of the sediments. Coarse-grained material comprises most of the sediments. Coarse-grained flats are subject to higher tidal-current velocities than mud flats.

F2 Seaweed-Covered Coarse-grained Flat

Coarse-grained, shallow subtidal and low intertidal flats which act as a stable substrate for seaweed such as Ulva, Enteromorpha [PAD Note: outdated taxon, now merged with Ulva], Ascophyllum, and Laminaria.

F3 Mussel Bar

Low mounds of living mussel, Mytilus edulis, and/or disarticulated and broken mussel shells accumulated by wave shoaling. Mussel bars generally occur at the mouths of estuaries or embayments at tidal channel margins where nutrient-laden oceanic waters first flood flat environments. Mussel bars accumulate on intertidal flats.

F4 Channel Levee

Linear accumulations of sediment along margins of tidal channels built several tens of centimeters above the surrounding intertidal flats. Channel levees are constructed from sediment deposited on the flat as the tide rises above the channel margins.

F5 Algal Flats

High, coarse and fine-grained intertidal flats covered with green algae, Enteromorpha erecta [PAD Note: outdated taxon, now merged with Ulva].

F6 Veneered Ramp

Former boulder ramps presently covered by fine-grained sediment settling out of the water column.

Miscellaneous Environment

M Ledge

Subaerially or subaqueously exposed bedrock.

Mc Fluvial-Estuarine Channel

Transitional channel between river and estuarine channels. The fluvial, tidal fluvial, or estuarine state depends upon the volume of river discharge entering the estuarine basin.

Mp Point or Lateral Bars

Accumulations of sediment adjacent to intertidal channel margins at channel bends (point bars) ir along straight segments (lateral bars)

Ms Swash Bars

Accumulations of sediment which occur where wave shoal onto intertidal flats.

Mf Flood-Tidal Delta

Lobate bars of sediment which accumulate landward of an inlet separating a back-barrier estuary or lagoon from open ocean water.

Me Ebb-Tidal Delta

Lobate bars of sediment which accumulate seaward of an inlet separating a back-barrier estuary or a lagoon from open ocean water.

Mb Fan Delta
Coarse-grained, fan-shaped deposits which accumulate on intertidal flats where upland streams drain onto high tidal-range shorelines.

Md Spillover lobes
Lobate bars of sediment which extend from flood-tidal deltas into estuarine or tidal channel areas.

SUBTIDAL ENVIRONMENTS

Environments existing below lowest low water and subject to tidal current forces and wave-generated current forces.

Flat Environments Submerged, gently sloping, or level environments composed primarily of fine sand, silt, and flay. Includes subaqueous exposures of coarse-grained Pleistocene glacial sediments.

Fm Mud Flat
Fine grained subtidal flats.

Fc Coarse-Grained Flat
Coarse-grained subtidal flats.

Fe Eelgrass Flat
Fine-grained and coarse-grained, shallow subtidal (low intertidal) flats which support dense stands of eelgrass (Zostera marina).

Channel Environments Linear, intertidal and subtidal depressions carrying tidal-current water.

C1 High-Velocity Tidal Channel
Tidal channels where maximum flow velocities probably exceed 2 meters per second (mps).

C2 Medium-Velocity Tidal Channel
Tidal channels where maximum flow velocities probably attain values between 1 and 2 (mps).

C3 Low-Velocity Tidal Channel
Tidal channels where maximum flow velocities probably do not exceed 0.5 mps.

C4 Estuarine Channel

Estuarine channels where flood-tide currents and river waters mix. Estuarine water salinities range between 0.5 ppt and 30 ppt.

C5 Estuarine Flood Channel
Estuarine tidal channels where flood-tide current velocities greatly exceed velocities attained during ebb tide.

C6 Estuarine Ebb Channel
Estuarine tidal channels where ebb-tide current velocities greatly exceed velocities attained during flood tide.

C7 Inlet Channel
High current-velocity channels cut through barrier beaches and connecting back barrier estuaries or lagoons with the open ocean.

C8 Dredged Channel
Man-made artificially deepened or widened tidal channel.

Cs Channel Slope
Gently to moderately sloping wall margins of large tidal channels. Channel slopes are confined to channel wall margins composed of sediment.

Cb Abandoned Tidal Channel
Former tidal channel no longer carrying flow sufficient to erode the channel floor or margin walls. Abandoned channels usually occur in salt marsh tracts where meandering of the central drainage channel cuts off former channel segments.

Cf Tidal Fluvial Channel
Lower portions of river channels under tidal influence but not carrying estuarine waters.

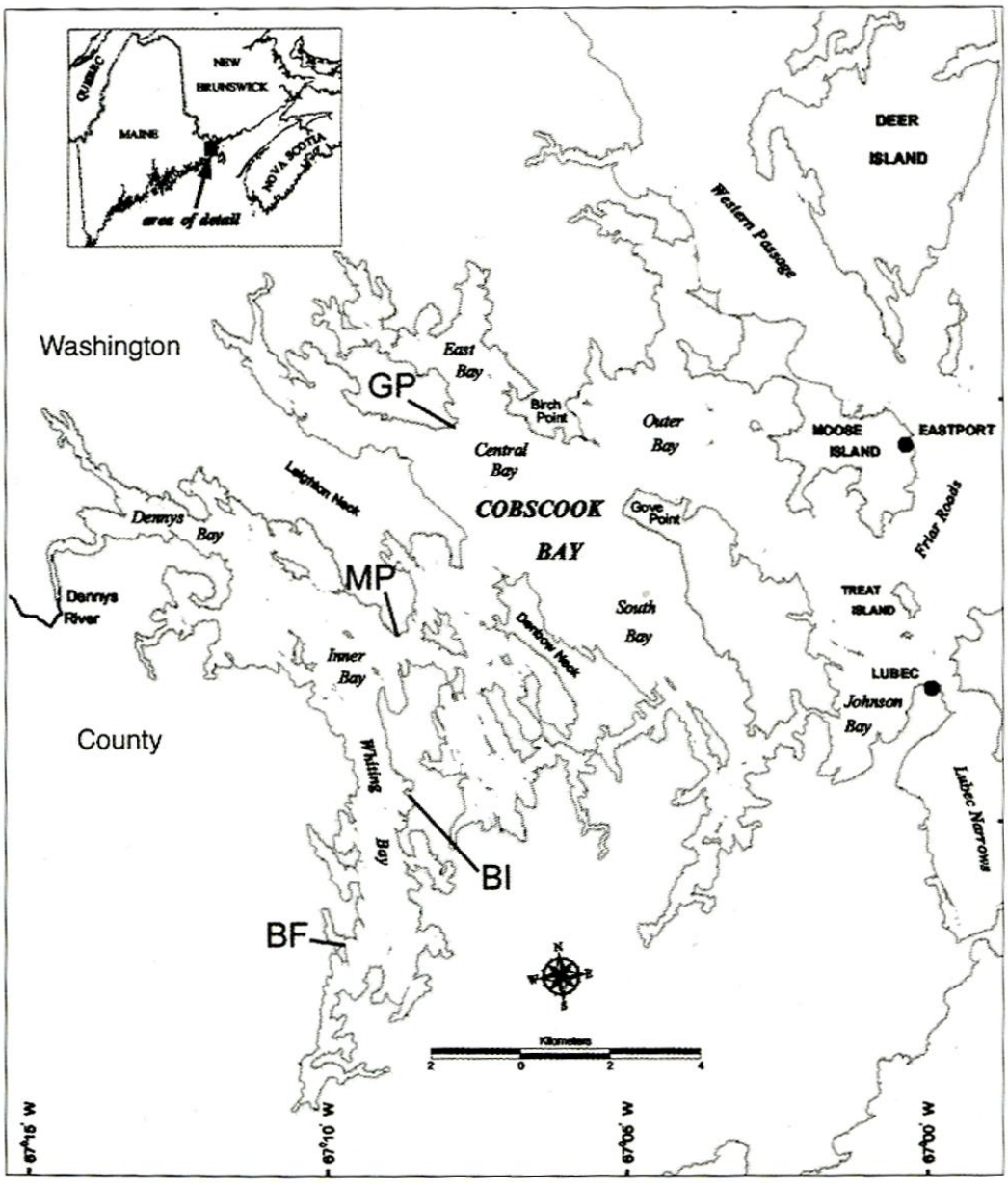

Figure 1. Map of Cobscook Bay kelp study sites during 1995–96 (BF = Bell Farm, BI = Bar Island, GP = Garnet Point, MP = Mahar Point).

