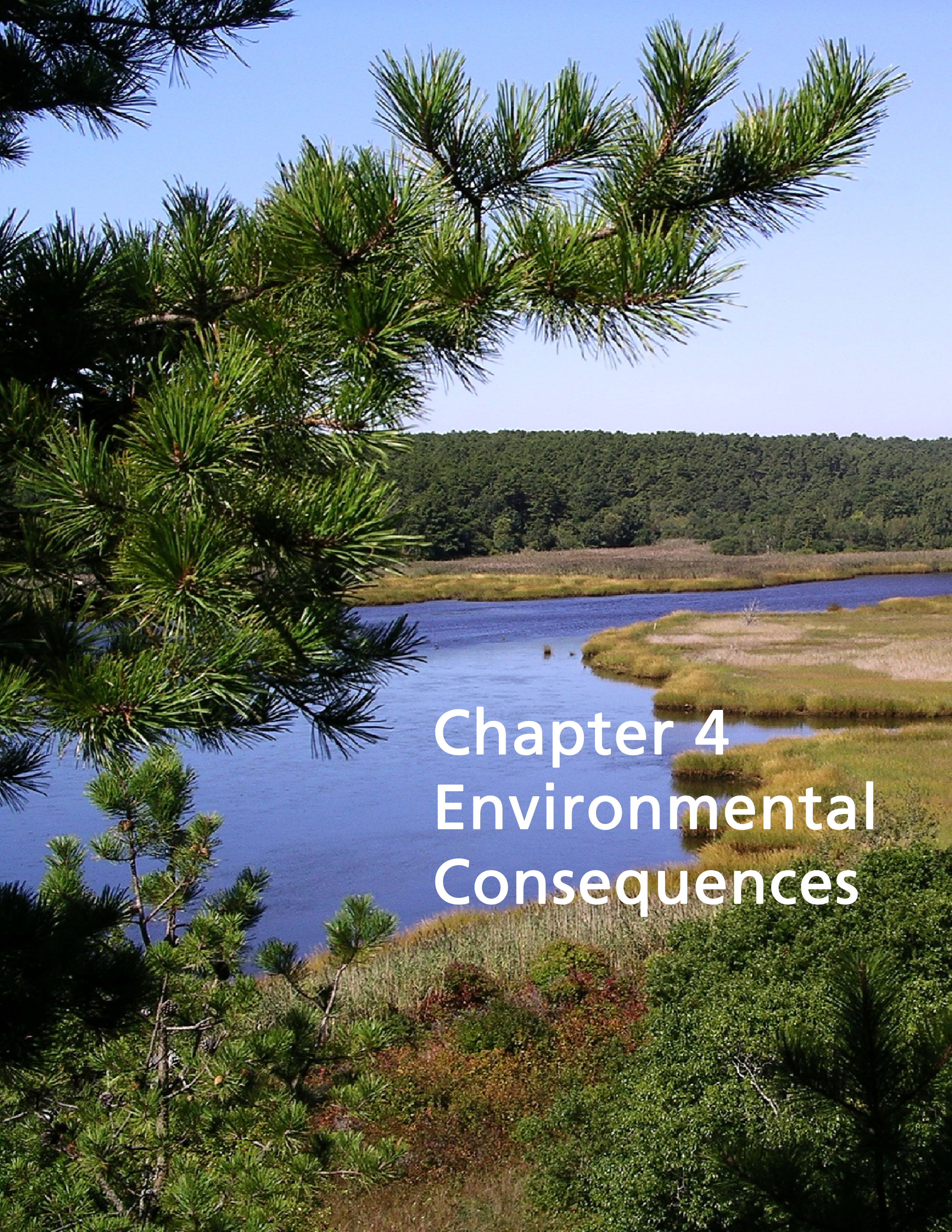
Chapter 4 Environmental Consequences



CHAPTER 4: ENVIRONMENTAL CONSEQUENCES

4.1 INTRODUCTION

The Environmental Consequences chapter analyzes the impacts that would result from implementing any of the alternative elements described in chapter 2. It is organized by resource topic and provides a comparison among alternatives based on topics discussed in chapter 1 and further described in chapter 3. For a complete discussion of guiding authorities, refer to "Appendix D: Applicable Laws, Policies, and Regulations."

Massachusetts Environmental Policy Act (MEPA) requires a detailed description and assessment of the "negative and positive potential environmental impacts" of the project and its alternatives. Thus, this *Herring River Restoration Project, Draft Environmental Impact Statement / Environmental Impact Report* (draft EIS/EIR) assesses (in quantitative terms, to the maximum extent practicable) the direct and indirect potential environmental impacts from all aspects of the Herring River Restoration Project. The assessment presented for each impact topic includes the anticipated long-term impacts of restoration efforts. As permitted in MEPA regulations, this draft EIS/EIR combines a variety of impact topics to cover the spectrum of analyses required [301 CMR 11.07(6)(g) through (l)] (State of Massachusetts 2009). Construction impacts are included in "Section 4.11: Construction Impacts of the Action Alternatives."

In addition to the related laws, plans and constraints discussed in chapter 1, Section 4.5 of the National Park Service (NPS) Director's Order 12 Handbook adds to this guidance by stating when it is not possible to modify alternatives to eliminate an activity with unknown or uncertain potential impacts, and such information is essential to making a well-reasoned decision, the NPS will follow the provisions of the Council on Environmental Quality (CEQ) regulations (40 CFR 1502.22).

4.1.1 GENERAL ANALYSIS METHOD

The NPS must state in an environmental analysis (1) whether such information is incomplete or unavailable; (2) the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment; (3) a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment; and (4) an evaluation of such impacts based on theoretical approaches or research methods generally accepted in the scientific community. Collectively, these guiding laws and corresponding regulations provide a framework and process for evaluating the impacts of the alternatives considered in this draft EIS/EIR. The analysis incorporates the best available scientific literature applicable to the region and setting, the species and areas being evaluated, and the actions being considered in the alternatives. For each resource topic addressed in this chapter, the applicable analysis methods are discussed, including assumptions.

Hydrodynamic Modeling

As described in chapters 1 and 2, the anticipated outcome of the efforts to restore the Herring River estuary by re-introducing tidal flows have been estimated using two-dimensional hydrodynamic modeling. A successful model provides information needed to meet the goals of a project. The model needs to be dynamic, be capable of handling 2-way flows, include important processes, be capable of determining change in water surface elevation over time, and account for freshwater inflow (see appendix B).

By integrating hydrodynamic modeling and Geographic Information System (GIS) mapping, areas of inundation by tide level were estimated (see maps for the alternatives in chapter 2). However, over time, tidal flushing will scour channels in the existing flood plain, and relocate some of this sediment to the intertidal areas. These channels will effectively move water and sediment in and out of the estuary. The sediment transport process will include deposition (accretion) of sediment on the tidal plains, and salt-tolerant vegetation will colonize as the tidal plain elevation increases. These processes are described in detail in this chapter, and maps developed for each resource and each alternative represent the anticipated outcome of these processes. Estimated acres of transformation from freshwater or upland vegetation to salt-tolerant and flood-tolerant marsh vegetation were also developed using model results and GIS.

Analysis Period

This draft EIS/EIR is intended to describe and compare foreseeable long term, permanent outcomes of restored tidal exchange resulting from specified tidal control gate configurations that differ for each action alternative. No matter which alternative is ultimately chosen, tidal restoration would be implemented gradually over several years by making incremental openings to adjustable tide gates. That process, and the ecological monitoring and implementation of subsequent management decisions will be addressed in detail in the project's adaptive management plan (see appendix C).

The impact analysis completed in this chapter is based on the end-point conditions (i.e., final tide gate configuration) specified under each action alternative after the adaptive management process is completed and the project is fully implemented. Some impacts, such as improvements to water quality and sub-tidal habitat, are expected to begin relatively soon after tidal exchange is restored. Other changes, especially those involving vegetation/wetland habitat change and marsh surface accretion, are expected to continue for decades, until the system reaches a state of self-sustainable equilibrium and long after tidal range reaches the maximum extent prescribed by the preferred alternative. It is possible that the maximum tide gate openings described in the action alternatives (especially alternative D) would not be reached if ecological and social constraints are identified in the adaptive management process.

When considering impacts of the no action alternative, it is assumed that the current conditions of resources of the Herring River flood plain would remain, with continuing degradation of natural estuarine conditions.

Geographic Area Evaluated for Impacts

The general geographic study area for this EIS/EIR is the Herring River flood plain and adjacent properties. However, the area of analysis may vary by impact topic beyond the boundaries of the existing flood plain, as applicable.

Assessing Significance of Impacts

The impacts of the alternatives are assessed using the CEQ definition of "significantly" (1508.27), which requires consideration of both context and intensity:

1. Context – This means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole.

2. Intensity – This refers to the severity of impact. Responsible officials must bear in mind that more than one agency may make decisions about partial aspects of a major action. The following should be considered in evaluating intensity:
   a. Impacts that may be both beneficial and adverse. A significant effect may exist even if the federal agency believes that on balance the effect would be beneficial.
   b. The degree to which the proposed action affects public health or safety.
   c. Unique characteristics of the geographic area such as proximity to historic or cultural resources, parklands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.
   d. The degree to which the effects on the quality of the human environment are likely to be highly controversial.
   e. The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.
   f. The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.
   g. Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.
   h. The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places (National Register) or may cause loss or destruction of significant scientific, cultural, or historical resources.
   i. The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.
   j. Whether the action threatens a violation of federal, state, or local law or requirements imposed for the protection of the environment.

An assessment of significance of the impacts of the alternatives is provided in the “Conclusions” section following the analysis of impacts of the alternatives.

4.1.2 CUMULATIVE ANALYSIS METHOD

The CEQ regulations that implement National Environmental Policy Act (NEPA) require the assessment of three types of impacts in the decision-making process for federal projects: direct, indirect, and cumulative. Direct impacts are those impacts that happen in the same place and at the same time as the federal action; whereas indirect impacts are those that happen later in time or farther removed from the area of the federal action. Cumulative impacts are defined as “the impact on the environment which results from the incremental impact of the action when added to other past, present, or reasonably foreseeable future actions regardless of what agency (federal or nonfederal) or person undertakes such other actions” (40 CFR 1508.7). As stated in the CEQ handbook, “Considering Cumulative Effects under the National Environmental Policy Act” (CEQ 1997b), cumulative impacts need to be analyzed in terms of the specific resource, ecosystem, and human community being affected and should focus on impacts that are truly meaningful. Cumulative impacts are considered for all alternatives, including alternative A, the no action alternative.

Cumulative impacts were determined by combining the impacts of the alternative being considered with other past, present, and reasonably foreseeable future actions. Therefore, it was necessary to identify other ongoing or reasonably foreseeable future projects and plans in the Herring River watershed and, if applicable, the surrounding region. Reasonably foreseeable future projects are those expected to occur within the life of the project. The analysis of cumulative impacts was accomplished using four steps:

1. **Identify Resources Affected**—Fully identify resources affected by any of the alternatives. These include the resources addressed as impact topics in chapters 3 and 4 of this document.
2. **Set Boundaries**—Identify an appropriate spatial and temporal boundary for each resource. The temporal boundaries are described by the analysis period noted above and the spatial boundary for each resource topic is listed under each topic.
3. **Identify Cumulative Action Scenario**—Determine which past, present, and reasonably foreseeable future actions to include with each resource. Reasonably foreseeable future actions include those federal and non-federal activities not yet undertaken, but sufficiently likely to occur, that a reasonable official of ordinary prudence would take such activities into account in reaching a decision. These activities include, but are not limited to, activities for which there are existing decisions, funding, or proposals identified. Reasonably foreseeable future actions do not include those actions that are highly speculative or indefinite (U.S. Department of the Interior NEPA regulations 43 CFR 46.30).
4. **Cumulative Impact Analysis**—Summarize impacts of these other actions (x) plus impacts of the proposed action (the alternative being evaluated) (y), to arrive at the total cumulative impact (z). This analysis is included for each resource in chapter 4.

Table 4-1 summarizes the actions that could affect the various resources of the Herring River flood plain.

TABLE 4-1: CUMULATIVE IMPACT SCENARIO

Project	Brief Description	Connection to Herring River	Possible Impact Topics/Comments
Town of Wellfleet Comprehensive Wastewater Management Plan	This project would address nutrient loading in Wellfleet Harbor and propose possible mitigation measures. The plan could lead to "natural" solutions to nutrient attenuation that could avert the setting of total maximum daily loads by the Massachusetts Estuaries Project, and possibly avert a state mandate to build a public wastewater system.	The restoration of the Herring River estuary could contribute to the Comprehensive Wastewater Management Plan by opening the estuary for nitrogen attenuation and restoring a large amount of oyster habitat, which could reduce Wellfleet Harbor nutrient loads.	• Water and Sediment Quality • Aquatic Species

Project	Brief Description	Connection to Herring River	Possible Impact Topics/Comments
Mayo Creek Salt Marsh Restoration Project, Wellfleet	This is a tidal restoration project near the town pier which is still in the planning phase. No decision about implementation has been made. The project would restore a limited amount of habitat similar to that of the Herring River estuary.	Similar vegetation change and water quality improvements are expected from both restoration projects.	• Water and Sediment Quality • Wetland Habitats and Vegetation • State Listed Species: (Diamond-back terrapin, Eastern Box Turtle) • Terrestrial Wildlife • Socioeconomics
Oyster spawning experiments in Wellfleet Harbor	The Town of Wellfleet Wastewater Committee Project is sponsoring a pilot demonstration project associated with the wastewater treatment plan. This would create a 1.3-acre artificial oyster reef in Duck Creek. The pilot is intended to sequester or attenuate nitrogen concentrations.	There is no direct connection to the Herring River restoration, but the pilot project could enhance local shellfish.	• Water and Sediment Quality • Aquatic Species (Shellfish)
Federal Emergency Management Agency (FEMA) remapping of flood zones on Cape Cod	As part of the Barnstable County Flood Study, FEMA is remodeling and remapping the 100-year storm surge elevations for Wellfleet Harbor. This also includes evaluation of coastal structures and could lead to a “decertification” of the existing Chequessett Neck Road Dike, meaning that the 100-year flood zone in the Herring River flood plain would be calculated as if the dike did not exist. Thus, under the no action alternative, the flood hazard zone (FEMA "Zone A") could potentially be at a much higher elevation than it is today if measures are not taken to improve the dike to meet FEMA design and operational guidelines.	As the restoration project is implemented, the Town of Wellfleet will need to consult with FEMA and submit a letter of map revision to establish a new 100-year flood elevation based on the long-term goals of the project, flood protection requirements within the flood plain, and the operations and maintenance plan for the new Chequessett Neck Road dike. The restoration project, with a controlled and managed tidal control system, would probably result in a lower FEMA flood elevation than the no action alternative (which retains the old, poorly maintained structure), despite the fact that actual storm surges during 100-year storm events would be higher under the action alternatives than under the no action alternative.	• Salinity of Surface Waters • Wetland Habitats and Vegetation • Socioeconomics

Project	Brief Description	Connection to Herring River	Possible Impact Topics/Comments
Dredging of Wellfleet Harbor	The federal navigation channel between the town pier and harbor is regularly maintained by the U.S. Army Corps of Engineers (USACE) by dredging the L-Shape Pier, Boat Channel, and possibly Mooring Basin. Dredging has occurred four times since 1971, with the last dredging in 2007. Dredged materials are taken to the designated Cape Cod Bay disposal site 8 miles off shore. The schedule for dredging is unknown.	Through the adaptive management process for the Herring River restoration, the project could potentially involve the beneficial re-use of dredged material to enhance the sediment supply and promote marsh accretion within the flood plain.	• Water and Sediment Quality • Sediment Transport and Soils • State Listed Species (terrapins)

4.2 IMPACTS ON SALINITY OF SURFACE WATERS

Estuaries are dynamic interfaces between land-based freshwater systems and the marine environment where physical and chemical attributes show marked variation. Salinity is variable throughout estuaries such as the Herring River, mostly controlled by tidal action and freshwater inputs from river flow and groundwater. Salinity is a fundamental factor influencing the soil and water biogeochemical processes and the occurrence and distribution of flora and fauna. Therefore, the impacts of the Herring River Restoration Project are strongly influenced by the areal extent of tidal inundation with saline water, the variable salinities (or salt content) of that water, the frequency and depth of inundation (both during daily cycles and infrequent storm events), and the volume of tidal water (i.e., tidal prism) moving in and out of the estuary.

4.2.1 METHODS AND ASSUMPTIONS

The impact analysis is primarily based on a hydrodynamic model that was developed for the estuary (WHG 2011a), which includes simulation of water surface elevations, salinities, and flow velocities throughout the Herring River. Predicted water surface elevations and salinities were used to estimate the spatial extent of tidal exchange achieved under the various alternatives. The model itself relies upon water surface elevation and water column salinity data collected by the Cape Cod National Seashore (the Seashore) and other investigators between 2005 and 2010 (see appendix B for additional details of hydrodynamic modeling).

The hydrodynamic model predicts tidal conditions based on ground-surface elevations estimated from aerial photography and ground-based topographic/bathymetric surveys conducted in 2006. However, as the estuary adjusts to restored tidal flows under any of the action alternatives, topography and bathymetry are expected to change through both natural sediment transport processes and potential restoration actions undertaken to facilitate accretion of the subsided marsh surface. Thus, hydrologic parameters (e.g., hydroperiod) and salinity projections generated by the model are expected to change over the long term and will be subject to adaptive management actions.

Additionally, simulation of future salinities throughout the estuary was based on calibration of the model under existing salinity conditions. However, under these conditions (with the Chequessett Neck Road Dike inhibiting tidal exchange), saline water from Wellfleet Harbor does not penetrate very far upstream into the Herring River. Specifically, tidal water only reaches upstream to approximately High Toss Road, and therefore the model can only use salinity data that currently exists in the Lower Herring River. Because of the lack of a salinity gradient throughout the system under existing conditions, calibration and validation of the modeled salinities for the mixing, transport, and diffusion processes have a degree of uncertainty. Thus, whereas the hydrodynamic model is fully calibrated for water surface elevations throughout the entire system and accurately represents the water surfaces for both existing and proposed alternatives to the system, the salinity component of the model could only be calibrated in the Lower Herring River. This reduces the level of certainty of the salinity estimates for the upper portions of the system. In the upper sub-basins of the Herring River, the salinity model uses standard coefficients for the transport and diffusion of salt and presents a reasonable estimate of the expected salinity levels. In general, salinity values should track closely to the water surface elevation results in the lower portions of the system (Lower Herring River, Mill Creek, and Lower Pole Dike Creek) where the large inflow of high-salinity Cape Cod Bay water will clearly dominate; this relationship is less clear from the Middle Herring River and further upstream because of the diminishing contribution of saline water. As restoration progresses, increasing the size of opening at the Chequessett Neck Road Dike may also result in greater salt penetration than that predicted by the model because of erosion (deepening) of the tidal channels and improved low tide drainage, both effectively increasing the rate of tidal flushing. With each incremental dike opening and associated monitoring of water elevations and salinity, the model can be further validated and the level of uncertainty reduced for future incremental openings.

4.2.2 Impacts of Alternative A: No Action

Under the no action alternative, the estuary would remain a freshwater system upstream of High Toss Road. Limited tidal flows, and marginally saline waters, would remain confined to the Lower Herring River sub-basin, except during major storm events when tidal surges cause saline water to extend slightly further upstream into the estuarine channels (see figure 3-1 in chapter 3). Under the no action alternative, approximately 70 acres of sub- and inter-tidal habitat would be subject to tidal exchange during mean spring tides (see table 4-2) and poor water quality is expected to persist throughout much of the Herring River estuary (see section 4.3). The existing tide gates and dike would continue to limit the mean tidal range in the Lower Herring River to approximately 2.4 feet, compared to 10.3 feet in Wellfleet Harbor. Over the long term and without management and maintenance of the existing tide gates, the tidal range upstream of the dike would be expected to increase slightly as sea level continues to rise.

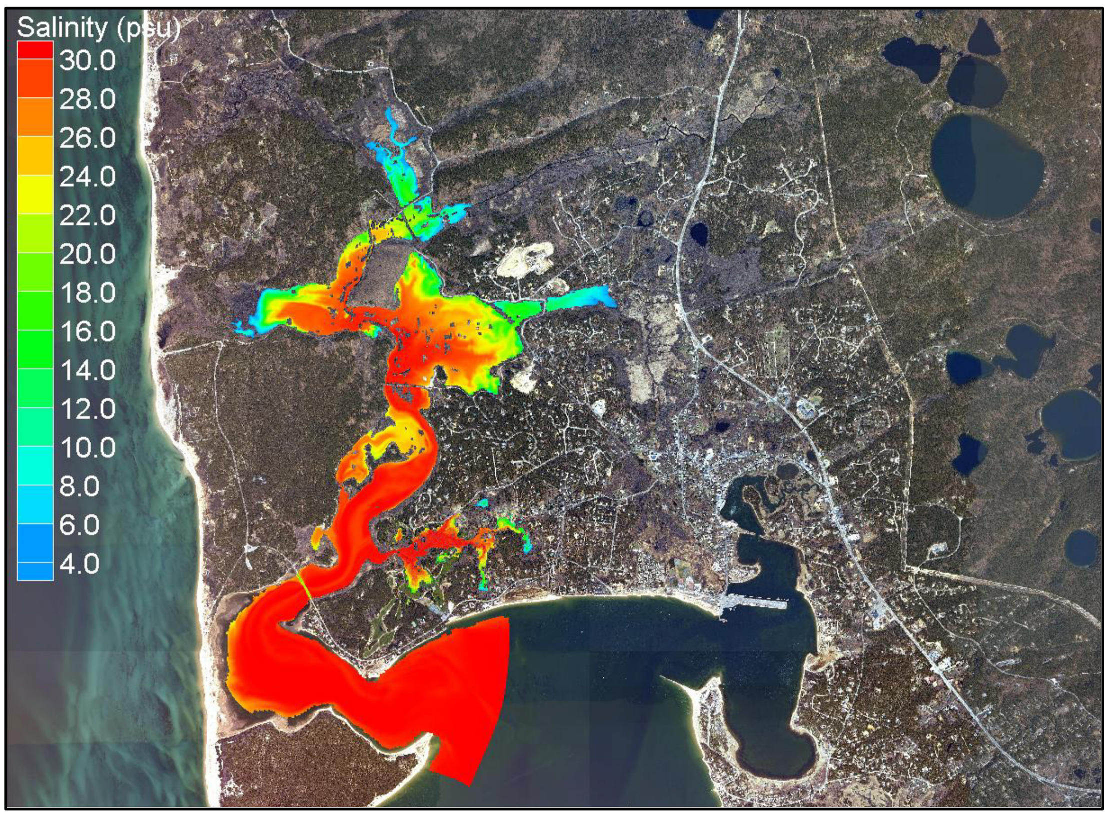
Table 4-2: Area of Herring River Estuary Subject to Tidal Exchange for Each Alternative

Alternative	Acres			
	Mean High Water	Mean High Water Spring	Annual High Water	100-year Storm
A	68	70	72	N/A
B Options 1/2	662/654	800/789	898/888	961/946
C	673	830	899	991
D Options 1/2	718/709	889/881	961/952	1,059/1,048

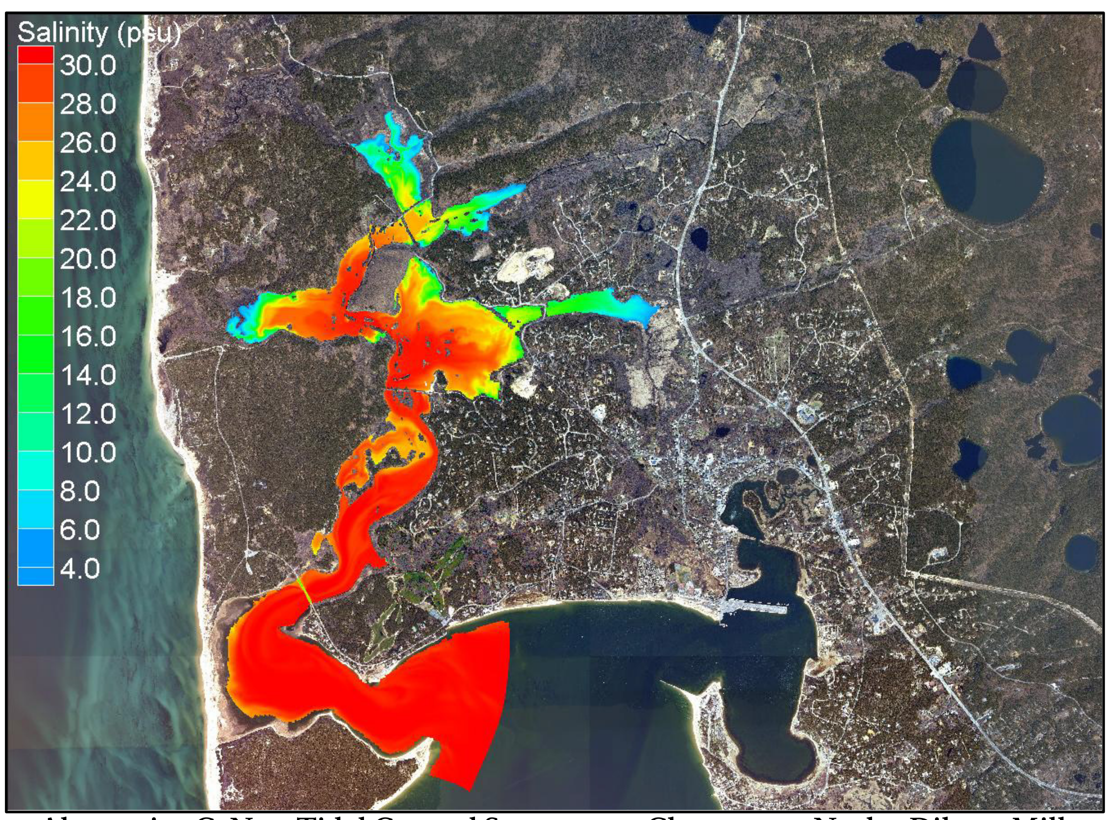
4.2.3 Impacts Common to All Action Alternatives

Under all action alternatives, the Herring River estuary upstream of High Toss Road would change from a freshwater system to a tidally influenced environment with saline water penetrating much farther upstream compared to current conditions. Table 4-2 and figure 4-1 compare the extent of tidal exchange and salinity distribution for each alternative on a system-wide basis.

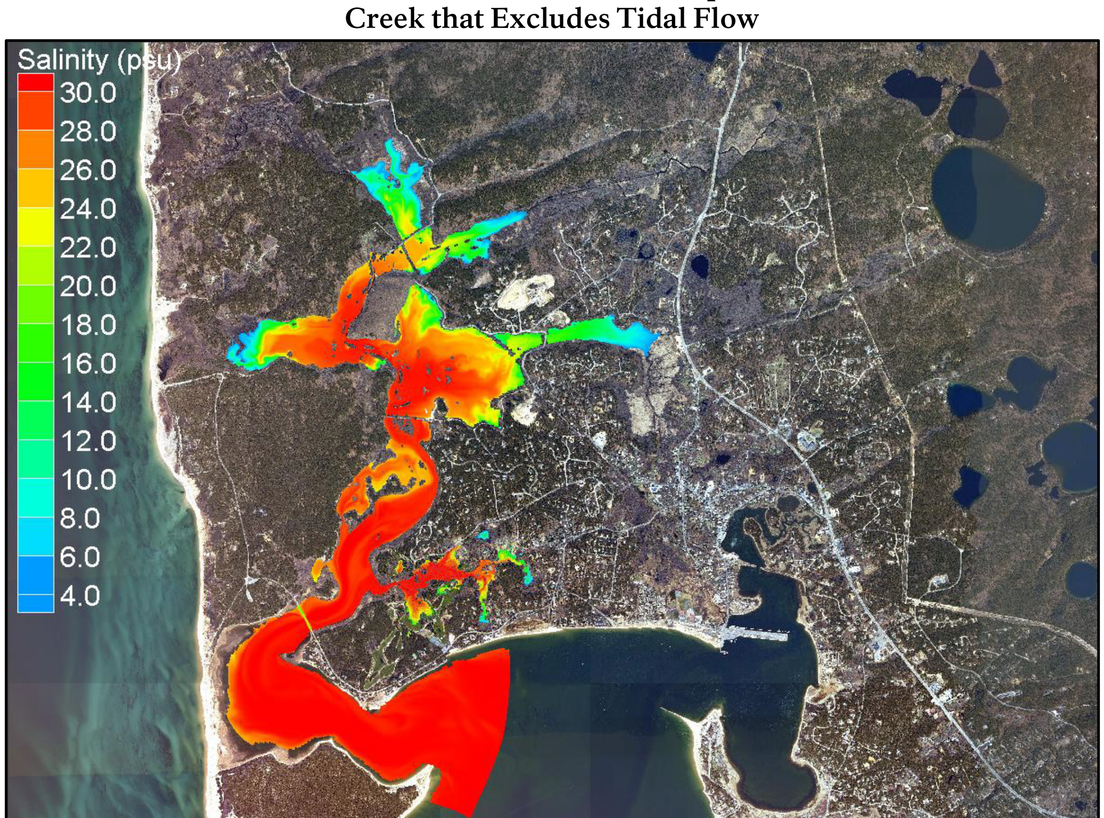
As summarized in table 4-2 and in chapter 2, alternatives B, C, and D would increase the areal extent of tidal influence by an order of magnitude compared to existing conditions. While alternatives C and D would provide only marginal increases to the area of restored intertidal habitat when compared to alternative B, hydrodynamic modeling revealed that the larger tide range achieved by alternatives C and D would result in much higher salinities in several sub-basins. These model results are summarized in table 4-3 and reported in detail in appendix B. Additionally, as described in detail in "Section 4.3: Impacts on Water and Sediment Quality" greater flushing with saline water, resulting in lower residence times, is expected to substantially improve water quality in all sub-basins under all three action alternatives. As previously described, there is some uncertainty in predicting future salinities, especially within middle and upper sub-basins, and actual salinities may be expected to trend somewhat higher as the restoration process proceeds (see section 4.2.4). Within a given sub-basin, the estimated salinity in the tidal channel is generally greater than that predicted for the marsh surface (see table 4-3). This is especially true in the upper sub-basins, which are subject to much less tidal influence and receive proportionately more fresh groundwater discharge. Specific uncertainties, hypotheses, monitoring strategies, and potential management actions aimed at assessing impacts associated with changes in salinity throughout the Herring River system will be addressed in the project's adaptive management plan (see appendix C).



Alternative B: New Tidal Control Structure at Chequessett Neck – No Dike at Mill Creek



Alternative C: New Tidal Control Structure at Chequessett Neck – Dike at Mill Creek that Excludes Tidal Flow



Alternative D: New Tidal Control Structure at Chequessett Neck – Dike at Mill Creek that Partially Restores Tidal Flow

FIGURE 4-1: COMPARISON OF MODELED SALINITY PENETRATION INTO THE HERRING RIVER FLOOD PLAIN UNDER THE RESTORATION ALTERNATIVES

TABLE 4-3: MODELED MEAN AND MAXIMUM SALINITY (PSU, PPTS) FOR EACH SUB-BASIN AND ALTERNATIVES

Sub-basin	Alt. A		Alt. B		Alt. C		Alt. D	
	Mean	Max.	Mean	Max.	Mean	Max.	Mean	Max.
Lower Herring River								
Salinity in Channels	26	30	28	29	29	30	29	30
Salinity Range on Marsh Surface (N = 6)	0–25		22–27		25–30		25–30	
Mill Creek								
Salinity in Channels	0	0	28	30	0	0	29	30
Salinity Range on Marsh Surface (N = 5)	0		0–30		0–0		0–30	
Middle Herring River								
Salinity in Channels	0	0	25	29	27	29	27	29
Salinity Range on Marsh Surface (N = 3)	0		7–28		12–29		12–29	
Duck Harbor								
Salinity in Channels	0	0	7	25	18	24	18	24
Salinity Range on Marsh Surface (N = 2)	0		0–14		3–20		3–20	
Lower Bound Brook								
Salinity in Channels	0	0	11	24	25	27	25	27
Salinity Range on Marsh Surface (N = 1)	0		2–5		7–12		7–12	
Upper Bound Brook								
Salinity in Channels	0	0	1	3	10	15	10	15
Salinity Range on Marsh Surface (N = 3)	0		0–0		0–0		0–0	
Upper Herring River								
Salinity in Channels	0	0	0	0	10	17	10	17
Salinity Range on Marsh Surface (N = 3)	0		0–1		0–14		0–14	
Lower Pole Dike Creek								
Salinity in Channels	0	0	15	21	17	26	17	26
Salinity Range on Marsh Surface (N = 3)	0		20–30		24–30		24–30	
Upper Pole Dike Creek								
Salinity in Channels	0	0	2	6	5	12	5	12
Salinity Range on Marsh Surface (N = 4)	0		0–14		0–20		0–20	

PSU is the practical salinity unit; whereas ppt is parts per thousand. For the purposes of this analysis these units are used interchangeably.

N = number of marsh points

4.2.4 COMPARISON OF IMPACTS OF THE ACTION ALTERNATIVES

Impacts of Alternative B

Under alternative B, the modeled mean high spring tide water surface elevation of approximately of 4.8 feet in the Lower Herring River would restore tidal influence to about 800 acres of the former Herring River flood plain (see table 4-2 and chapter 2). Average channel salinities in the lower sub-basins, including Lower Herring River, Mill Creek, Middle Herring River, and Lower Pole Dike Creek, would consistently reach above 15 ppt and occasionally rise close to 30 ppt during spring and storm tides. Even with some attenuation of salinity on the marsh surface in the upper portions of the Middle Herring River and Lower Pole Dike Creek, salinity values in this range should largely suppress existing brackish and freshwater vegetation and sustain a steady transition to salt marsh vegetation throughout these sub-basins.

Model results suggest that the Duck Harbor and Lower Bound Brook sub-basins would be subjected to mean channel salinity levels between 7 and 11 ppt, occasionally rising above 20 ppt during spring and storm tides. Salt marsh vegetation would not be expected to dominate these areas, except perhaps in locations immediately adjacent to the tidal channels (see "Section 4.5: Impacts on Wetland Habitats and Vegetation"). The mid-range salinity values predicted for the Duck Harbor and Lower Bound Brook sub-basins may provide conditions that are suitable for non-native *Phragmites*, which could be afforded a competitive advantage over native wetland plants in salinity ranges of less than 5 to 20 ppt (Chambers et al. 2003; Smith et al. 2009). In nearby Hatches Harbor, it wasn't until salinity reached 25 ppt that *Phragmites* was greatly diminished (Smith et al. 2009). *Phragmites* can persist at 25 ppt, although with reduced vigor (Burdick et al. 2001; Warren et al. 2001).

Upper sub-basins, including Upper Herring River, Upper Pole Dike Creek, and Upper Bound Brook would be subjected to small tidal fluctuations and salinities generally would remain very low (below 5 ppt). Except for the most sensitive salt-intolerant vegetation in these upstream sub-basins, substantial vegetation change would not be expected.

Impacts of Alternative C

Impacts with respect to salinity changes for alternative C are identical to those for alternative D (see the following section), except that the 78-acre Mill Creek sub-basin would not be influenced by tidal exchange and would remain a tidally restricted, freshwater system. The area of the Herring River flood plain restored by tidal exchange during mean spring tides would be 830 acres (see table 4-2).

