§ 5.6 (d)(3) Description of Existing Environment and Resource Impacts

§ 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 reach, and tailrace. Components of the description must include:

The drainage area for the proposed project is not a relevant term since a reservoir, in the conventional sense, will not be created as a result of the project's construction and operation. The surface area of Half-Moon Cove will not increase in size as a result of retaining tidal waters. Operation will start when an elevation of approximately four (4) feet is created between the impoundment and the receding waters of Cobscook Bay. The nature of tidal power generation utilizes the natural tidal exchange which in this case averages eighteen (18) feet with a range of twelve (12) feet for neap tide conditions to approximately twenty-six (26) feet for spring tide conditions.

This section [§ 5.6 (d)(3)(iii)] will focus on the tidal resources of the Cobscook Bay region which provides a predictable source of water without substantial seasonal or annual variations. The ability to accurately predict a tidal function provides a substantial and reliable source of energy without being dependent on a fresh water supply. Information will be presented in compliance with FERC standards with the understanding that tidal power generation is significantly different than conventional hydro-electric generation from fresh water which flows in one direction.

§ 5.6(d)(3)(iii)(A): Drainage Area

(A) Drainage Area;

The drainage area for the proposed Half-Moon Cove project is comprised of a water body with a 1.27 square mile surface area at mean high tide for an average tidal range of 18'. As previously noted, a water volume from the lowest low tide level to approximately 2-3 feet above this elevation forms the permanent reservoir which falls below the highest high tide levels in effect for this project. Less than one percent of the water feeding into Half-Moon Cove is comprised of fresh water from the abutting area in the form of rain and snow melt. This volume of fresh water is considered inconsequential for maintaining the energy production potential of a tidal power plant at the entrance to Half-Moon Cove.

§ 5.6(d)(3)(iii)(B): Tidal Flow Characteristics

B) The monthly minimum, mean, and maximum recorded flows in cubic feet per second of the stream or other body of water at the powerplant intake or point of diversion, specifying any adjustments made for evaporation, leakage, minimum flow releases, or other reductions in available flow;

The water volume of water ebbing from and flowing into Half-Moon Cove at the entrance to the tidal basin is listed below for a typical year to represent available flow for power production. Adjustments for evaporation and other mechanisms have been incorporated into energy calculations for this relatively unique form of energy production. Once again, contributions from fresh water inflow have been neglected due to the lack of substantial volume when compared with normal tidal exchange.

MONTH	AVE TIDAL RANGE – FT	DISCHARGE NEAP – CFS	DISCHARGE AVE – CFS	DISCHARGE SPRING – CFS
JANUARY	18.37	13850	17960	19910
FEBRUARY	18.34	13830	17940	19880
MARCH	18.47	13930	18060	20020
APRIL	18.35	13840	17950	19890
MAY	18.22	13740	17820	19750
JUNE	18.25	13760	17850	19780
JULY	18.53	13970	18120	20090
AUGUST	18.68	14085	18270	20250
SEPTEMBER	18.56	14000	18150	20120
OCTOBER	18.46	13920	18050	20010
NOVEMBER	18.41	13880	18000	19960
DECEMBER	18.11	13660	17710	19630

The average discharge values are approximately the same for ebbing and flooding tides with a slight variation for the time dependent tide function.

§ 5.6(d)(3)(iii)(C): Flow Duration Curve

(C) A monthly flow duration curve indicating the period of record and the 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;

Information on tidal flow is listed above based on accurate predictions of tidal range anticipated at the proposed site in subsequent years. Due to uncertainties associated with predicting the impact of global warming on tidal ranges in the Bay of Fundy, an attempt has not been made to estimate this potential mitigating factor. Based on the resonance character of the Bay of Fundy, any prediction of tidal range availability as a function of global warming effects would be extremely difficult to predict and beyond the scope of the pre-application document. Historical observations points out the accuracy of tidal range predictions based on both empirical data and mathematical models.

In summary, a flow duration curve is not a relevant function for a tidal power plant since a traditional reservoir is not created behind the dam and since the average monthly tidal range varies only slightly and is extremely predictable. On a yearly basis, NOAA publishes a prediction of tidal range and high / low tide occurrences which is extremely accurate when compared with historical observations.