Figure 16.a. During 1995-1996 Vadas et al. studied environmental factors affecting growth rate of kelp (*Laminaria longicruris)* in sublittoral habitats. They carried out measurements at four locations including Garnet Point, about 1.5 km from the Pennamaquan Tidal Power Plant location. As part of their study, they measured temperature, salinity, nitrate, and phosphorous, densities over the course of the year. (Vadas, Beal, Wright, Nickl, and Emergson, Growth and Productivity of Sublittoral Fringe Kelp (*Laminaria longiruris*) Bach.Pyl. in Cobscook Bay, Maine, in Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary, Northeastern Naturalist, Volume 11, Special Issue 2, 2004)

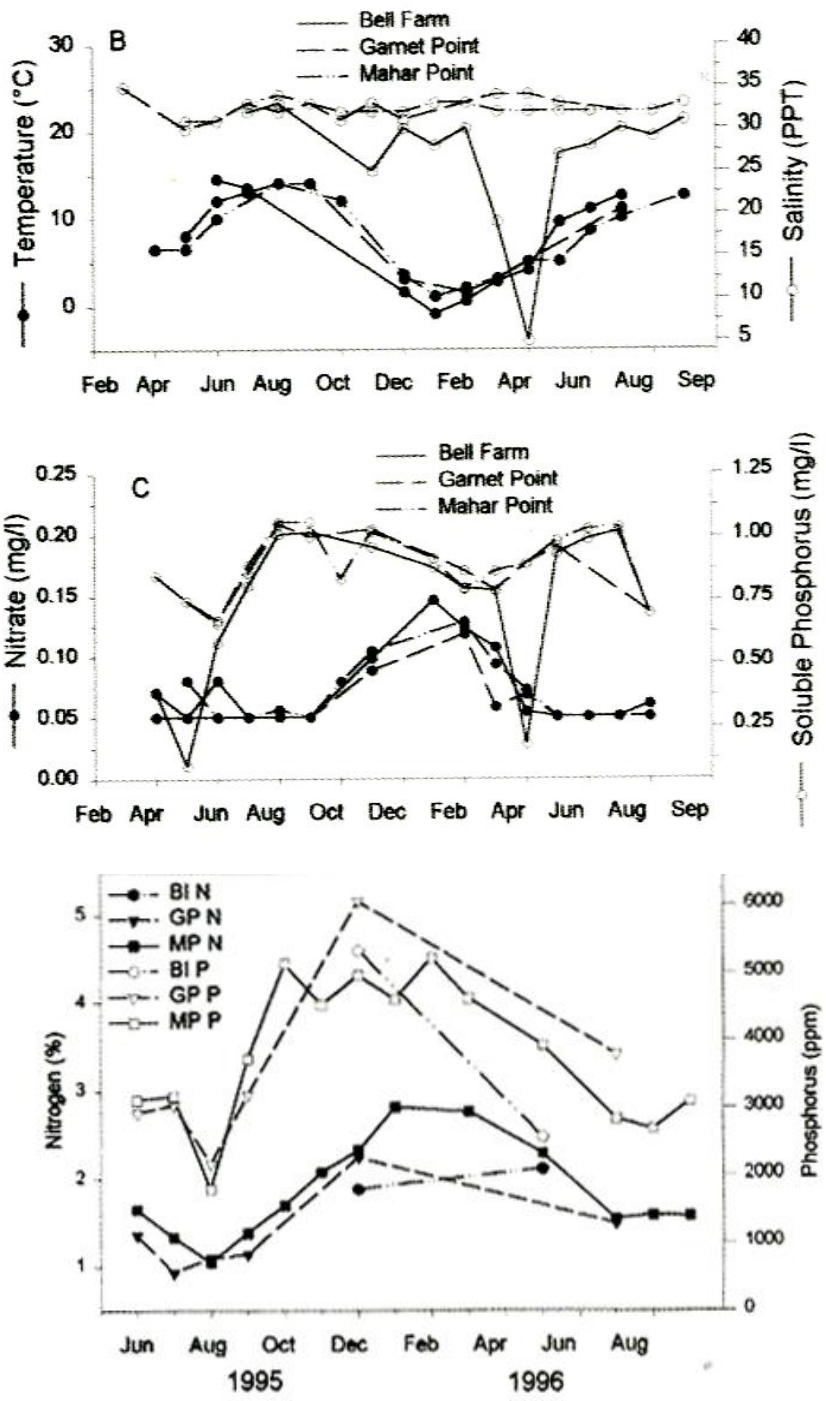

Figure 16.b Temperature, Salinity, and density of Nitrates, Nitrogen and Soluble Phosphorous over the course of the year at four locations including Garnet Point near the location of the proposed tidal power plant. (Vadas, Beal, Wright, Nickl, and Emergson, Growth and Productivity of Sublittoral Fringe Kelp (*Laminaria longiruris*) Bach.Pyl. in Cobscook Bay, Maine, in Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary, Northeastern Naturalist, Volume 11, Special Issue 2, 2004)

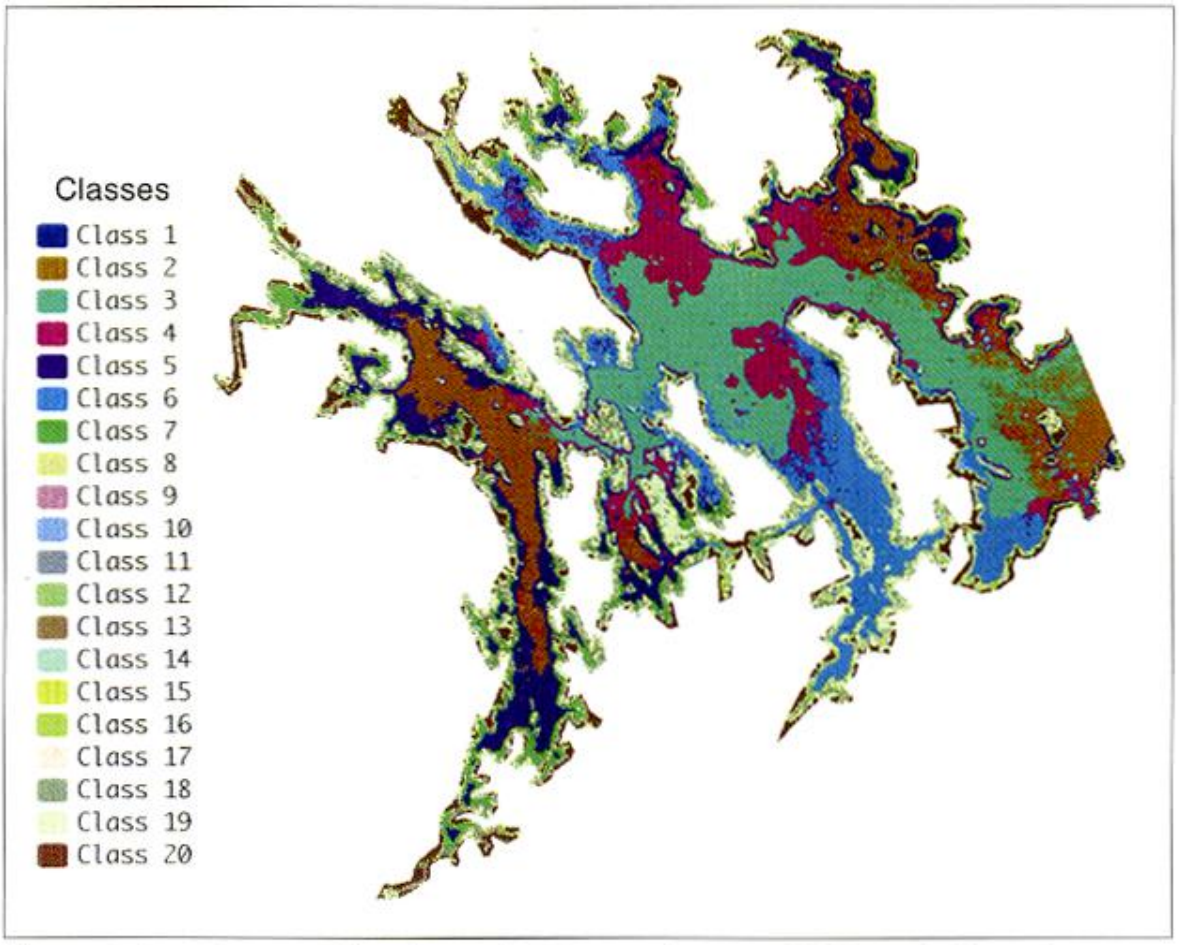

Figure 9. Landsat satellite Thematic Mapper image of Cobscook Bay taken near the time of maximum flood. The color scheme indicates relative levels of surface turbidity. The class 3 green color marks relatively clear offshore water entering the Bay. Image provided by Cynthia Erickson, Bigelow Laboratory for Ocean Sciences.

Figure 17. Turbidity levels in Cobscook Bay(From D.A. Brooks, Modeling Tidal Circulation and Exchange in Cobscook Bay, Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary, Northeastern Naturalist, Volume 11, Special Issue 2, 2004)