Impacts of Alternative D

Under alternative D, the predicted mean high spring tide water surface elevation of approximately of 5.6 feet in the Lower Herring River would restore tidal influence to about 890 acres of the former Herring River flood plain (approximately 80 acres more than alternative B) (see table 4-2 and chapter 2). Similar to alternative B, average channel and marsh surface salinities in the Lower Herring River, Middle Herring River, Mill Creek, and Lower Pole Dike Creek sub-basins would generally reach into the mid-20s ppt and occasionally rise close to 30 ppt during spring and storm tides.

In direct comparison with alternative B, channel salinities predicted under alternative D should be much greater (averaging above 17 ppt) in the Duck Harbor, Lower Pole Dike Creek, and Lower Bound Brook sub-basins. Predicted salinities on the marsh surface (range 3–30 ppt) for these three sub-basins are also much greater than those predicted by alternative B. The generally high channel salinities predicted for these three basins should sustain a transition to salt marsh vegetation through most of this 317-acre area. However, the mid-range salinity values predicted for the marsh surface areas in most upstream portions of Lower Bound Brook and Duck Harbor may provide conditions that are suitable for non-native *Phragmites*, which could be afforded a competitive advantage over native wetland plants in salinity ranges of 5 to 18 ppt (Smith, pers. comm. 2011).

Under alternative D, model results predict that maximum channel salinities might not exceed the mid-range levels of approximately 12-17 ppt, in the Upper Herring River, Upper Pole Dike Creek and Upper Bound Brook sub-basins and that marsh surface salinities would remain very low (generally below 5 ppt) in the upper portions of these basins. All three of these upper sub-basins would be subjected to small tidal fluctuations, and salt marsh species would not be expected to dominate these areas, except perhaps in locations immediately proximal to the tidal channels (see "Section 4.5: Impacts on Wetland Habitats and Vegetation"). Except for the most sensitive salt-intolerant vegetation, in upstream sub-basins where salinities are expected to remain below 5 ppt, extensive vegetation change would not be expected.

4.2.5 Cumulative Impacts

Based on the cumulative impact scenario, there are no anticipated impacts on salinity that would result in cumulative impacts different from the direct and indirect impacts of each action alternative.

4.2.6 Conclusion

Under alternatives B, C, and D, high salinity water should consistently reach the Lower Herring River, Middle Herring River, Lower Pole Dike Creek sub-basins and the eastern half of the Duck Harbor sub-basin, all of which should sustain a transition to salt marsh plant communities. However, salinity levels would remain low, generally below 5 ppt, in the upper portions of the Herring River, Bound Brook, and Upper Pole Dike Creek sub-basins, where only the most salt intolerant vegetation would be stressed or killed.

Mill Creek would also be subject to high salinity tidal flow under alternatives B and D, and salt marsh would become the dominant habitat within the sub-basin. Existing freshwater conditions would remain in Mill Creek under alternative C.

Therefore, under all action alternatives, permanent, estuary-wide changes in the penetration of high salinity water into lower and mid-flood plain sub-basins, which currently receive little or no tidal influence, would occur. This increase in salinity is a critical factor in achieving the desired transition from a degraded freshwater wetland to a functioning estuarine wetland, which is an ecologically critical component of the coastal ecosystem of Cape Cod. Based on the degree of salinity change, particularly in the lower sub-basins, the importance of salinity as an ecological factor, and the regional importance of tidal wetlands in terms of biodiversity, this would likely constitute a significant beneficial local and regional impact. Of the action alternatives, alternative D would be most successful in restoring salinity penetration to a pre-dike condition, but all of the action alternatives would represent a substantial change relative the no action alternative.

Under alternative B, mid-range salinity levels also may provide conditions suitable for non-native *Phragmites* in the Duck Harbor, Lower Pole Dike Creek, Lower Bound Brook sub-basins and perhaps portions of the Middle Herring River sub-basin; however, under alternatives C and D salinity should be high enough to sustain a transition to salt marsh habitats over most of these four sub-basins. In the Upper Bound Brook, Upper Pole Dike Creek, Upper Herring River, and the upstream portions of the Lower Bound Brook and Duck Harbor sub-basins salinities should remain low enough to sustain the existing freshwater plant communities under alternative B. Under alternatives C and D, freshwater conditions are expected to persist in the upper portions of these sub-basins, but mid-range salinity levels throughout the remainder of these sub-basins may provide conditions suitable for brackish water vegetation including non-native *Phragmites*. Specific uncertainties, hypotheses, monitoring strategies, and potential management actions aimed at addressing impacts associated with low water-column salinity will be addressed in the project's adaptive management plan (see appendix C), and would be expected to prevent widespread expansion of *Phragmites*, although, as the previous discussion indicates, there are expected changes in distribution. Therefore, despite the uncertainty associated with changes to *Phragmites* distribution, the impacts are not anticipated to be significant for any of the action alternatives.

Under the no action alternative, there would be no detectable change in salinity penetration compared to the current, degraded condition on the estuary. Therefore, despite the significance of past adverse environmental impacts caused by diking and draining the estuary, there would be no significant new adverse impacts from not taking action.

4.3 IMPACTS ON WATER AND SEDIMENT QUALITY

More than 100 years of restricted tidal influence and marsh drainage has severely degraded water and sediment quality of the Herring River, resulting in low pH, increased mobilization of aluminum and iron, periods of low dissolved oxygen, and high levels of fecal coliform bacteria. This degradation of the Herring River has resulted in periodic fish kills and the listing of segments of the river on U.S. Environmental Protection Agency's (EPA's) 303(d) list of impaired waters. Tidal restoration would substantially improve water and sediment quality by allowing increased flows of seawater, creating higher high tides and increased low tide drainage. Tidal restoration would also substantially decrease system residence times which is a measure of the amount of time required to exchange water from a given area in the Herring River system with Wellfleet Harbor. Water and sediment quality improvements are major objectives for the project and are integral for restoring the natural habitat conditions required for the re-establishment of native fish, shellfish, and other estuarine animals.

4.3.1 METHODS AND ASSUMPTIONS

In addition to findings of published studies of the Herring River estuary and other natural and restored estuaries in the northeastern United States, this impact analysis used unpublished water quality and sediment quality data collected by the Seashore between 2006 and 2010 (the most relevant results are summarized in chapter 3). The analysis also integrated findings of the hydrodynamic modeling of the estuary (WHG 2012).

4.3.2 IMPACTS OF ALTERNATIVE A: NO ACTION

Lack of tidal flushing and continued drainage in the Herring River would sustain the unnaturally narrow tidal range and likely would continue the oxidation of marsh peat, primarily in the Mill Creek, Middle Herring River, Lower Pole Dike Creek sub-basins, and the eastern portion of Duck Harbor sub-basin. Oxidation of pyrite stored abundantly in salt-marsh soils would continue, releasing sulfuric acid and lowering the pH of porewater and surface water in nearby channel segments, especially those with low flows or standing water. Acidic water would also continue to cause leaching of iron and aluminum and concentrate these metals in drainage ditch water. Under current conditions in the Herring River, iron has been observed to exceed USEPA guideline values for freshwater chronic conditions and prolonged exposure (several days) can have deleterious impacts on aquatic life (see "Section 4.6 Impacts on Aquatic Species"). Aluminum in the Herring

River has been observed to exceed concentrations considered toxic by some researchers (see "Section 3.3: Water and Sediment Quality"). Under the no action alternative, the segments of the Herring River upstream of High Toss Road likely would remain on the 303(d) list for low pH and high aluminum (MassDEP 2011a).

Under the no action alternative, decomposition of marsh soils likely would continue to cause high biological oxygen demand and low summer dissolved oxygen concentrations, especially within subsided and water-logged parts of the estuary. Dissolved oxygen levels would periodically fall below the USEPA regulatory standard of 6 mg/l, which is the threshold for maintaining healthy aquatic life such as resident and migratory fish and invertebrates. Normal estuarine processes of nutrient and energy (organic matter) exchange between Wellfleet Harbor and the Herring River estuary would also remain restricted, thus providing only limited benefits to the coastal ecosystem.

Fecal coliform concentrations in the Lower Herring River and adjacent portions of Wellfleet Harbor would continue to be elevated at times, exceeding the Massachusetts regulatory standard for shellfish harvest. High fecal coliform concentrations would likely keep the Herring River estuary downstream of the dike permanently closed for shellfishing in some areas and only conditionally opened in other areas. Water with elevated fecal coliform levels would continue to flow into Wellfleet Harbor during outgoing tides. The Lower Herring River would likely remain on the 303(d) list as impaired for pathogens (MassDEP 2011a).

4.3.3 IMPACTS COMMON TO ALL ACTION ALTERNATIVES

With system residence times upstream of High Toss Road reduced (table 4-4) by at least a factor of 25 (4801 hours vs. 191 hours), regular tidal flushing of the Herring River estuary with well-oxygenated water from Wellfleet Harbor is expected to maintain dissolved oxygen concentrations above state water quality standards at all times. Adequate dissolved oxygen concentrations are expected to benefit migratory diadromous fish as well as resident fish and invertebrates (see section 4.6).

TABLE 4-4: MODEL CALCULATED SYSTEM RESIDENCE TIMES OF THE HERRING RIVER ESTUARY

Basin / Sub-basin	Alternatives	Residence Time (hrs)	Improved Flushing over Existing Conditions	Extent of Tidal Exchange (acres)
Mill Creek with Wellfleet Harbor	A	12,553	—	70
	B	504	96%	800
	(C), D*	424	97%	(830), 889
Sub-basins above High Toss Road with Wellfleet Harbor	A	4,801	—	70
	B	191	96%	800
	(C), D *	144	97%	(830), 889

Source: Hydrodynamic Model (Woods Hole Group 2011).

System residence time is a measure of tidal exchange from a given sub-basin with Wellfleet Harbor.

* Residence Times are identical for alternatives C and D, but alternative C does not include tidal flushing in Mill Creek which would not change from existing conditions.

Summertime dissolved oxygen levels could remain low in ponded areas and obstructed ditches that are not regularly flushed by tidal waters. This condition could persist until a more natural tidal channel system becomes established, i.e., in equilibrium with restored tides and wetland topography. As part of the adaptive management plan, the extent of standing water, dissolved oxygen, and other parameters would be monitored and ponding could be reduced by targeted excavation of silted-in channels to increase circulation and promote low-tide drainage.

Soil Chemistry

Restored tidal flushing from any of the action alternatives is expected to reduce acidification within the mid-portion of the Herring River estuary where saline water would again saturate drained peat. The rate of aerobic decomposition and acid production within the soil would decrease substantially, and the pH of porewater and surface water would increase (Portnoy and Giblin 1997a). With restored salinities, aluminum and iron would no longer be leached from the soil to receiving waters in concentrations that stress aquatic life. Decreased decomposition and increased saturation of soil pore spaces with water would also prevent further subsidence of the marsh surface.

The flooding of the lowest and most waterlogged and organic sediments with seawater could result in elevated porewater sulfide concentrations, especially in areas with poor low-tide drainage. Despite some tolerance, even salt marsh plants can be stressed by very high sulfide concentrations. Therefore, porewater sulfide levels and salt marsh plant colonization will be monitored in these low areas. As part of the adaptive management program, some tidal channel excavation may be required to improve low-tide drainage and, consequently, peat aeration.

Nutrients

Despite drainage and decomposition of peat in the middle portion of estuary over the last century, concentrations of nitrogen and phosphorus in the wetland sediments of Herring River have remained high. Portnoy and Giblin (1997a) demonstrated that renewed tidal flushing of acid sulfate soils would allow ammonium-nitrogen to be released into receiving waters, at least over the short term (months), (i.e., until the reserve of ammonium-nitrogen adsorbed onto soil particles is depleted). However, with the great improvement of tidal flushing (minimum 24 times faster), nutrients would be diluted and removed from the system with each tide cycle.

Overall, released nutrients would benefit growth of salt marsh vegetation in the restored marsh. However, if large volumes of sea water were introduced suddenly, abundant nutrient release and sulfide production could inhibit the growth of salt marsh grasses while promoting algal blooms both in the river and downstream into Wellfleet Harbor. The gradual reintroduction of tidal exchange should allow ammonium-nitrogen to be slowly released, thus avoiding nitrogen loading that could contribute to algal blooms in receiving waters. Increased concentrations of released nutrients would likely be short-lived (probably months) and not persist beyond an initial adjustment period. Wellfleet Harbor is open to Cape Cod Bay and thus well-flushed, limiting the potential impacts of any temporary increases in nutrient loading. Therefore, with small, incremental increases in tidal exchange, informed by appropriate water quality monitoring, the release of nutrients from the estuary would likely be small and would not result in persistent algae blooms in the harbor (Portnoy 1999).

Pesticides and Other Organic Compounds

As described in section 3.3.5, there likely has been historical use of pesticides throughout the Herring River watershed. Under all of the action alternatives, a tidal channel system likely would be re-established. During restoration, sediment is expected to be mobilized within the estuary in response to the increased volume of tidal exchange (see section 4.4.1 for further discussion). Mobilized sediment is expected to mostly be transported upgradient onto the marsh surface, and partially downgradient toward Wellfleet Harbor. Potential impacts on the aquatic ecosystem from chemicals bound to mobilized sediments will be assessed once background levels of pesticides have been determined by ongoing efforts of the Seashore prior to completion of the final EIS/EIR.

Fecal Coliform

Regular tidal flushing is expected to substantially decrease fecal coliform concentrations in the Herring River. The tidally influenced area within the estuary would increase significantly compared to existing conditions. Flushing rates would be increased (i.e., residence time would be decreased) at least 24 fold (see table 4-4). In addition, the survival time of fecal coliform bacteria would be reduced by higher salinity (e.g., Bordalo et al. 2002), as well as by higher dissolved oxygen and lower water temperature.

Greatly reduced fecal coliform concentrations within Herring River and Wellfleet Harbor would likely allow for removal of the river from the 303(d) list for impairment of pathogens, leading to the potential for additional areas of shellfish beds that could be reopened for harvest.

Even with tidal restoration, elevated bacteria concentrations could still occur within some upstream reaches of the Herring River system especially after rainstorms. However, increasing salt penetration and flushing will substantially reduce bacteria survival time and density prior to discharge into Wellfleet Harbor. Therefore, fecal coliform concentrations should be minimal in lower sections of the river and adjacent parts of the harbor. Nonetheless, fecal coliform will continue to be monitored during the restoration process, particularly after rainstorms.

4.3.4 Comparison of Impacts of Action Alternatives

While the differences between existing conditions and any of the action alternatives are substantial, differences among each of the alternatives are comparatively small. Two parameters which can be used to quantify these differences are residence time and size of area inundated. As shown in table 4-2, the size of the area regularly influenced by tidal waters under each of the action alternatives ranges from 800 to 889 acres. The area of expected water quality improvements correlate closely with the areas that experience restored tides, although the exact nature and extent of any water quality changes will also depend on actual surface water salinity and other local conditions (particularly elevation and sediment quality).

The substantially lower residence times (i.e., improved flushing with Wellfleet Harbor) estimated under all action alternatives will be a major component of improved water quality. However, water quality also is dependent upon nutrient loading, naturally occurring chemical breakdown processes, and the quality of water outside the embayment.

Residence times under all action alternatives would be significantly reduced (see table 4-4). For example, in areas upstream of High Toss Road, flushing would be more than 25 times greater under alternative B than under current conditions (i.e., 8 days system residence time as compared to the current 200 days). Residence times above High Toss road would decrease to 6 days under alternatives C and D. Reducing residence times to this extent is expected to substantially dilute any water quality constituent of concern (e.g., nutrients, bacteria, and other potential contaminants) that would be exported downstream of the dike.

4.3.5 CUMULATIVE IMPACTS

Other projects and plans in the area with the potential to beneficially affect local water and sediment quality include the Town of Wellfleet Comprehensive Wastewater Management Plan, the Mayo Creek salt marsh restoration project, and oyster spawning experiments in Wellfleet Harbor. The Wellfleet wastewater management plan would improve water quality in the project area by reducing the potential for nutrient loading and domestic sewage contamination of local surface waters. The Mayo Creek restoration project, although smaller in scale that the Herring River Restoration Project, would improve water quality in a nearby location. The oyster spawning experiments in Wellfleet Harbor could directly increase the local population of oysters which could improve the overall local water quality because oysters filter nitrogen out of the water, improving water quality. Recurrent, but infrequent, dredging of Wellfleet Harbor has the potential to adversely affect water quality through sedimentation and turbidity. Dredging delivers sediment to the water column and increases turbidity. Fine sediments would likely be transported out of Wellfleet Harbor on ebbing tides while coarser sediments could settle to the bottom within the harbor. Although these impacts are temporary, they recur with each dredging event, thus resulting in long-term, intermittent impacts.

Overall, the combined impact of the Comprehensive Wastewater Management Plan, the Mayo Creek salt marsh restoration project, and oyster spawning experiments in Wellfleet Harbor would have a beneficial impact on water and sediment quality in the project area and in Wellfleet Harbor. In combination with the substantial beneficial impacts of the proposed project, the cumulative impacts would be considered beneficial and long term.

4.3.6 CONCLUSION

All action alternatives would result in a permanent increase in tidal flushing that would greatly improve water quality in the estuary and in Wellfleet Harbor. This improvement to water quality is an important factor in achieving the desired transition from degraded freshwater marsh to a functioning estuarine wetland, which is ecologically critical in the geographic area of Cape Cod. There is an unknown risk of adverse water quality impacts, but if they occurred they would be transient, localized, and mitigated by adaptive management actions. Based on the probable degree of long-term water quality improvements, the importance of water quality as an ecological factor and the regional importance of estuarine wetlands, this would likely constitute a significant beneficial impact.

4.4 IMPACTS ON SEDIMENT TRANSPORT AND SOILS

4.4.1 IMPACTS ON SEDIMENT TRANSPORT

Healthy salt marshes rely on the interchange of marine inorganic and organic sediments to remain at equilibrium with coastal processes. The construction of the Chequessett Neck Road Dike in 1909 interrupted sediment transport and likely caused extensive changes to the dimensions of the Herring River channel and a cessation of the deposition of sediment on the surface of the salt marsh. This interruption of coastal sediment transport processes likely was most pronounced during storm events when inorganic marine sediments (primarily sands) historically were moved into the Herring River estuary.

Restoration of sediment transport processes are an important aspect of the overall restoration project because they would enhance accretion of sediment on subsided marsh plains, restore the dimension and pattern of tidal channels, and could potentially influence ecological processes and resources in the river and Wellfleet Harbor. This section analyzes the potential impact of mobilized sediments to the former Herring River salt marsh and tidal channel system. Sediment deposition on the marsh plain and a concurrent increase in elevation to the subsided salt marsh surface is a critical element for the re-establishment and long-term sustainability of marsh habitat. The potential impacts of sediment movement on commercial shellfish resources in Wellfleet Harbor are addressed in "Section 4.10: Impacts on Socioeconomics."

Methods and Assumptions

This impact analysis is primarily based on findings from a quantitative sediment transport study of the Herring River system using time-varying results from a two-dimensional hydrodynamic model and sediment data collected throughout the existing system (see appendix B). This study also provided a qualitative and quantitative comparison of sediment transport potential and its spatial movement during normal and 100-year storm tides under existing and restored conditions. One important condition inherent to the hydrodynamic model is that the topography of the salt marsh and bathymetry of the tidal channel bathymetry are held constant, i.e., elevations do not change from either deposition or erosion, a situation that would not occur when tides are incrementally restored in the Herring River. The model output indicates potential areas of erosion and deposition but does not provide estimates of depth or volumes of erosion or deposition.

Impacts of Alternative A: No Action

Tidal flows would continue to be restricted by the existing tide gates at the Chequessett Neck Road Dike (6-foot wide opening for incoming tides and 18-foot wide opening for ebb tides). Even though the Herring River is a flood-dominated system, the tidal restriction at the dike would continue to limit upstream sediment transport under all tidal conditions. As described in section 3.4, there is essentially no tidal influence, and consequently little or no movement of sediments, in areas upstream of the Lower Herring River sub-basin even during a 100-year storm event. Sand-sized particles, for example, would not be transported upstream beyond the immediate vicinity of the Chequessett Neck Road Dike due to inadequate flow velocities.

The restriction of the tides likely has resulted in extensive siltation within the Herring River channel (including the flood tide shoal immediately upstream of the Chequessett Neck Road Dike), leading to a decrease in width and depth and an overall decrease in channel capacity. Under the no action alternative, there would be no change in sediment transport between the river and Wellfleet Harbor. The area of the estuary immediately downstream of the Chequessett Neck Road Dike would continue to be subject to potential sediment movement during both normal and storm-driven tides (see table 4-5). Insufficient delivery of marine sediments to the former salt marsh surface throughout all of the Herring River sub-basins would continue, as would the potential for continued subsidence of the marsh due to pore space collapse and decomposition of organic matter.

Impacts Common to All Action Alternatives

Under all of the action alternatives, sediment transport throughout the Herring River estuary would be enhanced. Three classes of sediment transport would occur; the relative importance of each would be dependent on the size and configuration of the restored tidal opening at the Chequessett Neck Road Dike. Under the action alternatives sediment would be transported as follows:

- **Bedload**—sediment that moves along the bottom of the tidal channels

- **Suspended load**—sediment that is picked up by tidal currents and moves within the water column, but eventually settles out somewhere in the Herring River estuary
- **Suspended fines**—material that is transported by tidal currents that remains in suspension for greater than one tide cycle.

Two primary impacts of enhanced sediment transport are relevant for all of the action alternatives. First, in response to increased tidal flow, the fine sediments that have accumulated in the tidal channels upstream and downstream of the dike would be mobilized as suspended load and suspended fines. This process is expected to be temporary and would diminish considerably once the hydrologic system reaches equilibrium with restored tidal conditions. Over a longer period, bank and bed erosion is expected to increase the dimensions of the restored tidal channels. Much of this sediment movement would take place as bedload and suspended load, and the duration of this process would largely depend on the rate at which tides are incrementally restored, as well as the size and configuration of the final opening.

Second, the increased size of the tide gate opening would alter the long-term sediment transport patterns in the marsh. Because the system is flood-dominated, the restoration of sediment transport processes would provide a source of marine sediment to the marsh surface, and would be crucial to the establishment of a sustainable tidal marsh system.

Both types of sediment transport impacts are discussed in more detail below.

Changes to Tidal Channels

Over the last 100 years much of the tidal channel network throughout the estuary has accumulated sediment and has been partially modified by ditching for mosquito control. With an increase in the size opening at the Chequessett Neck Road Dike and associated increased tidal prism and flow velocities, channel sediment will be mobilized and channel geomorphology changed. Sediment mobilization in tidal channels is supported by preliminary model results (see appendix B). The model found that velocity increases would be significant enough under normal tidal conditions for all of the action alternatives to initiate movement of sediment, increasing sediment transport within the system. As tidal flows are increased incrementally, both the width and depth of the channels are expected to increase due to bank erosion and erosion of the channel bed. Over time, a much deeper, wider, and well-defined channel would be expected to form from just below the Chequessett Neck Road Dike upstream to the Middle Herring River and Lower Pole Dike Creek sub-basins.

Different pathways would exist for fine-grained sediment and coarse-grained sediment. Coarser-grained sediment (dominated by sands) would be transported primarily as bedload along the bottom of tidal channels. Model results indicate that bedload transport from areas just upstream and downstream of the dike would be slightly seaward toward Wellfleet Harbor, whereas finer-grained suspended sediments would be transported predominantly upstream to eventually settle out in the upper sub-basins of the Herring River. Very fine particles would remain in suspension and may be transported upstream into the Herring River or downstream toward the harbor and Cape Cod Bay.

Changes to Marsh Surface Elevation

Much of the suspended load component of the remobilized sediments that is transported under restored tidal conditions is expected to be deposited on the marsh surface. In addition, once the tidal channel reaches equilibrium, deposition of sediment on the marsh surface is expected to continue, especially during storm-driven tidal events (WHG 2012). During flood tide and storm events, suspended sediment will reach the marsh plain including the subsided areas of the former salt marsh where flow velocities will decrease and particles suspended in the water will settle out. As velocities decrease further, sediment will deposit in the marsh channels. Initially, deposition of sediment is expected to occur primarily in the subsided areas of the Lower Pole Dike Creek, Duck Harbor Lower Bound Brook, and Upper Herring River sub-basins. Over time, sediment accretion is expected to contribute to the long-term sustainability throughout the Herring River marsh. While enhanced accretion on the salt marsh from organic and inorganic sediments is expected to occur under all of the action alternatives, a program will be developed to monitor the long-term changes in the elevation of the marsh surface.

Three primary sources of sediment which could affect long-term salt marsh accretion are as follows:

Inorganic Matter from Wellfleet Harbor—An important long-term sediment source would be inorganic materials that would be transported into the restored Herring River estuary by tidal currents from nearshore waters (i.e., Wellfleet Harbor and Cape Cod Bay). Sediment mobilization would be particularly high during storm events associated with tidal surges (Roman et al. 1997; Christiansen 1998). Even though they are relatively rare, storm-driven tides have been shown to contribute a disproportionate amount of sediment to the salt marsh surface, underscoring the influence of storms in sediment transport.

Upland Sediment Sources—There is little runoff from upland sources to the Herring River estuary due to sandy soil and the rural nature of the watershed. Therefore, upland inputs of sediment are assumed to be comparatively minor.

Organic Matter—Organic matter from macrophyte production on the marsh surface is an important contributor to salt marsh accretion. Anisfeld, Tobin, and Benoit (1999) stated that even in situations where inorganic matter inputs dominate the mass accumulation of sediment, organic matter could have a crucial role in vertical accretion of the salt marsh because of its lower particle density and its ability to increase sediment pore space. In addition, several studies have documented the role of belowground root and rhizome production and associated expansion of peat substrate as an important mechanism contributing to marsh surface elevation increases (e.g., Bricker-Urso et al. 1989).

Organic matter on the marsh surface is also important as a sediment trapping mechanism. Studies have demonstrated that salt-marsh cordgrass (*Spartina alterniflora*) can have a significant dampening impact on the turbulence of tidal flows, promoting the settling of particles suspended in the water column (Stumpf 1983). Similar processes are expected to assist in sediment trapping in the restored Herring River marsh.

Currently, due to pore space collapse and decomposition of the organic matter, the marsh surface in the Herring River estuary upstream of the Chequessett Neck Road Dike has subsided as much as 90 cm compared to the marsh surface elevation downstream of the dike. The rate with which sediment would be deposited under restored tidal conditions would be dependent on several previously described factors. Accretion rates in established southern New England salt marshes typically range from 0.2 to 0.6 cm/year (Bricker-Urso et al. 1989; Roman et al. 1997; Donnelly and Bertness 2001). However, an accretion rate of 2.4 cm/year was measured subsequent to major storm events (Roman el al. 1997). Salt marshes exposed to restored tidal conditions have also undergone accretion rates of 0.7 to 1.0 cm/year over a period of three decades since restoration (Anisfeld, Tobin, and Benoit 1999).

Comparison of Impacts of the Action Alternatives

The focus of the three action alternatives is to increase tidal influence and concurrently restore sediment transport processes to all of the Herring River sub-basins. Alternatives B, C, and D would result in different amounts of tidal exchange and different levels of potential sediment transport in the estuary. Generally, with the greater tidal flows under alternatives C and D, greater amounts of potential sediment mobilization would be expected when compared to alternative B. This would be especially true during storm events when greater tidal flows would result in greater transport potential in areas both upstream and downstream of the Chequessett Neck Road Dike (see table 4-5).

TABLE 4-5: TOTAL MAXIMUM AREA OF POTENTIAL SEDIMENT MOBILIZATION (EROSIONAL AREA)

Tidal Conditions	Simulation Case	Alternatives	Chequessett Neck Road Dike (Acres)[a]		
			Upstream	Downstream	Sum
Normal Tides	Existing Conditions	A	0.1	56	56
	3-ft tide gate opening	B	42	102	144
	10-ft tide gate opening	(C), D [b]	58	98	156
100-year Storm Tide	Existing Conditions	A	0.1	153	153
	3-ft tide gate opening	B	132	217	349
	10-ft tide gate opening	(C), D [b]	217	230	447

a Area estimated from graphical outputs of the hydrodynamic model (see appendix B) (WHG 2012).

b Impacts for alternative C are identical to alternative D but exclude the Mill Creek sub-basin.

By inference, sediment accretion rates resulting from suspended sediment being deposited on the marsh surface would in part be a function of the different amount of tidal exchange under each of the alternatives. Actual depths of sediment deposition and rates of accretion under each of the action alternatives would be dependent on a variety of complex factors and cannot be quantified with certainty. As stated previously, a program will be developed to monitor the long-term changes in the elevation of the marsh surface.

Impacts of Alternative B

In areas upstream of the Chequessett Neck Road Dike, the restoration of tides under alternative B would greatly increase the area of potential sediment mobilization during normal tidal conditions (42 acres) and 100-year storm conditions (132 acres), both substantially greater than the 0.1 acre of potential sediment mobilization under existing conditions. The predicted areas showing increased erosion potential are confined mostly to the future location of a more defined Herring River channel, whereas areas of potential sediment deposition are predicted along the edges of the channel and the upper Herring River sub-basins.

For areas downstream of the dike, the area of potential sediment mobilization during normal tidal conditions would increase from 56 acres to 102 acres over existing conditions and from 153 acres to 217 acres during 100-year storm events (see table 4-5).

Impacts of Alternative C

Areal estimates of potential sediment mobilization for alternative C are expected identical to those for alternative D (see next section) excluding the Mill Creek sub-basin. The dike at the mouth of Mill Creek is not expected to change sediment mobilization potential in the Mill Creek sub-basin, except perhaps for minor accumulations of sediment upstream of the new structure.

Impacts of Alternative D

In areas upstream of the Chequessett Neck Road Dike, the restoration of tides under alternative D would greatly increase the area of potential sediment mobilization during normal tidal conditions (58 acres) and 100-year storm conditions (217 acres), both substantially greater than the 0.1 acre of potential sediment mobilization under existing conditions. When compared to alternative B, this would also represent increases in potential sediment mobilization of 38 percent (58 acres vs. 42 acres) and 64 percent (230 vs. 217 acres) for normal and 100-year storm conditions respectively. The areas showing increased erosion potential upstream of the dike are confined mostly to the future location of a more defined Herring River channel and would likely extend farther upstream in the Herring River when compared to alternative B. Areas of potential deposition are predicted along the margins of the channel and the upper Herring River sub-basins.

For areas downstream of the dike, the area of potential sediment mobilization during normal tidal conditions would increase by 75 percent (98 vs. 56 acres) over existing conditions and by 50 percent (230 vs. 153 acres) during 100-year storm events. Alternatives D and B are predicted to have similar areas of potential sediment mobilization downstream of the dike (102 vs. 98 acres for normal tides, and 230 vs. 217 acres for 100-year storm events).

Cumulative Impacts

In terms of sediment transport, there are two potential cumulative interactions between the impacts of harbor dredging and the impacts of any of the action alternatives. First, increased tidal range can mobilize and transport a small volume of sediment to Wellfleet Harbor. Because of the small quantity of this mobilized sediment and the predicted hydrodynamics, increased deposition of fine-grained sediment in aquaculture areas is not expected. If this sediment is mobilized concurrently with Wellfleet Harbor dredging, the combined impact is difficult to predict. However, any cumulative impacts are improbable, because the sediment sources are separated by greater than one mile and it is not currently known if harbor dredging will occur during the Herring River project implementation period.

The second potential interaction between harbor dredging and estuary restoration is that harbor dredging could produce sediment that could be used for beneficial reuse in the Herring River flood plain if it is demonstrated that additional sediment is needed to enhance the pace of marsh surface accretion.

Additional study and assessment would be necessary to determine the suitability and impact of this action, and the availability of this sediment for beneficial reuse is speculative. Past and future harbor dredging are therefore unlikely to have cumulative impacts on sediment transport that differ from the overall beneficial impacts of each of the action alternatives.

Conclusion

Over the long term, all action alternatives would mobilize sediment that would permanently restore marsh surface elevation to conditions that approximate pre-dike natural conditions. The degree and rate of sediment mobilization would be largely determined by the amount of tidal influence and rate of incremental opening of the tide gates. The rate of incremental opening of the tide gates would determine to a large extent the time required to reach equilibrium conditions in the restored tidal channel. Tide gates would be used to manage water levels and flows in a manner that promotes deposition of sediment upstream of the dike. Adaptive management would be informed by appropriate monitoring, evaluating both upstream and downstream transport and deposition of sediment during the incremental dike opening process (see appendix C).

The accretion rate and marsh elevation response would depend on factors such as flow regime, inorganic sediment supply (sand, silt, clay) from downstream sources, organic matter supply from above and belowground vegetation production, and sediment that is mobilized during the natural re-configuration of the tidal channel. The highest sediment transport potential would occur during storm tides. Accretion rates on the Herring River marsh plain in the lower and Middle Herring River sub-basins are expected to be greater than the 0.2 to 0.4 cm/year observed in established marshes, but restoration of marsh surface elevations would proceed for many decades given the extent of marsh surface subsidence. The recovery of the marsh surface is an important factor in achieving the desired transition from a degraded freshwater marsh to a functioning estuarine wetland, which is an ecologically critical component of the coastal ecosystem of Cape Cod. Based on the degree of expected marsh surface recovery, the importance of marsh surface recovery as an ecological factor, and the regional importance of estuarine wetlands, this would likely constitute a significant beneficial impact that would be realized as a long-term goal of the restoration process.

Sediment mobilization would also pose potential adverse impacts in the form of sedimentation of shellfish beds downstream of the dike. These uncertain impacts would be mitigated by monitoring sediment deposition and taking management action to avoid adverse impacts; the potential for adverse impacts would therefore not be considered significant under any of the action alternatives.

Under the no action alternative, sediment interchange between the Herring River upstream Chequessett Neck Road Dike and Wellfleet Harbor would remain largely non-existent, while the area immediately downstream of the Chequessett Neck Road Dike would still be subject to potential sediment mobilization for both normal tides and 100-year storm events. This potential for sediment transport is very limited relative to pre-dike conditions, and would remain unchanged under the no action alternative, leading to further subsidence of marsh surfaces due to pore space collapse and organic matter decomposition. Therefore, despite the significant reduction in sediment transport, there would be no significant new adverse impacts on sediment transport from taking no restoration action. However, continued subsidence of the marsh surface could constitute a significant new impact of failing to take restoration action.

4.4.2 IMPACTS ON SOILS

Potential impacts were assessed based on the extent of disturbance to soils, including natural undisturbed soils, the potential for soil erosion resulting from disturbance, and limitations associated with soils. The analysis is based on the Soil Survey of Barnstable County, MA, the soils map (figure 3-15 in chapter 3), on-site inspection of resources within the Herring River flood plain, review of existing maps and literature on soil and vegetation of the Herring River flood plain from NPS and other agencies, and professional judgment of subject matter experts.

Impacts of Alternative A: No Action

Under the no action alternative, no tidal restoration would occur. Oversight and maintenance of the structures would continue along the same schedule used since the dike was reconstructed in 1974. Physical factors acting on the dike will continue and the tide gates will entail maintenance costs over the next several years. Ecological conditions with the Herring River would continue to be affected by tidal restrictions. The soils will continue to evolve as they have since the dike was built, as there will be no change in tide height or salinity within the system.