§ 5.6(d)(3)(iii)(D): Ancillary Uses of Tidal Waters

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

The project does not anticipate any competing use for the tidal waters of Half-Moon Cove.

§ 5.6(d)(3)(iii)(E): Instream Flow

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

Tidal water uses within Half-Moon Cove will be unaffected by the proposal. State of Maine by virtue of authority under the submerged lands lease will be the deciding entity on water use.

§ 5.6(d)(3)(iii)(F): Federal Water Quality Standards

(F) Any federally-approved water quality standards applicable to project waters;

State of Maine establishes water quality standards for the tidal waters of Half-Moon Cove. The following information from the Quoddy Bay LNG application summarizes existing conditions based on regulatory input.

2. **Class SB waters.** Class SB waters shall be the second 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, hydro electric power generation, navigation and as habitat for fish and other estuarine and marine life. The habitat must be characterized as unimpaired.

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.

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C. Discharges to class SB waters shall not cause adverse impact to estuarine and marine life in that the receiving waters shall be of sufficient quality to support all estuarine and marine life indigenous to the receiving water without detrimental changes in the resident biological community. There shall be no new discharge to Class SB waters, which would cause closure of open shellfish areas by the Maine Department of Marine Resources (MDMR).

The waters of Half Moon Cove and Western Passage are classified by the State of Maine as SB (Figure 2.1.2-25). Class SB waters are designated by the State of Maine to be the second highest classification in terms of overall water quality.

§ 5.6(d)(3)(iii)(G): Seasonal Water Quality Variation
§ 5.6(d)(3)(iii)(G)(1)
§ 5.6(d)(3)(iii)(G)(2)

(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 vertical 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, cholorphyll a, suspended sediment concentrations, total nitrogen (mg/L as N), total phosphorus (mg/L as P), and fecal coliform (E. Coli) concentrations;

The only water body which would be affected by the operation of the proposed tidal project is Half-Moon Cove. The possibility of linking with Passamaquoddy Bay by installing filling / emptying gates at the causeway between Pleasant Point Reservation and Carlow Island would not adversely affect the water quality of Passamaquoddy Bay due to the vast disparity in volume.

The only permanent "reservoir" created in this project refers to the volume element between the lowest low tide and the upper level approximately 2-3 feet above this elevation. As previously noted, the natural volume of water ebbing from and flooding into Half-Moon Cove would change as a result of the plant's operation and dependent on the tidal cycle (i.e., neap tide to spring tide conditions).

Waste water from Eastport once discharged into Half-Moon Cove; however, a treatment facility was constructed in the early 1990s with outfall pipes now leading to Passamaquoddy Bay. During earlier investigations, the discharge of untreated waste was a problem area even with a minor reduction in the tidal range for Half-Moon Cove.

The following data from the Quoddy Bay LNG project has been provided as reference material for the characterization of Half-Moon Cove and the surrounding area.

2.1.2.6 Bathymetry

The bathymetry of the two marine areas of the LNG Terminal site, Western Passage and Half Moon Cove are very different (Figure 2.1.2-12). Western Passage has a steeply sloping subtidal seafloor that in cross section looks more like a large river profile. The high current velocities prevent extensive deposition of fine sediments and the underlying geologic characteristics reveal abundant bedrock ledge and areas of harder substrates such as coarse sand, gravel, and cobble. The intertidal zone is relatively narrow as a result of its steeper slope than in the nearby Half Moon Cove. Half Moon Cove is a shallow embayment, with extensive shallow sloping intertidal mudflats in the upper region. A narrow wedge shaped subtidal region with its apex near the pipeline crossing, widens towards the southern portion of Half Moon Cove until a restriction occurs at the mouth, at the location of the former bridge between the mainland and Moose Island. The southern end of the Cove is characterized by coarse sediments of sand and gravel often exhibiting sand waves from the tidal currents. In most locations in the Cove, and certainly in the vicinity of the pipeline crossings, the slopes are all gradual without the presence of extensive vertical ledge or steeply angled gravel/cobble slopes. Results of geophysical surveys performed in the spring and summer of 2006 for the Project, in both Western Passage and Half Moon Cove, utilizing multibeam and side-scan sonar as well as both chirp and boomer sub-bottom profilers are presented and discussed in Appendix 6-A of Resource Report 6.