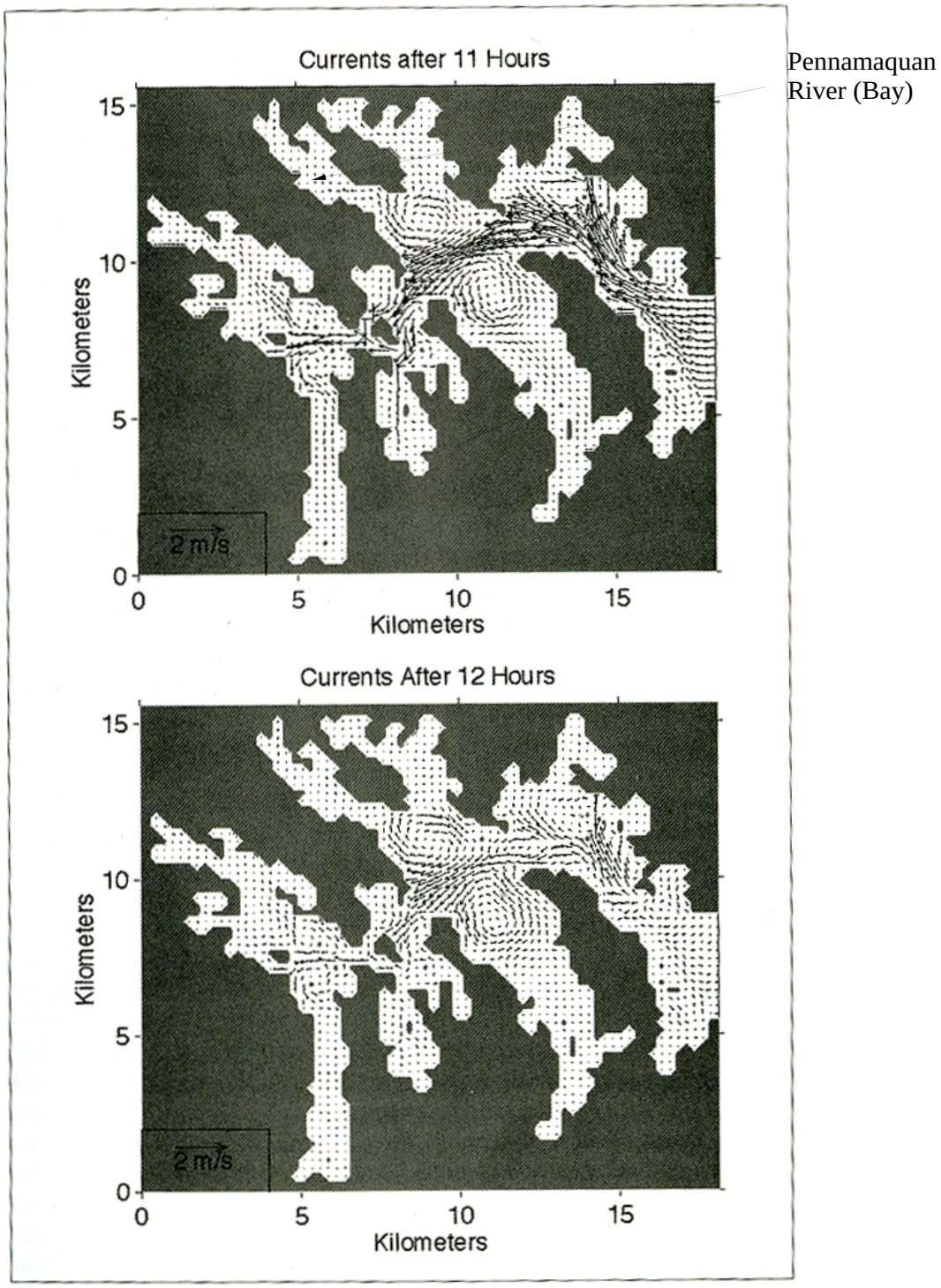

Figure 5A. Model surface currents in Cobscook Bay at 11 and 12 lunar hours after high water at Eastport.

Figure 18. Dipole Circulation in Central Bay (From: Brooks, David Modeling Tidal Circulation and Exchange in Cobscook Bay, Maine, in *Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary,* Northeastern naturalist, Volume II, Special issue 2, 2004

Figure 11A. Color-coded map of tidal-average residence time (in days) for particles released in each grid cell at the surface. Particles not flushed from the bay after 8 days were assigned a residence time of 8 days.

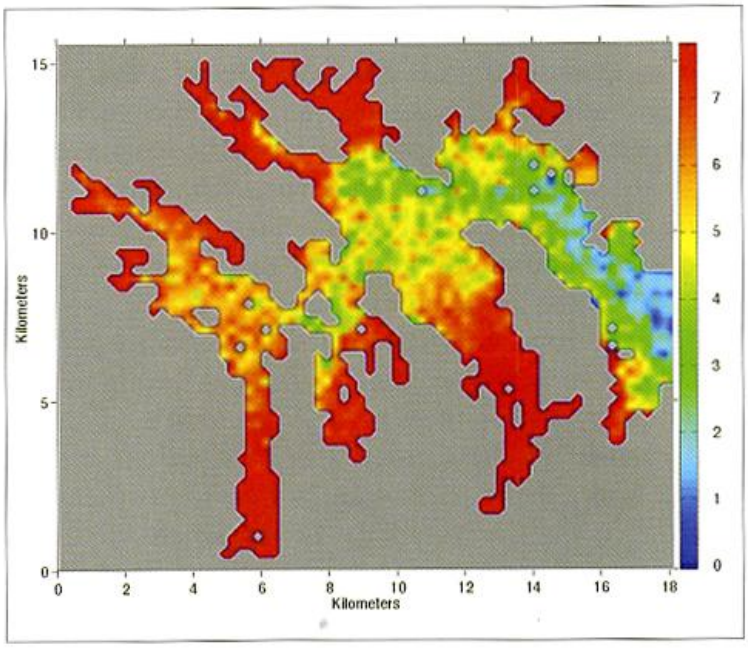

Figure 11B. Vertically-averaged time (in days) for a conservative tracer to exponentially decay by one e-folding scale, i.e., to 37% of the original 100% concentration initialized in every grid cell at every level. From Baca (1998).

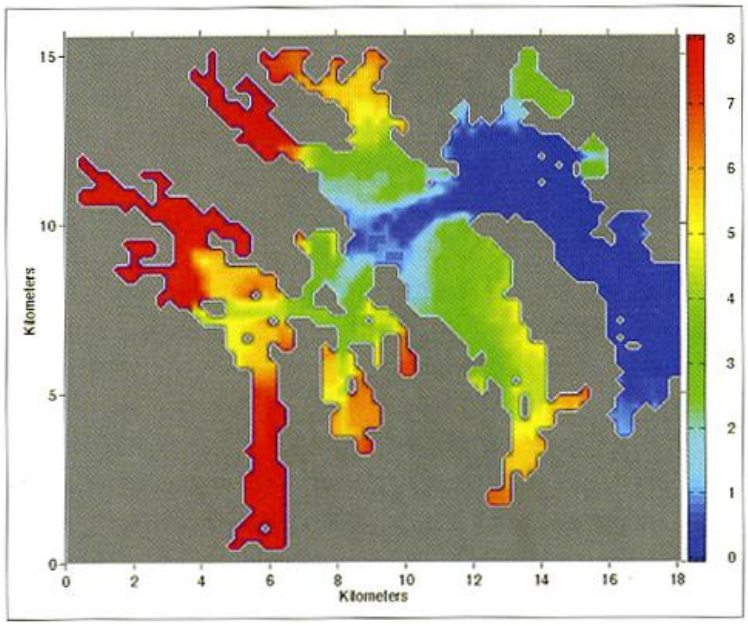

Figure 19. Residence Time of Surface Particles (From: Brooks, David Modeling Tidal Circulation and Exchange in Cobscook Bay, Maine, in *Ecosystem Modeling in Cobscook Bay, Maine: A Boreal, Macrotidal Estuary*, Northeastern naturalist, Volume II, Special issue 2, 2004)

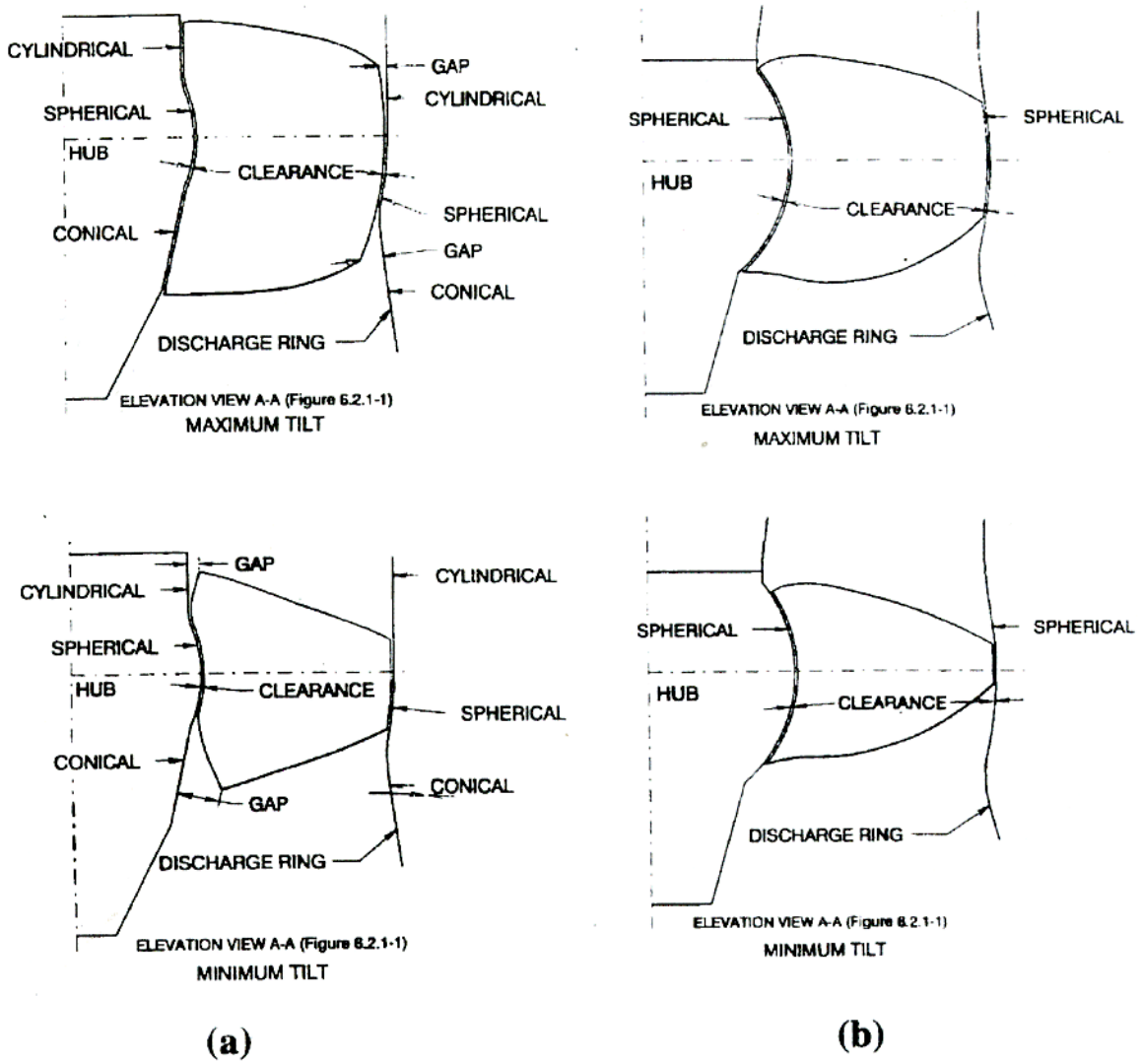

Figure 20. Schematic diagrams of a Kaplan runner blade showing (a) runner with gaps, (2) gapless runner (fish friendly) . (Odeh, M. A Summary of Environmentally Friendly Turbine Design Concepts, US DOE, Idaho Operations Office, Advanced Hydropower Turbine System Program, 1999, p.26).