Impacts Common To All Action Alternatives

Other sections of this document have discussed the specific changes to the flood plain soils that would result from the restoration process. In general, they can be described in the following ways. There would be physical changes such as when pore space redevelops as the dried soil responds to being saturated again by the tides. There would be chemical changes such as the increase in the soil pH as seawater returns to the area; this would be especially important for the highly acid Maybid Variant Silty Clay Loam soil type. There would also be changes in soil texture as the surface either loses or gains sand, silt, or clay depending on whether tidal sedimentation processes erode or deposit those materials. The organic content of the soil is likely to increase as fresh and/or salt marsh peats once again are created. All of these changes would interact with the vegetation and wildlife that will grow on and in the soil to re-establish the complex marsh ecosystem. While some of the characteristics used to classify the soil into named types may rapidly or slowly change, a number of characteristics would not change because they are based on the soil's parent material. Overall, there may not ultimately be enough difference to rename a soil, but the changes are of great importance to the restoration.

Since the Maybid Variant Silty Clay Loam soil type is likely the most affected by the tidal restriction, it is anticipated that it will be the soil type most affected by the reintroduction of the tidal flows. Wherever saline tidal flow is restored and salt marsh plants re-establish, it is likely that it will change back, over a long period of time, to eventually resemble (at least in some way) what it was before the flow was limited and the flood plain drained. Since the soil was not examined before the dike was constructed as it was in the 1980s when the soil survey was conducted, it is not possible to describe exactly what this soil was like prior to diking.

All action alternatives would result in estuary-wide, similar beneficial changes to other hydric soil types within the flood plain by increasing pore space, soil pH, and organic content as these soils are subjected to tidal inundation. Various local changes in soil texture are also possible as soils are subjected to different erosional and/or depositional forces that alter the sand, silt, or clay content. These changes in structure, organic content, and chemistry play an important overall role in the expected transition from degraded freshwater wetland to functioning estuarine wetland. This local, permanent change in soil structure, organic content, and chemistry, in the context of the project objective of restoring an estuarine wetland ecosystem, would be considered a substantial beneficial impact. Upland (non-hydric) soil types currently mapped within the limits of predicted inundation, including Carver Coarse sand Hooksan sand upland soil type likely reflect mapping inaccuracies and would be unaffected since all hydrologic modifications would take place in the hydric soil flood plain.

Comparison of Impacts of the Action Alternatives

As depicted on the soils map (figure 3-15 in chapter 3), the Maybid Variant Silty Clay Loam soil is located in the following sub-basins: Lower River, Lower Pole Dike, Middle River and the eastern side of Duck Harbor. Under all of the action alternatives, tidal flow would return to those areas creating pre-dike conditions. Salinity conditions for alternative B are expected to be high enough to favor salt marsh plants in all those sub basins except Duck Harbor where conditions probably will be brackish. However, alternatives C and D will impact a larger area, pushing higher salinity conditions into the eastern portion of Duck Harbor, thus covering nearly all of the areas occupied by this soil type.

Widespread change to existing soils from freshwater nontidal soils to Estuarine sub-tidal and inter-tidal soil types would be expected to occur over the adaptive management period. The majority of the project-wide restoration of inter-tidal soil types would occur within Maybid Variant Silty Clay Loam, Freetown and Swansea mucks, Carver coarse sand, Pipestone loamy coarse sand and subaqueous open water.

Impacts of Alternative B

Alternative B would vary in its impacts to certain soils based on the two options being considered. Since option 2 would impact a lower percentage of the particular soil, it is listed first when a difference occurs. Under alternative B, approximately 94 to 96 percent of the existing 332 acres of Maybid Variant Silty Clay Loam, 69 percent of the existing 489 acres of Freetown and Swansea mucks, 42 to 44 percent of the existing 205 acres of Carver coarse sand, 4 percent of the existing 313 acres of Pipestone loamy coarse sand, and 99 percent of the existing 39 acres of subaqueous open water, would be encompassed by the predicted mean high water spring tide line. Lesser amounts of tidal habitat restoration would occur within other soils types including Hooksan sand and Ipswich, Pawcatuck, Matunuck peats.

Impacts of Alternative C

Under alternative C, approximately 83 percent of the existing 332 acres of Maybid Variant Silty Clay Loam, 77 percent of the existing 489 acres of Freetown and Swansea mucks, 46 percent of the existing 205 acres of Carver coarse sand, 11 percent of the existing 313 acres of Pipestone loamy coarse sand, and 100 percent of the existing 39 acres of subaqueous open water, would be encompassed by the predicted mean high water spring tide line. Lesser amounts of tidal habitat restoration would occur within other soils types including Hooksan sand and Ipswich, Pawcatuck, Matunuck peats.

Impacts of Alternative D

Under alternative D, approximately 97 percent of the existing 332 acres of Maybid Variant Silty Clay Loam, 77 percent of the existing 489 acres of Freetown and Swansea mucks, 53 percent of the existing 205 acres of Carver coarse sand, 11 percent of the existing 313 acres of Pipestone loamy coarse sand, and 100 percent of the existing 39 acres of subaqueous open water, would be encompassed by the predicted mean high water spring tide line. Lesser amounts of tidal habitat restoration would occur within other soils types including Hooksan sand and Ipswich, Pawcatuck, Matunuck peats.

Cumulative Impacts

Few actions would result in cumulative impacts to soils. There is the potential for beneficial impacts as a result of dredging, if dredge spoils are reused in the Herring River floodplain or estuary.

Conclusion

All action alternatives would result in estuary-wide, beneficial changes to hydric soils by increasing pore space, soil pH, and organic content as these soils are subjected to tidal inundation. Various local changes in soil texture are also possible as soils are subjected to different erosional and/or depositional forces that alter the sand, silt, or clay content. While impacts on particular soils may not be substantial (i.e., enough to require a change in classification), these changes in structure, organic content, and chemistry play an important overall role in the expected transition from degraded freshwater wetland to functioning estuarine wetland. The most substantial changes would occur to Maybid Variant Silty Clay Loam in Lower River, Lower Pole Dike, Middle River, and the eastern side of Duck Harbor. In these locations, soil changes would be substantial and may approximate pre-dike conditions. This local, permanent change in soil structure, organic content, and chemistry, in the context of the project objective of restoring an estuarine wetland ecosystem, would be considered a significant beneficial impact.

Under the no action alternative, there would be no predicted changes in soil chemistry, structure, or organic content. While soil conditions would continue to reflect past adverse impacts of tidal exclusion, there would be no significant new impacts on soils.

4.5 IMPACTS ON WETLAND HABITATS AND VEGETATION

Re-introduction of tidal flows within the Herring River flood plain under all of the action alternatives would result in the widespread restoration of degraded coastal wetlands to estuarine sub-tidal and inter-tidal habitats.

4.5.1 METHODS AND ASSUMPTIONS

The following impact analysis is based on the results of hydrodynamic modeling (see appendix B) which shows that salinity within restored inter-tidal habitat (area inundated up to the mean high spring tide line) will range from near full strength seawater (approximately 30 ppt) in the lower portions of the system (i.e., those areas nearest to Wellfleet Harbor and the Chequessett Neck Road Dike) to freshwater (< 5 ppt) in the upper reaches. Varying mid-range salinities (5–18 ppt) would be dependent on which action alternative is implemented, and would occur predominantly in the middle portions of the flood plain. High salinity is expected to stress salt-sensitive plants that have become established on the former salt marsh flood plain and sustain re-colonization of native salt marsh plants. In areas with predicted lower salinities, brackish and freshwater plants would be expected to persist and in some areas little or no change to existing vegetation communities is expected to occur. In addition to the hydrodynamic model, the impact analysis used unpublished vegetation data and plant community mapping completed by the Seashore to project potential change to existing wetland habitats.

An idealized relationship between restored tidal water surface elevations and vegetation within the restored Herring River flood plain is presented in figure 4-2. Areas below predicted mean low water (sub-tidal) include the limits of tidal creeks, as well as subsided portions of the former marsh surface. Inter-tidal habitat would occur between mean low water and the annual high tide line. As stated previously, in areas with higher salinities, the inter-tidal habitats would eventually become salt or brackish marsh, while freshwater habitats would be expected to persist in peripheral areas and upper sub-basins of the Herring River.

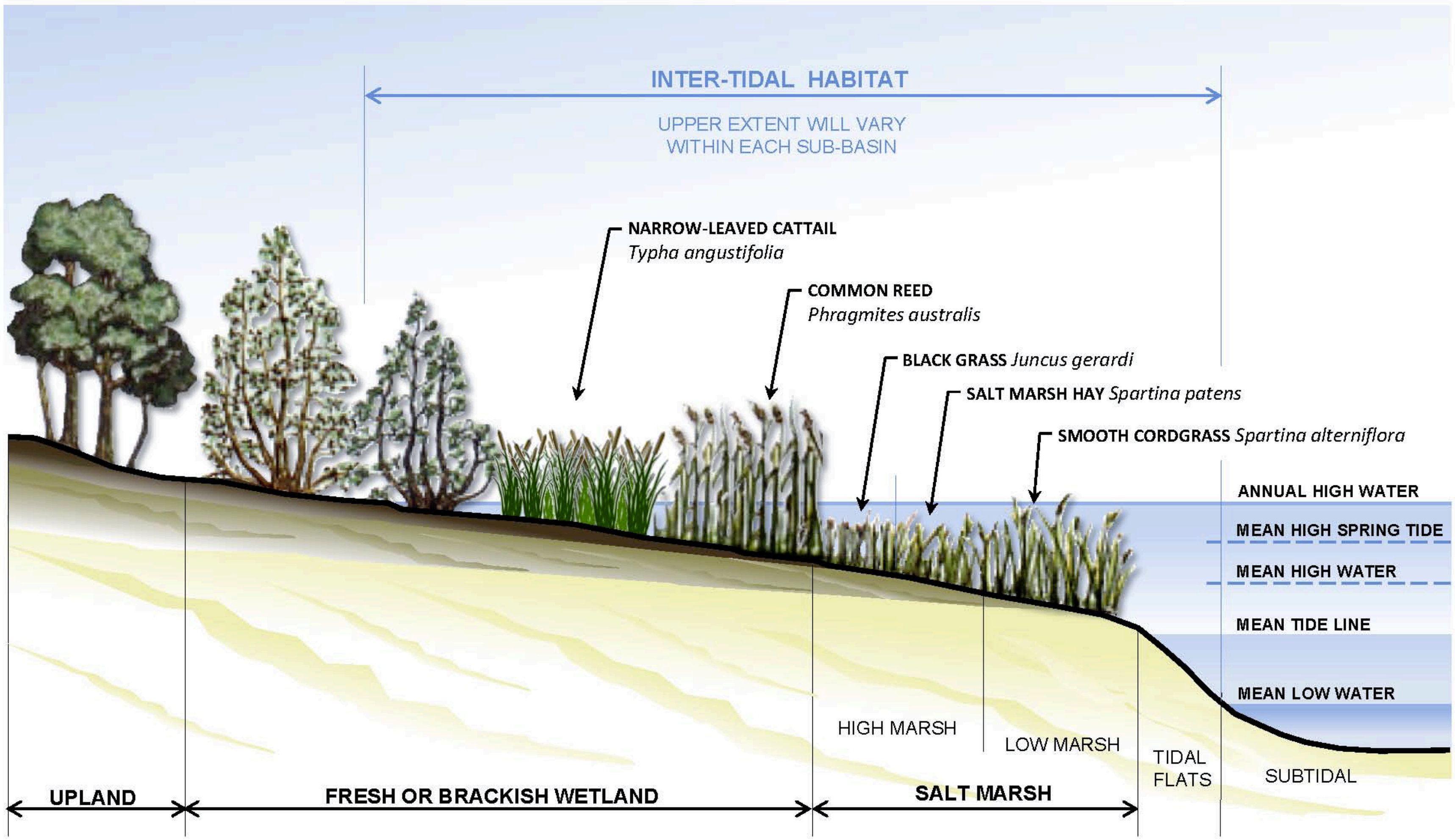


FIGURE 4-2: CONCEPTUAL ESTUARY SALT MARSH HABITATS AND VEGETATION OCCURRENCE RELATED TO TIDAL DATUM

4.5.2 IMPACTS OF ALTERNATIVE A: NO ACTION

Continued absence of tidal flushing in the Herring River would limit sub- and inter-tidal habitats to 80 acres, all confined to the Lower Herring River sub-basin. The no action alternative would cause freshwater conditions to persist in over 1,000 acres of former salt marsh habitats. These freshwater conditions are currently classified as degraded due to poor water quality and taking no action would result in the continued degradation of the system including continued encroachment and possible expansion of invasive plant species including the existing non-native common reed (*Phragmites australis*). The no action alternative likely will result in the continued subsidence of former salt marsh peat soils and will maintain limits in detrital, nutrient, and biota exchange between the estuarine flood plain and the nearshore coastal waters.

4.5.3 IMPACTS COMMON TO ALL ACTION ALTERNATIVES

Vegetation Change within Restored Inter-Tidal Habitat

All of the action alternatives are expected to result in the widespread change of existing, degraded freshwater wetlands to estuarine sub-tidal and inter-tidal habitats. Restored inter-tidal habitat subjected to higher salinity waters, generally 18 ppt and higher, is expected to transition to salt marsh. However, lower salinities would likely occur on the landward periphery of the project area and in the upper reaches of many sub-basins where brackish and freshwater plant species are expected to persist. While the changes occurring in higher salinity areas are relatively clear and predictable, experience with other tidal restoration projects makes predictions of vegetation change in restored inter-tidal areas with lower salinity less certain and difficult to quantify.

Potential Sulfide Toxicity

With restored tidal flooding and biogeochemical conditions within the peat, it is possible that resulting sulfide toxicity may impact salt marsh plant colonization. In experimental microcosms of diked-waterlogged peat collected from the Herring River flood plain, Portnoy (1999) found that sudden introduction of seawater resulted in a decline in cordgrass production (likely due to sulfide toxicity) and further subsidence. As described in section 4.3.3, the small, incremental increases in tidal exchange, as well as the likely beneficial impacts of restored daily tidal flushing, including improved low tide drainage, are expected to limit sulfide production to acceptable levels.

Potential Changes in the Distribution of *Phragmites*

Reducing the overall coverage of this non-native invasive plant species and increasing coverage of native salt marsh halophytes are objectives of the Herring River Restoration Project. Hydrodynamic modeling indicates that restored salinity levels under all of the action alternatives will be above those conducive to *Phragmites* and likely will lead to the elimination of 42 acres that currently exist in the Lower Herring River and Mill Creek sub-basins. However modeling also indicates that mid-range salinity levels of approximately 5 to 18 ppt may persist in some upper reaches of the estuary, especially in the Bound Brook and the Upper Herring River sub-basins. Salinities within this range may not be high enough to allow native salt marsh plants to outcompete *Phragmites* without active management, and could lead to expansion of *Phragmites* into areas where it currently does not occur. This is similar to what occurred at the Hatches Harbor restoration project in Provincetown, Massachusetts where *Phragmites* has greatly diminished or disappeared where porewater salinities reach 22 ppt and higher, but in areas subjected to lower salinities has migrated landward a considerable distance and has not decreased in overall abundance (Smith 2007; Smith et al. 2009). To manage this in the Herring River, herbicide likely would have to be used to greatly reduce coverage of *Phragmites* from the system prior to tidal restoration and subsequently in a targeted fashion if new stands of *Phragmites* colonize elsewhere in the estuary. As tidal exchange is incrementally restored, monitoring will be conducted to track vegetation change and salinities throughout the system. If *Phragmites* is observed to be significantly expanding its range or colonizing new areas, supplemental management actions in addition to herbicide application, including mechanical control or hydrological (increased inundation and salinity) alterations could be implemented to limit or control its spread. Any herbicide application would be planned and implemented carefully as a component of the adaptive management plan. Techniques would be used that specifically target *Phragmites* while minimizing the chance for any collateral impacts on non-target resources.

Woody Vegetation on the Flood Plain

With the restoration of tidal inundation and its associated increase in soil saturation and salinity, mortality of approximately 700 acres of the existing upland shrubland and woodland vegetation that is growing on former salt marsh soils is anticipated. Large volumes of dead standing and fallen woody debris on the flood plain surface may be undesirable since it could result in obstructions within tidal channels and may impact the establishment of marsh grasses by decreasing natural seed dispersal and germination. Options for vegetation management include the removal of woody vegetation through cutting, chipping, and/or burning as well as the processing of biomass that has been cut (harvest for firewood or wood chips and burning brush and branches). Any future vegetation management program would necessitate the concurrence of landowners (both private and public) as well as regulatory agencies. Future management would likely specify the types of mechanized equipment that could be allowed in the project area in order to minimize rutting of the marsh surface and potential time-of-year restrictions to minimize unintentional adverse impacts to fish, wildlife, and natural seedling establishment.

4.5.4 COMPARISON OF IMPACTS OF THE ACTION ALTERNATIVES

To evaluate the changes in vegetation resulting from each of the action alternatives, the modeled areal extent of the mean high water spring tide was used to estimate the total area of restored inter-tidal habitat (see figure 4-3). The area of existing vegetation cover types affected up to the mean high water spring tide line for each alternative are summarized in table 4-6. In addition, a relatively small area of wetland-to-upland transitional habitat along the periphery of the mean high water spring tide line would be affected by annual high water (AHW) (the highest tide within a given year). Some vegetation change would be expected in these areas depending on the species present and the exact frequency and duration of tidal influence.

TABLE 4-6: AREA OF EXISTING VEGETATION COVER TYPES AFFECTED BY MEAN HIGH WATER SPRING TIDE FOR EACH ACTION ALTERNATIVE

Existing Cover Type	Existing Acreage	Estimated Acreage				
		Alt B Option 1	Alt B Option 2	Alt C	Alt D Option 1	Alt D Option 2
Open Water	29	29	29	29	29	29
Salt Marsh	13	13	13	13	13	13
Brackish Marsh	40	39	39	37	40	40
Freshwater Marsh/ Meadow	222	176	178	189	194	196
Shrublands	299	203	204	217	231	232
Woodlands	403	314	314	321	342	342
Dune/ Heathland	20	6	6	14	14	14
Developed	21	17	7	0	17	7
Total Area	1047	797	790	820	880	873

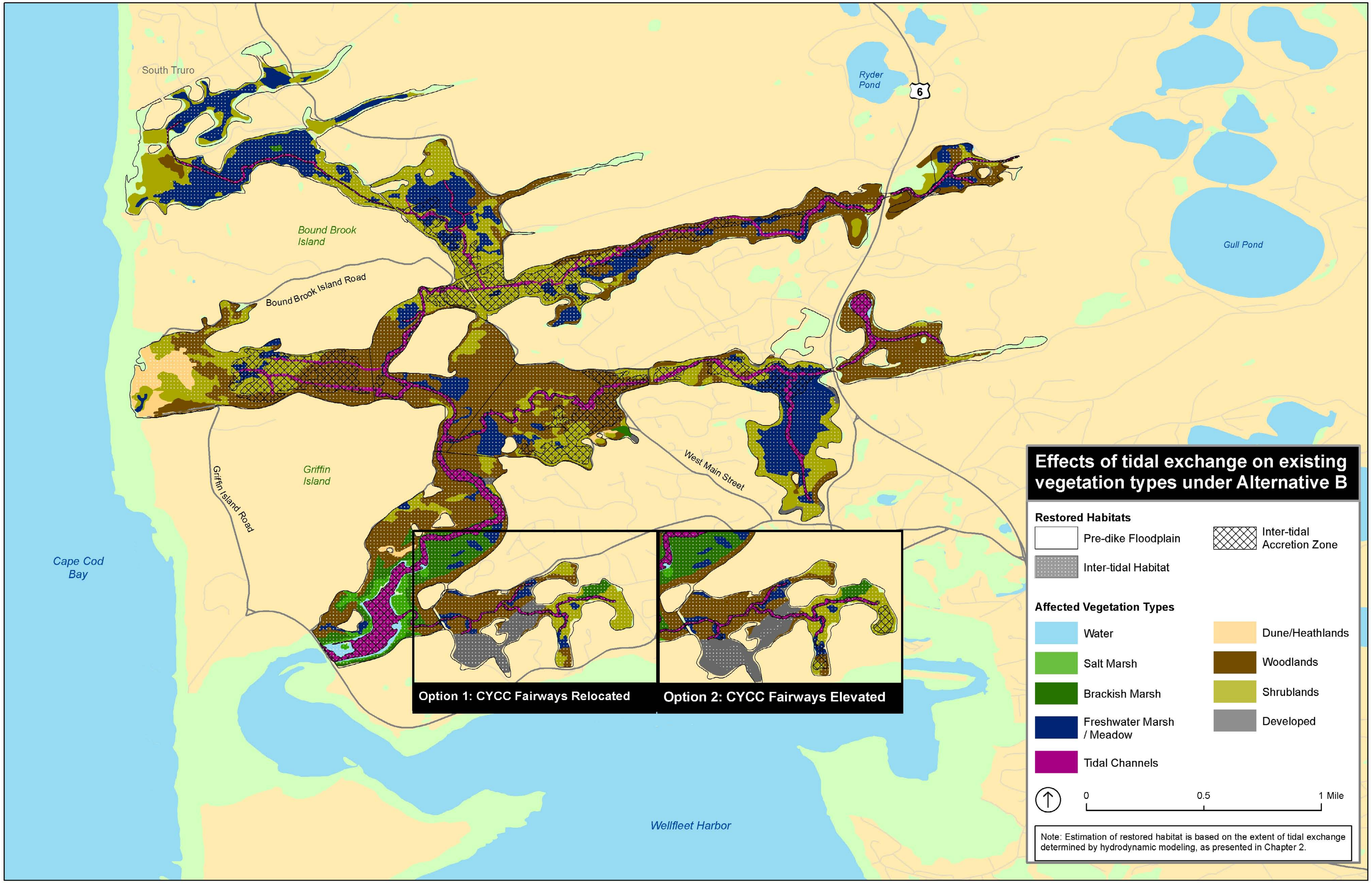
Lower Herring River

Under all of the action alternatives there would be extensive vegetation change within the 162-acre Lower Herring River sub-basin. Over the long term, tidal waters with salinity levels consistently in the mid-20s and higher would affect the existing freshwater and brackish marsh (much of this area is currently dominated by *Phragmites*), woodland, and shrubland plant communities that has replaced the historic salt marsh habitats. This area would largely be restored to low and high salt marsh vegetative communities, but would also include sub-tidal and inter-tidal habitats. The small area of existing salt marsh in this sub-basin would be subjected to increased periods of salt water inundation as the existing marsh surface likely would be too low relative to increased tidal elevations. This could stress even the most salt and flood tolerant vegetation, such as *Spartina alterniflora*, ultimately leading to vegetation die-back and conversion of existing salt marsh to inter-tidal mud flats. This condition is expected to be temporary but could remain until the marsh surface accretes and the marsh surface elevation reaches equilibrium in relation to the restored tide regime. Impacts to existing vegetation cover types in the Lower Herring River are summarized in table 4-7.

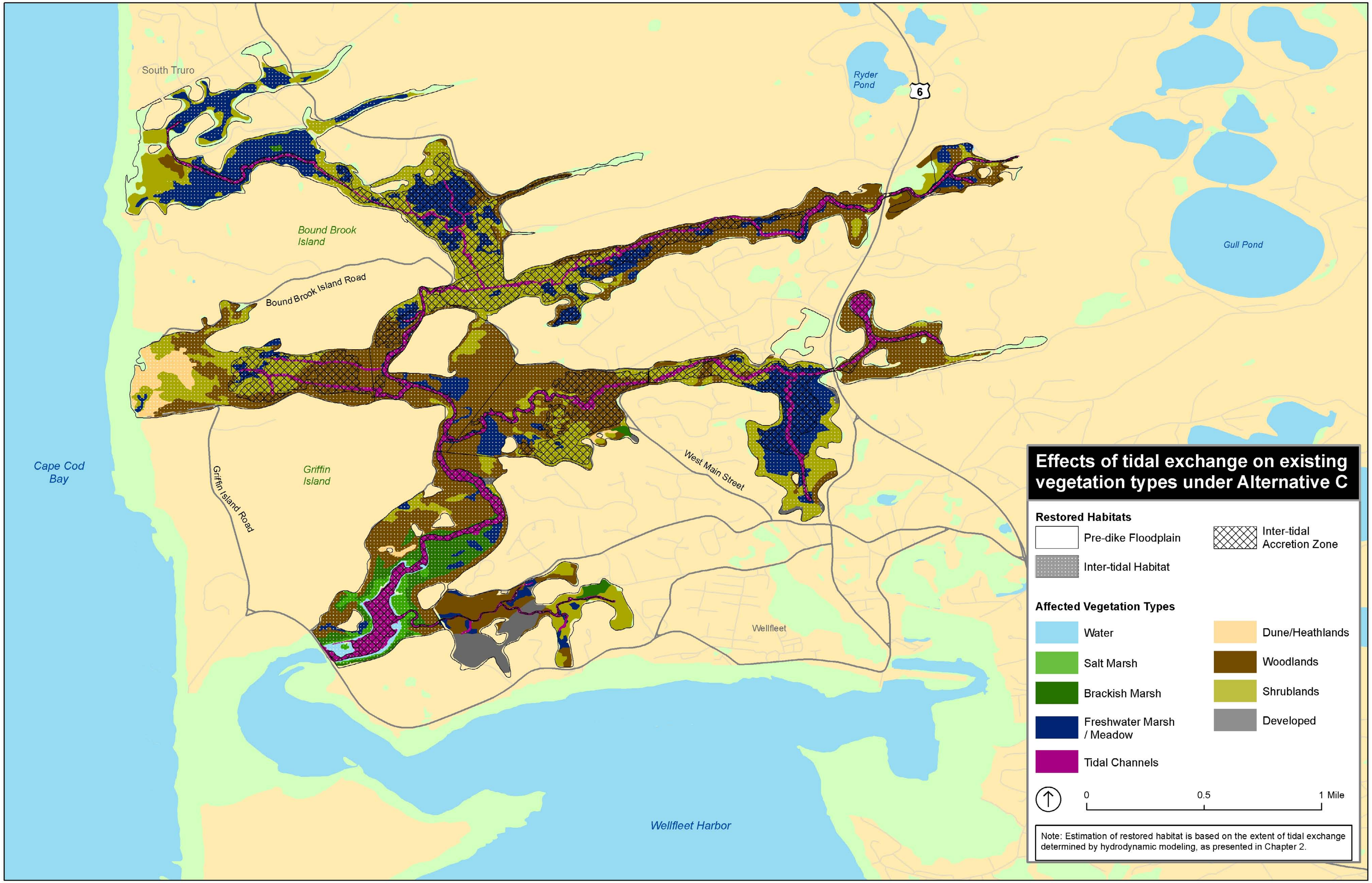
TABLE 4-7: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN THE LOWER HERRING RIVER

	Existing Conditions	Alternative B	Alternatives C and D
Mean high water (MHW) Spring Tide (Feet, NAVD88)	0.4	4.8	5.6
Salinity (ppt)			
In Channels	0 - 30	28 - 30	29 - 30
On Marsh Surface	0 - 30	29 - 30	25 - 30
Cover Type	**Acres Affected**		
Water (Sub-tidal)	29	29	29
Salt Marsh	13	13	13
Brackish Marsh	37	36	37
Freshwater Marsh	11	10	11
Shrubland	7	7	7
Woodland	62	54	58
Dune/Heath	2	< 1	1
Developed	1	0	0
Total	**162**	**150**	**156**
Transition Zone (AHW)		1	2

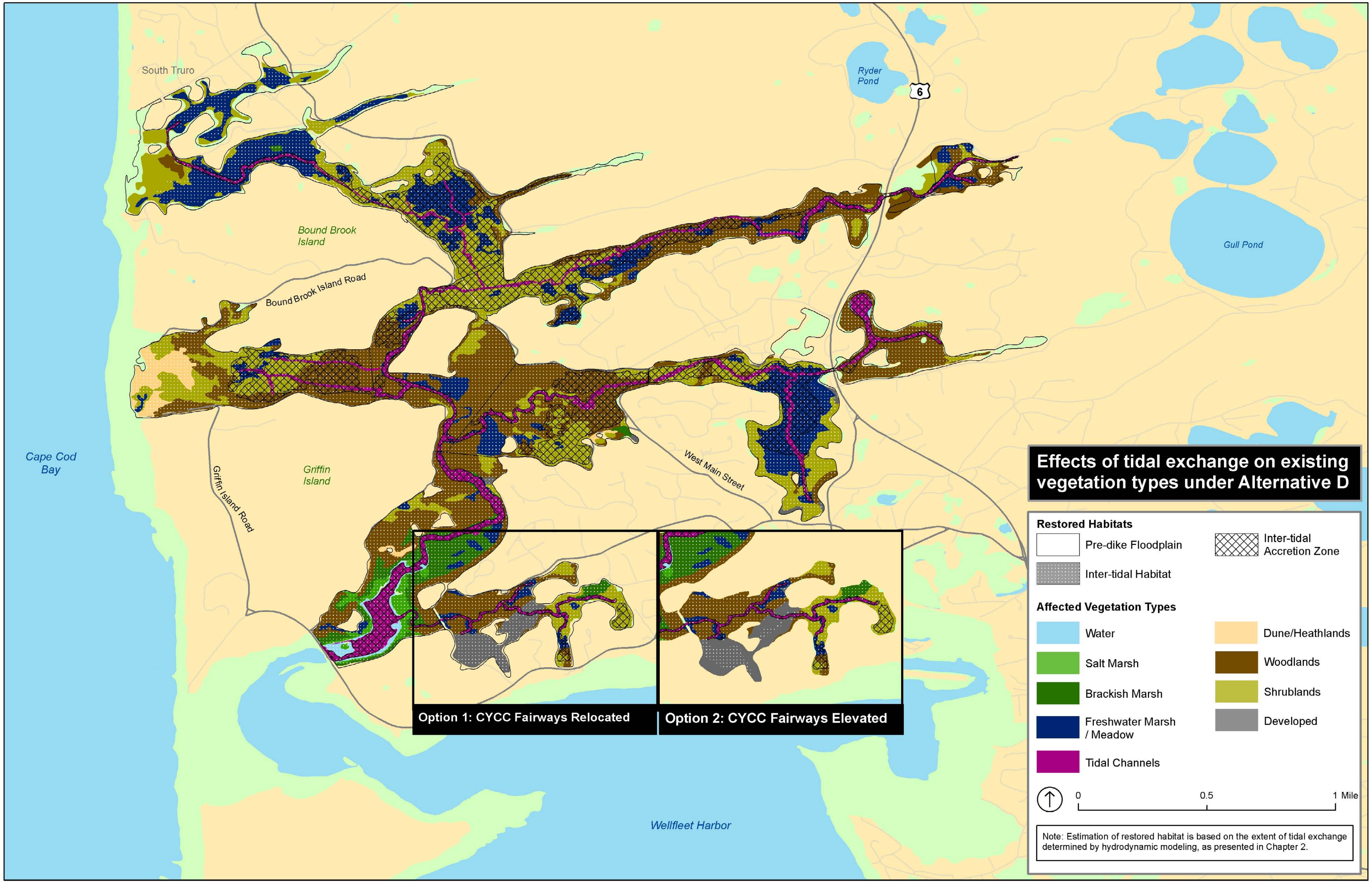
In comparison with alternative B, the higher mean high spring tides of approximately 0.8 feet achieved under alternatives C and D would affect four additional acres of primarily woodland habitat. In addition, a small area of wetland-to-upland transitional habitat (1 acre under alternative B and 2 acres under alternatives C and D) along the periphery of the sub-basin would be affected by AHW (the highest tide within a given year). Some vegetation change would be expected in these areas depending on the species present and the exact frequency and duration of tidal influence.



Wetland Habitats and Vegetation Change Anticipated under Alternative B: New Tidal Control Structure at Chequessett Neck – No Dike at Mill Creek



Wetland Habitats and Vegetation Change Anticipated under Alternative C: New Tidal Control Structure at Chequessett Neck –Dike at Mill Creek Excluding Tidal Flow



Wetland Habitats and Vegetation Change Anticipated under Alternative D: New Tidal Control Structure at Chequessett Neck – Dike at Mill Creek that Partially Restores Tidal Flow with Relocation (option 1) and Elevation (option 2).

FIGURE 4-3: CONCEPTUAL ESTUARY SALT MARSH HABITATS AND VEGETATION OCCURRENCE RELATED TO TIDAL DATUM

Mill Creek

The impacts of tidal restoration on existing vegetation within the 72-acre Mill Creek sub-basin would be identical under alternatives B and D because in both cases high tide would be limited to a maximum elevation of approximately 4.8 feet during spring tide periods. Under both of these alternatives, salinity levels would consistently reach the mid-20s ppt and low and high salt marsh vegetation would be expected to eventually replace the existing brackish marsh, freshwater marsh, shrubland, and woodland that is growing in this former salt marsh area. In addition, 2-3 acres of wetland-to-upland transitional habitat along the periphery of the sub-basin would be affected by AHW (the highest tide within a given year). Some vegetation change would be expected in these transitional areas depending on the species present and the exact frequency and duration of tidal influence. Under alternative C there would be no tidal restoration in the Mill Creek sub-basin and therefore there would be no anticipated impacts to existing vegetation. Vegetation impacts in Mill Creek are summarized in table 4-8.

TABLE 4-8: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN MILL CREEK

	Existing Conditions	Alt B Option 1 Alt D Option 1	Alt B Option 2 Alt D Option 2
MHW Spring (Feet, NAVD88)		4.8	4.8
Salinity (ppt)			
In Channels	0	28 – 30	28 – 30
On Marsh Surface	0	0 – 30	0 – 30
Cover Type	**Acres Affected**		
Salt Marsh	0	--	--
Brackish Marsh	3	3	3
Freshwater Marsh	7	5	7
Shrubland	17	14	15
Woodland	25	21	21
Dune/Heath	0	--	--
Developed (CYCC golf course)	20	17	7
Total	**72**	**60**	**53**
Upland Vegetation (CYCC Flood Remediation)		30	5
Transition Zone (AHW)		2	3

Although the impacts of tidal restoration in the Mill Creek sub-basin do not differ between alternatives B and D, the extent of vegetation impacts vary depending on which option is selected for addressing flood impacts on the Chequessett Yacht and Country Club (CYCC) golf course. These impacts primarily involve the managed, i.e., mowed, portions of the golf course and are reflected in the "Developed" cover type category in table 4-8. Alternative B option 1 and alternative D option 1 involve reconfiguration of the golf course through the relocation of portions of the course to higher ground. Alternative B option 1 and alternative D option 1 would result in approximately 12 low-lying acres of the existing golf course being abandoned which then would be expected to revert to salt marsh. Under alternative B option 2 and alternative D option 2 the existing course configuration would largely be retained and approximately 10 acres of low-lying playing surfaces would be filled, elevated, and regraded, although 7 acres would remain and would revert to salt marsh.