2.1.2.7 Water Quality

2.1.2.7.1 Temperature

Temperature is one of the most important physical environmental factors as it influences or controls the rates of chemical and many biological processes. This is especially true for the marine organisms whose respiration, feeding, and reproduction are temperature sensitive. The area around the mouth of the Bay of Fundy, including the Quoddy region, is often characterized biogeographically as a boreal or cold temperate region. This designation refers to the reduced summer temperatures. Bousfield and Thomas (1975) note that species needing warm water for reproduction are excluded from the region while many Arctic species are present because they can reproduce at the temperatures prevalent in the winter and early spring.

The operative factor controlling water temperature is tidal mixing. The nearly vertical isotherms exhibited in a vertical section across the main axis of Cobscook Bay about 2.75 km past the mouth of Half Moon Cove demonstrates the thorough mixing (Figure 2.1.2-13). A 50-year water temperature record from Eastport, ME, about 6 km south of the project site, indicates that mean temperature varies seasonally from less than 2 to 12 °C (Figure 2.1.2-14). In 2002, the Gulf of Maine Ocean Observing System (GoMOOS, 2005c) established an oceanographic buoy in outer Cobscook Bay about 3.5 km from the mouth of Half Moon Cove (Figure 2.1.2-15). Water temperatures at 1 m and 10 m are remarkably similar, a result of extreme tidal mixing, and vary from about 0 to almost 14 °C (Figure 2.1.2-16). A hydrodynamic modeling study (Brooks et al., 1997) was able to project the temperature distribution throughout Cobscook Bay. This exercise indicates that water temperatures within Half Moon Cove should be at or near the temperature of the offshore water entering Cobscook Bay from Head Harbor Passage and Friar Roads (Figure 2.1.2-17).

Robinson et al. (1996) monitored temperature and salinity at several depths at 24 stations throughout Passamaquoddy Bay from 1990-1995. Some stratification was noted at stations in northern Passamaquoddy Bay far removed from the LNG site. Station 16, located 6.5 km from the site, showed characteristics very similar to those of Eastport and at the Gulf of Maine Ocean Observing System

(GoMOOS) buoy in Cobscook Bay, *i.e.,* a seasonal mean range from just above 0 to almost 14 °C. There was an almost 2 degree difference in mean summer surface and bottom temperatures indicating that Passamaquoddy Bay might be somewhat less well mixed than Eastport and Cobscook Bay.

Cobscook Bay and Head Harbor Passage may be the most species rich area in the western North Atlantic and this may be attributed to tidal mixing and the resulting water temperature moderation (Larsen, 2004b). The mixing cools the surface waters in summer and limits freezing temperatures and the buildup of ice in the winter. It is these characteristics that have made the region the center of the salmon aquaculture industry in the eastern United States and Canada. Several other ecological phenomena related to cool summer temperatures operate that give the region some unique attributes. The first is fog. The clash of warm air masses with the cool surface waters produces a high incidence of fog. Eastport, ME has a 40 percent incidence of fog in July which is three times the amount experienced in Portland, ME 300 km to the southwest (Larsen, 2004b). This fog insulates intertidal organisms from the desiccating effects of sun and wind and allows for better survival (Lewis, 1964). Several species limited to subtidal regions elsewhere can be found intertidally in the Quoddy region (Bousfield and Laubitz, 1972; Larsen, 2004b). Furthermore, several species in the region grow to an unusually large size, a phenomenon called giantism or gigantism (Larsen, 2004b). The operative mechanism has been theorized to be a delay in reproductive maturity, due to cool temperatures, allowing for sustained somatic growth. Species affected include periwinkles, sea urchins, starfish and tunicates.