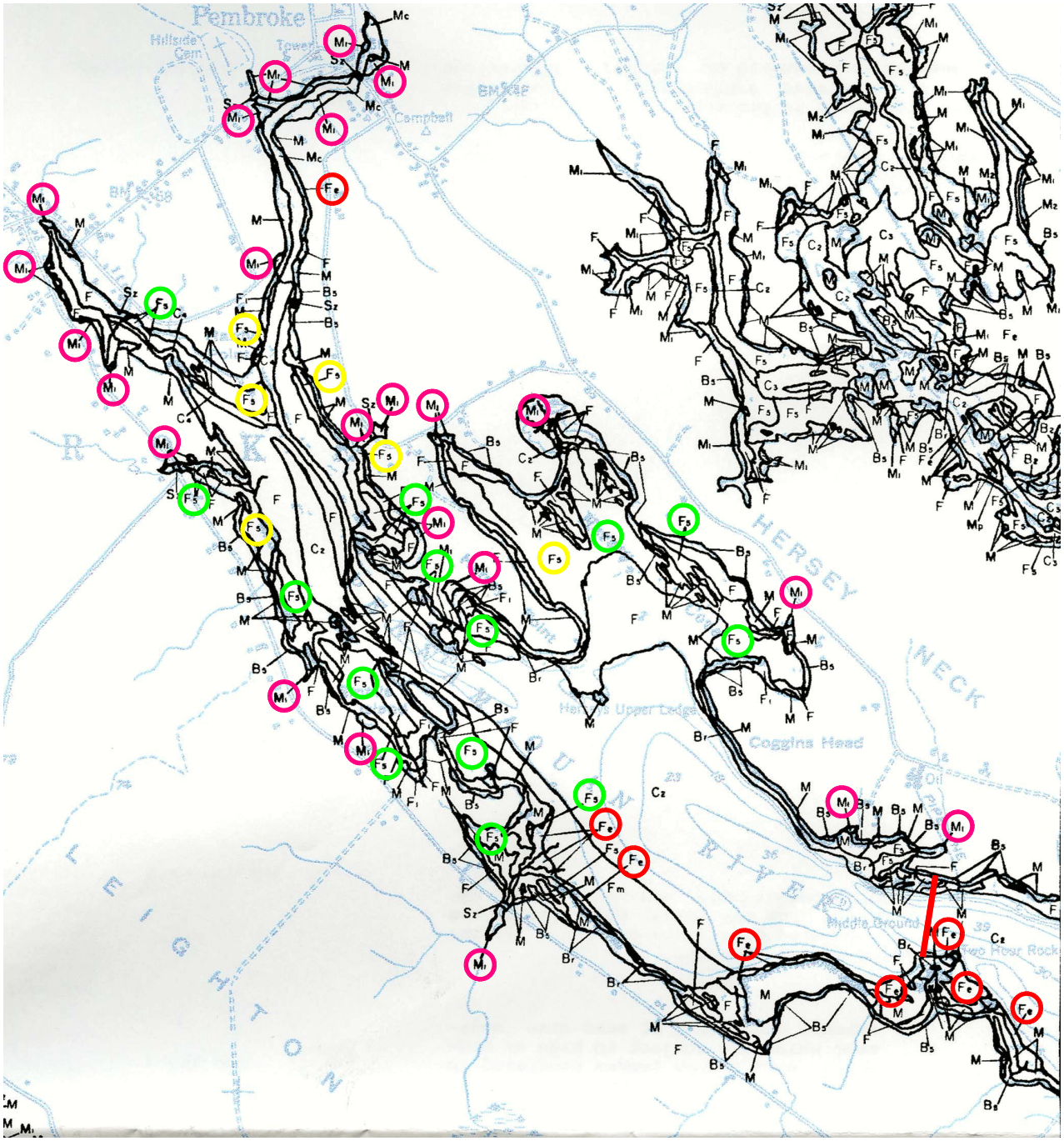

Figure 21. Aquatic Plants From Coastal *Marine Geologic Environments of the Pembroke Quadrangle, Maine* By Barry S. Timson 1976, Maine Geological Survey.

Red Fe - Eel grass flat
Green F5- Algal Flats
Mauve M1 High Salt Marsh
Yellow F3 Mussel Bar

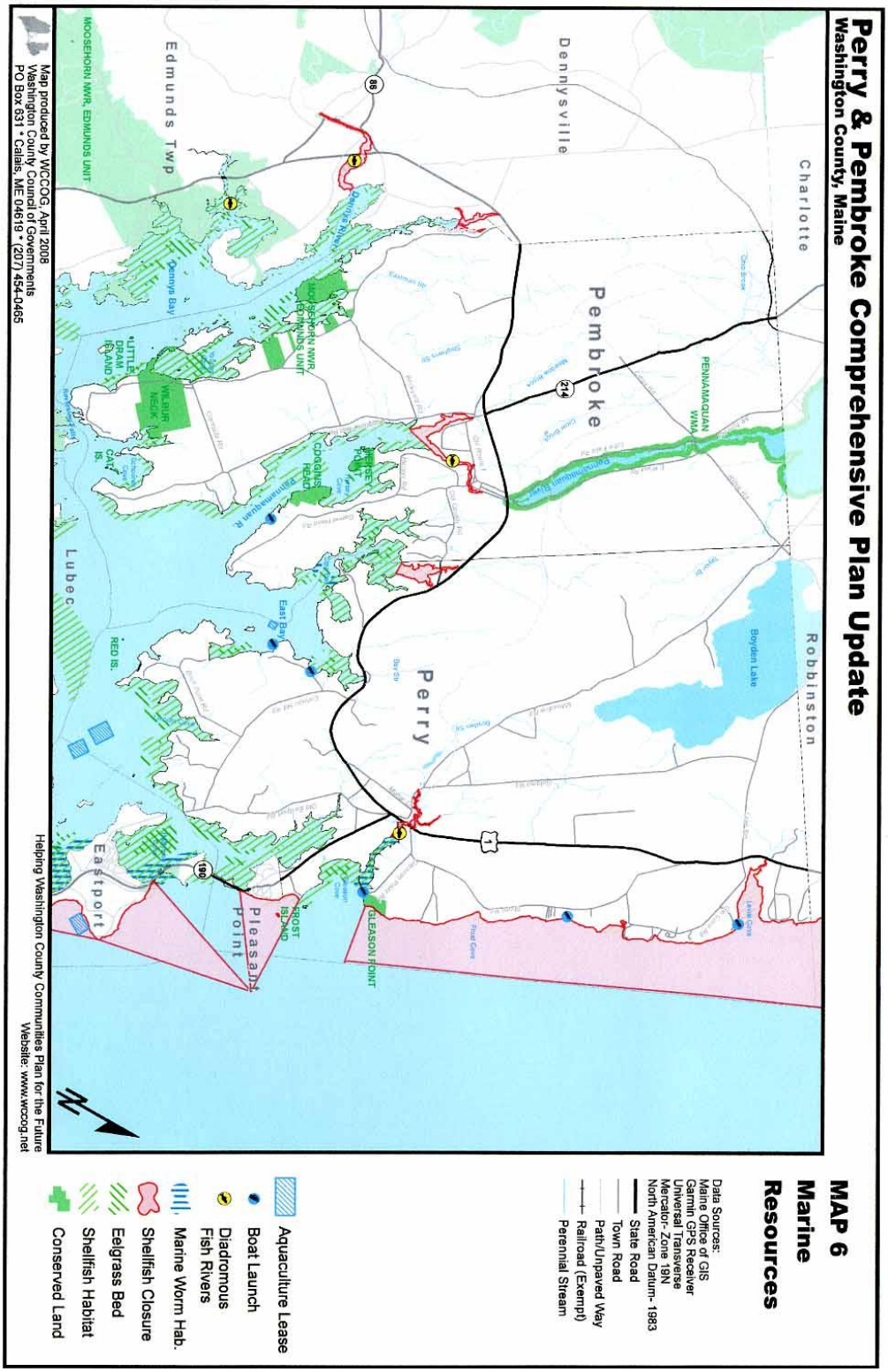

Figure 22. Marine Resources (Pembroke and Perry Joint Comprehensive Plan Update Committee, *The Town of Pembroke, 2009 Comprehensive Plan*).