In addition to impacts driven directly by restored tidal exchange, CYCC flood remediation would also incur indirect impacts to upland areas owned by the CYCC where existing vegetation is comprised primarily of scrub oak-pitch pine woodlands. Under alternative B option 1 and alternative D option 1, this area would become almost completely developed and subsequently managed as a golf course resulting in conversion of most of the 30 acres of existing woodland. Under alternative B option 2 and alternative D option 2, most of this 30-acre area would remain undisturbed. However, a borrow area which would disturb approximately 5 acres of existing woodland would have to be established within the area in order to generate the clean fill required to raise the elevation of the low-lying portions of the golf course. CYCC representatives have expressed a desire to regrade this 5-acre area after excavation for future use as a golf practice area.

Middle Herring River

Within the 89-acre Middle Herring River sub-basin, vegetation changes would be substantial under all of the action alternatives. Most of the change would occur within existing 61 acres of woodlands that are growing on former salt marsh soils (see table 4-9). Salinity levels would reach the mid-20 ppt range in tidal channels and adjacent areas of marsh, where existing woodlands and, to a lesser degree, shrublands and freshwater marsh, would be restored to a mix of low and high salt marsh. Hydrodynamic modeling suggests that salinity would decrease with increasing distance from the channels with predicted salinities in some areas between 7-28 ppt for alternative B and 12-29 ppt for alternatives C and D. While some salt sensitive plant species would be adversely affected under alternative B, salt marsh vegetation would not be expected to dominate these transitional areas. However, under alternatives C and D, the higher salinities in the Middle Herring River likely would be able to sustain salt marsh habitat over much of the sub-basin. The ultimate vegetation that eventually results in marsh areas away from the channel is difficult to predict given the uncertainty with predicted salinity levels in comparison to the actual salinity levels experienced in the future from the tidal restoration.

The Middle Herring River sub-basin also contains areas of significant subsidence of the former salt marsh surface. The lowest of these areas (2 acres under alternative B and 10 acres under alternatives C or D) would lie below mean low water if the current topography remains unchanged. However, sediment transport modeling indicates that these severely subsided areas are expected to receive large volumes of sediment as higher tides are incrementally restored (see section 4.4). In the long term, these areas should accrete to support salt marsh plant communities as the marsh surface reaches equilibrium with a restored tidal regime. As restoration in the subsided areas progresses, a transition in vegetation from the existing cover types (woodland, shrubland, and freshwater marsh) to sub-tidal habitat and unvegetated mud flats with a trajectory to low salt marsh communities is expected. These subsided areas will be monitored to track sediment deposition and revegetation, and decisions about applying additional restoration management actions, such as supplementing sediment supply, removing blockages to salt water circulation, and planting appropriate native species, will be a component of the adaptive management process.

TABLE 4-9: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN THE MIDDLE HERRING RIVER

	Existing Conditions	Alternative B	Alternatives C and D
MHW Spring (Ft, NAVD88)		3.7 ft	4.5 ft
Acres below mean low water (MLW)	--	2	10
Salinity (ppt)			
In Channels	0	25 – 29	27 – 29
On Marsh Surface	0	7 – 28	12 – 29
Cover Type	**Acres Affected**		
Salt Marsh	0	--	--
Brackish Marsh	0	--	--
Freshwater Marsh	16	15	15
Shrubland	12	11	12
Woodland	61	59	60
Dune/Heath	0	--	--
Total	**89**	**85**	**87**
Transition Zone		1	< 1

Upper Herring River

Vegetation changes in the 147-acre Upper Herring River would be limited compared to the lower sub-basins. Although this sub-basin was historically dominated by salt marsh vegetation, the relatively low maximum tidal elevations achieved by alternative B would largely maintain the existing freshwater conditions as salinity levels within the channel and on the marsh surface would remain near zero (see table 4-10). Although no salt marsh or brackish species would colonize under these conditions, pulses of tidally forced freshwater would resaturate the marsh surface, favoring riparian and palustrine wetland species over upland species which have colonized the sub-basin since the river was diked and channelized. Representative upland species which are expected to be displaced by the restored hydrologic regime include quaking aspen (*Populus tremuloides*), black cherry (*Prunus serotina*), and black oak (*Quercus velutina*) and could be replaced by wetland dependent species.

In contrast to alternative B, hydrodynamic modeling shows that with the greater tidal exchange afforded by alternatives C and D, that salinity levels in tidal channels could reach as high as 17 ppt and 14 ppt on portions of the marsh surface. Generally, higher salinities would occur closer to the channels and diminish landward. Uncertainty about salinity modeling in the upper sub-basins and the wide range of predicted low to intermediate salinity levels make specific projections about vegetation change difficult. Generally, the salinity levels predicted by the model would not be high enough or occur consistently enough to support extensive salt marsh plant communities, although some salt marsh plants could grow adjacent to the channels. Species tolerant of low to moderate salinity levels, such as narrow-leaf cat-tail (*Typha angustifolia*), northern bayberry (*Morella pennsylvanica*), and northern arrowwood (*Viburnum recognitum*), would likely persist and perhaps expand as they displace less salt tolerant species. Intermediate salinity levels could also make the Upper Herring River sub-basin suitable for *Phragmites*. As stated in section 4.5.3, efforts will be made to control this non-native species throughout the project area prior to restoring tidal exchange. During restoration vulnerable areas will be monitored for *Phragmites* occurrence, and measures implemented to control its spread in accordance with guidelines laid out in the adaptive management plan.

TABLE 4-10: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN THE UPPER HERRING RIVER

	Existing Conditions	Alternative B	Alternatives C and D
MHW Spring (Feet, NAVD88)		2.6	3.4
Acres below MLW		39	56
Salinity (ppt)			
In Channels	0	0	10 – 17
On Marsh Surface	0	0 – 1	0 – 14
Cover Type	**Acres Affected**		
Salt Marsh	0	--	--
Brackish Marsh	0	--	--
Freshwater Marsh	29	24	26
Shrubland	49	41	44
Woodland	69	39	43
Dune/Heath	0	--	--
Developed	0	--	--
Total	**147**	**104**	**113**
Transition Zone (AHW)		22	20

The Upper Herring River sub-basin also contains areas of significant subsidence of the former salt marsh. The lowest of these areas (39 acres under alternative B and 56 acres under alternatives C or D) would lie below mean low water if the current topography remains unchanged. However, sediment transport modeling indicates these severely subsided areas are expected to receive large volumes of sediment as higher tides are incrementally restored (see section 4.4). In the long term these areas should accrete to support brackish and tidal freshwater marsh plant communities as the marsh surface reaches equilibrium with a restored tidal regime. As restoration progresses in the subsided areas, a transition in vegetation from the existing cover types (woodland, shrubland, and freshwater marsh) to sub-tidal habitat and unvegetated mud flats with a trajectory toward brackish and tidal freshwater marsh communities is expected. These subsided areas will be monitored to track sediment deposition and revegetation, and decisions about applying additional restoration management actions, such as supplementing sediment supply, removing blockages to salt water circulation, and planting appropriate native species, will be a component of the adaptive management process.

Along the landward periphery of the Upper Herring River sub-basin, the action alternatives would result in a wetland-to-upland habitat transition zone (20 acres under alternative B and 22 acres under alternatives C and D). These areas would be tidally influenced during the annual high tides (the highest predicted tides in a given year). Impacts to existing freshwater marsh, woodland, or shrubland plant species are expected to be minimal in this zone.

Duck Harbor

Within the 129-acre Duck Harbor sub-basin, expected vegetation changes would be extensive under all of the action alternatives. Most of the change would occur within the 105 acres of existing shrublands and woodlands that have come to dominate the sub-basin since tides were restricted by the construction of the Chequessett Neck Road Dike (see table 4-11). Salinity levels are predicted to reach the mid 20-ppt range in tidal channels, and adjacent areas of marsh where existing vegetated habitats likely would be restored to a mix of low and high salt marsh. Hydrodynamic modeling suggests that salinity would decrease with increasing distance from the channels with predicted salinities ranging from 0-14 ppt for alternative B and 3-20 ppt for alternatives C and D. While some salt sensitive plant species would be adversely affected under these conditions, under alternative B salt marsh vegetation would not be expected to colonize the landward margins of the sub-basin, while larger portions of these areas likely would transition to salt marsh under alternatives C or D. Intermediate salinity levels, especially those expected under alternative B, could also make conditions in the Duck Harbor sub-basin suitable for *Phragmites*. As stated in section 4.5.3, efforts will be made to control this non-native species throughout the project area prior to restoring tidal exchange. During restoration, vulnerable areas will be monitored for *Phragmites* occurrence, and measures implemented to control its spread in accordance with guidelines laid out in the adaptive management plan. The vegetation that ultimately grows in marsh areas away from the channel is difficult to predict because of the uncertainty associated with the actual salinity levels achieved by tidal restoration.

TABLE 4-11: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN DUCK HARBOR

	Existing Conditions	Alternative B	Alternatives C and D
MHW, Spring (Feet, NAVD88)		3.6	4.3
Acres below MLW		33	35
Salinity (ppt)			
In Channels	0	7 – 25	18 – 24
On Marsh Surface	0	0 – 14	3 – 20
Cover Type	**Acres Affected**		
Salt Marsh	0	--	--
Brackish Marsh	0	--	--
Freshwater Marsh	6	4	4
Shrubland	47	30	41
Woodland	58	41	49
Dune/Heath	18	6	13
Developed	0	--	--
Total	**129**	**81**	**107**
Transition Zone (AHW)		25	13

The Duck Harbor sub-basin also contains areas of significant subsidence of the former salt marsh. The lowest of these areas (33 acres under alternative B and 35 acres under alternatives C or D) would lie below mean low water if the current topography remains unchanged. However, sediment transport modeling indicates that these severely subsided areas are expected to receive large volumes of sediment as higher tides are incrementally restored (see section 4.4). In the long term these areas should accrete and support salt marsh and brackish marsh vegetation as the marsh surface reaches equilibrium with a restored tidal regime. As restoration progresses in the subsided areas, shifts in vegetation from the existing cover types (woodland, shrubland, and freshwater marsh) to sub-tidal habitat and unvegetated mud flats, with a trajectory to low salt marsh communities is expected. These subsided areas will be monitored to track sediment deposition and revegetation, and decisions about applying additional restoration management actions, such as supplementing sediment supply, removing blockages to salt water circulation, and planting appropriate native species, will be a component of the adaptive management process.

Along the upstream periphery of the Duck Harbor sub-basin, all of the alternatives would result in a wetland-to-upland habitat transition zone (25 acres under alternative B and 13 acres under alternatives C and D). These areas would be tidally influenced only during the annual high tides (the highest predicted tides in a given year). Impacts to existing freshwater marsh, woodland, or shrubland plant species are expected to be minimal in this zone because of the infrequency of flooding and likely low salinity levels.

Lower Pole Dike Creek

Under alternatives B, C, or D, there would be extensive vegetation change within the 109-acre Lower Pole Dike Creek sub-basin. Over the long term, tidal waters with predicted salinity levels consistently in the mid-20s and higher would restore conditions suitable for low and high marsh that would replace the existing freshwater marsh, woodland, and shrubland communities, that have become established since tides were restricted. Impacts to existing vegetation cover types in the Lower Pole Dike Creek sub-basin are summarized in table 4-12.

TABLE 4-12: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN LOWER POLE DIKE CREEK

	Existing Conditions	Alternative B	Alternatives C and D
MHW Spring (Feet, NAVD88)		4.1	4.8
Acres below MLW		27	43
Salinity (ppt)			
In Channels	0	15 – 21	17 – 26
On Marsh Surface	0	20 – 30	24 – 30
Cover Type	**Acres Affected**		
Salt Marsh		--	--
Brackish Marsh		--	--
Freshwater Marsh	10	10	10
Shrubland	29	27	27
Woodland	70	67	68
Dune/Heath		--	--
Developed		--	---
Total	**109**	**104**	**105**
Transition Zone (AHW)		< 1	< 1

The Lower Pole Dike Creek sub-basin also contains areas of significant subsidence of the former salt marsh. The lowest of these areas (27 acres under alternative B and 43 acres under alternatives C or D) would lie below mean low water if the current topography remains unchanged. However, sediment transport modeling indicates that these severely subsided areas are expected to receive large volumes of sediment as higher tides are incrementally restored (see section 4.4). In the long term these areas should accrete and support salt marsh vegetation as the marsh surface reaches equilibrium with a restored tidal regime. As restoration progresses in the subsided areas, shifts in vegetation from the existing cover types (woodland, shrubland, and freshwater marsh) to sub-tidal habitat and unvegetated mud flats, with a trajectory toward low salt marsh communities is expected. These subsided areas will be monitored to track sediment deposition and revegetation, and decisions about applying additional restoration management actions, such as supplementing sediment supply, removing blockages to salt water circulation, and planting appropriate native species, will be a component of the adaptive management process.

Upper Pole Dike Creek

Vegetation changes in the 146-acre Upper Pole Dike Creek sub-basin would be limited in comparison to the lower sub-basins. Although most of this sub-basin is thought to have been historically dominated by salt marsh vegetation, the relatively low maximum tidal elevation achieved by alternative B would not allow salt water to regularly propagate into this sub-basin and salinity levels within both the channel and on the marsh surface are predicted to remain low. Although no salt marsh or brackish species likely would colonize the marsh surface under these conditions, pulses of tidally forced freshwater would favor riparian and palustrine wetland species over the upland tree and shrub species that have colonized the sub-basin since the river was diked and channelized. Representative upland woodland species which are expected to be displaced by the restored hydrologic regime include quaking aspen (*Populus tremuloides*), black cherry (*Prunus serotina*), and black oak (*Quercus velutina*) and could be replaced by more freshwater wetland dependent species.

In contrast to alternative B, hydrodynamic modeling shows that with the greater tide exchange afforded by alternatives C and D, salinity levels in tidal channels could reach as high as 12 ppt, and 20 ppt on portions of the marsh surface. Uncertainty about salinity modeling in the upper sub-basins and the wide range of predicted low to intermediate salinity levels make specific projections about vegetation change difficult. Generally, the salinity levels predicted by the model would not be high enough or occur consistently enough to support extensive salt marsh plant communities, although some salt marsh plants could grow in areas adjacent to the channels. Species tolerant of low to moderate salinity levels, such as narrow-leaf cat-tail (*Typha angustifolia*), northern bayberry (*Morella pennsylvanica*), and northern arrowwood (*Viburnum recognitum*), likely would persist and perhaps expand as they displace less salt tolerant species. Intermediate salinity levels could also make conditions in the Upper Pole Dike Creek sub-basin suitable for *Phragmites*. As stated in section 4.5.3, efforts will be made to control this non-native species throughout the project area prior to restoring tidal exchange, vulnerable areas will be monitored for its occurrence, and measures implemented to control its spread in accordance with guidelines laid out in the adaptive management plan.

The Upper Pole Dike Creek sub-basin also contains areas of significant subsidence of the former salt marsh. The lowest of these areas (16 acres under alternative B and 42 acres under alternatives C or D) would lie below mean low water if the current topography remains unchanged. However, sediment transport modeling indicates these severely subsided areas are expected to receive large volumes of sediment as higher tides are incrementally restored (see section 4.4). In the long term, these areas should accrete to support brackish and freshwater marsh plant communities as the marsh surface reaches equilibrium with a restored tidal regime. As restoration in these subsided areas progresses, shifts in vegetation from the existing cover types (woodland, shrubland, and freshwater marsh) to sub-tidal habitat and unvegetated mud flats, with a trajectory toward vegetated marsh communities is expected. These subsided areas will be monitored to track sediment deposition and revegetation, and decisions about applying additional restoration management actions, such as supplementing sediment supply, removing blockages to salt water circulation, and planting appropriate native species, will be a component of the adaptive management process.

Along the landward margins of the Upper Pole Dike Creek sub-basin, all of the action alternatives would result in a wetland-to-upland habitat transition zone (17 acres under alternative B and 13 acres alternatives C and D) (see table 4-13). These areas would be tidally influenced only during the annual high tides (the highest predicted tides in a given year). Impacts to existing freshwater marsh, woodland, or shrubland plant species are expected to be minimal in this zone given the infrequency of flooding and low expected salinity levels.

TABLE 4-13: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN UPPER POLE DIKE CREEK

	Existing Conditions	Alternative B	Alternatives C and D
MHW Spring (Feet, NAVD88)		3.4	4.1
Acres below MLW		16	42
Salinity (ppt)			
In Channel	0	2 – 6	5 – 12
On Marsh Surface	0	0 – 14	0 – 20
Cover Type	**Acres Affected**		
Salt Marsh		--	--
Brackish Marsh		--	--
Freshwater Marsh	49	47	48
Shrubland	49	33	40
Woodland	48	28	37
Dune/Heath		--	--
Developed		--	--
Total	**146**	**108**	**125**
Transition Zone (AHW)		17	13

Lower Bound Brook

Within the 80-acre Lower Bound Brook sub-basin, vegetation changes would be extensive under all of the action alternatives. Most of the vegetational change would occur within existing shrublands (see table 4-14). This sub-basin was historically dominated by salt marsh vegetation prior to construction of the Chequessett Neck Road Dike. Restored salinity levels are expected to reach the mid 20-ppt range in tidal channels and adjacent marsh areas where existing shrublands and, to a lesser degree, woodlands and freshwater marsh, would be replaced with a mix of low and high salt marsh. Hydrodynamic modeling suggests that salinity would decrease with increasing distance from the channels with modeled salinities as low as 2 ppt for alternative B and 7 ppt for alternatives C and D in some areas. While some salt sensitive plant species could be adversely affected under these conditions, salt marsh vegetation would not be expected to colonize in marsh areas away from the channel. The vegetation that ultimately grows in areas distant from the channel is difficult to predict given the uncertainty associated with the actual salinity levels achieved by tidal restoration.

TABLE 4-14: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN LOWER BOUND BROOK

	Existing Conditions	Alternative B	Alternatives C and D
MHW Spring (Feet, NAVD88)		2.7	3.3
Acres below MLW		11	56
Salinity (ppt)			
In Channel	0	11 – 24	25 – 27
On Marsh Surface	0	2 – 5	7 – 12
Cover Type	**Acres Affected**		
Salt Marsh		--	--
Brackish Marsh		--	--
Freshwater Marsh	29	29	29
Shrubland	41	33	36
Woodland	10	5	6
Dune/Heath		--	--
Developed		--	--
Total	**80**	**67**	**71**
Transition Zone (AHW)		6	5

The Lower Bound Brook sub-basin also contains areas of significant subsidence of the former salt marsh. The lowest of these areas (11 acres under alternative B and 56 acres under alternatives C or D) would lie below mean low water if the current topography remains unchanged. However, sediment transport modeling indicates that these severely subsided areas are expected to receive large volumes of sediment as higher tides are incrementally restored (see section 4.4). In the long term, these areas should accrete to support a mix of salt, brackish, and tidal freshwater marsh communities as the marsh surface reaches equilibrium with a restored tidal range. As restoration in the subsided areas progresses, shifts in vegetation from the existing cover types (woodland, shrubland, and freshwater marsh) to sub-tidal habitat and unvegetated mud flats, with a trajectory toward a mixed vegetated marsh community is expected. These subsided areas will be monitored to track sediment deposition and revegetation, and decisions about applying additional restoration management actions, such as supplementing sediment supply, removing blockages to salt water circulation, and planting appropriate native species, will be a component of the adaptive management process.

Along the landward margins of the Lower Bound Brook sub-basin, all of the action alternatives are predicted to result in a wetland-to-upland habitat transition zone (6 acres under alternative B and 5 acres alternatives C and D). These areas would be tidally influenced only during the annual high tides (the highest predicted tides in a given year). Impacts to existing freshwater marsh, woodland, or shrubland plant species are expected to be minimal in this zone given the infrequency of flooding and low expected salinity levels.

Upper Bound Brook

Vegetation changes in the 113-acre Upper Bound Brook sub-basin would be limited in comparison with the lower sub-basins. Even though much of this sub-basin was likely dominated by salt marsh vegetation prior to construction of the Chequessett Neck Road Dike, the relatively low maximum tidal range achieved by alternative B likely would not allow salt water to propagate this high into the system and existing freshwater conditions are expected to persist (see table 4-15). Although no salt marsh or brackish species would colonize under these conditions, pulses of tidally forced freshwater would resaturate the marsh surface, favoring riparian and palustrine wetland species over the upland tree and shrub species that have colonized the sub-basin since the river was diked and channelized. Representative upland species which are expected to be displaced by the restored hydrologic regime include quaking aspen (*Populus tremuloides*), black cherry (*Prunus serotina*), and black oak (*Quercus velutina*) and could be replaced with freshwater dependent species.

TABLE 4-15: SUMMARY OF AFFECTED VEGETATION COVER TYPES IN UPPER BOUND BROOK

	Existing Conditions	Alternative B	Alternatives C and D
MHW Spring (Feet, NAVD88)		2.3	2.5
Acres below MLW		0	0
Salinity (ppt)			
In Channels	0	1 – 3	10 – 15
On Marsh Surface	0	0	0
Cover Type	**Acres Affected**		
Salt Marsh		--	--
Brackish Marsh		--	--
Freshwater Marsh	65	32	46
Shrubland	48	7	10
Woodland		--	--
Dune/Heath		--	--
Developed		--	--
Total	**113**	**39**	**56**
Transition Zone (AHW)		21	14

In contrast to alternative B, hydrodynamic modeling shows that with the greater tidal exchange afforded by alternatives C and D, that salinity levels in tidal channels could reach as high as 15 ppt with predicted salinities remaining near zero in marsh areas away from the channel. Uncertainty about salinity modeling in the upper sub-basins makes specific projections about vegetation change difficult. Generally, the salinity levels predicted by the model would not be high enough or occur consistently enough to support extensive salt marsh plant communities, although some salt marsh plants could grow adjacent to the channels. Species tolerant of low to moderate salinity levels, such as narrow-leaf cat-tail (*Typha angustifolia*), northern bayberry (*Morella pennsylvanica*), and northern arrowwood (*Viburnum recognitum*), likely would persist and perhaps expand as they displace less salt tolerant species. The intermediate tidal channel salinity levels achieved under alternatives C or D could also make the Upper Bound Brook sub-basin suitable for *Phragmites*. As stated in section 4.5.3, efforts will be made to control this non-native species throughout the project area prior to restoring tidal exchange. During restoration, vulnerable areas will be monitored for *Phragmites* occurrence and measures implemented to control its spread in accordance with guidelines laid out in the adaptive management plan.

Along the landward margins of the Upper Bound Brook sub-basin, all alternatives would result in a wetland-to-upland habitat transition zone (21 acres under alternative B and 14 acres under alternatives C and D). These areas would be tidally influenced only during the annual high tides (the highest predicted tides in a given year). Impacts to existing freshwater marsh, woodland, or shrubland plant species are expected to be minimal in this zone given the infrequency of flooding and low expected salinity levels.

4.5.5 CUMULATIVE IMPACTS

The Mayo Creek salt marsh restoration project would restore a limited amount of tidal salt marsh habitat on Wellfleet Harbor. This project, like each of the action alternatives in the Herring River Restoration Project, would increase the total amount of native tidal salt marsh habitat available on Cape Cod, having a beneficial cumulative impact on the availability of wetland habitat and vegetation.

4.5.6 CONCLUSION

Over the long term, all action alternatives are expected to result in extensive restoration of salt marsh vegetative communities, primarily in the Lower Herring River, Middle Herring River, and Lower Pole Dike Creek sub-basins. Alternative B is expected to restore 339 acres and alternatives C and D 346 acres of vegetated inter-tidal habitat in these sub-basins. Approximately 53 acres of salt marsh would be restored in the Mill Creek sub-basin if alternative B option 2 and alternative D option 2 (elevating) were implemented for the CYCC golf course. An additional 7 acres of salt marsh would be restored if alternative B option 1 and alternative D option 1 (relocating) were implemented. No restoration or tidally driven vegetation change would occur within Mill Creek under alternative C.

Due to the low salinity levels expected in the upper reaches of the system, little if any salt marsh vegetation would colonize the Upper Herring River, Upper Bound Brook, and Upper Pole Dike Creek sub-basins under any of the action alternatives. However, wetter conditions driven by tidal forcing with periodic influxes of brackish water, especially under alternatives C and D, may cause some degree of vegetation change, favoring facultative and obligate wetland plant species over upland species. Up to 251 acres of habitat could be affected within these sub-basins under alternative B and up to 294 acres under alternatives C and D. In most of the Duck Harbor and Lower Bound Brook sub-basins, an area of approximately 200 acres, the amount of vegetation change would be highly dependent on the degree of tidal restoration. Under alternative B, changes would be minimal and would be similar to those occurring in the upper sub-basins under any of the action alternatives. With the larger tidal ranges and higher salinity levels afforded by alternatives C and D, vegetation changes would be more extensive, with salt marsh species colonizing marsh areas adjacent to tidal channels and in some areas extending landward across the marsh surface.

A wetland-to-upland transition zone (between the mean high water spring tide and AHW tide elevations) is expected to occur primarily along the landward periphery of most of the upstream sub-basins. Astronomic high and storm-driven tides may result in some vegetation change in this zone depending on the frequency, duration, and salinity of tidally forced inundation and the flood and salt tolerances of affected plant species. The approximate size of this zone is estimated to be 95 acres under alternative B and 70 acres under alternatives C and D. Extensive areas of subsided, former salt marsh occur in the Middle and Upper Herring River, Lower and Upper Pole Dike Creek, Duck Harbor, and Lower Bound Brook sub-basins. Sediment transport modeling indicates these severely subsided areas (128 acres under alternative B and 242 acres under alternatives C or D) are expected to receive large volumes of sediment as higher tides are incrementally restored (see section 4.4). In the long term these subsided areas should accrete to support a mix of salt marsh, brackish, and tidal freshwater marsh plant communities as the marsh surface reaches equilibrium with a restored tidal regime.

Therefore, all action alternatives would result in a permanent, estuary-wide transition from a degraded freshwater marsh to a functioning estuarine wetland. Also, all action alternatives would significantly increase the total regional acreage of functioning estuarine wetlands; these estuarine habitat types are ecologically critical in this geographic area of Cape Cod. Based on the degree of salt marsh recovery and the regional importance of estuarine wetlands in terms of biodiversity, this would likely constitute a locally and regionally significant beneficial impact, which would be most pronounced for alternative D, but would be significantly beneficial for all action alternatives relative to the no action alternative.

In some areas, intermediate salinity levels, between approximately 5 and 18 ppt, could create conditions suitable for common reed (*Phragmites australis*). As stated in section 4.5.3, efforts will be made to control this non-native species throughout the project area prior to restoring tidal exchange. During restoration, vulnerable areas will be monitored for *Phragmites*, and measures implemented to control its spread in accordance with guidelines laid out in the adaptive management plan. Because the spread of *Phragmites* would be actively controlled, it would not be likely to constitute a significant adverse impact, despite some uncertainty about its response intermediate salinity levels that would occur in some areas.

All action alternatives would result in temporary construction impacts during construction, as described in "Section 4.11: Construction Impacts of the Action Alternative." Short-term disturbance of construction sites, including dewatering and staging, may occur on approximately 8 acres, and would be restored when construction is complete. A permanent loss of up to 9 acres of vegetation/wetland habitat would also occur to accommodate CYCC golf course elevation (8.26 acres of total), and the footprint of new dikes or raised/relocated roads. These wetland losses would effectively be mitigated by the restoration of hundreds of acres of sub and inter-tidal habitat. All construction impacts would be mitigated through use of construction best management practices (BMPs). Activities related to secondary restoration and residential flood proofing would be limited in scale. Overall, the adverse impacts of construction impacts would not be considered significant when viewed in the context of the estuary-wide restoration that necessitates these construction impacts.

Under the no action alternative, there would be no predicted changes to wetland function, which is currently degraded, or to the distribution of vegetation types in the estuary. Sub-tidal and inter-tidal habits, which are of unique importance ecologically, would continue to be confined to 80 acres in the lower Herring River sub-basin, while freshwater conditions would continue to prevail in over 1,000 acres of pre-dike salt marsh. Therefore, there would be no significant new adverse impacts from taking no restoration action, despite the significance of past adverse environmental impacts caused by diking and draining the estuary. There would also be no construction impacts.

4.6 IMPACTS ON AQUATIC SPECIES

Estuary habitat is extremely important for a variety of aquatic species, providing spawning, nursery and feeding grounds for fish, macroinvertebrates, and shellfish. Some species migrate in and out do the system while others spend their entire life-cycle in the estuary.

4.6.1 METHODS AND ASSUMPTIONS

Potential impacts on estuarine fish and macroinvertebrates, anadromous and catadromous species, and shellfish, as well as their habitats were evaluated based on known life histories and habitat requirements, and their past and present occurrence in the Herring River estuary and Wellfleet Harbor. Information on habitat, occurrence within the Herring River estuary and Wellfleet Harbor, and potential impacts on species from salt marsh restoration efforts was acquired from park staff at the Seashore, Wellfleet town officials, and available literature. The analysis also integrated the findings of the hydrodynamic modeling of the estuary, using the predicted mean high spring tide as the best approximation of the extent of tidal influence and the areal extent of estuarine habitat that would occur under the different alternatives. In accordance with Magnuson-Stevens Fisheries Conservation and Management Act, an Essential Fish Habitat Assessment has been included in this EIS/EIR as appendix F.

4.6.2 IMPACTS OF ALTERNATIVE A: NO ACTION

Under alternative A, the tide gate openings at the Chequessett Neck Road Dike would remain in their current configurations. The sluice gate opening of 24 inches would continue to limit the amount of tidal exchange upstream of the dike, resulting in a depressed mean tidal range of approximately 2.4 feet upstream of the dike as compared to the mean tidal range of approximately 10.3 feet downstream of the dike. As indicated in "Section 4.3: Impacts on Water and Sediment Quality," the Herring River estuary under this configuration would remain a freshwater system upstream of High Toss Road and tidal flows, and thus saline waters, would remain confined to the Lower Herring River sub-basin (see figure 3-1 in chapter 3). Under these conditions, the total acreage of estuarine waters (based on the mean high spring tide) within the Herring River estuary would remain 70 acres (25 acres of sub-tidal and 45 acres of intertidal habitat) located in the Lower Herring River sub-basin. The Herring River estuary would remain a degraded system adversely impacting estuarine fish, macroinvertebrate communities, anadromous and catadromous fish, and shellfish that inhabit Wellfleet Harbor and the Herring River estuary.

Estuarine Fish and Macroinvertebrates

The degraded estuarine system under alternative A would continue to result in the existing estuarine fish assemblages described in section 3.6.1 being confined to the approximately 70 acres of estuarine waters below High Toss Road in the Lower Herring River sub-basin. Species composition of the resident fish assemblage would continue to be similar to that found below the dike, with the mummichog, striped killifish, and Atlantic silverside being dominant species; however, the overall abundance of these species upstream of the dike would continue to be greatly reduced. A contributing factor to this dissimilarity in abundance upstream and downstream of the dike is the dike itself, for Eberhardt, Burdick, and Dionne (2010) found that undersized culverts with accelerated currents that restrict tidal flow in estuarine systems can also restrict the upstream/downstream movement of resident fish, such as the mummichog. Raposa and Roman (2003) also found dissimilarities in the nekton communities upstream and downstream of tidal restrictions in several New England salt marshes.

With the depressed tidal range under alternative A, salinity levels upstream of the dike would continue to be limited as would the amount of intertidal habitat available for use by resident estuarine species for spawning and nursery areas, adversely affecting the abundance of these species in the Herring River upstream of the dike. With reduced abundances of these species which act as forage for birds and predatory fish, alternative A would also continue to adversely affect the function that these fish play in transferring energy within and out of the Herring River estuary.

The occurrence of non-resident marine fish migrants utilizing the system upstream of the dike would also remain limited. Fish such as the Atlantic menhaden and winter flounder use the estuary as a nursery and for forage. However, with the limited amount of estuarine sub-tidal and intertidal salt marsh habitat available upstream of the dike and with the relatively small sluice gate opening impeding fish passage, the abundance of these species upstream of the dike would continue to be low under alternative A.

As discussed in section 3.6.1, predatory fish such as striped bass and blue fish use estuaries as foraging grounds, feeding on small tidal marsh fish such as killifish and Atlantic silversides. However, because the population of prey species would continue to be limited upstream of the dike under alternative A, and because the dike itself likely impedes upstream migration of the larger predatory fish, their abundance and use of the Herring River estuary upstream of the dike under alternative A would also continue to remain low. Fish play an important role in exporting energy and nutrients out of salt marshes, and in tidally restricted systems the decreased connectivity of fish populations upstream and downstream of the restriction inhibits the transfer of marsh-derived production to the coastal ecosystem (Eberhardt, Burdick, and Dionne 2010). With limited abundance of resident fish species and few predatory fish being able to access the river upstream of the dike to forage, the amount of energy production transported out of the estuary to the surrounding coastal waters would continue to be limited.

With no change in the tide gate configuration at the Chequessett Neck Road Dike, the Herring River upstream of High Toss Road would continue to remain a freshwater system and both the abundance and number of freshwater fish species would remain low.

For macroinvertebrate species, the upstream/downstream distribution of the species currently shows a trend that is related to the presence of the Chequessett Neck Road Dike. This is due to the depressed mean tidal range limiting the amount of salinity penetrating upstream as well as the limited amount of sub-tidal and intertidal estuarine habitat. The density of individual macroinvertebrate species, except for grass shrimp, is greater downstream of the dike than upstream and this trend is likely to continue under alternative A. There is a moderate abundance of freshwater species in the Herring River system upstream of High Toss Road (Gwilliam unpublished data; Johnson unpublished data; Lassiter unpublished data, Raposa unpublished data; Roman 1987). This trend would continue under alternative A.

Anadromous and Catadromous Fish

The headwater ponds of the Herring River provide approximately 157 acres of spawning habitat for river herring and the only major obstruction on the river is Chequessett Neck Road Dike. While passable, the 24-inch sluice gate opening is undersized and limits fish passage. As noted in section 3.6.3, prior to the construction of the dike the Herring River supported a productive river herring fishery of about 200,000 to 240,000 fish, with the actual river herring run size likely much larger. While other factors, such as offshore fishing and abundance of predators, have likely contributed to some of the decrease in river herring runs in Herring River and other areas throughout the northeast United States, construction of the dike has been a major factor in the decrease in river herring within the Herring River system (Curley et al. 1972). Besides impeding upstream migration, the sluice gate and the two flapper gates that allow river discharge on the ebbing tide may also increase the mortality of post-spawning adults migrating back into the coastal waters. The natural mortality of post-spawning alewifes is known to be high (estimated to be 57.4 percent by Kissil 1974 as cited in Roman 1987), so hazards encountered during the outmigration may increase the already high mortality rate of post-spawning adults, which may affect the size of subsequent spawning runs. Current run sizes have averaged approximately 12,400 fish over the past three years (APCC 2011), and with continued limited fish passage at the dike under alternative A run sizes would likely continue to remain below what a restored system could accommodate.

In addition to the dike, the narrower upstream reaches of the Upper Herring River sub-basin can become so choked with primarily watercress (*Rorippa nasturtium-aquaticum*) that it impedes the emigration of juvenile herring moving out of the freshwater ponds into the downstream waters. Plant growth can be so thick that the fish cannot get through or around it, so they attempt to swim over it and often times die in their attempt as they get preyed upon by birds (Hughes 2011). As a result, the Wellfleet Herring Warden spends as much as 150 hours during late summer/early fall clearing the aquatic plants to enhance fish passage (Hughes 2011). Under alternative A, these conditions would not change and would continue to adversely impact juvenile river herring.