2.1.2.7.2 Salinity

Salinity is another important environmental factor controlling the distribution of organisms through their ability to osmoregulate. Marine ecologists recognize several salinity zones and species typical of the zones (Carriker, 1967). Generally speaking, salinities over 30 parts per thousand (ppt) are considered fully marine and do not limit the penetration of marine species into estuaries and embayments. As the proportion of freshwater increases, usually in a landward direction, fewer and fewer marine species are able to survive.

Freshwater inputs to the Quoddy region are limited. The largest source, in terms of volume, comes from the St. John River in the lower Bay of Fundy. Indeed, fully one third of the freshwater entering the Gulf of Maine is from the St. John River with a strong spring pulse (Apollonio, 1979). The signal from this input can be seen as reduced salinities of water entering Letite and Western Passages (Robinson et al., 1996), however, as these waters are very well mixed with Gulf of Maine water, salinities remain above 30 ppt. Rivers entering directly into Passamaquoddy Bay include the St. Croix, Magaguadavic and Digdeguash. The latter two have a combined drainage area of 2,300 km^2 and enter into the eastern part of Passamaquoddy Bay, *i.e.,* they do not have an influence in Western Passage. The St. Croix River has a drainage area of 4,300 km^2 above St. Andrews (Trites and Garrett, 1983). There is sufficient freshwater flow in the spring to depress the salinity in western Passamaquoddy Bay to below 30 ppt. Robinson et al., (1996) show that surface salinities at the station closest to the project site is lowered to 28 ppt. Salinities at 10 m and below, however, remain above 30 ppt. Both Larsen and Doggett (1979) and NOAA (1997) put the downstream limit of the estuarine zone in the vicinity of Devils Head, a full 22 km above the LNG Terminal location (see Figure 2.1.2-1).

Cobscook Bay salinities are also generally marine. The Bay's drainage basin is about 1,000 km^2 and freshwater flow represents less than 1 percent of the tidal volume (Brooks, 2004). Data from the GoMOOS buoy show that salinities range from over 28 to nearly 33 ppt over a seasonal cycle (Figure 2.1.2-16). The lower salinities appear as short term spikes resulting from runoff events. Figure 2.1.2-13 shows the vertical salinity section across the main axis of Cobscook Bay at approximately low tide in July 1995. Note the limited salinity range and steep isohalines.

A hydrodynamic modeling study (Brooks et al., 1997) was able to project the salinity distribution throughout Cobscook Bay. This exercise indicates that water salinities within Half Moon Cove should be at or near the salinity of the offshore water entering Cobscook Bay from Head Harbor Passage and Friar Roads (Figure 2.1.2-13).

Results of sampling performed in Western Passage and Half Moon Cove in April 2006 and August 2006 by Quoddy Bay LNG, suggest that on certain tides there may be a slight indication of some freshwater mixing at the surface, since the vertical profile from a CTD-pH-turbidity profiler revealed about a 0.5 PSU lowering of salinity (from 31 to 30.5) in the top 20 meters of an 80 meter deep profile (see CTD vertical profiles in the OSI report in Appendix 2-B). However, neither in Half Moon Cove or Western Passage did salinity get below 30 PSU, indicating that both areas are fully marine in terms of salinity conditions.

2.1.2.7.3 Turbidity

Turbidity refers to the ability of light to pass through, in this case, a column of water. Water devoid of suspended solids, usually sediments and phytoplankton, transmits light well and is said to have low turbidity. Water containing higher quantities of suspended solids, as might occur during phytoplankton blooms, heavy river runoff, or a wind event causing resuspension of bottom sediments, has higher turbidity. High turbidity impedes the passage of light and has the effect of reducing the euphotic zone resulting in reduced phytoplankton productivity. Likewise, turbid waters shade beds of microphytobenthos, macroalgae and submerged aquatic vegetation and diminishes their productivity. In severe cases, as in the upper Bay of Fundy, high turbidity can clog the gills of fishes and filter-feeding invertebrates and interfere with visual feeders.