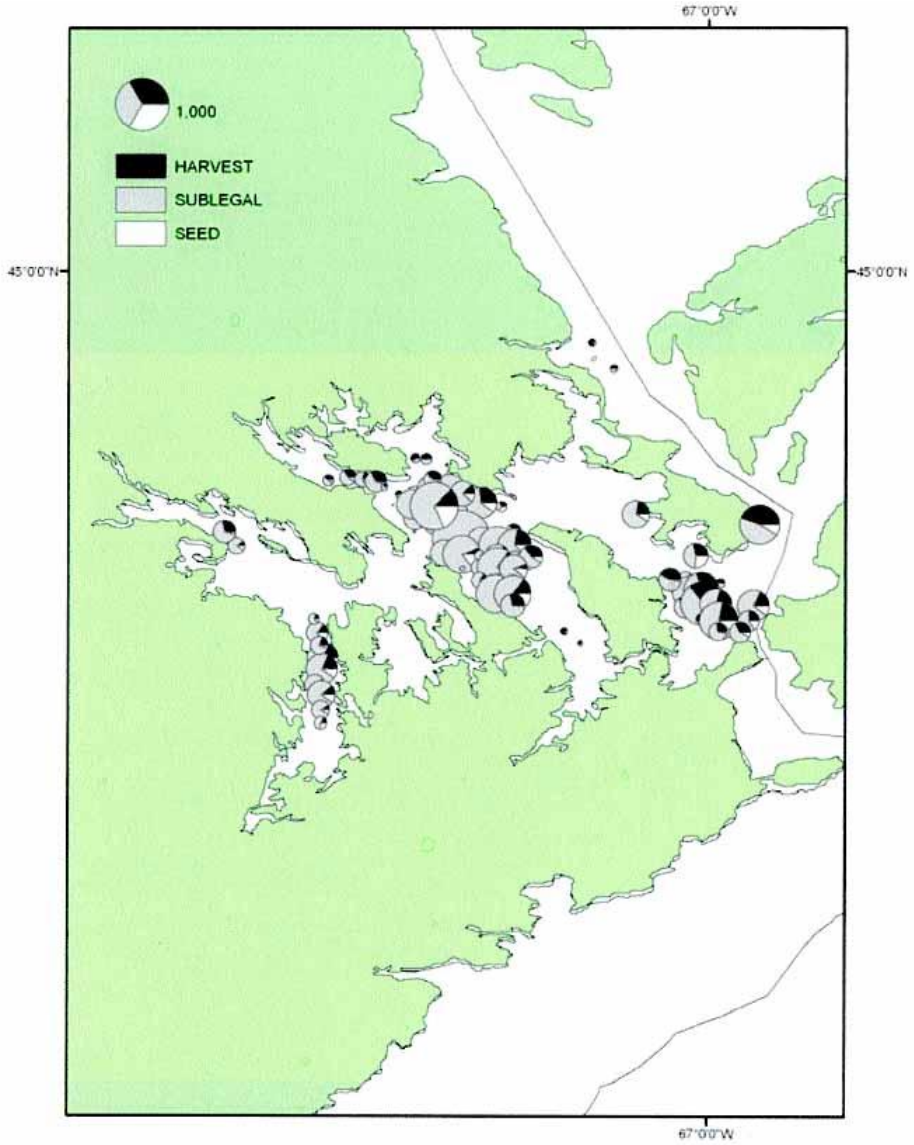

Figure 4. Number of scallops and size class composition by tow (Cobscook Bay), 2009 survey (tows with 0 scallops not shown).

Figure 23 a. (From Results from Kevin H. Kelley, *The 2010 Maine Sea Scallop Survey*, Maine Department of Marine Resources)

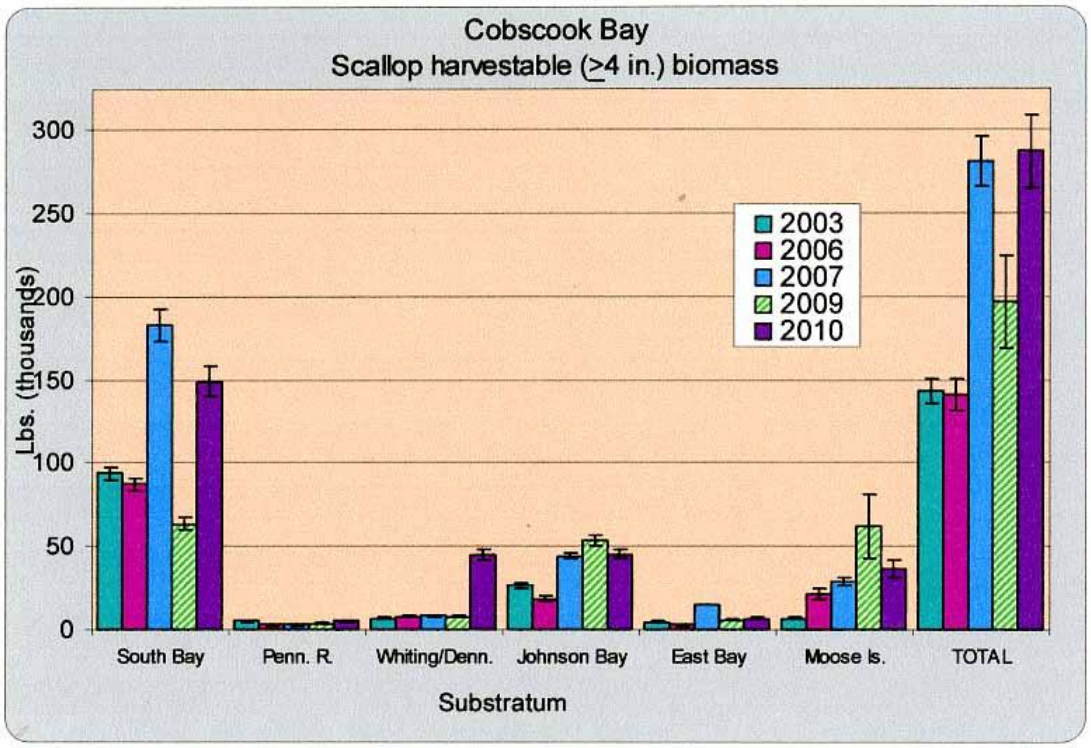

Figure 15. Biomass (meat weight, with standard error) of harvestable (legal-size) scallops in Cobscook Bay, 2003-10.

Figure 23.b (From Results from Kevin H. Kelley, *The 2010 Maine Sea Scallop Survey*, Maine Department of Marine Resources)

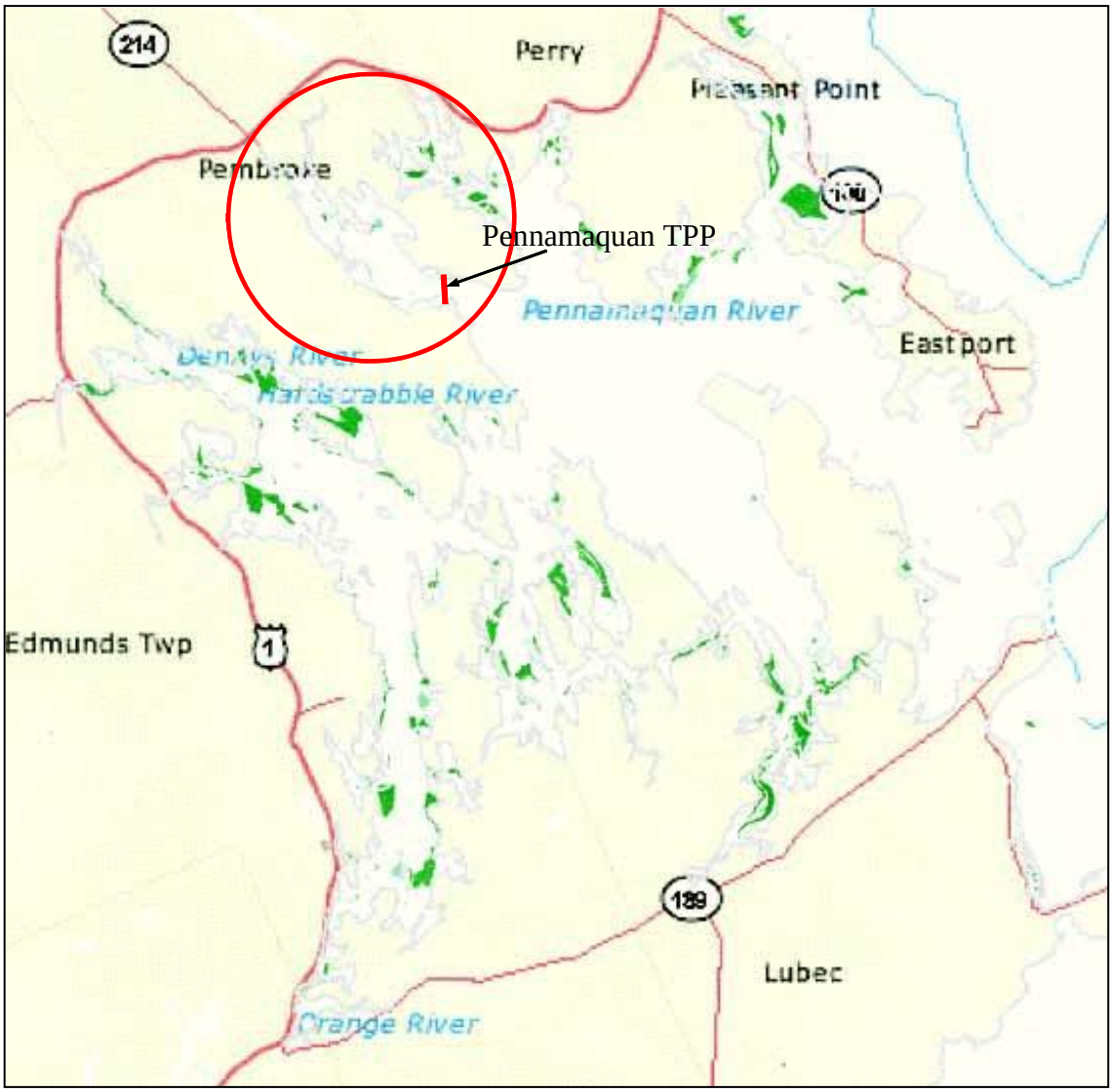

Figure 24.a Eel grass in Cobscook Bay. Pennamaquan River is shown within the red circle.