Poor water quality upstream of High Toss Road would continue to occur under alternative A and would continue to adversely affect river herring. Alewife and blueback herring juveniles have been shown to prefer areas with dissolved oxygen levels ranging from 2.4 to 10.0 parts per million (ppm) and pH levels from 5.2 to 6.8 (Roman 1987); however, levels below these have been recorded in the upper reaches of the Herring River (Portnoy 1991). Additionally, high concentrations of suspended solids within the upper Herring River system may also affect river herring. Suspended solid concentrations have been recorded as high as 300 ppm in the upper part of the Herring River system (Portnoy 1984b) and levels this high can lead to the direct mortality of adult migrating fish and can reduce the viability of embryos (Roman 1987).

Besides river herring, hickory shad also migrate from offshore waters to spawn in the Herring River and under alternative A the Chequessett Neck Road Dike would continue to pose an obstacle to their upstream migration. They would also likely be adversely affected by the continued poor water quality of the system upstream of High Toss Road.

Under alternative A, white perch would continue to inhabit the Herring River system and spawn in the upper main river stem where salinities are generally less than 4 ppt and in the freshwater ponds. American eel elvers would also continue to migrate upstream to the freshwater ponds, and adult eels would continue to emigrate out of the system on their spawning migration to the Sargasso Sea. However, as with all fish inhabiting or migrating through the river upstream of High Toss Road, poor water quality conditions such as low dissolved oxygen and pH would continue to create a stressful environment for these species to inhabit and migrate through.

Shellfish

Under alternative A, shellfish populations upstream of the Chequessett Neck Road Dike would continue to be limited, mainly due to the salinity range and availability of suitable substrate. While oysters are abundant downstream of the dike and in Wellfleet Harbor, the few that exist upstream of the dike are limited to the area of the Lower Herring River sub-basin immediately adjacent to the dike. Upstream of this area, salinity levels are frequently below 5 ppt, which is the lower limit for oyster survivability.

Oysters also require a stable substrate for attachment and growth. Suitable substrates are not common immediately upstream of the dike, because the tide velocities near the sluice gates leave mostly coarse, shifting sands. Further upstream the sediments are fine and organic, which is also a poor oyster substrate. These conditions would continue to limit oyster populations in the Lower Herring River under alternative A. Hard and soft shelled clams are extremely rare upstream of the dike because salinity levels are frequently below the species threshold for survivability. These conditions would also continue under alternative A. Wild and cultivated shellfish populations downstream of the dike and in Wellfleet Harbor are expected to continue at current population levels.

4.6.3 IMPACTS COMMON TO ALL ACTION ALTERNATIVES

Estuarine Fish and Macroinvertebrates

Under any of the action alternatives, opening the tide gate structure to allow increases in the mean spring tide would change the Herring River estuary from a largely freshwater system to a largely tide-influenced system with saline waters extending much farther upstream than under alternative A.

Upstream of the dike, throughout the Lower Herring River and more upstream areas where salinity penetrates, the diversity of resident estuarine fish species would increase and reflect that of the Herring River downstream of the dike, while the abundance of individual species would also increase as documented in other New England salt marsh restoration projects (e.g., Burdick et al. 1997; Raposa and Roman 2003). The larger tide gate openings at the new dike would enhance fish passage allowing both resident species such as the mummichog, and migrants such as striped bass and others to readily move between downstream and upstream habitats. The additional intertidal habitat (tidal wetland and intertidal flats) upstream of the dike would also provide more spawning and nursery habitat for species such as mummichog, striped killifish, Atlantic silversides and other common tidal salt marsh species, greatly increasing their populations throughout the Herring River estuary. However, exactly how much of that habitat is actually available for use by various fish species is dependent upon its accessibility. The number and location of tidal creeks, marsh surface water depth, and hydroperiod (the length of time the marsh surface is inundated) all play key roles in determining how accessible the marsh surface is to various species and life stages (Kneib and Wagner 1994; Minello et al. 1994; Peterson and Turner 1994; Rozas et al. 1988). The larger volumes of water moving upstream through the system under the action alternatives onto the marsh surface may create new tidal creeks in addition to widening the mainstem tidal creeks, creating new habitat for both resident and transient species.

For migrant species such as striped bass and bluefish, the increased fish passage afforded by the new dike and the increased abundance of small resident forage species and macroinvertebrates would increase their accessibility and their numbers upstream of the dike; however, they would not likely use the entire restored estuary as habitat, because predatory fish such as striped bass often move up into estuaries on the late ebb or early flood tides (i.e., around low tide) when prey are more concentrated in the tidal creeks than on the marsh surface (Tupper and Able 2000).

For freshwater fish species such as chain pickerel, golden shiner and pumpkinseed, and freshwater macroinvertebrate species, such as isopods and freshwater shrimp, available habitat would be somewhat reduced in lower sub-basins where higher salinity levels would occur. However, in the upper sub-basins – Upper Pole Dike Creek, Upper Herring River, and Upper Bound Brook – these, and other, species would benefit from increased flow, water levels and water quality as compared to alternative A.

With increased salinity, especially throughout the lower sub-basins where salinity levels would be relatively high (i.e., 20-30 ppt), habitat for estuarine macroinvertebrate species such as grass shrimp, fiddler crab, clam worm, moon snail, and common periwinkle would greatly expand with individual species moving into areas within their individual salinity tolerance ranges.

Anadromous and Catadromous Fish

The design of the new dike under the action alternatives would benefit all species of anadromous and catadromous fish, including river herring (alewife and blueback herring), hickory shad, white perch and American eels through better fish passage. In addition to allowing more fish to move upstream, the new tide gates would also reduce the direct mortality of emigrating juveniles and post-spawning adult river herring by creating larger openings for passage and likely lower water velocities that need to be overcome. Improved water quality upstream of High Toss Road, as described in sections 4.2.3 and 4.3.3, would decrease the mortality of juvenile and post-spawning adult river herring, as well as American eels. Though total suspended solids from sediment mobilized during the initial increased flushing of the system could temporarily adversely impact adult and juvenile river herring, small, incremental openings of the tide gates will mitigate these temporary impacts. With the increased tidal range under the action alternatives, intertidal waters on spring high tides would expand into the upper reaches of Upper Herring River. With increased salinity levels the creek channels leading to the headwater ponds would likely become free of the emergent and submergent freshwater aquatic plants that often choke and block the waterway, benefiting juvenile river herring as they emigrate from the ponds and move downstream. With increased intertidal and sub-tidal habitat and access to small tidal creeks and ditches there would also be an increase in the amount of nursery habitat for juvenile fish. Though there are outside factors that also influence the population size of river herring, all of the above benefits that would occur under any of the action alternatives would increase the probability that the river herring run size would significantly increase in the years after restoration.

Increased fish passage and estuarine nursery habitat under the action alternatives would also increase the utilization of the Herring River estuary by white perch and hickory shad. In addition, the increased fish passage, improved water quality, and improved habitat within the Herring River estuary could lead to favorable conditions for restoration of a sea-run brook trout population to the Herring River.

Shellfish

The new tide gate openings at the Chequessett Neck Road Dike would allow increased tidal flow upstream of the dike bringing increased salinity levels. Oysters could potentially recolonize areas where salinity values fall within their preferred range of 10 to 30 ppt; however, oysters need stable, clean, hard substrate to settle on, for which there is little upstream of the dike. Even with restoration upstream of the dike it is unlikely that oysters would establish themselves naturally, unless the bottom substrate of the river hardens naturally with restoration.

Hard clams prefer a salinity range of 15 to 35 ppt and can be found in sediments ranging from pure mud to coarse sand. Given the range of sediments they can be found in, and the wild populations in Wellfleet Harbor that could provide spawn, hard clams would likely be able to colonize tidal creek habitat upstream of the dike within their preferred salinity range.

Softshell clams have a salinity range of 5 to 35 ppt and can be found in sediments ranging from mud to sand. Though softshell clams have not been found upstream of the dike in recent studies, during the 1973 period when the dike was in disrepair allowing some increased tidal flow to increase the salinity levels upstream of the dike, softshell clams occurred along approximately 0.5 acre of sub-tidal sandy shoreline in the Lower Herring River sub-basin (Gaskell 1978), indicating that with increased salinity under any alternative conditions could be suitable for softshell clams.

In addition to providing suitable habitat for shellfish, the action alternatives would also provide additional habitat for predators of shellfish, such as moon snail, green crab and mud crab, whose populations upstream of the dike would also likely increase. However, without knowing just how populous they would be come, it is not possible to assess what their potential impact would be on shellfish that become re-established upstream of the dike.

Increased tidal flows would erode sediments in the existing tidal creeks upstream and downstream of the dike, both deepening and widening them. Higher current velocities on the incoming tide than on the outgoing tide, would deposit a greater proportion of sediment upstream on to the marsh surface. However, peak velocities during the outgoing tides would also erode sediment that would be transported downstream into Wellfleet Harbor. It is not known how much deposition would occur or how much sediment would be mobilized in areas of new or existing erosion. Species such as hard clams and softshell clams can move up and down in the sediment column and would not likely be affected by sediment. Oysters, however, are sedentary and would be susceptible to burial by excessive sedimentation. However, because of the fine grain size of the mobilized sediment in the Herring River, these sediment accumulations would likely be temporary. The accumulated sediment would be redistributed by currents and waves in the harbor with the finest particles flushed into Cape Cod Bay, or transported into tidal estuaries surrounding the harbor.

4.6.4 COMPARISON OF IMPACTS OF THE ACTION ALTERNATIVES

The drivers which distinguish between the action alternatives are 1) the volume of the restored tidal prism and 2) the amount of estuarine habitat (sub-tidal and intertidal habitat) that would be restored under each alternative. The differences in areal extent of impacts between the action alternatives are comparatively small as the areas influenced by mean high water spring tides are not substantially different, though additional estuarine habitat would become available for use by aquatic species in Mill Creek under alternatives B and D. However, the increased tidal range and variation of salinity levels afforded by alternatives C and D, could result in differences in habitat types in several sub-basins. Table 4-16 indicates the amount of sub- and intertidal estuarine habitat that would be restored and made available to aquatic species and provides general ranges of expected salinity for each alternative. For each action alternative table 4-17 indicates the amount of mainstem tidal creek habitat that would be available for use by species along the marine-to-freshwater gradient.

Impacts of Alternative B

The total estuarine habitat within the Herring River system available to estuarine fish and macroinvertebrate species would be approximately 11 times more than under alternative A (table 4-16). Additionally, the restored habitat would include approximately 11.5 miles of mainstem tidal creek for use by resident as well as migratory species, and anadromous species (table 4-17). Salt water habitat, with salinity levels of approximately 18 to 30 ppt would occur throughout the Lower and Middle Herring River, Mill Creek, and parts of the Lower Pole Dike Creek sub-basins, encompassing about 49 acres of sub-tidal and 394 acres of intertidal habitat. Freshwater conditions would persist in the Upper Herring River and Upper Bound Brook sub-basins, however increased flow, tidal exchange, and water quality would expand and improve habitat for aquatic species using these habitats. Varying levels of brackish habitats would develop in the transitional sub-basins between the lower and upper portions of the system.

TABLE 4-16: TOTAL ESTUARINE HABITAT BY SUB-BASIN FOR ACTION ALTERNATIVES

Sub-basin	Alternative A			Alternative B			Alternatives *C and D		
	Sub-tidal (acres)	Intertidal (acres)	Total Estuarine (acres)	Sub-tidal (acres)	Intertidal (acres)	Total Estuarine (acres)	Sub-tidal (acres)	Intertidal (acres)	Total Estuarine (acres)
Lower Herring River	45	25	70	33.0	117.3	150.3	33.0	123.2	156.2
Mill Creek* (option 1)	0	0	0	5.5	59.0	64.5	5.5	57.3	62.8
Mill Creek* (option 2)	0	0	0	5.5	48.3	53.8	5.5	49.8	55.3
Middle Herring River	0	0	0	10.5	74.6	75.1	10.5	76.6	87.1
Duck Harbor	0	0	0	6.0	74.6	80.6	6.0	101.7	107.7
Lower Pole Dike Creek	0	0	0	7.8	96.4	104.2	7.8	97.9	105.7
Upper Pole Dike Creek	0	0	0	17.8	93.9	111.7	17.8	109.4	127.2
Upper Herring River	0	0	0	17.2	79.7	96.9	17.2	96.8	110.2
Lower Bound Brook	0	0	0	4.3	61.9	66.2	4.3	67.4	71.7
Upper Bound Brook	0	0	0	4.8	35.7	40.5	4.8	51.8	56.6
Total Acres (Option 1)	**NA**	**NA**	**NA**	**107**	**693**	**800**	**107**	**778**	**885**
Total Acres (Option 2)	**NA**	**NA**	**NA**	**107**	**683**	**790**	**107**	**771**	**878**

Sub-tidal: habitat below modeled extent of Mean Low Water

Intertidal: areas between modeled high extent of Mean Low and Mean High Spring Tides

Salinity:

- [blue] = salt water (18-30 ppt)
- [orange] = brackish, mixed (5-18 ppt)
- [green] = freshwater (<5 ppt)

* = No Restored Estuarine Habitat in Mill Creek under alternative C.

TABLE 4-17: MAINSTEM TIDAL CREEK ESTUARINE HABITAT

Sub-basin	Estuarine Tidal Creek Habitat (miles)			
	Alternative A	Alternative B	Alternative C	Alternative D
Lower Herring River	1.4	1.4	1.4	1.4
Mill Creek (option 1)	0	0.9	-	0.9
Mill Creek (option 2)	0	0.9	-	0.9
Middle Herring River	0	1.2	1.2	1.2
Duck Harbor	0	0.9	0.9	0.9
Lower Pole Dike Creek	0	0.9	0.9	0.9
Upper Pole Dike Creek	0	1.9	1.9	1.9
Upper Herring River	0	2.4	2.4	2.4
Lower Bound Brook	0	0.7	0.7	0.7
Upper Bound Brook	0	1.2	1.2	1.2
Total Acres (Option 1)	**NA**	**11.5**	**10.6**	**11.5**
Total Acres (Option 2)	**NA**	**11.5**	**-**	**11.5**

Impacts of Alternative C

The total restored estuarine habitat within the Herring River system would be approximately 12 times more than under alternative A and slightly more than alternative B; though the Mill Creek sub-basin would not be restored to estuarine habitat (table 4-16). Additionally, the restored habitat would include approximately 10.6 miles of mainstem tidal creek for use by resident as well as migratory species, and anadromous species (table 4-17). This amount is slightly less than alternative B due to Mill Creek sub-basin not being restored to estuarine habitat. Salt water habitat, with salinity levels of approximately 18 to 30 ppt would occur throughout the Lower and Middle Herring River, Mill Creek, Lower Pole Dike Creek, and parts of the Duck Harbor sub-basins, encompassing about 60 acres of sub-tidal and 402 acres of intertidal habitat. Freshwater conditions would persist in most of the Upper Bound Brook sub-basins, however increased flow, tidal exchange, and water quality would expand and improve habitat for aquatic species using these habitats. Varying levels of brackish habitats would develop in the transitional sub-basins between the lower and upper portions of the system.

Impacts of Alternative D

The total restored estuarine habitat within the Herring River system would be approximately 12-13 times more than under alternative A and slightly more than alternatives B and C (table 4-16). Additionally, the restored habitat would include approximately 11.5 miles of mainstem tidal creek for use by resident as well as migratory and anadromous species (table 4-17). Salinity levels would be identical to those achieved by alternative C, with the addition of about 5 acres of high salinity sub-tidal habitat and 50 to 57 acres of intertidal habitat in Mill Creek, depending which golf course option is implemented.

4.6.5 CUMULATIVE IMPACTS

The Town of Wellfleet Comprehensive Wastewater Management Plan, the Mayo Creek salt marsh restoration project, and oyster spawning experiments in Wellfleet Harbor have the potential to beneficially affect aquatic species. Wellfleet's wastewater management plan would improve water quality in the project area waters by reducing the potential for nutrient loading and domestic sewage contamination of local surface waters, improving the habitat for estuarine fish and macroinvertebrate species. The Mayo Creek restoration project would improve and increase the amount of habitat available for all aquatic species. The oyster spawning experiments in Wellfleet Harbor could directly enhance the local population of oysters and provide additional spat that could settle in restored areas of Herring River. The oysters used in the experiments could also potentially improve local water quality by filtering nitrogen out of the water; improving habitat conditions for all aquatic species.

Recurrent dredging of Wellfleet Harbor has the potential to adversely affect aquatic species through temporary disturbance, decreases in local water quality, sedimentation, and direct mortality. Mobile species, both fish and macroinvertebrates, would temporarily move out of the area during dredging, returning once the activities are over. Dredging delivers sediment to the water column and increases turbidity. Increased turbidity can adversely impact aquatic species, including shellfish, and sedimentation can adversely affect shellfish through burial. Dredging could also result in the direct mortality of some benthic species that are not mobile enough to move out of the area, impacting feeding resources for predatory species. However, once dredging activities cease, species would quickly recolonize the affected area. Although these adverse impacts are temporary, they may recur with each dredging event.

Overall, each of the action alternatives, when combined with the impacts of the actions in the cumulative impact scenario, would have long-term beneficial impacts on aquatic species and habitats; any adverse impacts would be temporary and localized.

4.6.6 Conclusion

Under all action alternatives, the amount of estuarine habitat in the Herring River estuary would be greatly increased relative to the no action alternative. The estuary would change from being a freshwater system upstream to a tide-influenced estuarine system. The restored estuarine waters and salt marsh would provide substantially more spawning and nursery habitat for both resident and transient fish species as well as for estuarine macroinvertebrates, greatly increasing their abundance and use of the estuary compared to existing conditions, which would continue under the no action alternative. The new dike at Chequessett Neck Road would provide better fish passage for all fish including anadromous and catadromous species. This, combined with improved water quality and access to the head waters of the river, would likely enhance the river herring run size and allow for the possible reintroduction of sea-run brook trout into the Herring River estuary. With increased salinity upstream of the dike, habitat for shellfish would be enhanced. The permanent increase in spawning and nursery habitat for fish species and estuarine macroinvertebrates, and their corresponding increase in abundance, would constitute a significant beneficial impact for those aquatic species. For shellfish and resident estuarine fish these beneficial impacts would be local, limited to the estuary. For diadromous fish the benefits would be regional.

Under all action alternatives, sedimentation and erosion downstream of the dike in Herring River and Wellfleet Harbor could pose some adverse impacts to shellfish. Different pathways would exist for fine-grained sediment and coarse-grained sediment. Coarser-grained sediment (dominated by sands) would be transported primarily as bedload along the bottom of tidal channels. Model results indicate that bedload transport from areas just upstream and downstream of the dike would be slightly seaward toward Wellfleet Harbor, whereas finer-grained suspended sediments would be transported predominantly upstream to eventually settle out in the upper sub-basins of the Herring River. Very fine particles would remain in suspension and may be transported upstream into the

Herring River or downstream toward the harbor and Cape Cod Bay. However, if the dike is opened slowly so that all of the sediment is not mobilized at once or over a short period, adverse impacts would be avoided or minimized. Therefore, this uncertain impact is not likely to constitute a significant adverse impact.

Under the no action alternative, there would be no predicted changes for aquatic species, which receive limited habitat benefits from the estuary due to its degraded condition. Aquatic species in the estuary would remain lacking in number and/or variety due to the past environmental impacts of diking and draining the estuary, but there would be no significant new adverse impacts from taking no restoration action.

4.7 IMPACTS ON STATE-LISTED RARE, THREATENED, AND ENDANGERED SPECIES

As described in chapter 3, the Herring River flood plain supports populations of several state-listed species, including northern harrier (*Circus cyaneus*), eastern box turtle (*Terrapene c. carolina*), diamondback terrapin (*Malaclemys terrapin*), and water willow stem-borer (*Papaipema sulphurata*). In addition, there have been occurrence records of the state-listed American bittern (*Botaurus lentiginosus*) and least bittern (*Ixobrychus exilis*) recorded on outer Cape Cod, including within the Herring River project area. The Massachusetts Endangered Species Act (MESA) (M.G.L c.131A and regulations 321 CMR 10.00) protects rare species and their habitats by regulating the "taking" of any plant or animal species listed as endangered, threatened, or species of concern. Taking includes harassing, killing, trapping, collecting, as well as the disruption of nesting, breeding, feeding, or migratory activity, including habitat modification or destruction.

State-listed species were identified through informal consultation with the Natural Heritage and Endangered Species Program (NHESP) and formally through comments submitted to MEPA by the NHESP in 2008 on the environmental notification form (ENF) (see chapter 5). This impact analysis is primarily based on the results of hydrodynamic modeling and the projected changes to vegetation and habitats resulting from increased tide range and salinity presented in section 4.6.

Herring River restoration under any of the action alternatives may be permitted by MESA through an exemption process (321 CMR 10.14), which allows for greater flexibility through development of a habitat management plan. This is discussed in greater detail in chapter 5.

4.7.1 IMPACTS OF ALTERNATIVE A: NO ACTION

Under the no action alternative, the continued degradation of the former salt marsh habitats of the Herring River would result. There would be no expected changes to habitats for state-listed wildlife over the short term (years). However, even with the tidal opening at the Chequessett Neck Road Dike remaining in its current condition, the habitat within the tidally restricted flood plain is expected to change over the long term. The most obvious changes during the past few decades have been the establishment of forest and shrubland habitats and the occurrence of non-native *Phragmites* both of which have largely replaced the former salt marsh, brackish and tidal freshwater herbaceous plant communities on the marsh plain. This process was initiated by the construction of the Chequessett Neck Road Dike in 1909, which eliminated salt water and lowered wetland water levels (soil saturation). Forest and shrub growth and expansion of *Phragmites* has the potential to continue to expand under existing conditions which would adversely affect the herbaceous habitats required by northern harriers, water willow stem borers, American bitterns, and least bitterns. Additional forestland and the expansion of *Phragmites* would continue to reduce harrier foraging habitat, could shade out water willow (*Decodon verticillatus,* the critical host plant for water willow stem-borer), and degrade freshwater habitat used by bitterns. Therefore, under the no action alternative, the occurrence of the northern harrier, both species of bitterns, eastern box turtle, and water willow stem-borer may remain unaffected over the short term, but could decline locally in the longer term. Under no action, diamondback terrapins, a state-listed marine and brackish water species, would continue to be limited to the tidally influenced areas of the Lower Herring River sub-basin below and immediately above the Chequessett Neck Road Dike.

Northern Harrier

Under the no action alternative, northern harrier nesting and foraging opportunities likely would remain unchanged during the short term, with low-lying herbaceous wetland habitats, e.g., cat-tail marshes within Bound Brook and upper Pole Dike Creek sub-basins continuing to persist. However, harrier hunting habitat would likely continue to deteriorate throughout the remainder of the Herring River system as woodland habitat and *Phragmites* continues to spread across the original marsh plain. Harriers have been documented to hunt and nest in the Bound Brook sub-basin (Bowen 2006) and would likely persist in open habitat, i.e., herbaceous wetlands and nearby uplands and low shrub thickets. Nesting would likely continue on slightly elevated "islands" within the areas of the upper Herring River or possibly in adjacent upland thickets.

American Bittern/Least Bittern

Taking no action would allow both species of bitterns to continue to use freshwater marsh habitats throughout the project area as they do currently (approximately 242 acres), although the potential expansion of woodlands and *Phragmites* across the original marsh plain may degrade foraging habitat.

Diamondback Terrapin

Under the no action alternative, the terrapin's limited range and foraging opportunities in the Herring River estuary would remain unchanged (13 acres of salt marsh habitat). The Chequessett Neck Road Dike would continue to impede terrapin movements, allowing passage only during a short period of the tidal cycle. Diamondback terrapins would not be restored to their original distribution in the Herring River estuary, which probably included several hundred acres of salt-marsh habitats that provided critical wintering, foraging, and nursery areas upstream of the Chequessett Neck Road Dike.

Eastern Box Turtle

Eastern box turtles have been documented in wooded upland areas adjacent to the Herring River basin and may occur in the woodland habitats that have largely replaced the former estuarine wetland habitats. Under the no action alternative, box turtle habitat is expected to remain unchanged.

Water-Willow Stem-Borer

Under the no action alternative, populations of water willow stem-borer and its host plant, water willow (*Decodon verticillatus)*, would probably remain unchanged in the short term, (i.e., restricted to the shallow freshwater areas adjacent to the Herring River). Although tidal freshwater habitat, including patches of *Decodon,* likely existed in portions of the upper sub-basins of the Herring River prior to the construction of the Chequessett Neck Road Dike, the area suitable for *Decodon* growth likely has increased when compared to that which occurred prior construction of the dike (Mello 2006). Under this alternative, the dike would continue to impede salt water influence allowing freshwater plant communities to persist in the Herring River. Mello (2006) indicated that the water willow stem-borer population found in the tidally restricted Herring River is relatively new, likely the result of the expansion of *Decodon* into nutrient-rich wetlands. Although over the long term, the potential expansion of woodlands and *Phragmites* may degrade emergent freshwater habitats, the stem-borer is expected to persist in these *Decodon* patches; 174 stands are mapped in the project area along approximately 41,000 linear feet of available streambank habitat.

4.7.2 IMPACTS COMMON TO ALL ACTION ALTERNATIVES

Restoration of the Herring River estuary under any of the action alternatives will likely affect state-listed species and their habitats, although not all impacts would be adverse. For the diamondback terrapin, a turtle dependent on marine and estuarine conditions, tidal restoration is expected to restore additional habitat which would provide critical wintering, foraging, and nursery areas. The restoration of tides is expected to change the mix of freshwater and brackish marsh vegetation which would influence how and where northern harriers and American and least bitterns utilize habitat. Tidal restoration is likely to adversely affect the eastern box turtle and water-willow stem borer which are more dependent on freshwater wetland or upland habitats.

Northern Harrier

Northern harriers occur throughout the project area and several pairs have been recorded as nesting within the Bound Brook sub-basin (Bowen 2006). Any of the action alternatives could result in small habitat changes within Bound Brook sub-basin, but these are not expected to hinder future nesting activity. Other plant community changes throughout the Herring River project area likely will restore and enhance harrier foraging habitat as existing forest is replaced by herbaceous tidal fresh, brackish, and salt marsh.

Current northern harrier nesting sites in the Upper Bound Brook sub-basin are located in cat-tail-dominated plant communities which have replaced the original salt marsh vegetation. Tidal restoration in this area under any of the action alternatives is not expected to result in the complete restoration tidal fresh, brackish, and salt marsh habitats. Narrow-leaf cat-tail (*Typha angustifolia*), the existing dominant species in Bound Brook, is somewhat salt tolerant and likely would remain and could expand its distribution as woodland communities are displaced under the restored hydrology. Thus, areas suitable for harrier nesting should remain unchanged or potentially could increase. If nesting sites were to be impacted by brackish or salt water, harriers are expected to relocate to other suitable locations within the Bound Brook sub-basin or other nearby suitable locations.

Tidal restoration is expected to provide improved habitat for foraging by increasing the extent of tidal fresh, brackish, and salt marsh. Harriers hunt for small mammals, especially meadow voles (*Mircotus pensylvanicus*), throughout the year in marshes and elimination of *Phragmites* and woody vegetation would likely enhance the populations for some prey species while also enhancing foraging success for harriers.

American Bittern and Least Bittern

Although both American and least bitterns primarily use freshwater marsh habitats, both species also use brackish marsh habitats. Under each of the action alternatives, existing foraging, resting, or migratory habitat for American bitterns and least bitterns would be affected by restored tidal exchange. In the Lower Herring River, Mill Creek, Middle Herring River, Lower Pole Dike Creek sub-basins, where salinity levels would regularly reach above 18 ppt, existing cat-tail and other freshwater emergent plant species would be replaced by salt marsh plants. In the upper sub-basins, where salinity would remain below 5 ppt, existing freshwater marsh habitat should persist. Additionally, tidal freshwater and low salinity brackish marsh could expand as the existing shrubland and woodland habitats become wetter and are replaced by herbaceous emergent plants.

Diamondback Terrapin

In the short term, a small amount of salt marsh habitat occurring upstream of the Chequessett Neck Road Dike, which has recently been used by nesting terrapins, (unpublished MA Audubon data) would likely be impacted as tidal range increases. Terrapins nest in sandy dunes and open habitat within upland areas adjacent to salt marshes, but not in salt marshes (Cook 2008a). In addition, terrapins would probably not be able to pass through the dike while it is being reconstructed and could be affected by construction noise, vibrations, and other activities. However, over the long term, tidal restoration is expected to restore hundreds of acres of nesting, nursery, wintering, and foraging habitat in the Lower Herring River, Mill Creek, Middle Herring River, Lower Pole Dike Creek sub-basins, and portions of Duck Harbor sub-basin, allowing diamondback terrapins to almost fully reoccupy their historic distribution within the Herring River flood plain. Terrapins would have improved access to restored habitats in the Herring River estuary and increased opportunities to use sandy shorelines along the river as nesting habitat. Under all the action alternatives, restoration would provide at least 30 times more habitat for the terrapin and other estuarine-dependent species within the Herring River system than under the no action alternative.

Eastern Box Turtle

Restoration of tidal conditions throughout the Herring River flood plain are expected to affect eastern box turtles by restoring more saline and/or wetter conditions in areas that have dried out in response to diking of the river and drainage of salt marsh soils. Restored tidal influence may also limit the ability of box turtles to access freshwater for thermoregulation and hydration. As conditions gradually change through the incremental restoration of tides, turtles would be expected to move to adjacent uplands. There is some potential for isolating individuals that are now able to move freely throughout the project area. During periods of high storm-driven tides, it is possible that groups of turtles that occur on Griffin, Bound Brook, and Merrick Islands may be restricted to those islands. However, during normal tidal conditions, eastern box turtles should be able to move among the islands and the mainland along the upper boundaries of the flood plain where areas are expected to remain as freshwater and periodically dry.

Water Willow Stem-Borer

Under any of the action alternatives, varying amounts of freshwater wetland habitat supporting *Decodon* would be changed with tidal restoration. *Decodon* is predicted to have low tolerance to frequent inundation by salt water; therefore, any long-term level of salt water influence is likely to adversely affect its distribution. However, increased water levels and subsequent change from forested to palustrine shrub- and emergent-dominated habitats could increase the occurrence of *Decodon* in the upstream areas of the Duck Harbor, Bound Brook, Upper Herring River, and Upper Pole Dike Creek sub-basins, areas where salinity of tidally influenced water is expected to remain low. Specific impacts to *Decodon* associated with each alternative are summarized below. The assessment of impacts to stands of *Decodon* is intended to serve as a proxy for direct impacts to the state-listed water willow stem-borer. Although the coverage of *Decodon* was recently inventoried and mapped (Mello 2006), the occupancy of the stem-borer in individual stands of *Decodon* at any given time is not known. Therefore, impacts to *Decodon* do not necessarily correlate to the exact impacts to water willow stem-borer, but do serve to illustrate a worst-case scenario if all affected stands are occupied and used by stem-borers. In any case, *Decodon* is abundant along pond margins, vernal pools, and freshwater streams on outer Cape Cod, and the regional population would not be affected by tidal restoration at the Herring River.

4.7.3 COMPARISON OF IMPACTS OF THE ACTION ALTERNATIVES

Impacts of Alternative B

Northern Harrier

Restored tidal hydrology would eventually restore a small tidal fluctuation in about 106 acres of the 193-acre Bound Brook basin (Lower and Upper Bound Brook sub-basins combined). This potentially would affect the general area used by northern harriers for nesting in recent years. However, hydrodynamic modeling indicates that salinities would generally remain less than 5 ppt under alternative B; therefore, *Typha*-dominated areas would not be expected to change significantly and harrier nesting areas should not be affected. Throughout the rest of the project area, hundreds of acres of degraded shrublands and *Phragmites*-dominated habitat would be restored to tidal fresh, brackish and salt marsh, which should increase the quality and extent of harrier foraging areas.

American Bittern and Least Bittern

Alternative B would retain freshwater habitat in the Upper Bound Brook, the Upper Herring River, and the Upper Pole Dike Creek sub-basins, an area comprised of approximately 251 acres. Wetter conditions in these areas could lead to die-off of woody-species dominated habitats and an expansion of suitable freshwater and low salinity brackish marsh habitat. Existing freshwater marshes in lower sub-basins – Duck Harbor, Middle Herring River, Lower Pole Dike Creek, Mill Creek, and the Lower Herring River would likely revert to brackish or salt marsh. Some habitat functions for bitterns and other wading marsh birds could be expected to continue in these areas depending on specific vegetational changes.

Diamondback Terrapin

Alternative B would result in the restoration of approximately 393 acres of salt marsh habitat suitable for terrapin foraging and nesting in the Lower Herring River, Mill Creek, Lower Pole Dike Creek, and Middle Herring River sub-basins.

Eastern Box Turtle

High tide elevations achieved by alternative B could potentially displace turtles from the 800-acre flood plain which would experience restored mean high spring tides. However, as tidal influence is restored incrementally over a period of years, turtles would move to adjacent upland areas and would still be able to traverse the flood plain along the periphery of most sub-basins where salinity levels will remain low and dry land would still occur.

Water-Willow Stem-Borer

Under alternative B, the majority of *Decodon* occurrences would be affected by high salinity, tidally driven flow. Modeling indicates that as many as 103 of 174 *Decodon* stands mapped by Mello (Mello 2006) occurring along approximately 12,800 linear feet of streambank in the Lower and Middle Herring River, Duck Harbor, and Lower Pole Dike Creek sub-basins would eventually be impacted by salt and brackish water when alternative B is fully implemented. Stands occurring higher in the system in the Upper Herring River, Bound Brook, and Upper Pole Dike sub-basins would likely remain unaffected, depending the exact extent and frequency of salinity penetration. However, approximately 28,000 linear feet of suitable streambank habitat would remain and it is also likely that *Decodon* coverage would increase in these upper reaches of the system as tree-dominated woodland habitat becomes wetter and gradually develops into palustrine shrub- and emergent-dominated habitat. Thus, the overall long-term impact on *Decodon*, and the population of water willow stem-borer supported in the Herring River flood plain, should be minimal.

Impacts of Alternative C

Northern Harrier

Impacts to northern harrier under alternative C would potentially be greater than those of alternative B and depend on the actual extent of salt penetration and salt marsh restoration within the existing nesting areas of the Bound Brook basin. Hydrodynamic modeling projects that approximately 127-acres of the 193-acre sub-basin would be subjected to tidal influence in the Upper and Lower Bound Brook sub-basins, where the harrier nesting was last confirmed. As tide range is increased beyond that attained by alternative B, salinities would increase, at times reaching about 20 ppt in the tidal channels of the Lower Bound Brook Basin, which could support development of salt marsh vegetation adjacent to tidal channels. Salinities would be lower landward and in the upper reaches, but could still affect stands of *Typha* and potentially limit harrier nesting habitat.