Waters in the Cobscook/Western Passage area are generally very transparent especially in the spring and summer, *i.e.,* they have low turbidity. A major reason for this is that, unlike coastal plain estuaries, the predominant source of water is from offshore sources, *i.e.,* there is not a land-derived load of suspended sediments in the water column. In addition, there are limited areas of fine grained sediments that might be subject to tidal resuspension (Kelley and Kelley, 2004). Also, tidal exchange and grazing by herbivores prevents the buildup of phytoplankton populations (Garside and Garside, 2004; Campbell, 2004). Phinney et al., (2004) show that the clearest water is found along the main axis of the tidal flow at high tide. These authors demonstrate that sufficient light reaches the bottom throughout Cobscook Bay in spring and summer to drive photosynthesis by both phytoplankton and microphytobenthos. Even at the extreme inner arms of Cobscook Bay, where there is some freshwater influence, at least 1 percent of the surface light, *i.e.,* the euphotic zone, reached the bottom except at low sun angles in the fall.

Based on preliminary results of water quality monitoring being performed at the berth area in Western Passage in June and July of 2006, TSS levels follow a diurnal pattern with average peak readings of about 25 mg/l at or near high tides and average low readings of about 15 mg/l at or near low tide. Final calibration of the ADCP data with collected water sample analytical results has not been completed and so these data should be viewed as preliminary.

Another method of data collection that is currently on-going involves the use of a Conductivity Temperature and Depth (CTD)- pH- turbidity vertical profiler. This work involves lowering a sampling device through the water column which has sensors and on-board data recording capabilities. CTD-pH-turbidity vertical profiles have been collected in late April and early August 2006 in both Western Passage and Half Moon Cove. Results in Western Passage were relatively uniform over different tidal stages during the two sampling events, with average turbidity readings remaining between 1.5 and 2.6 NTUs. In Half Moon Cove there has been slightly greater variation, with April readings ranging from 1.2 to 8.3 NTUs and August readings ranging from 1.5 to 4.3 NTUs. For both Western Passage and Half Moon Cove, the vertical profile is relatively uniform from the surface readings to the near bottom readings, suggesting that in neither environment was there stratification or a substantial amount of bedload or near bottom sediment transport occurring.

The turbidity situation changes in the autumn (Campbell, 2004). Dragging for sea urchins begins in October and scallop dragging starts in November. These activities roil the bottom and mix nutrients and sediments into the water column. It is at this time that the highest levels of silicates are found in the water column (Campbell, 2004). Campbell hypothesizes that the higher suspended sediments, *i.e.*, turbidity, may account for the reduction of autumnal eelgrass production reported at a nearby site by Beal et al., (2004). Furthermore, Trott (2004) notes decadal changes in intertidal species composition from a rich hard bottom community to the dominance of mussel beds. He hypothesizes that increased sedimentation, due to the ever-increasing bottom dragging fishery, may have altered the environment to the advantage on the latter.

2.1.2.7.4 Dissolved Oxygen

The amount of oxygen dissolved (DO) in a water column is an important parameter for evaluating the environmental health of an ecosystem. High DO levels indicate a properly functioning system in which primary production equals or exceeds respiratory processes. Oxygen is a byproduct of photosynthesis (primary production) and is essential for animal respiration. When respiration exceeds primary production, hypoxia or anoxia, *i.e.*, reduced or no oxygen, can result which has devastating effects on animal life including mass mortalities. DO is commonly reported in two ways, as an absolute measure, milligrams of oxygen per liter of water, and as a relative measure, the percentage saturation. The latter is because the ability of water to hold oxygen is temperature dependent. Cold water retains more oxygen than warm water. A generally held standard for DO in coastal water bodies is 6 mg/l and 85% saturation and the 85% saturation is built into the State of Maine water quality standards for Class SB waters, which is the classification in Western Passage and Half Moon Cove (MDEP, 2006). State of Maine water quality classification for Class SB waters is discussed further in Section 2.1.2.7.6.