Eelgrass
Per Cent Cover

- GT 0 to 10 %
- GT 10 to 40 %
- GT 40 to 70 %
- GT 70 to 100%
- Present but not categorized

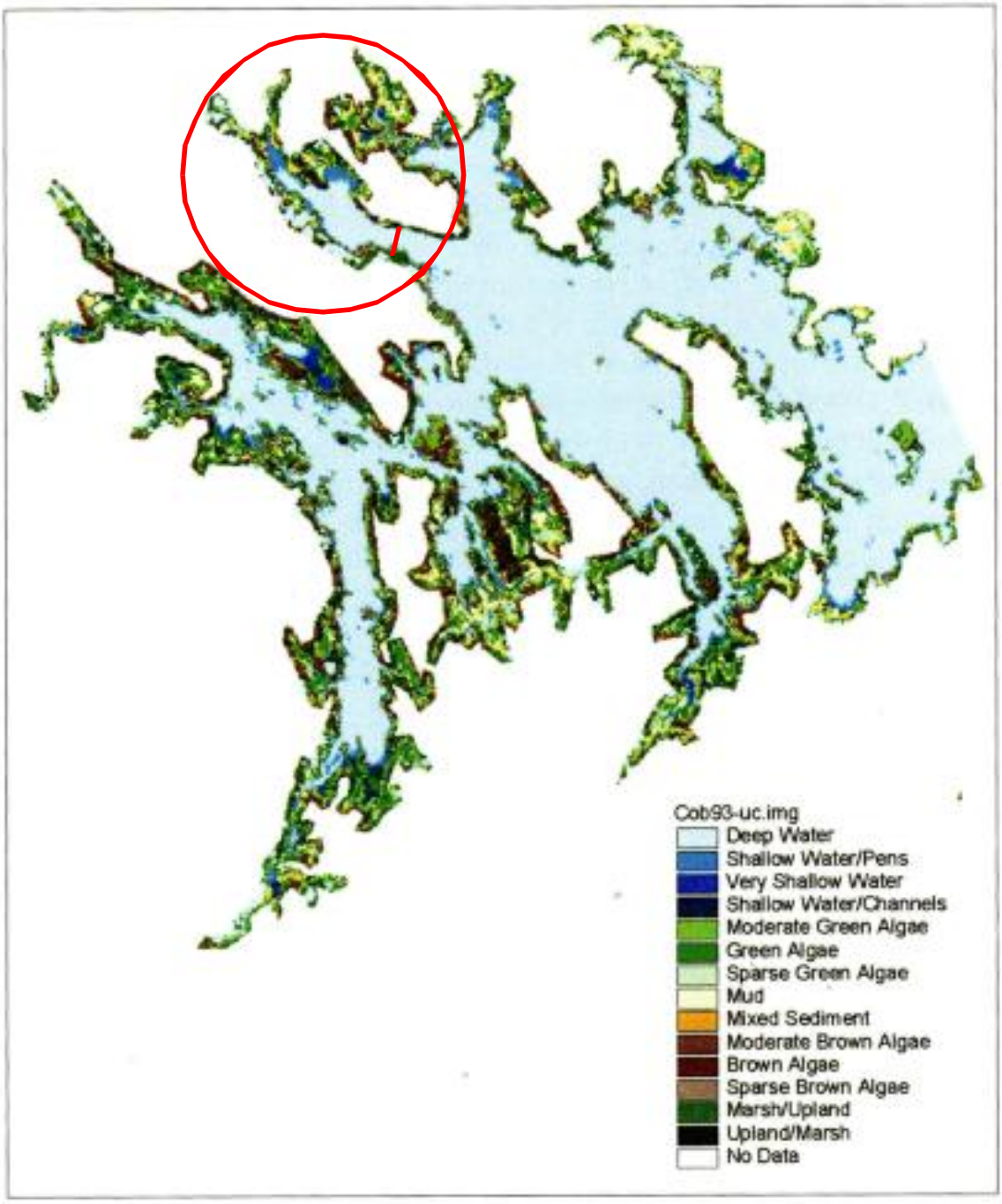

Figure 4. The 14-class representation of the low tide Landsat Thematic Mapper.

Figure 24.b Distribution of Algae

Figure 25 Pennamaquan River Aerial View – Pennamaquan Tidal Barrage is shown in red. The Transmission line to the existing substation is shown in purple.

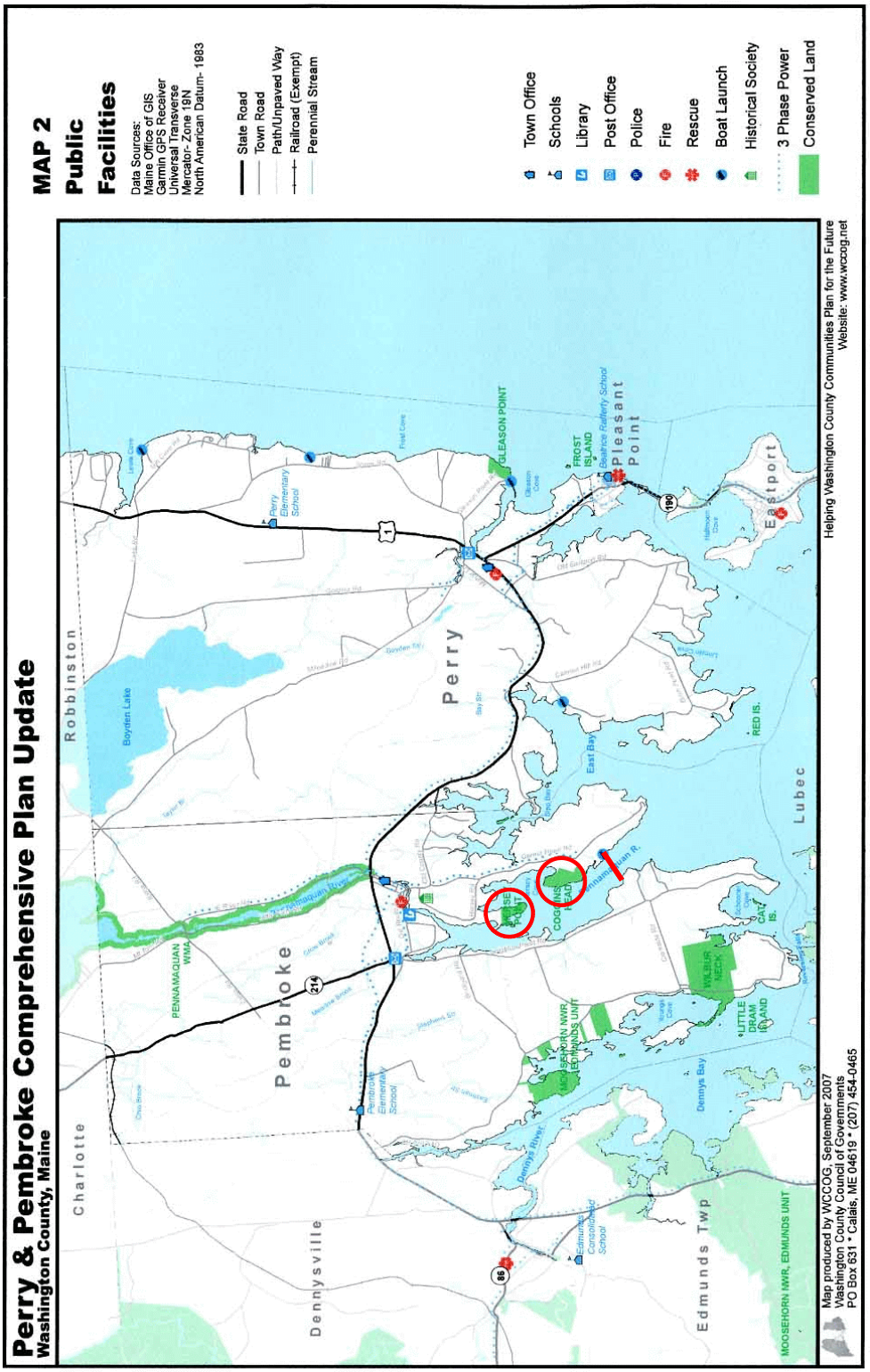

Figure 26.a Public Facilities including. Conserved land show circled. The Project is shown across the mouth of the Pennamaquan. (Tow of Pembroke, Maine *Comprehensive Plan*, November 2009)