American Bittern and Least Bittern

The higher tidal range and greater extent of tidal influence achieved by alternative C would increase the likelihood that brackish and salt water flow would displace existing freshwater marsh and would impact habitats used by American and least bitterns in the middle sub-basins of the Herring River project area. However, tidal freshwater and low salinity brackish conditions are projected for upper areas of the Bound Brook, Herring River, and Pole Dike Creek sub-basins during normal tidal conditions. Although storm-influenced tidal events may drive higher salinity water into these sub-basins, the frequency of these events is not expected to result in significant vegetation change on the marsh surface. In addition, higher tidal ranges would also result in wetter conditions and potentially enhance and expand freshwater marsh habitat through approximately 294 acres. Any habitat currently used by both bittern species that exists within the Mill Creek sub-basin would remain unchanged.

Diamondback Terrapin

Alternative C would result in the restoration of approximately 346 acres of salt marsh habitat suitable as terrapin foraging, wintering, and nesting areas in the Lower Herring River, Lower Pole Dike Creek, and Middle Herring River sub-basins. No terrapin habitat would be restored in the Mill Creek sub-basin.

Eastern Box Turtle

Impacts to eastern box turtle under alternative C are similar to those under alternative B, but would encompass an area of 830 acres. This accounts for a greater aerial extent of tidal influence during mean high spring tides and the exclusion of any tidal influence in the 70-acre Mill Creek sub-basin.

Water-Willow Stem Borer

Under alternative C, the majority of Decodon occurrences would be affected by high salinity, tidally driven flow. Modeling indicates that as many as 106 of 174 Decodon stands mapped by Mello (Mello 2006) occurring along approximately 13,800 linear feet of streambank in the Lower and Middle Herring River, Duck Harbor, Lower Pole Dike Creek, and Lower Bound Brook sub-basins would eventually be impacted by salt and brackish water when alternative C is fully implemented. Stands occurring higher in the system in the Upper Herring River, Upper Bound Brook, and Upper Pole Dike sub-basins would likely remain unaffected, depending the exact extent and frequency of salinity penetration. However, approximately 25,000 linear feet of suitable streambank habitat would remain and it is also likely that *Decodon* coverage would increase in these upper reaches of the system as tree-dominated woodland habitat becomes wetter and gradually develops into palustrine shrub- and emergent-dominated habitat. Thus, the overall long-term impact on *Decodon*, and the population of water willow stem-borer supported in the Herring River flood plain, should be minimal.

Impacts of Alternative D

Northern Harrier

Impacts to northern harrier nesting habitat under alternative D are identical to alternative C because suitable habitat does not occur in the Mill Creek sub-basin. However, salt marsh restoration in Mill Creek as part of alternative D could provide as much as 53 acres of additional harrier foraging area. Impacts are shown in table 4-18.

American Bittern and Least Bittern

In addition to the impacts described previously for alternative C, alternative D would also restore up to 53 acres of freshwater marsh habitat to salt marsh in the Mill Creek sub-basin. Much is this area is currently dominated by non-native *Phragmites*.

Diamondback Terrapin

Impacts to terrapins under alternative D would include the restoration of approximately 53 acres of salt marsh in the Mill Creek sub-basin, in addition to impacts described for alternative C. Thus, the total area of restored terrapin habitat would be 399 acres.

Eastern Box Turtle

Box turtle impacts for alternative D are identical to those for alternative C, but would also include any potential habitat within the Mill Creek sub-basin. Thus, the total area of impacted habitat could reach approximately 890 acres.

Water Willow Stem-Borer

Impacts to water willow stem-borer and *Decodon* under alternative D are identical to those of alternative C, as *Decodon* has not been documented within the Mill Creek sub-basin.

TABLE 4-18: SUMMARY OF IMPACTS ON STATE-LISTED RARE, THREATENED, AND ENDANGERED SPECIES

Species	Alternative A	Alternative B	Alternative C	Alternative D
Northern Harrier	Nesting activity within 193-acre *Typha* dominated Bound Brook sub-basin.	106 acres in Bound Brook becomes tidally influenced; salinity near 0 ppt. Area of salt marsh foraging increased by 393 acres.	127 acres in Bound Brook becomes tidally influenced; salinity in channels may reach 20 +/- ppt during storms. Area of salt marsh foraging increased by 346 acres.	Same as alternative C, no species occurrence in Mill Creek. Area of salt marsh foraging increased by 399 acres.
American Bittern and Least Bittern	Exact distribution and activity not known Brackish and Freshwater Marsh = 242 acres.	251 acres of freshwater marsh in upper basins becomes tidally influenced; salinity near 0 ppt.	294 acres of freshwater marsh in upper basins tidally influenced; Salinity in channels may reach 20 +/- ppt during storms.	347 acres (includes 53 acres of freshwater marsh in Mill Creek) becomes tidally influenced (unknown whether species occur).
Diamond-back Terrapin	13 acres of salt marsh habitat potentially used in Lower Herring River.	393 acres of salt marsh restored in Lower Herring River, Mill Creek, Middle Herring River, Lower Pole Dike Creek.	346 acres of salt marsh restored in Lower Herring River, Middle Herring River, Lower Pole Dike Creek.	399 acres of salt marsh restored in Lower Herring River, Mill Creek, Middle Herring River, Lower Pole Dike Creek, Duck Harbor.
Eastern Box Turtle	Occur throughout 1000+ acre project area.	Displaced from 800-acre area influenced during mean high spring tide.	Displaced from 830-acre area influenced during mean high spring tide.	Displaced from 890-acre area influenced during mean high spring tide.
Water Willow Stem-Borer	174 *Decodon* stands mapped throughout 41,000 linear feet of streambank habitat (High Toss Road and above); exact occupancy by stem-borer not known. Wet shrub coverage = 347 acres.	103 stands occurring along 12,800 linear feet of streambank in Lower Herring River, Middle Herring River, and Lower Pole Dike Creek likely affected by tidal waters. Potential increase along 28,000 linear feet in upper sub-basins .	106 stands occurring along 13,800 linear feet of streambank in Lower Herring River, Middle Herring River, and Lower Pole Dike Creek likely affected by tidal water. Potential increase along 25,000 linear feet in upper sub-basins.	Same as alternative C.

4.7.4 CUMULATIVE IMPACTS

The Mayo Creek salt marsh restoration project would restore a limited amount of tidal salt marsh habitat available to the diamondback terrapin in Wellfleet Harbor. Dredging of Wellfleet Harbor has the potential to adversely affect diamondback terrapin through temporary disturbance and temporary decreases in local water quality. Impacts would depend on the timing and duration of the dredging and on the type and placement of the dredge spoils. Overall, each of the action alternatives, when combined with the impacts of harbor dredging and the Mayo Creek salt marsh restoration, would have long-term beneficial impacts on diamondback terrapins; any adverse impacts associated with dredging would be temporary and localized. No cumulative impacts are anticipated for the other state-listed rare species discussed above.

4.7.5 CONCLUSION

All action alternatives would have the potential to affect the habitat of eastern box turtles, water willow stem-borers, American and least bitterns, diamondback terrapins, and northern harriers. In the case of eastern box turtles, water willow stem-borers, and American and least bitterns, the action alternatives would cause a change to species distribution as the transition to estuarine wetland took place. These impacts would be local and limited in degree, because of the mobility of these species relative to the pace of restoration and availability of adjacent habitat, and therefore would not be considered significant. For box turtle, as tidal influence is restored individuals would move to adjacent upland areas and would still be able to traverse the flood plain along the periphery of most sub-basins where salinity levels will remain low and dry land would still occur. For northern harriers, some local nesting habitat may be affected by tidal exchange under alternatives C and D, but harrier nesting habitat and nesting opportunities should remain unaffected. Harriers would gain some tidal marsh foraging habitat under all action alternatives. Again, these impacts would be limited in degree, and given the harrier's mobility; they would not result in population level impacts and would therefore not be considered significant. For diamondback terrapin, the increase in tidal marsh habitat, particularly the increase in the species' preferred nesting habitat, would represent a significant beneficial impact in the context of the local terrapin population.

Under the no action alternative, there would be no predicted changes for state-listed species in terms of distribution or abundance. While the assemblage of species would remain dissimilar from the assemblage that existed under unmodified, pre-dike habitat conditions, there would be no significant new adverse impacts on state-listed species.

4.8 IMPACTS ON TERRESTRIAL WILDLIFE

As described in chapter 3, even in its existing degraded state the Herring River flood plain contains diverse habitats for a wide array of insect, reptile, amphibian, bird, and mammal species. Tidal restoration for the river will initiate changes to many of these habitats and could potentially affect certain wildlife populations.

4.8.1 METHODOLOGY AND ASSUMPTIONS

Given the lack of detailed information regarding the local status of most wildlife species and their specific use of the Herring River flood plain, this analysis is necessarily a broad view of general wildlife habitat changes resulting from tidal restoration. It is based primarily on the analysis of vegetation and wetland habitat change presented in section 4.5, which coupled findings of hydrodynamic modeling of the estuary (WHG 2011a) and vegetation mapping completed by the Seashore (HRTC 2007) to predict how increased tidal range and varying salinity levels throughout the project area would drive vegetation and habitat changes.

4.8.2 IMPACTS OF ALTERNATIVE A: NO ACTION

Under the no action alternative, species present within the Herring River basin would continue to occur under current degraded conditions with no expected changes to habitat beyond those which already may be occurring. The system would remain dominated by freshwater and mixed upland vegetation. Although tidal restriction would continue to contribute to poor water quality conditions in the Herring River, brackish and freshwater wetlands, woodlands, and shrublands would continue to provide habitat for birds, mammals, reptiles, and amphibians.

4.8.3 IMPACTS COMMON TO ALL ACTION ALTERNATIVES

As discussed in section 4.5, under any of the action alternatives wildlife habitats within the project area would generally change from degraded brackish and freshwater wetland, shrubland, and woodland habitats to tidally influenced marsh habitats. In the lower sub-basins of the flood plain, increased salinity levels would displace salt-sensitive, non-native plants that have invaded the flood plain and allow for recolonization of native salt marsh plants. Lower salinities, however, would likely occur in the upper sub-basins where existing woodland and shrubland habitats dominated by upland species would, over the long term, gradually develop into brackish and freshwater marsh habitat. Existing freshwater marsh habitat would likely be enhanced by higher water levels and improved water quality.

During construction, wildlife species would likely temporarily avoid the areas because of construction noise and habitat disturbance. Because none of the potential construction sites provide unique or critical habitat most wildlife species are likely to use other habitats nearby. Mobile species would likely leave the area and return when construction is complete. Once construction is completed, wildlife species are expected to re-establish in the restored area.

Birds

Shifts in avian community structure following tidal restoration and increases in open-water habitat generally include an overall increase in avian abundance and an accompanying transition from a community dominated by generalists and passerines to one dominated by waterfowl, shorebirds, and wading birds (see e.g., Seigel et al. 2005). A similar response is anticipated for most of the Herring River avian community following restoration.

Several high priority salt marsh- and tidal creek-dependent species such as salt marsh sharp-tailed sparrows, willets, great and snowy egrets, osprey, and common and roseate terns, are expected to benefit directly through restoration of nesting (salt marsh habitat) and/or foraging opportunities (primarily estuarine fish) in the Herring River. Tidal restoration would also restore wetland and open-water habitats for resident and migratory waterfowl and shorebirds such as wintering black ducks, mergansers, bufflehead, willets, and yellowlegs. Existing shrublands and woodlands dominated by upland vegetation, habitats widely used by generalist resident and migrating passerine species, such as upland sparrows and wood warblers, would be reduced and replaced by tidally influenced brackish and freshwater marsh. This would likely increase the amount and quality of habitat for wetland dependent bird species such as bitterns (see preceding section), rails, marsh wrens, red-wing blackbirds, and common yellowthroats.

Generalist upland bird species could potentially be affected in the long term by a reduction in nesting and feeding opportunities as herbaceous marsh plants replace woodland and shrub habitat. However, these generalist populations would persist in the abundant uplands surrounding the project area and at the wetland/upland edge where some shrub thickets and relic tree stands would remain after restoration. These areas would continue to provide nesting, foraging, and perching sites for sparrows, nuthatches, woodpeckers, catbirds, and other passerines along the upland border.

Mammals

It is expected that adequate habitat elements (e.g., suitable food, cover, and den sites) would remain for most mammalian species as a result of tidal restoration. Tidal restoration, provided it occurs gradually, would allow these animals to readjust to the restored salt marsh system and shift their local range within and adjacent to the river and its flood plain.

The most common group of mammals found in salt marsh habitats in the region are rodents, such as the meadow vole and white-footed mouse, which are an important prey-species for northern harriers and other raptors. Initial restoration would result in gradual flooding of habitat and landward migration of many species, but eventually habitats for voles, mice, and other rodents would be dramatically expanded. As tidal restoration progresses, many mammals would continue to forage on the invertebrates, fish, and marsh vegetation and would still use surrounding wooded uplands for den sites and refugia.

Other mammal species in the Herring River are generalists and opportunists that can occupy a variety of habitats. Although in the short term, medium and large mammal species such as raccoon, skunk, muskrat, river otter, and white-tailed deer may be displaced from currently occupied habitat, increased tidal range and salinity, restored salt, brackish, and freshwater marsh habitat may provide long-term benefits with improved water quality, more abundant and diverse prey species, and a more open, expansive habitat structure.

Reptiles and Amphibians

The Herring River flood plain provides habitat for a variety of reptiles and amphibians. Snapping and spotted turtles and northern water snake generally inhabit the freshwater areas upstream of High Toss Road, but can survive in brackish water and salt marsh habitats. Amphibians such as green and wood frogs, Fowlers toad, and spotted salamander generally are not present within high salinity portions of coastal environments due to the detrimental impacts of salt water on their biological functions. These species are more commonly found along the periphery and in the upper reaches of most sub-basins and in upland transitional habitats (see chapter 3 for a detailed list of species). Increases in tidal range associated with restoration may, in the short term, limit and disrupt reptile and amphibian breeding, foraging, and nesting in lower areas of the flood plain if salinities and water levels increase suddenly. However, these areas are less likely to be occupied initially and restoration will proceed at a gradual pace, allowing any affected populations to relocate to suitable habitat. In the long term, reptile and amphibian populations should shift and adjust their ranges, but no significant declines in species diversity or abundance is expected.

4.8.4 Comparison of Impacts of the Action Alternatives

While the nature of impacts to terrestrial wildlife populations described in section 4.8.2 do not vary among the three action alternatives, the magnitude of impacts slightly differ depending on which alternative is implemented. The magnitude of impacts is based primarily on projected habitat changes driven by increased tidal range and salinity described in section 4.5.

4.8.5 Cumulative Impacts

Based on the cumulative impact scenario, there are no anticipated impacts on terrestrial wildlife that would result in cumulative impacts different from the direct and indirect impacts of each of the action alternatives.

4.8.6 Conclusion

All action alternatives would result in habitat changes that would affect the distribution of terrestrial wildlife. Mammals, reptiles, and amphibians would gradually relocate to suitable habitat as the estuary undergoes the expected transition from degraded freshwater wetland to functioning estuarine wetland. Because of the gradual pace of environmental change and the animals' mobility, no significant adverse impacts on regional populations are anticipated. For bird species, within the geographic context of the estuary, there would be a substantial change in the composition of species using the estuary. Species dependent on estuarine wetlands would become more abundant, while species dependent on woodland, shrubland or heathland would become less abundant. This estuary-wide, permanent change in species composition, in the context of the project objective of restoring an estuarine wetland ecosystem, would be considered a significant beneficial impact.

Under the no action alternative, there would be no predicted changes for terrestrial wildlife species, in terms of distribution or abundance. While the assemblage of species would remain dissimilar from the assemblage that existed under unmodified, pre-dike habitat conditions, there would be no significant new adverse impacts on terrestrial species, as shown in table 4-19.

TABLE 4-19: SUMMARY OF IMPACTS ON TERRESTRIAL WILDLIFE

Species Group	Alternative A	Alternative B	Alternative C	Alternative D
Birds	• Salt marsh species: limited to 13 acres in Lower Herring River. • Other wetland species: 264 acres of freshwater/brackish habitat available. • Upland and other species: 723 acres of woodland, shrubland, and heathland habitat.	• Salt marsh species: 393 acres of habitat restored in Lower Herring River, Mill Creek, Middle Herring River, and Lower Pole Dike Creek. • Other wetland species: 407 acres of freshwater/brackish habitat restored/enhanced in upper sub-basins. • Upland and other species: woodland, shrubland, and heathland habitat limited to periphery and uppermost sub-basin; species utilize adjacent upland habitats.	• Salt marsh species: 346 acres of habitat restored in Lower Herring River, Middle Herring River, and Lower Pole Dike Creek. • Other wetland species: 484 acres of freshwater/brackish habitat restored/enhanced in upper sub-basins. • Upland and other species: woodland, shrubland, and heathland habitat limited to periphery and uppermost sub-basin; species utilize adjacent upland habitats. • No change in Mill Creek.	• Salt marsh species: 399 acres of habitat restored in Lower Herring River, Mill Creek, Middle Herring River, Duck Harbor and Lower Pole Dike Creek. • Other wetland species: 491 acres of freshwater/brackish habitat restored/enhanced in upper sub-basins. • Upland and other species: woodland, shrubland, and heathland habitat limited to periphery and uppermost sub-basin; species utilize adjacent upland habitats.
Mammals	Widespread throughout 1000+ acre project area.	Most species relocate to periphery and upper extents of 800-acre area affected by mean high spring tide.	Most species relocate to periphery and upper extents of 830-acre area affected by mean high spring tide; no change in Mill Creek.	Most species relocate to periphery and upper extents of 890-acre area affected by mean high spring tide.
Reptiles and Amphibians	Widespread throughout 1000+ acre project area.	Most species relocate to periphery and upper extents of 800-acre area affected by mean high spring tide.	Most species relocate to periphery and upper extents of 830-acre area affected by mean high spring tide; no change in Mill Creek.	Most species relocate to periphery and upper extents of 890-acre area affected by mean high spring tide.

4.9 IMPACTS ON CULTURAL RESOURCES

This section analyzes potential impacts to cultural resources based on the survey documented in the Public Archaeology Laboratory's (PAL) *Phase IA Archeological background Research and Sensitivity Assessment* report (Herbster and Heitert 2011) within the area of potential effect (APE) defined by each of the Herring River Tidal Restoration alternatives. No historic (above-ground) resources were identified within the APE for the study (Herbster and Heitert 2011). One historic district, the Atwood-Higgins Historic District extends to the Herring River on its southernmost edge, but no significant resources within the district are within the APE. No documented ethnographic resources are known to be located within the project APE, but consultation regarding the presence of ethnographic resources in the Herring River estuary is ongoing. As a result, this section considers potential impacts only to archaeologically sensitive areas and archaeological sites. For the purposes of this analysis, historic-era resources at, or primarily at, ground level are considered archeological sites or areas of sensitivity for historical archaeological resources. This includes historically documented resources that may be present in the APE.

4.9.1 METHODS AND ASSUMPTIONS

The archaeological resources reconnaissance survey (Phase IA) for the Herring River Tidal Restoration Project was undertaken in accordance with the Secretary of the Interior's *Standards and Guidelines for Identification* (48 FR 44720-23), the Massachusetts Historical Commission standards and guidelines set forth in *Public Planning and Environmental Review: Archaeology and Historic Preservation* (MHC 1985), and the Massachusetts Historical Commission historic resources survey standards. The survey complies with the standards of the Massachusetts Historical Commission, state archaeologist's permit regulations (950 CMR 70), the Secretary of the Interior's *Standards and Guidelines for Identification* (48 FR 44720-23), The Standards of the Massachusetts State Register of Historic Places (State Register), and the NPS guidelines for assessing eligibility for listing in the National Register, specifically *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation*.

The study area for cultural resources is limited to the areas within or immediately adjacent to the geographic project area as defined in figure 1-1 in chapter 1. For purposes of this study, the area of analysis is the APE as defined by the archeological resources reconnaissance survey, which has been generally defined as the 10-foot contour elevation of areas upstream of the existing Chequessett Neck Road Dike, although adjacent upland areas within the CYCC were included as well. This boundary was used for the Phase IA archeological survey conducted for the project (Herbster and Heitert 2011). As the alternative analysis proceeded, this boundary was further refined, and the final APE, dependent on the selected alternative, may be smaller. Currently, estimates of the area to be inundated by the action alternatives range from 897 to 960 acres, and approximately 30 additional acres would be disturbed by relocation of the CYCC fairways. With the exception of the CYCC Property, no upland areas are considered in this analysis, as no impacts are expected to occur in upland areas outside the CYCC, and are therefore outside the APE.

The study area for the Phase IA archeological survey encompassed approximately 1100 acres, with the majority of this area located within the inundated tidal wetlands of the Herring River estuary. The archeological sensitivity assessment was focused on the existing shoreline at and below the 10-foot elevation contour, as well on designated upland areas where project impacts may occur. These upland areas include the majority of the CYCC, the Chequessett Neck Road Dike, and several low-lying roadways including High Toss Road, Bound Brook Island Road, Pole Dike Road, and the former Cape Cod Railroad bed. Other ancillary areas may also be impacted by borrow activities or construction staging.

4.9.2 IMPACTS OF ALTERNATIVE A: NO ACTION

Alternative A is the no action alternative, in which conditions in the project area would remain unchanged. Estuary management practices would continue under the present constraints.

Under the no action alternative, no impacts to archeological resources would occur, because no ongoing impacts to existing archeological resources or archeologically sensitive areas have been documented within the APE (Herbster and Heitert 2011).

No impacts to cultural resources would occur as a result of the no action alternative, as existing conditions would be maintained. No data is available that indicates that archeological resources within the APE are currently being impacted, and this condition would continue.

4.9.3 IMPACTS COMMON TO ALL ACTION ALTERNATIVES

The precise location and extent of effects to archaeological sites cannot be fully identified at this time, as the design process is still ongoing, and the locations of ground-disturbing activities are not yet finalized. As these locations and actions are identified, potential impacts to archaeological sites will be assessed and any effects will be resolved through implementation of the Programmatic Agreement under Section 106 of the National Historic Preservation Act of 1966 (NHPA).

Increased Tidal Elevations and Tidal Flow

Increased tidal elevations may adversely affect recorded archeological resources or areas identified as archeologically sensitive. Archeological sites or archeologically sensitive areas where flooding would occur as a result of increased tidal flows may require additional documentation prior to flooding. Additional actions may be required for some archeological resources to mitigate impacts that may occur as a result of flooding.

Modeled erosional patterns expected to occur as a result of increased tidal flows do not overlap with any archeologically sensitive areas or known sites along the margins of the APE, and only resources which cross the existing channels are likely to be affected. Considering the greatest level of erosion potential as it relates to archeological resources (sites and sensitive areas), the only archeological resources that could potentially be impacted by increased erosion are along High Toss Road, and at the intersection of Bound Brook Island Road and the former Cape Cod Railroad alignment. No areas of pre-contact sensitivity fall within modeled erosional zones under any of the modeling scenarios.

Chequessett Neck Road Dike

Although the dike and roadway are not considered historic resources, staging or stockpiling areas outside the construction footprint could potentially impact archeological sites or sensitive areas (Herbster and Heitert 2011).

Impacts of Adaptive Management Actions

The adaptive management actions that could potentially affect archaeological resources are those actions which would require ground disturbance. Impacts to archeological resources associated with adaptive management actions relate to the impacts that would occur to existing and former transportation corridors through the raising of roadways or easements or the replacement of culverts beneath these roadways or easements. The Phase IA archeological investigation conducted as a part of this project identified archeologically sensitive areas along these transportation corridors, including the former Cape Cod railroad easement (Herbster and Heitert 2011, figure 5-4).

Potential Adverse Impacts that will be Avoided, Minimized, or Mitigated

In order to minimize potential impacts associated with the action alternatives and adaptive management plan, any archeologically sensitive areas or sites should be avoided. If avoidance is not possible, specifically if an action alternative requires construction in a sensitive area, then additional archeological assessment and/or survey should be conducted where ground-disturbing activities are to be conducted to determine if these areas contain archeological sites that are eligible to be included in the National Register. This would include construction footprints and any ancillary areas associated with construction, if these areas correspond to archeological sites or sensitive areas. If significant archeological sites were identified, then specific actions to mitigate impacts would need to be developed for these specific resources.

4.9.4 COMPARISON OF ACTION ALTERNATIVES

Impacts of Alternative B

Flood proofing measures in the Mill Creek Sub-basin (in which the CYCC fairways are raised by filling and grading) will not result in an impact to archeological resources as prior disturbance has likely impacted any archeological resources which may have been present (Herbster and Heitert 2011). However, if flood proofing measures within the Mill Creek sub-basin include the relocation of fairways to upland areas, or if these upland areas are used for borrow material to raise the fairways, then there is the potential for archaeological resources to be impacted. Additional archeological assessment and/or survey would be required in areas proposed for fairway development or borrow pits prior to implementation of this aspect of alternative B.

Impacts of Alternative C

Under alternative C, dike construction at Mill Creek could potentially affect areas archeologically sensitive for pre-contact resources located along the flood plain of the Mill Creek/Herring River confluence. No impacts to resources within the Mill Creek sub-basin would occur, as existing conditions would be maintained, and with no need to flood proof low-lying areas within CYCC or relocate fairways to upland areas, no archeological resources would be affected by this alternative in the Mill Creek Sub-basin.

Impacts of Alternative D

Under alternative D, impacts to archeological resources would be equivalent to the impacts discussed for alternatives B and C combined.

4.9.5 CUMULATIVE IMPACTS

Based on the cumulative impact scenario, there are no anticipated effects on archeological resources that would result in cumulative effects different from the direct and indirect effects of each of the action alternatives.

4.9.6 CONCLUSION

There is a potential for the project to adversely affect archeological resources within the APE. These effects would be primarily associated with the footprints of construction activities, as well as any other ground-disturbing activities, including borrow or construction staging areas. Prior to any construction, additional archeological assessment and/or survey should be conducted where ground-disturbing activities are planned to determine if these areas contain archeological resources that are eligible for inclusion in the National Register. Such activities would include dike construction, culvert replacement, and road reconstruction. Archeological sites or sensitive areas have been identified in proximity to all areas of potential construction, including existing or former transportation easements, but it has not yet been determined that impacts to these sites or sensitive areas would require mitigation.

Changes in tidal elevations may impact archeological resources, and additional documentation of these resources may be required prior to flooding. Site-specific mitigation measures would be implemented if adverse effects to these resources are identified as a result of inundation. Some transportation corridors that span the existing tide channels could be affected by erosion associated with increased tidal flows. Any impacts here would be identified in the adaptive management plan, and corrective actions are likely to be the same as those already discussed, such as culvert replacement.

Therefore, under all action alternatives, in an estuary-wide context, the gradually increasing tidal effects on some areas that may contain cultural resources would be subject to additional study as needed to ensure that there are no significant adverse effects on those resources. In the site-specific context associated with direct construction impacts, avoidance and mitigation would ensure that significant impacts do not occur. Under the no action alternative, there would be no changes regarding archeological resources, and therefore no significant effects from taking no restoration action.

4.10 IMPACTS ON SOCIOECONOMICS

The human environment is defined by CEQ as the natural and physical environment, and the relationship of people with that environment (NPS 1982). As described in chapter 3, the socioeconomic environment associated with the Herring River Restoration Project has been identified to include nuisance mosquitoes, shellfishing, finfishing, low-lying properties, low-lying roads, viewscapes, recreational use and experience, and regional economic conditions.

4.10.1 METHODOLOGY AND ASSUMPTIONS

Although the socioeconomic environment receives less emphasis than the physical or natural environment in the CEQ regulations, NPS considers it an integral part of the human environment. Whenever the NPS considers an action that could have impacts on the human environment, NEPA is triggered (NPS 1982). This is true whether NPS generates the action or the applicant is a private individual or another federal, state, or local agency. While NEPA is only triggered when there is a physical impact on the environment, the CEQ regulations require analysis of social and economic impacts in an EIS.

In addition, the Certificate and EIR Scope issued by the Massachusetts Secretary of Energy and Environment in November 2008 directs the Herring River project proponents to address several socioeconomic topics in the draft EIS/EIR. The requirement of MEPA for an EIR, also triggered review by the Cape Cod Commission (CCC) as a Development of Regional Impact (DRI) under the

Barnstable County Regional Policy Plan. In comments on the ENF submitted to MEPA in 2008, CCC also requested information in the draft EIS/EIR on these socioeconomic topics.

4.10.2 NUISANCE MOSQUITOES

Herring River tidal restoration would be undertaken incrementally, but would ultimately result in tidal waters inundating a large portion of the wetlands upstream of the Chequessett Neck Road crossing. Although lower low tides are also anticipated, resulting in much-improved drainage, anthropogenic changes to the marsh over the past 100 years could create stagnant-water breeding sites for floodwater mosquitoes. Marsh subsidence, old piles of dredged material and dense vegetation are all likely to impede low tide drainage. This concern, together with the knowledge that a primary impetus for the original diking in 1909 was a locally intense mosquito nuisance, urges careful planning to avoid worsening seasonal adult mosquito production.

Complicating the situation is the fact that 80 percent of the Herring River wetlands are under the management responsibility of the NPS, which protects native insect populations unless they threaten human health or safety by, for example, vectoring disease as determined by the U.S. Public Health Service. Unless a public health threat develops, which is unlikely on outer Cape Cod, nuisance mosquito control is against NPS policy; therefore, the NPS would not take any actions solely intended to control native mosquitoes. Nevertheless, NPS has in the past allowed hydrologic restorations (e.g., re-establishment of historic tidal channels) with the purpose of improving low-tide drainage to enhance wetland restoration success; coincidentally this management action may reduce floodwater mosquito breeding (Portnoy et al. 2003).

According to the Cape Cod National Seashore General Management Plan any program that is implemented to manage pests would use environmentally sensitive solutions that would protect important resources to the seashore. Furthermore, the plan states that pest-control methods would always to be the least toxic, use the minimal amount of control needed, and would be targeted at a specific pest without harming other plant or animal species. Finally, the General Management Plan states that the Park Service would work with the state's Cape Cod Mosquito Control District and the Cape Cod Cooperative Extension (through the University of Massachusetts) in developing appropriate responses and techniques to respond to nuisance insects affecting visitors and neighbors of the national seashore (NPS 1998).

Impacts of Alternative A: No Action

The Herring River currently supports productive mosquito breeding habitat, particularly between High Toss Road and Route 6. The dominant mosquito species caught in the Wellfleet area, *Ochlerotatus cantator,* breeds in fresh to brackish water, and its larvae can tolerate the acidified waters that keep its predators at bay. Under the no action alternative, this condition would persist.

Impacts Common to All Alternatives

Restored tidal exchange should decrease the overall production of floodwater mosquito species by (1) increasing flushing and low-tide drainage of presently stagnant pools and ditches within the wetland, and (2) greatly improving water quality (decreased acidity and increasing dissolved oxygen) for the predators of mosquito larvae and pupae, especially estuarine fish. As observed at the Hatches Harbor salt marsh restoration in Provincetown, Massachusetts, a shift in species could be expected as salinity is increased throughout the Herring River, with overall long-term decline of freshwater and generalist species such as *O. cantator* and *O. canadensis* (NPS 2003, unpublished data); however some increase in breeding activity of these species could be expected in subsided marsh areas. This would abate as subsided areas accrete sediment and develop into inter-tidal habitats. Eventually, salt marsh mosquito species such as *O. solicitans* may recolonize the salt marsh, however, with enhanced low tide drainage and increased populations estuarine fish feeding on mosquito larvae, it is expected that salt marsh mosquito populations would be naturally controlled. For these reasons, an increased opening in the dike is expected to decrease the mosquito nuisance within and surrounding the Herring River estuary.

The question of whether to maintain or fill historically dug drainage ditches is controversial. In the diked Herring River, where seawater has been completely excluded from hundreds of acres of original salt-marsh soils, ditch drainage lowers the water table and worsens the problem of acid sulfate soils and acidified surface waters. With tidal restoration, the ditches will have only a local impact within about 15 meters (Hemond and Fifield 1982) and concerns for biogeochemical disturbance diminish greatly. Decisions of ditch maintenance may therefore hinge more on the objectives of restoring water and sediment movement, than on controlling mosquito breeding. Regardless of what management action is taken with the ditches, mosquito experts agree that tidal restoration, and its anticipated improvement of river water quality and flushing, would reduce nuisance mosquito production as compared to existing conditions.

Comparison of Impacts of the Action Alternatives

Alternative B

Under alternative B, approximately 801 acres of the Herring River flood plain would be affected by mean high spring tides. The majority of this area would be well-flushed a minimum of several times per month, greatly reducing coverage of ponded, stagnant pools and ditches where most mosquito larvae are produced. Associated water quality improvements should also reduce the amount of available breeding habitat. Though some breeding would be expected to continue, especially along the periphery of some sub-basins and in the upper reaches of the system, predatory estuarine fish, such as mummichog (*Fundulus heteroclitus*), which eat mosquito larvae, would be more abundant and have easier access to potential breeding pools, further reducing successful emergence of adult mosquitoes. As part of the adaptive management approach, potential breeding sites will be identified and monitored and additional restoration actions will be taken to maximize tidal flushing and fish access. The Cape Cod Mosquito Control Project (CCMCP) will be consulted on any actions related to mosquito habitat management.

Alternative C

Under this alternative, impacts on mosquitoes within the project area are identical to those of alternative B, with the exception that 830 acres would be affected, encompassing a slightly larger area subjected to mean high spring tides. No changes would occur in the Mill Creek sub-basin.

Alternative D

Mosquito related impacts associated with alternative D would affect 890 acres, including the Mill Creek sub-basin and a slightly larger area subjected to mean high spring tides compared to alternative B.

Cumulative Impacts

Based on the cumulative impact scenario, there are no anticipated impacts on nuisance mosquitoes that would result in cumulative impacts different from the direct and indirect impacts of each of the action alternatives.

4.10.3 SHELLFISHING

As described in section 3.10.2, the four commercially important shellfish harvested in Wellfleet include the eastern oyster, hard clam (northern quahog), soft shell clam, and bay scallop. Oysters and quahogs dominate the Wellfleet shellfishery and are harvested from both wild stock and aquaculture operations. Soft shell clams and bay scallops are harvested from primarily from wild populations. Because of the valuable wild and aquaculture shellfish industry in Wellfleet Harbor there has been interest in the potential impacts on both the existing shellfishery and the potential for increased shellfishing that the restoration project could have in the Herring River. Increased tidal exchange to the Herring River likely will result in both short-term and long-term changes in water quality and patterns of sediment deposition and erosion which could affect existing opportunities for shellfish harvest. This section addresses these potential impacts and is primarily based on results of the Herring River hydrodynamic and sediment model (WHG 2012) and several studies and data sets pertaining to sediment particle size and sediment dynamics within the river and Wellfleet Harbor (Dougherty 2004; Harvey 2010; unpublished NPS data 2005, 2009).

Impacts of Alternative A: No Action

Currently, because of poor water quality due to high fecal coliform levels, all recreational and commercial shellfish harvest is permanently closed in areas immediately downstream of the Chequessett Neck Road Dike (see figures 3-21 and 3-22 in chapter 3). Water quality is not expected to improve under the no action alternative, so it is likely this area would continue to be subject to fecal coliform contamination and would remain closed to shellfish harvest. Shellfish harvests in Wellfleet Harbor under the no action alternative would continue based on current trends in shellfish abundance and environmental conditions. Shellfish re-colonization of historic shellfish habitat upstream of the Chequessett Neck Road Dike would not occur without restoration of tidal influence and improvements in water quality resulting from project implementation.