There are two recent sources of DO data for Cobscook Bay and Western Passage. The first is from 16 years of monitoring of salmon aquaculture sites in the region (FAMP, 1988-2003). During this period, the aquaculture industry expanded rapidly and the Quoddy region was home to the highest concentration of fish farms in eastern North America. Currently, the Quoddy region lies fallow in an effort to control fish disease, although this may change in the near future (J. Sowles, MDMR, personal communication). Fish pens are considered a threat to DO levels due to fish respiration and the oxygen consuming degradation of fish feces and excess fish food. The sites monitored include several within four kilometers of the mouth of Half Moon Cove and sites in Western Passage and Friar Roads (Figure 2.1.2-18). These data were analyzed by Sowles and Churchill (2004) who found that 30 m outside or under the pens oxygen levels have always remained above 7 mg/l and 85 percent saturation. In other words, even close to salmon pens there is no evidence of depleted oxygen levels in Cobscook Bay or Western Passage. The other source of DO data relevant to the proposed LNG site comes from a 1995 coast-wide study (Kelly and Libby, 1996). Five stations were monitored in inner Cobscook Bay, the area believed to be most sensitive to eutrophication. Even here summer samples showed that oxygen levels never fell below 7 mg/l and 85% saturation. Sowles and Churchill (2004) conclude that hypoxia is not a concern in our area of interest.

2.1.2.7.5 Nutrients

Inorganic nutrients are essential for the healthy growth of plants. In the marine environment the limiting nutrient, *i.e.,* the nutrient that controls the amount of production, is nitrogen, which occurs as nitrate, nitrite, and/or ammonium. We have seen previously that tremendous amounts of these compounds enter the Gulf of Maine with the North Atlantic slope water and are mixed to the surface at the mouth of the Bay of Fundy (Townsend et al., 1987). It is important to remember that, as in this example, high nutrient concentrations can be natural, do not necessarily lead to eutrophication, and can have tremendous ecological and economic value (Garside et al., 1978). In spite of the large nutrient supply to the Quoddy region, there is only one major consideration of nutrient distribution and fate within the system (Larsen and Webb, 1997; Garside and Garside, 2004; Garside et al., 2004) and this discussion draws heavily upon it.

One problem with studying nutrients in the Quoddy region is the large volume of water moving in and out with each tide on extremely strong currents. Indeed, tidal currents in Cobscook Bay reach 2 m/sec as a volume equal to the outflow of the Mississippi River passes through the narrow passages of Cobscook Bay on each ebb and flood tide (Brooks et al., 1999). It is assumed that movement in Western Passage is of the same magnitude. This means that a sample taken at a particular location half an hour ago came from water that is now miles away, and a water sample taken at one place now is from water that was elsewhere when the previous sample was taken. It too will be far away half an hour from now, and all the time water is mixing and changing as a result. In other words, trying to relate nutrient concentrations to geographical locations is not very practical in this area. In macrotidal estuaries it is possible to relate nutrient and other distributions to salinity, which varies from 0 at the river inflow to 32 – 33 ppt in the Gulf of Maine. Mixing of fresh and seawater in the estuary provides waters with a range of salinities and related properties in between the macrotidal salinity range (Ketchum, 1955). Instead of plotting measurements against geographical location or mile point along the estuary, we plot graphs of the measurements from a sample against the salinity of the same sample.

The reason for doing this is that properties that enter with freshwater will distribute with it, with higher concentrations in fresher water in Cobscook Bay, and those that enter from the sea will have higher concentrations in saltier water. In fact, if only mixing affects the concentration of a property, then concentration should be proportional to salinity forming a straight line between the freshwater concentrations and the saltwater concentration on the graph (Ketchum, 1951). We may have only a general idea of where water with a particular salinity is at any time, depending on the tide, but we can know what its properties such as nutrient concentration should be, and depending on its distribution with salinity, where the property originated. Often we find that the distribution is not proportional to salinity, which tells us that other processes have affected concentration, either removing or adding to what we would expect (Ketchum, 1955). With nutrients, this can tell us a lot about processes such as uptake and regeneration.