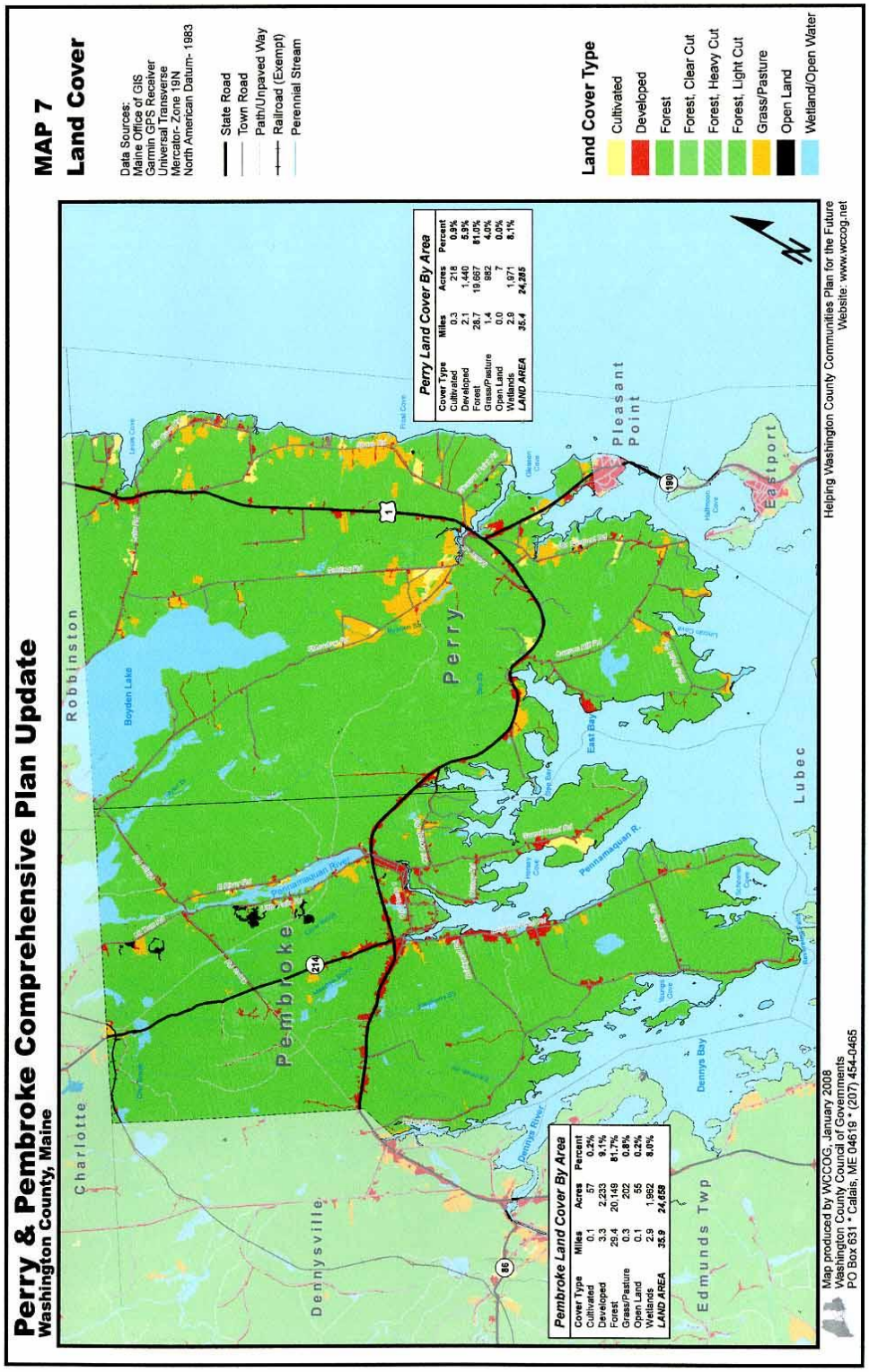

Figure 26.b Land Cover. (Tow of Pembroke, Maine *Comprehensive Plan*, November 2009)

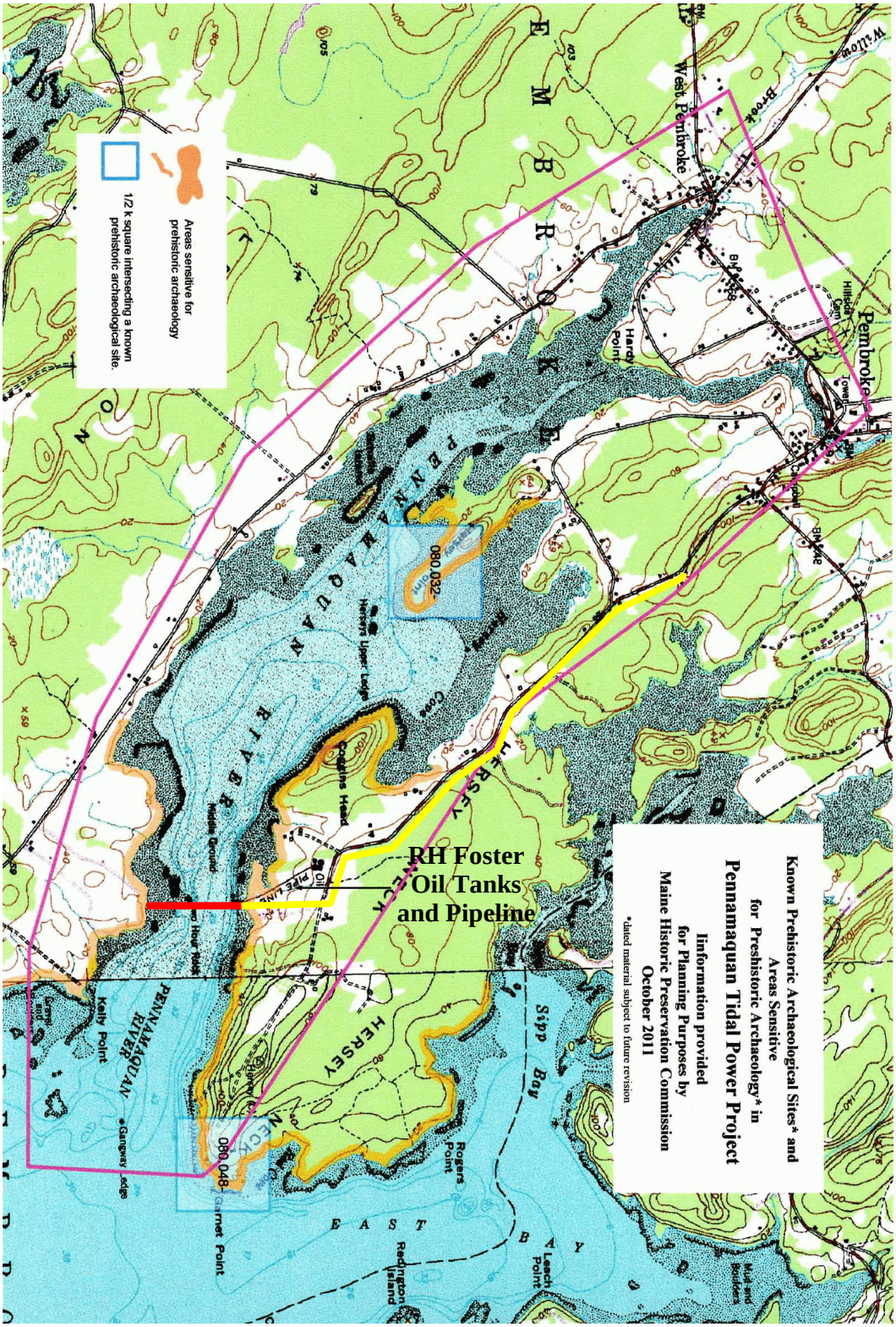

Figure 27 Prehistoric Archeological Resources. Project Alignment shown in red. Transmission is shown along the existing Bangor Hydro transmission line along Garnet Head Road to the substation. (Map courtesy of the Maine Historic Preservation Commission)

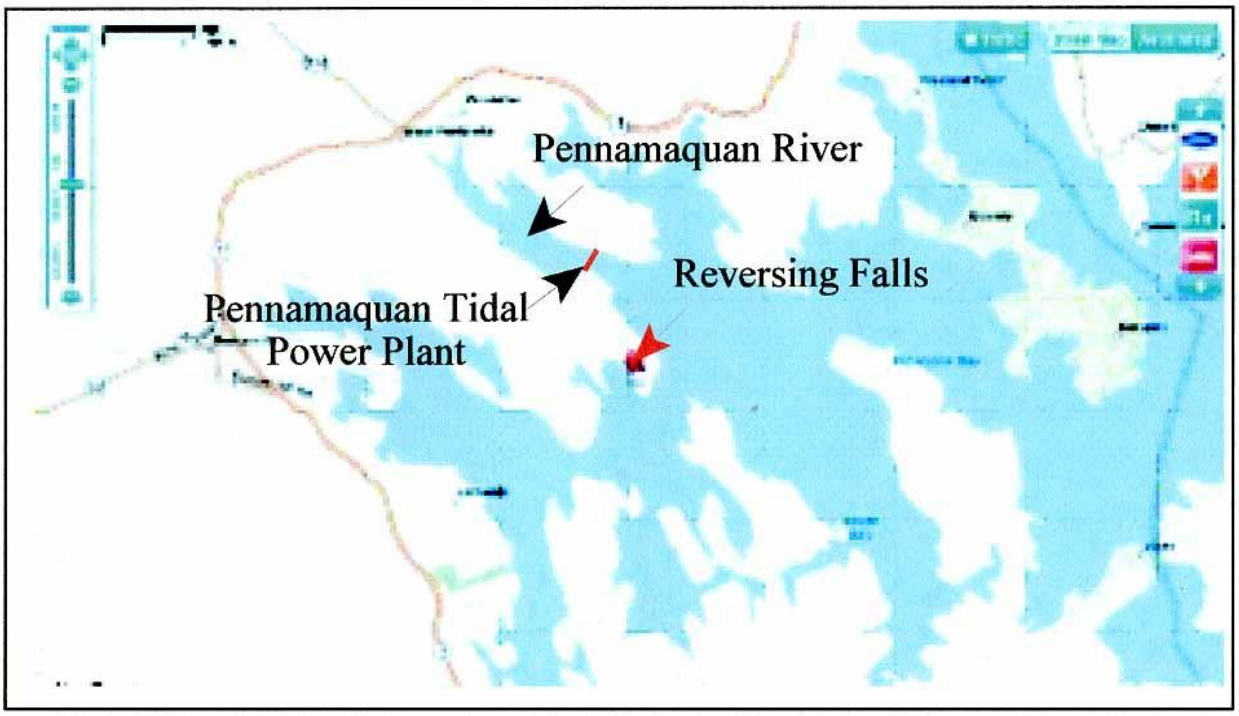

Figure 28 Reversing Falls

Figure 29.a Pennamaquan River From the Leighton Neck Side.