Impacts Common to All Action Alternatives

All action alternatives are expected to provide long-term benefits to shellfish populations and potentially provide increased opportunities for shellfish harvest. Because fecal coliform levels in the Herring River estuary are expected to decrease to levels below the regulatory limit, the closed area of the Herring River downstream of the Chequessett Neck Road Dike could be opened to harvesting and other areas of Wellfleet Harbor that are only conditionally available to harvesting could be opened year-round (Koch, pers. comm., 2011c). Subject to approval by the Town of Wellfleet and MA Division of Marine Fisheries, the improved environmental conditions downstream of the dike could provide enhanced opportunities for the harvest of oysters, quahogs and soft shell clams.

Under each of the action alternatives it is expected that restored salinities and daily tidal exchange will restore shellfish habitat upstream of the Chequessett Neck Road Dike. As described in section 3.6.4, oysters require salinities between 10-33 ppt, quahogs between 15-33 ppt, and soft shell clams between 10-33 ppt, which would be provided to varying degrees under each of the action alternatives. If tidal exchange also restores suitable substrates it is possible that oysters, quahogs, and soft shell clams would recolonize the lower Herring River. This would primarily occur in the wide portion of the 117-acre Lower Herring River sub-basin immediately upstream of the reconstructed Chequessett Neck Road Dike. This area falls within the Seashore's boundary where wild-picking is generally permitted; however, as described in chapter 3 and outlined in the Cape Cod General Management Plan, shellfishing activities in this area would need to be approved by the Town of Wellfleet and MA Division of Marine Fisheries. Regardless of any decision to change shellfish harvest areas, restored tidal conditions should increase populations of shellfish in the areas immediately above and below the Chequessett Neck Road Dike which will provide source populations of several species for the remainder of Wellfleet Harbor.

Shellfish harvests could also increase as improved tidal flows introduce more organic matter into the estuary. This would provide additional food for shellfish upstream and downstream of the dike and in Wellfleet Harbor (Koch, pers. comm., 2011c). As food availability increases, it is possible that the shellfish growth rates would increase, causing wild and aquaculture shellfish to mature to harvestable size more quickly than today, and therefore increasing the frequency of harvests and total yields (Koch, pers. comm., 2011c).

Valuable shellfish aquaculture exists in Wellfleet Harbor and there have been concerns that the restoration of tidal exchange to the Herring River may result in short-term sediment discharge to the harbor that may adversely affect these resources. However, recent data and historical documentation (unpublished NPS data 2004 and 2009; Dougherty 2004) show the flats and shoals of Egg Island and areas along Mayo Beach are currently, and were historically (prior to construction of the Chequessett Neck Dike), comprised of relatively coarse-grained sediment. Additionally, sediment particle size analyses and modeling of sediment transport dynamics (Harvey 2010; WHG 2012), show that the particle size of mobilized sediment and predicted flow velocities are inadequate to deposit sediment within the aquaculture areas. Sediment transport processes are far more dependent on tidally drive forces in Cape Cod Bay at present than whatever forces might be exerted by a new, larger tidal opening for the Herring River.

During the early stages of tidal restoration, the incremental opening of the tide gates at the Chequessett Neck Road Dike could transport some fine-grain material downstream into Wellfleet Harbor. The amount of this mobilized sediment is expected to be small and the predicted ebb-tide velocities too great for deposition of fine-grain particles to occur and a measurable impact in the harbor is not expected. Most suspended fine-grain particles would move through the system over several tidal cycles and eventually be transported through the harbor and into Cape Cod Bay (WHG 2012).

Although deposition upstream of the Chequessett Neck Road Dike is expected to be the most prominent sediment-related process occurring within the project area (see section 4.4), monitoring for potential sediment transport and deposition downstream of the dike, including within the aquaculture areas, will be a component of the project's long-term adaptive management and monitoring program. Monitoring will be designed to detect changes in volume of suspended particles, particle size, and rate of deposition at key areas. As part of the adaptive approach to restoring tide range, alternate management actions will be considered in response to detections of change beyond pre-established threshold values.

Comparison of Impacts of the Action Alternatives

Improvements to shellfishing conditions are driven by water quality improvements, particularly reduced fecal coliform levels, which are linked to improved tidal flushing (see section 4.2.3, table 4-3). As discussed in "Section 4.3: Impacts on Water and Sediment Quality," all of the action alternatives would greatly improve water quality relative to the existing conditions, with alternatives

C and D being slightly more effective in reducing residence time than alternative B. This slight difference in residence times, however, is not expected to translate into a detectable difference in shellfishing conditions.

Although not expected, any potential sediment impacts to shellfishing and aquaculture areas downstream of the Chequessett Neck Road Dike likely would occur only in the early stages of incremental tide gate openings, which would occur under any of the alternatives. Thus, alternatives B, C, and D are expected to have similar outcomes in terms of shellfishing opportunities.

Cumulative Impacts

Oyster spawning experiments in Wellfleet Harbor could beneficially affect socioeconomic resources in the local and regional area if the experiments in Wellfleet Harbor lead to an increase in oyster productivity. In combination with any of the proposed action alternatives, the cumulative impact would be beneficial and long term.

4.10.4 FINFISHING

Along with shellfishing, finfishing is an important recreational activity throughout Wellfleet and outer Cape Cod and an integral component of the region's natural and cultural history. Though the Chequessett Neck Road Dike has become a popular spot for anglers casting their lines on the harbor side, fishing rarely occurs in the river upstream of the dike. Removal of the tidal restriction caused by the dike would dramatically improve habitat for the full range of fish species formerly found in the estuary and provide a corresponding improvement to the recreational fishery. In addition, improvements to estuarine habitat and connectivity with Wellfleet Harbor would also improve the near shore fishery in Cape Cod Bay.

Impacts of Alternative A: No Action

Tidal exchange would continue to be limited upstream of the Chequessett Neck Road Dike. No new habitat would be created for river herring or other recreationally or commercially important species, such as bluefish or striped bass, which are dependent on estuarine habitat at some point in their life cycle. The herring run within the Herring River would remain obstructed. This would continue to adversely affect river herring, which once was a commercially important fish in Wellfleet. It is therefore expected that no improvement to recreational or commercial finfishing would occur and ongoing estuary degradation and obstructed access will contribute to continued regional population declines of estuary-dependent fisheries.

Impacts Common to All Action Alternatives

Any of the action alternatives would directly and indirectly benefit commercial and recreational finfishing by increasing the quantity and quality of habitat and components of the food web (i.e., nutrients, zooplankton, bait fish, and prey fish) that rely on estuarine conditions to survive (NRCS 2006). All of the action alternatives would increase available habitat for spawning, cover, and food (NPS 2011e). Additionally, restoration actions are expected to improve the water quality in the estuary and Wellfleet Harbor. These increases in habitat and water quality are assumed to be beneficial for populations of finfish and commercial finfishing industries. Additionally, an increase in the local fish supply could bring anglers to the area and increase the associated revenue from fishing permit sales (NRCS 2006). The beneficial socioeconomic impacts associated with the action alternatives are not anticipated to be measurably different.

Cumulative Impacts

Based on the cumulative impact scenario, there are no anticipated impacts on finfishing that would result in cumulative impacts different from the direct and indirect impacts of each of the action alternatives.

4.10.5 LOW-LYING PROPERTIES

More than 100 years of diking and drainage of the Herring River flood plain has allowed land uses and development of the former salt marsh and adjacent areas. Several dozen of these properties will be affected by restored tidal exchange to some degree. The largest of these is the CYCC. Most of the other potentially affected properties are residential parcels within the Mill Creek and Upper Pole Dike Creek sub-basins. This section describes both physical impacts to low-lying properties caused by increased tidal influence and potential changes to jurisdictional flood plains and wetland resource areas that will result in changes to local and state regulatory jurisdictions. Note that impacts to low-lying roads are addressed separately in the following section.

Physical Impacts to the CYCC Golf Course

Under alternatives B and D, all of or portions of CYCC golf holes number 1, 6, 7, 8, and 9 and the practice area would be impacted by tidal waters and require modifications to avoid flooding. Alternative B option 1 and alternative D option 1 would relocate the practice area and portions or all of holes 1, 6, 7, and 8 to upland areas west of the current golf course and would elevate part of fairway 9 in place as well as a portion of former fairway 1 for a new practice area. Most of the abandoned parts of the golf course would become subject to tidal exchange and would be part of the restored salt marsh in the Mill Creek sub-basin. Alternative B option 1 and alternative D option 1 would avoid wetland loss, but would still require filling 89,000 square feet (2 acres) on hole number 9, which cannot be relocated due to its proximity to the clubhouse. Permitting considerations for these wetland impacts are discussed in chapter 5.

Alternative B option 2 and alternative D option 2 would retain the current layout of the course, elevate the low-lying golf holes, and relocate the practice area to an upland site that would also serve as the borrow area for the fill needed to elevate the low fairways. The current practice area and the area between fairways 7 and 8 would be restored to tidal wetland. Alternative B option 2 and alternative D option 2 would result in approximately 360,000 square feet (8.3 acres) of direct wetland loss by filling the low areas.

During flood proofing for alternative B options 1 and 2, and alternative D options 1 and 2, the use of the golf course would be curtailed, resulting in lost golf course revenue to CYCC. After construction, the CYCC would have newer, improved golf holes, practice area, and appurtenances, which may increase use (and revenue) and improve golf quality. Under alternative C, no changes attributable to the project would be expected within the Mill Creek sub-basin. The addition of a dike at Mill Creek would block tides, and flood proofing of the golf course and other individual properties in the Mill Creek sub-basin would not be needed. Portions of the CYCC golf course would continue to experience periodic flooding and land subsidence issues due to its low elevation and underlying marsh peat.

Physical Impacts to Low-lying Residential Properties

Hydrodynamic modeling results, aerial photography, topographic and ground survey data, and property records from the town assessor's databases were used to compile a preliminary list of privately owned properties within the project area which could potentially be affected by increased tidal exchange. Potential physical impacts include any level of predicted tidal flow on any portion of a property. Potential regulatory impacts were also estimated based on changing jurisdictional boundaries. Properties were categorized based on the frequency of tidal water reaching the property and the nature of the land or structures impacted, as follows:

No Physical Impact—No physical impact will occur as properties lie outside the extent of maximum tidal influence for all action alternatives and tidal events.

Infrequent Impacts to Natural Vegetation—Natural (i.e., non-cultivated, non-landscaped, "wild") vegetation affected by tidal flow, on average, one time per year or less frequently. The impacts would only occur during the highest predicted tide of the year or during coastal storm events. Depending on the type of vegetation and salinity of tidal water, some species could be temporarily stressed, but would likely recover and persist. Tidal influence would not be frequent enough to convert the vegetation type to salt or brackish marsh.

Frequent Impacts to Natural Vegetation—Natural (i.e., non-cultivated, non-landscaped, "wild") vegetation affected by tidal flow with a frequency ranging from daily high tides up to monthly high spring tides. Tidal influence would be frequent enough to stress and kill salt-intolerant species and convert the area to salt or brackish marsh, depending on the exact frequency and salinity of tidal waters.

Infrequent Impacts to Cultivated Vegetation—Cultivated, landscaped vegetation (lawns, gardens, planted trees, etc.) affected by tidal flow, on average, one time per year or less frequently. The potential for impacts would only occur during the highest predicted tide of the year or during coastal storm events. Depending on the type of vegetation and salinity of tidal water, some species could be temporarily stressed, but would likely recover and persist. Tidal influence would not be frequent enough to convert the vegetation type to salt or brackish marsh. Properties in this category may also include impacts to natural vegetation on some land parcels.

Frequent Impacts to Cultivated Vegetation—Cultivated, landscaped vegetation (lawns, gardens, planted trees, etc.) affected by tidal flow with a frequency ranging from daily high tides up to monthly high spring tides. Tidal influence would occur frequently enough to stress and kill salt-intolerant species and convert the area to salt or brackish marsh, depending on the exact frequency and salinity of tidal waters. Properties in this category may also include impacts to natural vegetation on some land parcels.

Infrequent Impacts to Structures—Buildings (including residences, sheds, garages, etc.), driveways, private lanes, wells, and septic systems affected by tidal flow, on average, one time per year or less frequently. The potential for impacts would only occur during the highest predicted tide of the year or during coastal storm events. Depending on the exact nature of the structure, the impact could render it temporarily unusable or inaccessible (i.e., a flooded driveway) or cause minor, short-term damage. Properties in this category may also include impacts to natural or cultivated vegetation on some land parcels.

Frequent Flooding to Structures—Buildings (including residences, sheds, garages, etc.), driveways, private lanes, wells, and septic systems affected by tidal flow with a frequency ranging from daily high tides up to monthly high spring tides. Depending on the exact nature of the structure, the impact could render it regularly unusable or inaccessible and could cause long-term or permanent damage. Properties in this category may also include impacts to natural or cultivated vegetation on some land parcels.

Potential Jurisdictional Changes to Low-lying Land Uses

In addition to the physical changes discussed previously, restoration of tidal exchange throughout the Herring River flood plain will also result in changes to the jurisdictional limits of several state statutes and local bylaws which regulate activity in wetlands, flood plains, and associated buffer zones. These laws include

- **Town of Wellfleet Zoning Bylaw**—Defines "lot area" as the contiguous horizontal area of a lot exclusive of any area on a street or way open to public or private use and excluding that land which is swamp, pond, bog, dry bog, marsh, areas of exposed groundwater, or which is subject to flooding from storms and mean high tides. Tidal restoration could reduce the lot area on some properties.
- **Massachusetts Wetlands Wetland Protection Act and 310 CMR 10.00 et seq. and local wetland bylaws**—Although the entire project area was tidally influenced wetland in its natural, pre-dike state and the majority of the area remains freshwater wetland, it is possible that small areas on some properties may no longer exhibit standard indicator criteria for defining jurisdictional wetlands (supporting hydric soils, hydrophytic vegetation, and wetland hydrology) and could currently be defined as upland. In some cases, tidal restoration could reverse this, restoring areas of wetlands that in their current state are not subject to regulation. Proposed activities within 100 feet of these restored wetlands would require filing a Notice of Intent (NOI) with the town conservation commission. As discussed in section 4.5, the vast majority of changes to wetlands involves conversion of one wetland type to another and not the conversion of upland to wetlands.
- **Massachusetts Rivers Protection Act and 310 CMR 10.58**—In coastal areas, the Rivers Protection Act regulates development and other activities within the "riverfront area" 200 feet of the mean high tide line. Given the severely tide-restricted nature of the Herring River in its present condition, only a relatively small number of private properties within the flood plain are currently affected by these regulations; however, all of the tidal restoration alternatives under consideration would move the riverfront area landward by a significant distance and subject many properties to these regulations. Proposed activities located within the riverfront area on these parcels would require filing a NOI with the town conservation commission and would have to comply with associated regulatory performance standards.

Impacts of Alternative A: No Action

By taking no action, it would be assumed that the properties in the project area would continue to be protected from inundation by the Chequessett Neck Road Dike. There are no buildings, structures, wells, or septic systems impacted by tidal flows under existing conditions. However, a recent inspection report of the Chequessett Neck Road Dike, prepared for the Town of Wellfleet, has highlighted existing issues which need attention to maintain the existing level of flood protection.

In addition, the National Flood Insurance Program Flood Maps are in the process of being redrawn by FEMA. FEMA is currently conducting a Barnstable County Coastal Study, which includes new Risk Mapping Assessments. As part of the remapping, FEMA will also be considering existing flood control structures and whether they will meet specific standards. Structures that do need meet these specific standards will be decertified and therefore the areas landward will be mapped as flood plains under the assumption that the dike does not provide any flood protection. Early indications based on informal consultation with FEMA are that the existing Chequessett Neck Dike would not meet these standards and therefore low-lying areas which are currently not in a mapped flood zone may be remapped as flood plain areas. This may require certain properties to obtain flood insurance if the

Chequessett Neck Road Dike is not upgraded by the Town to comply with FEMA design guidelines. In addition, new development on these parcels may be subject to the Wellfleet Environmental Bylaw and potential other changes to set-back distances and lot sizes set forth by local and state regulations applicable to flood plains.

Impacts Common to All Action Alternatives

Increased tidal exchange under all action alternatives would result in a variety of both positive and adverse impacts to multiple low-lying properties. Positive impacts could include retreat of invasive vegetation and transition to open marsh and water vistas, resulting in potential increases in property values. Adverse physical impacts could include tidal flooding of low-lying structures and cultivated vegetation. Significant adverse impacts to properties would be avoided through various flood proofing measures as appropriate for specific impacts and properties. Any of the action alternatives would also cause changes to jurisdictional wetland resource areas and/or flood plains on some properties within the project area.

Comparison of Impacts of the Action Alternatives

Physical Impacts

Physical impacts range from very small portions of a property impacted only during very infrequent coastal storm events to large areas affected by every high tide. The approximate number of properties in each physical impact category, as defined previously in this section, are summarized in table 4-20. These figures are approximations based primarily on preliminary desktop analysis and will be refined upon consultation with individual property owners and development of more comprehensive, site-specific property data.

Regulatory Impacts

Under alternative D, there are approximately 170 parcels that are not physically impacted by water but are close enough to the flood plain to be affected by a change in the Riverfront Area (i.e., located within 200 feet of the estimated new mean high tide line). This includes properties currently outside the Riverfront Area where the line would move onto the lot and properties where the Riverfront Area already exists and would expand landward. Of the approximately 190 properties physically impacted by water (see table 4-20), approximately 150 properties would be affected to varying extents by landward movement of the line. Similarly, most of the properties within the area impacted by alternative D would be included within a new FEMA-delineated 100-year flood plain. Approximate Riverfront Area changes are summarized in table 4-20. Changes to jurisdictional wetlands under the MA Wetlands Protection Act could occur on a small number of properties, but would need to be assessed on a site-specific basis.

Similar impacts to regulatory boundaries would occur under alternative C in comparison to alternative D, with the exception that all impacts within the Mill Creek sub-basin would be avoided, reducing the total number of affected properties by about 80 and averting any impact to the CYCC golf course. Alternative B would involve the Mill Creek properties, while the slightly lower elevations of the mean high tide line and the 100-year flood plain would reduce the number of overall regulatory impacts.

TABLE 4-20: IMPACTS OF THE ACTION ALTERNATIVES ON LOW-LYING PRIVATE PROPERTIES

Physical Impacts due to Restored Tidal Influence	Number of Affected Parcels[a]		
	Alternative B	Alternative C	Alternative D
Natural Vegetation Only Total	126	120	145
Frequent Only[b]	8	7	8
Infrequent Only[c]	46	50	54
Both Frequent and Infrequent[d]	72	63	83
Cultivated Vegetation Only Total	2	1	2
Frequent Only[b]	None	None	None
Infrequent Only[c]	2	1	1
Both Frequent and Infrequent[d]	None	None	1
Both Natural and Cultivated Vegetation Total	28	24	32
Frequent Only[b]	None	None	None
Infrequent Only[c]	None	None	None
Both Frequent and Infrequent[d]	28	24	32
Total Physically Affected Parcels	**156**	**145**	**179**
Parcels with Affected Structures[e,f]			
Frequent[b]	6	7	11
Infrequent[c]	5	7	9
Changes to Riverfront Area			
Parcels with both Riverfront Area Change and Physical Impacts	318	247	322
Parcels with Riverfront Area Change Only[g]	165	126	169

a these figures are approximations based primarily on preliminary desktop analysis and will be refined upon consultation with individual property owners and development of more comprehensive, site-specific property data

b entire parcel or structure affected by mean high and mean high spring tides

c affected portion of the parcel or structure impacted only by annual high and storm tides

d parcels contain areas both above and below mean high spring tide

e includes physically affected driveways, wells, and buildings; several parcels include multiple affected structures; a total of approximately 29 structures could potentially be affected, of which 6 are residences

f lots with affected structures also include vegetation and Riverfront Area impacts

g no physical impacts expected

Mitigation of Low-lying Property Impacts

Minimizing and mitigating impacts to low-lying properties is an important objective of the Herring River Restoration Project. The analysis presented in this draft EIS/EIR represents the first step of a process to identify potentially affected properties, assess impacts, and work with substantially affected landowners on mutually acceptable solutions to mitigate impacts. Properties with estimated substantial impacts will require additional site-specific analysis to confirm and refine those impacts and to develop cost-effective flood mitigation measures. Generally, these measures could include elevating or relocating driveways and landscaping, moving wells, building small berms or flood walls, moving or elevating structures, and compensation for lost value or voluntary sale of easements or other interests in land.

All potentially affected landowners within the project area were contacted prior to the release of the draft EIS/EIR and have been offered opportunities to meet with members of the Herring River Restoration Committee (HRRC) to learn more about how the project might affect their property. In some cases, additional ground survey and other property-specific information will be needed to refine the assessment of impacts and effectiveness of flood mitigation options. A process for formal agreements between substantially affected landowners and the project proponents will be developed and will be an important component of the third Memorandum of Understanding (MOU) between the towns and Seashore needed for moving the project to implementation.

Cumulative Impacts

FEMA is currently in the process of determining if the Chequessett Neck Road dike would retain its certification as a flood control structure. If FEMA removes the dike's certification there could be some adverse impacts to persons living in the flood plain in the form of increased flood insurance costs. Any of the action alternatives would involve a new, certified dike structure, thereby eliminating any potential adverse impacts from FEMA remapping. Considered with any of the action alternatives, the cumulative impact would therefore be beneficial and long term.

4.10.6 Low-lying Roads

Several roadways have been constructed within and adjacent to the Herring River flood plain (see figure 3-24 in chapter 3). Roads built prior to construction of the Chequessett Neck Road Dike were presumably built higher than the high tide line but are now below this elevation because of marsh subsidence and would be vulnerable to flooding by restored tidal exchange. The tidal range restriction imposed by construction of the dike in 1908 allowed other road segments to be constructed or improved for automobile use at low elevations. These low-lying road segments would need to be addressed prior to tidal restoration to avoid flooding, erosion, and other impacts.

Low-lying road segments within the project area were inventoried and surveyed in 2007 (ENSR 2007a). The inventory included both paved roads frequently used by vehicles and sand or fire roads which today serve primarily as walking paths or provide access to relatively remote areas. The roads included in this analysis are listed in table 4-21. Output from the hydrodynamic model was used to compare potential high tide elevations resulting from each of the action alternatives to determine the extent of possible flood impacts. This comparison was then used to develop conceptual plans for road surface elevation and realignment options for several high road segments (CLE 2011). In addition, conceptual plans for High Toss Road flood proofing options are also summarized (The Louis Berger Group, Inc. 2010), as are potential flooding impacts to other road segments throughout the flood plain.

Impacts of Alternative A: No Action

Present road conditions would persist under the no action alternative. None of the roads are currently known to have serious flooding issues.

Impacts Common to All Action Alternatives

Under the action alternatives, several segments of roadways occurring at very low elevations would be flooded to varying degrees during most tidal cycles unless actions are taken to protect them.

TABLE 4-21: SUMMARY OF LOW ROAD IMPACTS

Road Name	Approximate Lowest Elevation (ft NAVD)	Maximum Length Affected (ft)	Impacts of Alternative B	Impacts of Alternative C	Impacts of Alternative D	Potential Flood Proof Solution(s)/Comments
Paved Roads						
Bound Brook Island Road/Old County Road	2.3	3,700	Flooded at MHW and above	Flooded at MHW and above	Flooded at MHW and above	Elevate, possibly relocate some sections; also replace two culverts
Pole Dike Creek Road	2.7	3,105 (two segments)	Flooded at MHW and above	Flooded at MHW and above	Flooded at MHW and above	Elevate, possibly relocate some sections; also replace culvert
Duck Harbor Road/Griffin Island Road	5.5	1,284 (two segments)	300 ft flooded by 100-yr storm	All flooded by 100-yr storm	All flooded by 100-yr storm	Elevate or accept minimal risk
Old Chequessett Neck Road (Snake Creek Rd)	5.4	703	Not affected	Not affected	Adjacent area flooded by 100-year storm	Elevate or accept minimal risk
Old County Road (Paradise Hollow), Wellfleet	3.2	289	Flooded at AHW and above	Flooded at MHWS and above	Flooded at MHWS and above	Elevate and replace culvert
Old County Road (Lombard Hollow), Truro	3.5	197	Not affected	Flooded at AHW and above	Flooded at AHW and above	Elevate and replace culvert
Old County Road (Prince Valley), Truro	4.0	119	Not affected	Flooded by 100-yr storm only	Flooded by 100-yr storm only	Elevate and replace culvert
Maximum length of affected paved roads		9,397	7394	8,694	9,397	

Road Name	Approximate Lowest Elevation (ft NAVD)	Maximum Length Affected (ft)	Impacts of Alternative B	Impacts of Alternative C	Impacts of Alternative D	Potential Flood Proof Solution(s)/Comments
Sand/Fire Roads						
Duck Harbor Road, Fire Road West of Herring River	4.0	4,574	• < 10% flooded at MHW • 10–25% flooded at MHWS • 25–50% flooded at AHW • 50–75% flooded at 100-yr storm	> 75% Flooded at MHWS and above	> 75% flooded at MHWS and above	• Elevate sections • Relocate to adjacent upland • Accept minimal risk
High Toss Road, from Pole Dike Rd to Snake Creek Rd.	4.0	3,299	• < 10% flooded at MHW • 10–25% flooded at MHWS • 25–50% flooded at AHW • 50–75% flooded at 100-yr storm	> 75% flooded at MHWS and above	> 75% flooded at MHWS and above	• Elevate sections • Relocate to adjacent upland • Accept minimal risk
High Toss Road, causeway across flood plain	3.1	1,017	Flooded at MHW and above	Flooded at MHW and above	Flooded at MHW and above	• Elevate • Remove • Culvert to be removed or enlarged
Snake Creek Road (Rainbow Lane)	4.0	992	• < 10% flooded at MHWS • 10–25% flooded at AHW • 25–50% flooded at 100-yr storm	> 75% flooded at MHWS and above	> 75% flooded at MHWS and above	• Elevate sections • Relocate to adjacent upland • Accept minimal risk
Mill Creek Lane	5.5	395	100 ft flooded at 100-yr storm	Not affected	100 ft flooded at AHW All flooded at 100-yr	• Elevate sections • Accept minimal risk

Road Name	Approximate Lowest Elevation (ft NAVD)	Maximum Length Affected (ft)	Impacts of Alternative B	Impacts of Alternative C	Impacts of Alternative D	Potential Flood Proof Solution(s)/Comments
Ryder Beach Road, Truro	4.0	176	Not affected	Affected by 100-yr storm only	Affected by 100-yr storm only	• Elevate • Accept minimal risk
Ryder Beach Road, Truro	4.0	118	Not affected	Affected by 100-yr storm only	Affected by 100-yr storm only	• Elevate • Accept minimal risk
DPW Yard Driveway	5.0	101	Not affected	Affected by 100-yr storm only	Affected by 100-yr storm only	• Elevate • Accept minimal risk
Ryder Beach Road, Truro	4.0	55	MHW and above	MHW and above	MHW and above	• Replace culvert • Elevate
Maximum length of affected sand and fire roads		10,727	10,332	10,332	10,727	
Maximum Length of All Affected Roads		**20,124**	**17,726**	**19,026**	**20,124**	

Bound Brook Island Road

Bound Brook Island Road is the most extensive stretch of paved road which would be vulnerable to flooding if it remains at its present elevation. The low-lying portion is approximately 3,700 feet long, extending from Pole Dike Creek Road and the intersection of Pamet Point and Old County Roads (see figure 3-24 in chapter 3). The lowest elevation of the road, which is near the Herring River crossing, is approximately 2.3 feet. The road also crosses Bound Brook. Culverts at both of these crossings may need to be enlarged to promote tidal exchange. Under any of the action alternatives, Bound Brook Island Road would begin to flood when high tide reaches approximately 2.5 feet in the Middle Herring River sub-basin and would be affected during most tide cycles at mean high water when tide gates reach their maximum opening size. To prevent flooding, the low segment of Bound Brook Island Road would have to be elevated above the maximum high tide. This would require widening the base of the road, depositing fill, and regrading the road surface to the required design elevation, which would differ by approximately one foot between alternatives B, C, and D. To minimize the length of road requiring fill and an increase in elevation, some portions of this road segment could alternatively be rerouted onto the abandoned railroad right-of-way nearby, although traffic and engineering studies and securing land rights to the right-of-way would be required to fully implement this option.

Pole Dike Creek Road

Pole Dike Creek Road is the second longest stretch of paved road which would be vulnerable to flooding if it remains at its present elevation. The low-lying portions total approximately 3,105 feet, in two segments extending from West Main Street to Bound Brook Island Road (figure 3-24 in chapter 3). The lowest elevation of the road is approximately 2.7 feet, occurring near the Herring River crossing. The culvert at this crossing may need to be enlarged to enhance tidal exchange. Under any of the action alternatives, Pole Dike Creek Road would begin to flood when high tide reaches approximately 3 feet in the Lower Pole Dike Creek sub-basin and would be affected during most tide cycles at mean high water when tide gates reach their maximum opening size. To prevent flooding, the low portions of the road would have to be elevated above the maximum high tide. This would require widening the base of the road, depositing fill, and regrading the road surface to the required design elevation, which would differ by approximately one foot between alternatives B, C, and D. To minimize the length of road requiring fill and an increase in elevation, some portions of Pole Dike Creek Road could alternatively be rerouted onto the abandoned railroad right-of-way nearby, although traffic and engineering studies and securing land rights to the right-of-way would be required to fully implement this option.

High Toss Road

Approximately 1,000 foot of High Toss Road crosses the Herring River flood plain from Snake Creek Road (a/k/a Rainbow Lane) to its dead end on Griffin Island. This section of High Toss Road is within the Seashore boundary, owned by the NPS with access rights granted to the public, and is an unpaved sand berm used primarily as a fire road and for recreational access to Griffin Island. The lowest elevation of the road segment is approximately 3.1 feet, occurring near the Herring River crossing. The 5-foot diameter culvert at this crossing must be removed or enlarged to restore tidal exchange. Under any of the action alternatives, this section of High Toss Road would begin to flood when high tide reaches approximately 3.5 feet in the Lower Herring River sub-basin and would be completely inundated during most tide cycles at mean high water when tide gates reach their maximum opening. To prevent flooding, this segment of High Toss Road could be elevated above the maximum high tide. This would require widening the base of the road, depositing approximately 2,800 cubic yards of fill, and regrading the road surface to the required design elevation of approximately 6 feet. Alternately, given its relative lack of use and that it is a dead end, the road could be left at the same elevation and stabilized by armoring the side slopes and top so that it could withstand periodic flooding, or be decommissioned and completely removed. Removal of the road would prohibit vehicular access, while allowing restoration of salt marsh within the road foot print. If High Toss Road is completely removed, pedestrian and bicycle access to Griffin Island could be maintained by constructing a boardwalk across the marsh; however, such a project is not currently proposed in this draft EIS/EIR. Impacts to the remaining section of High Toss Road, between Pole Dike Creek Road and Snake Creek Road (a/k/a Rainbow Lane). These and other impacts to low roads are summarized in table 4-21. Impacts to wetlands and construction-related impacts associated with flood proofing these roads are addressed in section 4.11.

Comparison of Impacts

There are several other shorter segments of roadways throughout the project area which could also be affected by tidal restoration (see table 4-21). The majority of these roadways are built at higher elevations or occur along the periphery of the project area and thus would be impacted to varying degrees depending on which project alternative is implemented. Some of the roads are seasonal sand/fire roads which could be relocated, abandoned or allowed to be affected by the tides. These road impacts, and those previously described, are summarized in table 4-21.

Cumulative Impacts

Based on the cumulative impact scenario, there are no anticipated impacts on low-lying roads that would result in cumulative impacts different from the direct and indirect impacts of each of the action alternatives.

4.10.7 VIEWSCAPES

As discussed in chapter 3, published literature and property tax assessment records show a clear positive correlation between higher property values and viewscapes of open water, tidal wetlands, and other dynamic water environments. Additionally, there is evidence that property values increase with proximity to wetlands and water features. The Town of Wellfleet Assessor's Office values water-influenced properties 2.2 times higher than comparable woodlot properties (Vail pers. comm., 2011). Although the magnitude and applicability of this correlation for specific properties depends on many site-specific variables, it is generally assumed that the values of properties in close proximity and within the viewshed of the Herring River flood plain may be increased by the open views, proximity to tidal habitats, and other aesthetic changes that will result from the restoration project.

For this analysis, the mean high spring tide level was used to approximate changes in vegetation across the alternatives. A map (see figure 4-4) was developed that estimates the maximum extent of non-wooded areas (white areas) after full tidal restoration is achieved, although the exact extent of conversion of wooded areas to more open viewscapes is not known due to a broad range of vegetation types within the transition and intertidal zones that could occur in the upper reaches of the sub-basins.

Impacts of Alternative A: No Action

The current natural features and landscape character, and therefore viewscapes, would not change under the no action alternative.

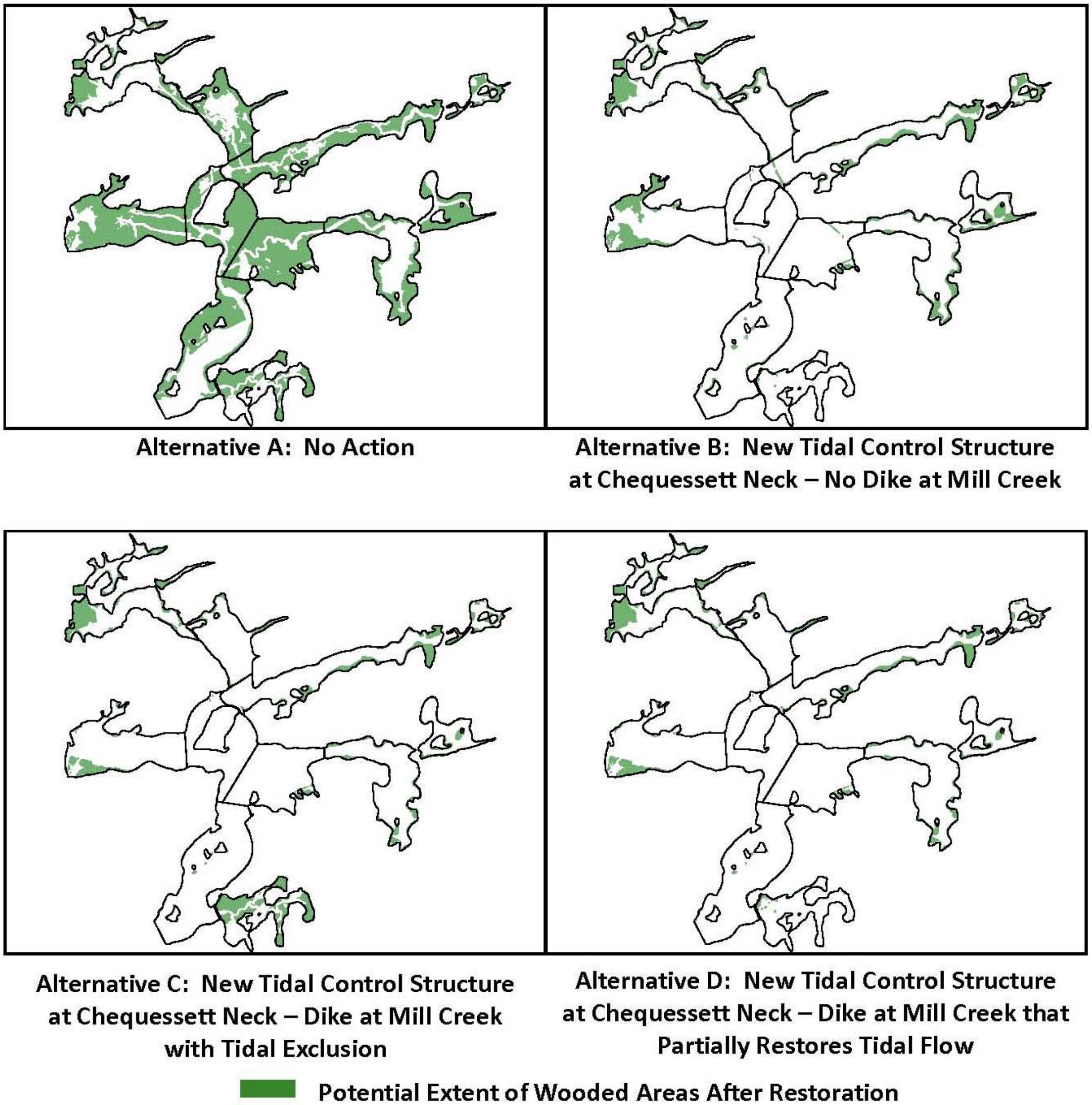


FIGURE 4-4: COMPARISON POTENTIAL EXTENT OF WOODED AREAS AFTER RESTORATION BY ALTERNATIVE

Impacts Common to All Action Alternatives

Under all action alternatives, there would be long-term viewscape benefits resulting from expanding intertidal habitat and open vistas. Inter-tidal habitats would vary by basin, but would be mostly open water, broad salt meadows, and salt water marshes, and may also include tidal brackish marsh, tidal fresh marsh, and wet shrublands. More native wildlife may also be observed under all action alternatives.