Water samples for nutrient analysis were collected through a series of hydrographic cruises in Cobscook Bay during 1995. The three-day cruises were centered on the extremes of the spring-neap tidal cycles in spring (May), summer (July), and fall (October and November), *i.e.,* six cruises. Stations consisted of three, five-station transects across the main flow axis of the prominent constrictions that separate Cobscook Bay into sub-basins (Figure 2.1.2-19) and 21 peripheral stations generally situated in the center of subtidal areas of the principal coves and sub-embayments. The transects were sampled at high and low water in an effort to obtain synoptic sections of physical, chemical and biological conditions across these constrictions. Peripheral stations were occupied at irregular times between high and low tide. Portions of the inner bays were inaccessible because of their shallowness. See Phinney et al., (2004) for detailed information on station locations. Complete data are available in Garside et al., (2004).

2.1.2.7.5.1 Spring and Summer

Nitrate is plotted against salinity in the spring (May points marked 1 and 2) and summer (July points marked 3 and 4) (Figure 2.1.2-20). There are differences between the two distributions, which one would expect, but both show a rapid decline of nitrate with decreasing salinity. This indicates that the source of nitrate is in the highest salinity waters, *i.e.,* seawater. In the spring, the concentrations are generally higher than in the summer and greater than zero because plant growth is just starting and nitrate is not used entirely or as quickly as it is in the summer. Salinities are lower than in the summer because freshwater run-off is higher in the spring causing slightly more dilution of the seawater. However, the general pattern in both cases is unequivocal evidence that nitrate enters from the seaward end, and the distribution is dominated by this source.

A second feature of this distribution is that in both spring and summer, nitrate would be depleted before salinity reached zero (Figure 2.1.2-20). This further reinforces the conclusion that the ocean and not the rivers provide the nitrate distribution in the region. It also tells us that nitrate is being utilized within Cobscook Bay by plants, since if it were not, nitrate concentrations would decline much more gradually with salinity, reaching low values only when salinities approach zero.

There are several other lines of evidence that suggest that the coastal sea is the source of nitrate. A much more complicated analysis of the nitrate and temperature/salinity data allows the creation of equations that can be used to predict nitrate from temperature and salinity (Garside and Garside, 1995). Combining these relationships with hydrodynamic models that can predict the distribution of salinity and temperature (Brooks et al., 1999), these models can also be used to describe nitrate distribution. Results (Figure 2.1.2-21) indicate high nitrate water entering Cobscook Bay from the seaward end and diminishing in concentration into the Bay's subdivisions and towards the rivers. Nutrient concentrations in Half Moon Cove are nearly as high as in the water along the major axis of Cobscook Bay.

A second line of evidence can be obtained by comparing the potential nitrogen fluxes from other candidates with the nitrate transported in and out of the Bay on the tide each day (Table 2.1.2-3). These calculations show that all the other likely candidate sources of nitrogen to Cobscook Bay combined only represent about 3 percent of the nitrogen that is transported by the tide each day as nitrate, and 5% of what is utilized each day in the growing season by plants. Thus, although local impacts of the other sources cannot be discounted, in the bigger picture, only tidal exchange of nitrate is comparable to plant utilization of nitrogen, and the lesser sources are insignificant. Sowles and Churchill (2004) and Campbell (2004) have done similar calculations, from different perspectives and using slightly different assumptions, and reached very similar conclusions.

Ammonium is excreted by animals that consume plants, and also by bacterial breakdown of nitrogen-containing organic matter (Glibert et al., 1988). It is used preferentially over nitrate by most marine plants, and is also oxidized quite rapidly by bacteria to nitrate. As a result it is important in phytoplankton nutrition, and its presence tells us about recent herbivory and recycling. In ocean waters, its presence often indicates that plant production and herbivorous grazing are closely balanced, and this is observed as the ecosystem matures in the summer.

The distribution of ammonium in Cobscook Bay in the spring and summer is shown in Figure 2.1.2-22. Unlike nitrate, ammonium is distributed quite randomly with respect to salinity in both the spring and the summer. Since ammonium is produced by regenerative processes and is relatively short lived, this strongly suggests that the ammonium is being regenerated within Cobscook Bay. What is most surprising is that ammonium concentrations are almost as high in the spring as they are in the summer. High concentrations in the summer and fall would be expected because the herbivore populations have had a chance to respond to the available plant food and grow to match the supply. This is not normally the case in the spring. The implication is that at least some of the herbivore population is already in place in Cobscook Bay and starts to consume plankton as soon as they grow in the spring. This scenario is consistent with large populations of long-lived filter feeding animals that are resident in Cobscook Bay, such as clams, mussels, and scallops.