Figure 29.b Pennamaquan River at the proposed Project site from the Leighton Neck Side

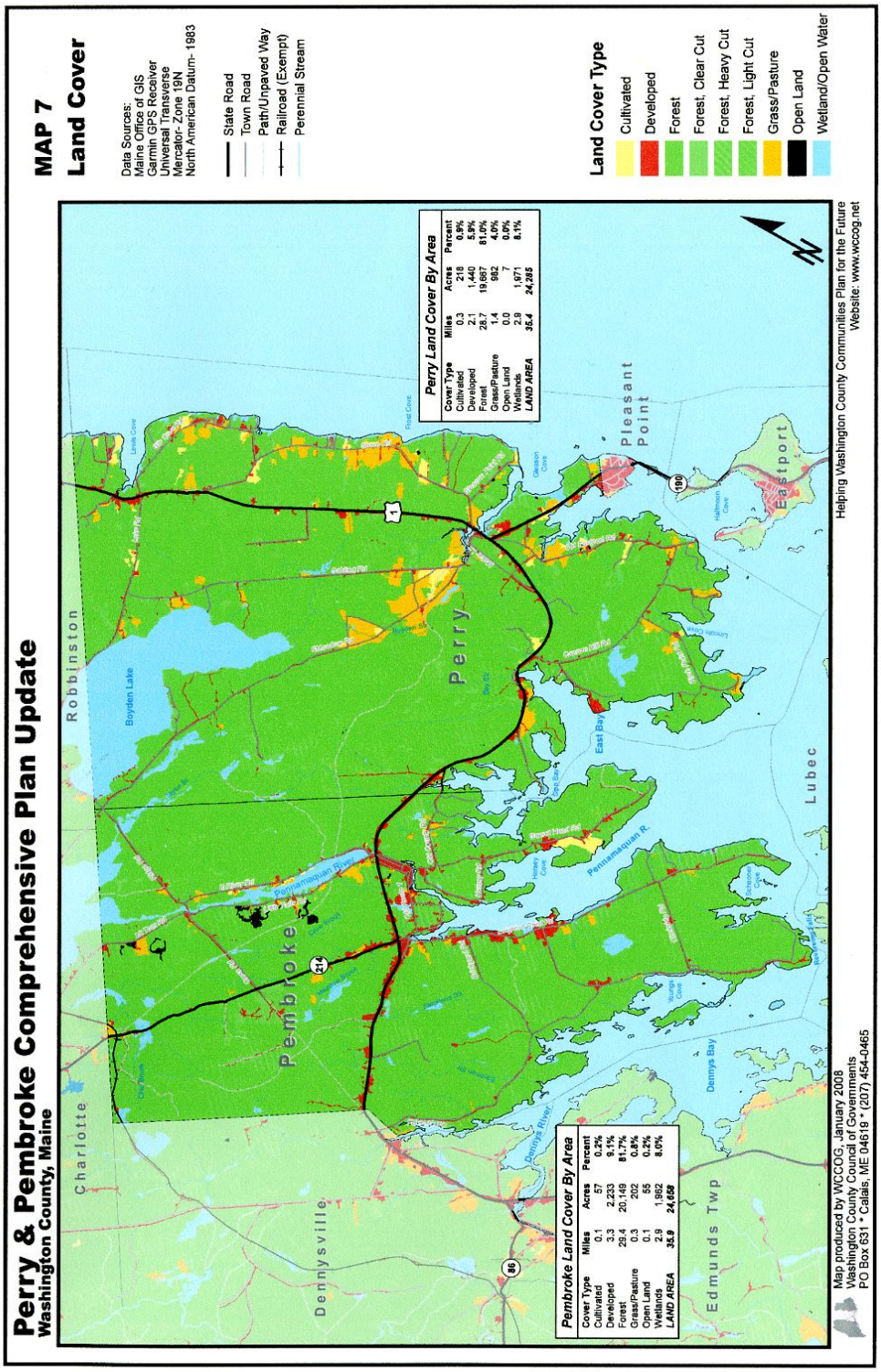

Figure 30 Land use in Pembroke and Perry (from Town of Pembroke, Maine, *Comprehensive Plan*, November 2009)

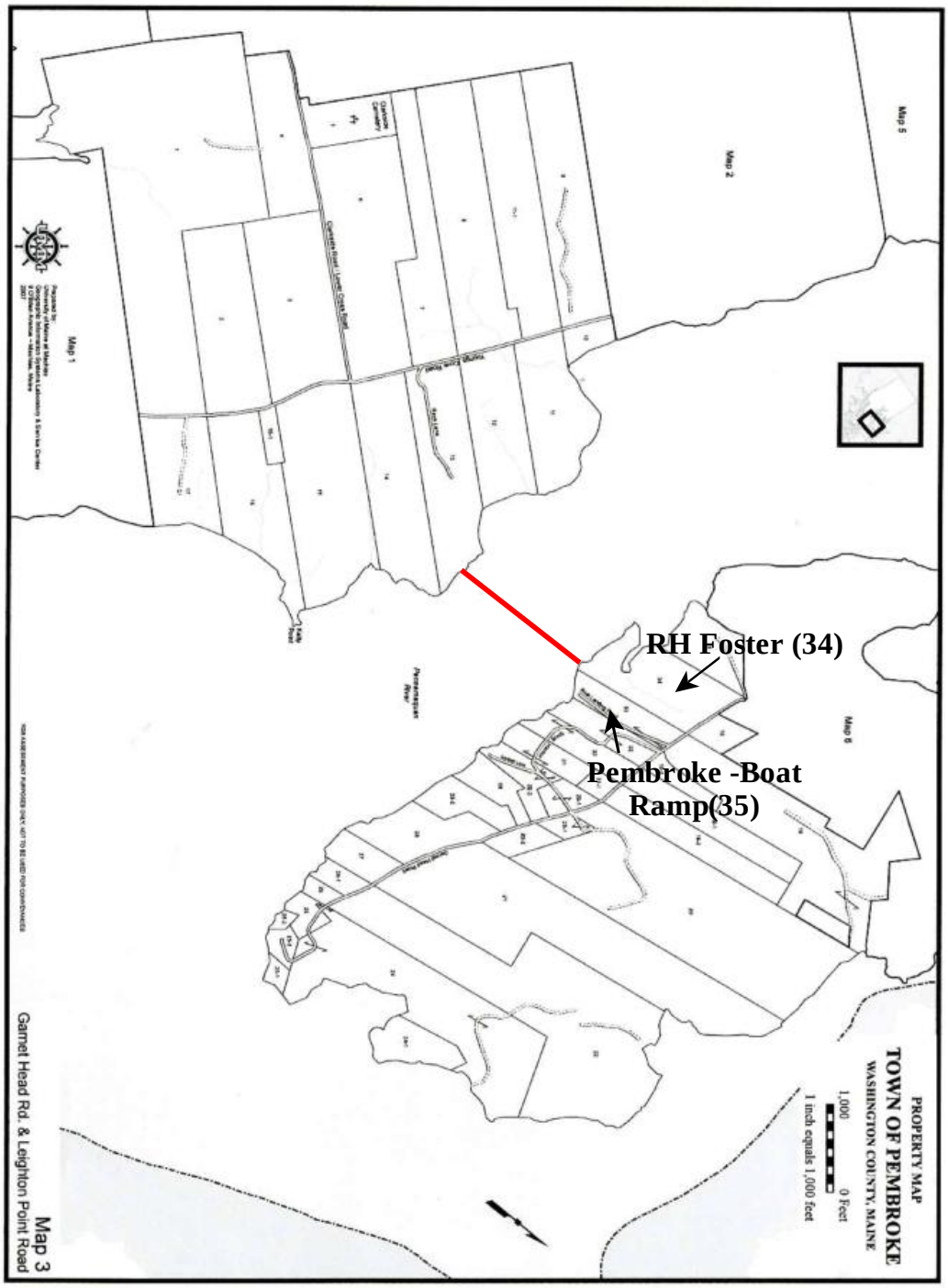

Figure 31 Town of Pembroke Property Map 3 showing the approximate alignment of the Pennamaquan Tidal Power in red. The alignment starts on the Leighton Neck side in the vicinity of property parcel 13. The structure may not have to extend to the property boundary itself. The project on the Hersey Neck side will have to extend to either the parcel owned by the town (Parcel 35) which is currently services the Pembroke public boat ramp or will have to extend to the RH Foster (Parcel 34). Currently the RH Foster site houses two decomissioned oil storage tanks.