This pool of nitrogen can be put in the same perspective as the other fluxes calculated above as ammonium tidal exchange (2uM NH_4 in Cobscook Bay) equaling 14.9 metric tons N per day that may be lost if ebbing water is not returned on the next flood. This flux is a factor of ten or more larger than any originating from current human activities based on inputs from agriculture and sewage (Table 2.1.2-3).

2.1.2.7.5.2 Fall

In the fall we see nitrate utilization continuing into October (points labeled 5) and the distribution is still similar to summer conditions (Figure 2.1.2-23). By November, however, nitrate uptake ceases or is very low and nitrate concentrations are both high and almost uniform over the salinity range sampled (points labeled 6). Despite the high nutrient concentrations there is reduced light to support plankton and algal growth, and phytoplankton populations decline while fixed algae respire more than they photosynthesize, which has implications for nitrogen regeneration.

Ammonium distributions in October are very similar to those in the summer, and for the same reasons: herbivores effectively crop the phytoplankton and regenerate ammonium within Cobscook Bay (Figure 2.1.2-24). The same distribution persists into November but primary production has been inferred to have decreased, based on the nitrate distribution, and so the source of this ammonium must be different, at least in part.

Nutrient data alone are insufficient to elucidate the source of the regeneration that continued high ammonium concentrations imply. However, by the fall there are large reservoirs of organic nitrogen in seaweeds and algal mats. These break down and are grazed, resulting in direct regeneration and a continued supply of particles for filter feeders. In fact, for a variety of reasons other than the nutrient distribution, it seems very likely that grazing on fixed algae is at least as important as filter feeding on phytoplankton in the regeneration of nitrogen as ammonium throughout the growing season and into the fall (see Campbell, 2004; Vadas et al., 2004).

It may be concluded that Cobscook Bay, and probably Western Passage, is nutrient rich throughout the year, and is potentially eutrophic. This is a totally natural circumstance brought about by an abundant supply of nutrients, most importantly nitrate, from the adjacent Gulf of Maine. These nutrients promote phytoplankton and fixed algal growth and the biomass produced is heavily grazed resulting in high ammonium concentrations from excretion and regeneration. The high ammonium concentrations and its incomplete re-utilization by the phytoplankton strongly suggest that plant biomass is controlled by grazing. In other words, despite a high natural nutrient loading, natural grazing processes serve to limit the accumulation of plant material and potential eutrophication. At least at the time these measurements were made, man-made contributions were not significant to the nutrient budget of Cobscook Bay, although they may have significant local impact. Consequently, the nutrient status of

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Cobscook Bay has probably changed little since the development of macrotidal ranges approximately 7,000 years BP (Scott and Greenberg, 1983).

2.1.2.7.6 Water Quality Classification

The State of Maine has codified three water quality standards for the classification of marine and estuarine waters throughout the state (MDEP, 2005) (Title 38 MRSA Sections 465-B, 469). All classes within these standards attain the minimum fishable-swimmable standards established in the Federal Clean Water Act. The State cautions that these standards of water quality classification are intended to be viewed as a hierarchical system of risk as opposed to one of use or quality. The risks are described as "the possibility of a breakdown of the ecosystem and loss of use due to either natural or human-caused events".

The State of Maine recognizes three marine water quality classes in the project region: SA, SB, and SC, which are defined as follows:

§ 5.6(d)(3)(iii)(H): Reservoir Characteristics

(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; and

N/A

§ 5.6(d)(3)(iii)(I): Downstream Consequences

(I) Gradient for downstream reaches directly affected by the proposed project.

Since the discharge from the proposed facility will not exceed normal high tide levels on the Cobscook Bay side of the barrage, an impact will not be affected on the "downstream" reaches of the proposed Half-Moon Cove project.