Long-term viewscape improvements would include the ability to observe broad expanses of salt marsh and meadows. Wooded areas within the flood plain would decrease, reducing obstructions to viewscapes across meadows, marshes, and open water. Fringing shrublands or woodlands in transitional or nontidal zones and stands of tall common reeds along the perimeter or upper reaches of the basins might continue to obscure views in some areas. Temporary adverse visual impacts may be caused by the presence of standing dead woody vegetation, including shrublands and woodlands. Reduction of dead vegetation from the landscape would be a function of both decomposition and adaptive management measures, such as physically removing it from the flood plain (see section 4.5).

Comparison of Impacts of the Action Alternatives

Figure 4-4 depicts the change in wooded areas after restoration. The green in the figure represents forest and shrubland land covers, which would be replaced by intertidal habitat dominated by salt marshes, meadows, and open water.

As previously mentioned, the Town of Wellfleet assesses water-influenced properties at higher values than comparable woodlot properties. It is possible that some frequently inundated woodlot properties and possibly infrequently inundated woodlot properties would be considered water-influenced after restoration, increasing their property values.

As figure 4-4 suggests, all action alternatives would likely improve a significant number of property viewsheds compared with the no action alternative. Of the action alternatives, alternative D would result in the greatest change to view-obstructing vegetation and therefore would result in the most improvement to viewsheds. Alternatives B and C are qualitatively different in that alternative C involves no improvement to Mill Creek sub-basin while alternative B has more limited improvement to all other sub-basins. The relationship to property values is assumed to be related to open viewsheds and water-influence on property. Therefore alternative D is assumed to have the greatest positive impact on property values; the difference between alternatives B and C is not readily assessed.

Cumulative Impacts

Based on the cumulative impact scenario, there are no anticipated impacts on viewscapes that would result in cumulative impacts different from the direct and indirect impacts of each of the action alternatives.

4.10.8 RECREATIONAL EXPERIENCE AND PUBLIC ACCESS

Numerous opportunities for public recreational activities, such as canoeing/kayaking, fishing, and wildlife viewing currently exist in the Herring River flood plain. Some of these access points are located just at the water's edge and could be affected by high tides and coastal flooding events as tidal influence is restored to the estuary. The public access and recreational experience analysis relies in part on an inventory of existing recreational access sites conducted from October 2009 through December 2009 by Seashore and Town of Wellfleet staff. The inventory identified 41 public use areas currently used within the Herring River flood plain (see table 4-22). Identified public use areas include parking areas, canoe and kayak launches, hunting access areas, walking routes, and scenic landmarks along the river. Hydrodynamic modeling output was then used to determine if any of these sites would be affected by the action alternatives. Additionally, there are management zones within Cape Cod National Seashore. These zones are divided into four classes: natural, historic, developed, and special use. The following public use areas within table 4-22 fall within one of these four zones (NPS 1998).

TABLE 4-22: PUBLIC USE AREAS WITHIN THE HERRING RIVER FLOOD PLAIN

Location Description	Notes
High Toss Parking Area	4 parking spaces
High Toss Culvert	Used as canoe crossing
Social trail from High Toss parking area to Duck Harbor	An alternate route- trail used to avoid N. section of Duck Harbor Rd. that is now overgrown
Social trail off Duck Harbor Rd.	On the left at end of High Toss
Vehicle access trail off Duck Harbor Road	On right off Duck Harbor Rd.
Duck Harbor Rd./Chequessett Neck Rd. Parking Area	2 parking spaces
Public Landing off Chequessett Neck Rd.	Approximately 94 feet of parking area; access to Great Island hikes
Chequessett Neck Dike (west)	Fishing spot
Chequessett Neck Dike (east)	Fishing spot
Great Island Parking Lot	40 parking spaces; 2 portable toilets
Tomb of Unknown Indian Woman	At head of stairs from Great Island parking lot
Sunset Point (Adjacent on northside of Great Island Parking Extension)	22 parking spaces in extension parking
Duck Harbor Parking Lot	45 parking spaces
Fire Road off of Griffin's Island Road	
2nd Fire Rd. off of Bound Brook Island Road/Merrick Island	3–4 parking spaces; road leads to bridge over Herring River
Bridge over Herring River	
1st Fire Rd. off of Bound Brook Island Road	3–4 parking spaces
3rd Parking Area at base of Bound Brook Island	2–3 parking spaces; next to Herring River
Bound Brook Island Beach	3–5 parking spaces
Bench up dune from Bound Brook Island Beach Parking Area	Possibly new bench
Railroad Bed off Bound Brook Island Road	
1st Trail on Bound Brook Island Road (Beyond Merrick Island)	1–2 parking spaces
Parking Area (Beyond Old County Sign, north of Pamet Pt. Rd.)	1–2 parking spaces; used for hunting access
Lombard Hollow	
Fire Road that connects Old Railroad Bed to Old County Rd. (Truro)	
Lombard Hollow Dead End	
River Crossing on Lombard Hollow	
End of Railroad Bed (Truro)*	
Access to Old Railroad Bed (S. Truro)	
Viewing Spot over Old Railroad Bed	Good view of flood plain and ocean

Location Description	Notes
Fire Road on Pamet Point (next to Le Hac House)	On the north side of the road
Ryder Pond Parking on Elsies Road	3 parking spaces
Ryder Pond	Access for kayaks, canoes, swimmers
Old King's Highway and Herring River Crossing	South of Black Pond Road
Herring Pond Public Landing	Signs saying "private"; 6-8 parking spaces
Slough Pond Triangle	6–8 parking spaces
Herring River Crossing at Higgins Pond/Herring Pond	
Parking west of Higgins Pond/east of Herring Pond	2 parking spaces
Parking spot east of Herring Pond	1 parking space
Sluiceway Herring/Gull Pond	2 parking spaces; popular fishing spot
Gull Pond Landing	Access for kayaks, canoes, swimmers; large parking area

* Only the End of Railroad Bed is located outside of Cape Cod National Seashore. All other locations are located within the national seashore.

Impacts of Alternative A: No Action

Under alternative A, public access points would remain unaffected and visitors could continue to utilize the sites for recreation. The physical character of the estuary and its impacts on the experience of canoeing, kayaking, and other non-motorized boating would continue unchanged over time, with generally unabated passage along the main channel and difficult boat access at the periphery due to the presence of denser vegetation in tributaries and in the upper basins. Water quality in the Herring River estuary would remain impaired and in non-compliance with Massachusetts Surface Water Quality Standards. Under these conditions, the quality of recreational experience would remain compromised and recreational visitation would be anticipated to remain at current levels.

Impacts Common to All Action Alternatives

Under the action alternatives, some low-lying recreational access areas currently at the water's edge could be impacted by high tides and coastal storm events. While there would be short-term impacts on certain sites during the initial phases of restoration, over the long term these river access sites could be replaced by other more suitable access points in response to the changing dynamics of the estuary system.

Of the 41 sites documented, a majority of them will remain unaffected (eight of the sites are east of Route 6). The public use sites located closest to the river's edge (including the sites off High Toss Road and Duck Harbor Road as well as the old rail road bed and fire roads off Bound Brook Island Road and through Lombard Hollow) may require slight reconfiguration to accommodate their continued use. Many of these areas are important to the residents and visitors of Wellfleet who have come to rely upon these lands for hiking, biking, hunting, wildlife viewing, and small boat launching.

It is also apparent that restoration would require a reconfigured tide control structure over the Herring River on Chequessett Neck Road. Presently a number of people use the buttresses of the existing tide control structure for fishing. Maintaining this use in the future is important to the Town of Wellfleet and will be included in the design of any new structure.

Links have been established between improvements to environmental conditions in estuaries and the quality of recreational experience in the form of recreational fishing success, wildlife viewing, and visitor attendance (Pendleton 2008). Under the action alternatives, closed recreational shellfishing areas would likely be opened due to water quality improvements downstream and potentially upstream of the dike. Recreational finfishing would improve in terms of fishing success rates and the types of fish that are caught.

Opportunities for wildlife viewing would be enhanced over the long term as a result of the more expansive views in the upper basins after woodlands are removed. While some river access points would be relocated from their present positions, there would be no net loss in public access and opportunities for visitor experience during all phases of restoration. Recreational boating access would improve along the periphery, on tributaries, and in upper basins that are now too thickly vegetated to pass a canoe/kayak. In general a more natural, tidally influenced environment should improve recreation aesthetics for all types of visitors.

Comparison of Impacts of the Action Alternatives

All action alternatives would improve recreation access and quality as compared to the no action alternative. The primary distinction among the action alternative is that conditions for recreation would not be improved in Mill Creek under alternative C.

Cumulative Impacts

Based on the cumulative impact scenario, there are no anticipated impacts on recreational experience and public access that would result in cumulative impacts different from the direct and indirect impacts of each of the action alternatives.

4.10.9 REGIONAL ECONOMIC CONDITIONS

The regional economic impact assessment of the Herring River Restoration Project is based on projected employment associated with construction and restoration activities. This approach utilizes employment estimates associated with coastal habitat restoration as described in a report by Restore America's Estuaries, "Jobs and Dollars: Big Returns from Coastal Habitat Restoration" (RAE 2011). These jobs figures are supported by two reports, one by the Department of the Interior and one by National Oceanic and Atmospheric Administration (NOAA), which have estimated the economic impact associated with restoration projects and other American Recovery and Reinvestment Act of 2009 investments (NOAA in press; DOI 2009).

Direct jobs include those in construction and engineering. Indirect jobs are jobs in industries that support construction activities, such as lumber yards, concrete plants, and fuel suppliers, etc. Induced jobs are those that are supported by the direct and indirect workers spending their money in the economy. The abovementioned reports estimate that between 20 and 32 direct, indirect, and induced jobs (full-time employment equivalent) for every $1 million invested in coastal habitat restoration construction activities. Direct jobs would be experienced in those areas within close proximity to the Seashore. Indirect and induced growth would be experienced in the local area as well as the larger region.

Impacts of Alternative A: No Action

There would not be any project expenditures under this alternative. Current regional economic conditions and trends are expected to continue into the future under this alternative.

Impacts Common to All Action Alternatives

All action alternatives would benefit regional economic conditions through considerable engineering, construction, and construction-related spending that will support jobs and increase economic activity. Project spending elements under all of the action alternatives include

- Replacing culverts along High Toss, Pole Dike and Bound Brook Roads;
- Flood proofing High Toss, Pole Dike Bound Brook, and Old County Roads;
- Flood proofing certain low-lying properties;
- Rebuilding Chequessett Neck Road Dike;
- Vegetation management;
- Engineering, design, and permits; and
- Post-construction monitoring and assessment.

Comparison of Impacts of the Action Alternatives

In addition to the elements outlined above, alternatives B and D include costs to either move or flood proof the CYCC's low fairways and flood proof other low-lying properties within the Mill Creek sub-basin, while alternatives C and D also include the costs of constructing the Mill Creek Dike. Under alternative C, no flood proofing would occur at specific Mill Creek properties. Rough estimates of construction spending for the action alternatives range from $40 million (for alternative C) to $48 million (for alternative D option 1).

It is likely that these construction activities would be undertaken with both local and non-local workforces. Restoration construction spending has been shown to stay within the county (80 percent) and the state (90 percent) (Moseley and Nielsen-Pincus 2010). However, more technical aspects of the project, such as those related to engineering for dike reconstruction, may require companies and expertise from outside the region. This may include the temporary relocation of skilled workers (and equipment) during the project.

Cumulative Impacts

Based on the cumulative impact scenario, there are no anticipated impacts on regional economic conditions that would result in cumulative impacts different from the direct and indirect impacts of each of the action alternatives.

Conclusion

While the primary changes associated with all action alternatives are physical environmental changes associated with the restoration of a functioning estuarine wetland, there are also diverse socioeconomic impacts related to the following topics: nuisance mosquitoes, shellfishing, finfishing, low-lying properties, low-lying roads, viewscapes, recreational use and experience, and regional economic conditions. Considered in the aggregate, nuisance mosquitoes, shellfishing, finfishing, viewscapes, recreational use and experience, and regional economic conditions should be affected beneficially, while low-lying properties and low-lying roads are expected have potential adverse impacts.

Reducing mosquito breeding areas was the main objective of building the Chequessett Neck Road Dike in 1909. Instead, it led to a replacement of salt marsh mosquito species with generalist and freshwater species. All action alternatives would restore estuarine conditions that are expected to reverse this species shift. Some existing marsh surface damage from subsidence and ditching could create stagnant mosquito breeding pools. However, because drainage would be improved in most parts of the estuary, and due to better control methods for salt marsh species, nuisance mosquito production is expected to be beneficially reduced under all action alternatives. Shellfishing would also be benefitted under all action alternatives, which should lead to newly opened aquaculture areas and better shellfish yields. Concerns that newly mobilized sediment could smother some cultured shellfish beds are not supported by sediment transport models; long-term monitoring will detect sediment deposition in these areas and allow for mitigation. Finfishing would also improve under all action alternatives by increasing fish habitat, fish populations, and fish species diversity. Viewscapes are expected to improve as wooded areas give way to open views of water and restored estuarine wetland. Alternative D is expected to have the most substantial beneficial impact on views, and potentially on property values. Recreation access may change as some existing access points for boaters and fishermen are lost, but new access points are created. Overall, the quality of recreational activities is expected to improve. Finally, construction spending is expected to generate some temporary benefits to employment and consumer spending that would be experienced locally and to a lesser extent regionally.

In terms of potential adverse impacts, restored tidal exchange would expose several dozen low-lying properties to some form of inundation, ranging from occasional exposure of naturally vegetated lands to storm tides or annual high tides to frequent flooding of structures such as buildings, driveways, wells, and septic systems. In total, it is expected that not more than approximately 20 properties would contain a structure affected at least occasionally. A variety of mitigation measures could be undertaken, including elevating or relocating driveways and landscaping, moving wells, building small berms or flood walls, moving or elevating structures, acquiring flood easements or fee ownership, and compensation for lost value. Alternatives B and D would also require that five golf holes on the CYCC golf course be elevated above high tides or be relocated to an adjacent upland area on the CYCC property. A number of low-lying roads would be affected in a like manner, requiring elevation or relocation to remain above flood waters. Alternately, some less important roads could be permitted to be occasionally flooded or could be permanently closed if elevation or relocation was not thought to be warranted. Under the action alternatives, the length of affected roads would range from 17,726 feet (alternative B) to 20,124 feet (alternative D).

In the broad view, the socioeconomic benefits of all the action alternatives would be experienced by a broad cross-section of residents and visitors to the local area in the form of improved social and economic conditions. While the individual impacts of each of the sub-topics discussed above are relatively minor, in the aggregate, considering the permanent nature of these benefits and the wide range of people that would be affected, these impacts could be considered significant at the local level. In a regional context these benefits would be less significant. The adverse socioeconomic impacts, in contrast, are highly site-specific, affecting particular properties and roads and the people who own or use them. In the absence of any effort to mitigate these impacts, they could constitute a significant adverse impact on a relatively small number of individuals, who could lose certain uses of a private property or lose road access to a private property or public use area. For this reason, mitigation measures will be undertaken to resolve the most significant potential adverse impacts on low-lying properties and roads.

4.11 CONSTRUCTION IMPACTS OF THE ACTION ALTERNATIVES

As described in chapter 2, each of the action alternatives includes construction of one or more dikes to control tidal exchange in the Herring River flood plain, relocation or elevation of several road sections (except alternative C), installation of new culverts at road crossings in upstream project areas, and relocating or filling in place portions of the CYCC golf course. Secondary management actions, such as clearing of weedy vegetation and channel dredging, would also incur construction-related impacts.

Along with the persistent, long-term, and mostly gradual impacts resulting from the incremental reintroduction of tidal exchange to the Herring River, the various restoration actions described as components of all action alternatives would incur short-term impacts during actual construction and, in some cases, would require direct, permanent adverse impacts to wetlands or other jurisdictional resource areas within or adjacent to construction areas. Impacts associated with each construction element are described below. Permitting considerations for these impacts are discussed in chapter 5.

Construction activities would result in soil disturbance and loss of vegetative cover in the construction area. This disturbance could lead to temporary adverse impacts to water quality during stormwater runoff events. However, BMPs would be implemented to limit sediment movement and protect water quality. Areas of temporary disturbance, such as access roads and equipment and material staging areas, would be returned to natural grade and seeded with native vegetation.

During construction of the new dike and any other infrastructure improvements such as upstream culverts or road relocations there could be local, temporary adverse impacts on both fish and macroinvertebrate species in the vicinity of the construction. Estuarine fish species could be temporarily displaced from habitat in the area of the construction due to noise and vibration impacts. There could also be some mortality of sedentary and less mobile species and life stages through burial and other in-water activities; however, many species are highly mobile and would just avoid the areas. The use of BMPs will minimize siltation and impacts on water column turbidity near the construction activities. Once construction was completed, both estuarine fish and macroinvertebrate species would be expected to readily recolonize and use the affected areas.

To protect marine resources in Massachusetts from in-water construction work during times when there is a higher risk of known or anticipated significant lethal, sub-lethal or behavioral impacts, the MA Division of Marine Fisheries recommends certain in-water time-of-year restrictions. For estuarine fish species that occur in the project area, there are recommended time-of-year restrictions for winter flounder; Atlantic silversides, mummichogs, and other *shore-zone fishes* (finfish that occupy and use nearshore waters (intertidal to 16 feet)); and juvenile life stages of commercially important species that also use the shore-zone such as winter flounder and tautog among others (Evans et al. 2011). These recommended time-of-year restrictions are shown in table 4-23. Whether or not time-of-year restrictions pertain to a specific project depends on the type of work proposed, the location of the project relative to the resource area, and the timing and duration of the activity. Therefore, the Herring River Restoration Committee (HRRC) would consult with MA Division of Marine Fisheries as well as National Oceanic and Atmospheric Administration (NOAA) Fisheries to develop appropriate in-water construction measures to mitigate any potential adverse impacts to estuarine fish in the project area. Also, provisions would be made in concert with the Division of Marine Fisheries and NOAA Fisheries to ensure that during construction of the dike existing levels of fish passage would be maintained.

TABLE 4-23: MASSACHUSETTS DIVISION OF MARINE FISHERIES RECOMMENDED TIME-OF-YEAR RESTRICTIONS FOR IN-WATER CONSTRUCTION FOR ESTUARINE FISH SPECIES IN THE HERRING RIVER

Species	Time-of-Year Restriction	Month																							
		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Winter flounder	Feb 1–Jun 30			■	■	■	■	■	■	■	■	■	■												
Shore-zone fishes	May 1–Nov 1									■	■	■	■	■	■	■	■	■	■	■	■				
Juvenile fishes	May 1–Nov 1									■	■	■	■	■	■	■	■	■	■	■	■				

Source: Evans et al. 2011

During construction activities there could be temporary adverse impacts to anadromous and catadromous fish species similar to those described above for other estuarine fish species, though provisions would be made to ensure the existing level of fish passage would occur during construction of the dike as currently exists. However, to protect anadromous and catadromous fish species during their inward and outward migrations within estuaries, in their comments on the MEPA ENF filing the MA Division of Marine Fisheries has proposed time-of-year restrictions for in-water construction activities (table 4-24) (MA DMF 2008). These in-water restrictions would limit the time for possible dike and other construction to the months of late November through early February, which would not provide enough time to complete construction activities, nor is winter the ideal time for construction.

TABLE 4-24: MASSACHUSETTS DIVISION OF MARINE FISHERIES PROPOSED TIME-OF-YEAR RESTRICTIONS FOR IN-WATER CONSTRUCTION FOR ANADROMOUS/CATADROMOUS FISH SPECIES IN THE HERRING RIVER

Species	Time-of-Year Restriction	Month																							
		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
In-Migration																									
Alewife	Mid Apr-May								■	■	■														
Blueback	Mid Apr-Jun								■	■	■	■	■												
White Perch	Mid Feb-May				■	■	■	■	■	■	■														
American eel	Mar-Jun					■	■	■	■	■	■	■	■												
Out-Migration																									
Alewife	Mid Jul-Sep														■	■	■	■	■						
Blueback	Sep-early Nov																	■	■	■	■	■			

Source: MA DMF 2008.

Therefore, the HRRC would consult with MA Division of Marine Fisheries and NOAA Fisheries to develop appropriate measures to allow construction to occur during months for which there are time-of-year restrictions to mitigate any adverse impacts to anadromous and/or catadromous species using the Herring River estuary.

Shellfish would be also adversely impacted by construction activities under the action alternatives, though most impacts would occur below the dike as currently few species occur. During construction, direct mortality of shellfish (oysters and hardclams) in the vicinity of the dike would occur through burial or other in-water construction activities. Employing BMPs would minimize the amount of sediment resuspended during construction activities. MA Division of Marine Fisheries also recommends in-water time-of-year restrictions to protect the vulnerable spawning, larval and settlement periods of shellfish during certain in-water construction projects (Evans et al. 2011) (table 4-25). Whether or not time-of-year restrictions pertain to a specific project depends on the type of work proposed, the location of the project relative to the resource area, and the timing and duration of the activity. Therefore, the HRRC would consult with MA Division of Marine Fisheries as well as NOAA Fisheries to develop appropriate in-water construction measures to mitigate any potential adverse impacts to shellfish in the project area.

TABLE 4-25: MASSACHUSETTS DIVISION OF MARINE FISHERIES RECOMMENDED TIME-OF-YEAR RESTRICTIONS FOR IN-WATER CONSTRUCTION FOR SHELLFISH SPECIES IN THE HERRING RIVER

Species	Time-of-Year Restriction	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
American oyster	Jun 15–Sep 15												
Northern quahog	Jun 15–Sep 15												
Soft-shell clam	May 1–Sep 30												
Blue mussel	May 15–Aug 31												
Bay scallop	Jun 1–Sep 30												
Surf clam	Jun 15–Oct 15												

Source: Evans et al. 2011

The presence of equipment and high levels of human activity would also be expected to affect wildlife in the project area. Mobile species, such as birds and larger mammals, would likely abandon the area for the duration of the construction activities. Individuals of less mobile species, such as invertebrates, may be killed or injured; but this is not expected to affect local wildlife populations.

During construction, the presence of heavy equipment (such as graders, earth-moving machines, and cranes) would result in temporary adverse impacts to automobile access along this section of the Chequessett Neck Road. During daylight work hours, equipment noise and emissions would be noticeable in the immediate project area. Heavy equipment may also be used in management of woody vegetation during the adaptive management phase of the plan. Temporary, localized noise and equipment emissions would be associated with these management actions.

Chequessett Neck Road Dike

Under any of the action alternatives, the Chequessett Neck Road Dike would be reconstructed to provide a 165-foot wide opening with adjustable tide gates. Preliminary designs of this new structure have not been prepared, thus construction related impacts can only be broadly estimated. Generally, reconstruction of the dike would incur temporary impacts to a construction foot print of approximately 103,200 square feet (2.4 acres) currently comprised of the dike itself and adjacent inter- and sub-tidal wetland areas. Dike reconstruction and associated dewatering, sub-grade preparation, slope protection, and other work is expected to be confined to this footprint. Impacts could include temporary loss of wetland habitat and short-term increased sedimentation of adjacent waters. However, impacts are expected to be minimal, as BMPs, including the use of erosion control measures and the maintenance of freshwater flow during dewatering will be required during construction activities. The site would recover quickly after construction is completed. Stockpiling, lay-down areas, storage, and field operations will be based in an appropriate, previously disturbed, upland location nearby.

Further design work and planning is needed to determine the final height of the new Chequessett Neck Road Dike. If the dike remains at its present crest elevation (approximately 11.3 feet), no permanent wetland impacts in the adjacent area are foreseen. However, if the project proponents decide that increased elevation of the crest height is warranted to comply with the FEMA, USACE, or other design guidelines, it is likely that the base of the dike would need to be widened to create a proper slope. In this case, filling along the base would be necessary and would result in the permanent loss of inter- and sub-tidal wetlands. The exact size of this area will be determined during subsequent design phases, but is currently expected to require filling approximately 400 linear feet on each side of the dike (800 linear feet in total) at a width to be determined.

Mill Creek Dike

As described in chapter 2, alternatives C and D would require construction of a dike at Mill Creek to control tidal flow within the Mill Creek sub-basin. More detail regarding this action is provided in chapter 2, section 2.5.2. Construction of this structure would require approximately 2,900 cubic yards of fill and would permanently impact 12,500 square feet of wetland. In addition, dewatering and other associated work would require a work area encompassing approximately 105,000 square feet (2.4 acres) of vegetated wetlands; this area would be temporarily impacted. Temporary impacts are expected to be minimal, as BMPs, including the use of erosion control measures and maintenance of freshwater flow will be required during construction activities. The site would recover quickly after construction is completed. Stockpiling, lay-down areas, storage, and field operations will be based in an appropriate upland location nearby.

High Toss Road

As described in chapter 2, several options exist for protecting High Toss Road from increased tidal range, including removal of the 1,000-foot long segment crossing the Herring River flood plain. If a decision is made to retain the road and elevate it above the reach of restored high tides widening the base of the road would be necessary. This would result in permanent loss of approximately 13,000 square feet of vegetated wetland. Alternatively, if High Toss Road were removed, approximately 12,000 square feet of additional wetland area would be restored. Indirect, temporary impacts associated with the removal or elevation of High Toss Road are expected to be minimal and would be mitigated by employing BMPs such as erosion and sediment control. In addition to replacing the culvert and widening the Herring River channel at High Toss Road, any impacts associated with High Toss Road are independent of which action alternative is implemented.

Pole Dike/Bound Brook Island Roads

Under any of the action alternatives, approximately 4,175 linear feet of roadway segments along these roads could be affected by the highest tide of any given year. An additional 2,000 feet would be impacted by a 100-year storm surge. To prevent this and maintain safe travel along these roads they must be elevated above these high tide elevations. In order to properly elevate these road sections, the road base would need to be widened, resulting in direct and permanent loss of vegetated wetlands. Elevating the roads above the 100-year storm elevation would require filling approximately 4,000 square feet of adjacent wetlands, while protecting against AHW would minimize wetland loss to 2,300 square feet. Wetland loss could be further reduced by relocating some sections of the roads onto an adjacent railroad right-of-way crossing the Herring River flood plain, however further engineering and planning is needed to assess the feasibility of this option. An exact determination about protecting these road sections from flood impacts will be made upon review of public comments on this draft EIS/EIR and further consultations with the Towns of Wellfleet and Truro and other stakeholders. Temporary impacts are expected to be minimal, as BMPs, including the use of erosion control measures and maintenance of freshwater flow will be required during construction activities. The site would recover quickly after construction is completed. Stockpiling, lay-down areas, storage, and field operations will be based in an appropriate upland location nearby.

CYCC Golf Course Flood Proofing

Although under alternatives B and D tidal exchange would be limited within the Mill Creek sub-basin, measures would still be needed to protect the CYCC golf course, and other residential properties, from flooding. As described in section 4.10, two basic options have been discussed to achieve this (relocation vs. elevation of low golf holes). Both of these would incur impacts to wetlands and other regulated areas.

Direct impacts to wetlands would be reduced by implementing the golf course relocation option (Option 1). Under the relocation option, most of the low-lying golf holes would be relocated onto approximately 30 acres of adjacent upland already owned by the CYCC. However, because of its proximity to the club house, the final hole must remain in its current location in a low spot on the CYCC property. In order to maintain playability as tidal range in increased, this hole would need to be filled and elevated, resulting in a loss of about 89,000 square feet (2.04 acres) of wetland. All of this area is currently managed by the CYCC of part of the current course. The relocation option would require extensive archeological investigation over a larger sensitive upland area before land disturbing activities could be undertaken compared to the elevation option. Relocation of low portions of the golf course to higher ground would also result in the conversion of approximately 30 acres of undisturbed pitch pine-scrub oak woodland to managed golf course uses.

For the elevation option (Option 2), approximately 360,000 square feet (8.3 acres) of wetlands would be filled (with 150,000 cubic yards of clean fill) and elevated above the high tide line and regraded as golf holes. The existing layout of the golf course would remain essentially unchanged. The majority of the wetlands to be filled are currently maintained by the CYCC as part of the golf course; however a small portion, approximately 4,800 square feet, is naturally vegetated.

If allowed by CYCC officials, fill would be generated from an approximately 5-acre borrow area on adjacent uplands under their ownership. Preliminary cultural resource assessment reports have identified the preferred area for a borrow pit as highly sensitive for potential pre-contact archeological resources. Unless an alternative borrow area or source of fill were identified, some degree of site-specific archeological inventory would be required before this site could be disturbed.

Residential Flood Proofing

As described in section 4.10.3, several low-lying residential properties would be impacted by restored tidal exchange unless measures are taken to protect them. Although no specific measures are identified or proposed in this draft EIS/EIR, and therefore cannot be quantified, it is likely that some of these actions could impact wetlands or other regulated resource areas. Examples of these include, but are not limited to, constructing a small berm or wall to protect a specific residential parcel, adding fill to a low driveway or lawn, and relocating a well. Implementation of any of these measures would occur with close consultation with landowners and would be subject to the regulatory review strategy described in chapter 5 and the adaptive management plan.

Secondary Restoration Actions/Minor Road Improvements

Secondary restoration actions are those needed to maximize the impacts of restoring tidal exchange beyond simply rebuilding the Chequessett Neck Road Dike and increasing tidal range. They include, but are not limited to, direct vegetation management, invasive vegetation control, sediment management, channel improvements, and planting vegetation. Specific impacts associated with any of these actions cannot be identified or quantified, but are expected to include work within wetland areas to remove trees and shrubs, dredge and/or deposit sediment, excavate or fill channels, and other actions to maximize tidal circulation and hasten the recovery of native estuarine habitats. Other actions impacting wetlands would likely include access for heavy equipment. These activities, and the associated impacts, would be similar to those of many regional mosquito control programs implementing Open Marsh Water Management or Integrated Mosquito Management in New England salt marshes. A review and permitting process for oversight of these activities in the Herring River is described in chapter 5. Short-term construction impacts will also occur while upgrading several short segments of other low-lying roads, improving roads for temporary bypass routes, and replacing small culverts.

Impacts from permanent infrastructure footprints are summarized in table 4-26. The expected footprint of the Chequessett Neck Road Dike, Mill Creek Dike, CYCC golf course flood proofing, and road realignment actions (under alternative D) would result in up to 11 acres of long-term vegetation/wetland disturbance.

TABLE 4-26: TEMPORARY AND PERMANENT VEGETATION/WETLAND DISTURBANCE RESULTING FROM THE HERRING RIVER RESTORATION PROJECT ALTERNATIVES

Location	Temporary Impacts	Permanent Impacts	Note
Chequessett Neck Dike	Up to 2.4 acre construction foot print (coffer dam, dewatering)	Up to 800 linear feet permanent inter- and sub-tidal wetland loss, if dike crest elevated (unknown width of fill)	Final design of dike would determine width at the dike base and the total acreage occupied by the structure.
Mill Creek Dike	Up to 2.4 acre construction footprint (coffer dam, dewatering)	Up to 12,500 (approximately 0.3 acres) square feet of dike footprint and vegetation/wetland loss	Applies to alternatives C and D only. Final design of dike would determine the total acreage occupied by the structure.
High Toss Road	Approximately 20 feet width of disturbance along 1,000 length of causeway (0.5 acre)	Up to 13,000 square feet (approximately 0.3 acres) vegetated wetland loss if elevated; up to 12,000 (approximately 0.28 acres) gain of restored wetland if removed	Independent of alternatives
Pole Dike/Bound Brook Island Roads	Construction corridor of approximately 20 feet along 6,200 linear feet adjacent to vegetated wetlands (2.85 acres)	Up to 4,000 square feet (0.1 acre) vegetation/wetland loss to elevate above 100-year storm surge, 2,300 square feet (just over 0.05 acre) lost to elevate to AHW	Independent of alternatives

Location	Temporary Impacts	Permanent Impacts	Note
CYCC Golf Course		Relocation (option 1): 89,000 square feet (just over 2 acres) wetland loss (most is existing maintained golf course; 4,800 square feet natural vegetation), ~30 acres potentially sensitive archeological resource disturbance Elevation (option 2): 360,000 square feet (8.26 acres) wetland loss (most is existing maintained golf course; 4,800 square feet natural vegetation), ~5 acres potentially sensitive archeological resource disturbance	Applies to alternatives B and D
Residential Flood Proofing	To be determined with input from landowners but could include wetland fill for elevation, berms, or walls		
Secondary Restoration Actions/Minor Road Improvements	Specific impacts cannot be identified or quantified at this time, but are expected to include work within wetland areas to remove trees and shrubs, dredge and/or deposit sediment, excavate or fill channels, and other actions to maximize tidal circulation and restoration benefits; would likely include access by heavy equipment for some restoration actions		
Total Impacts	Minimum of 8.15 acres of temporary vegetation/wetland disturbance plus that needed to implement vegetation management during adaptive management phase	Up to approximately 9 acres of long-term vegetation/wetland disturbance for dike(s), road elevation or realignment, and culvert installation	

4.12 SUSTAINABILITY AND LONG-TERM MANAGEMENT

4.12.1 RELATIONSHIP BETWEEN SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

Under the proposed action alternatives, dike construction, site-specific flood mitigation of roads and other infrastructure, and adaptive management actions would create local, short-term impacts to soils, water quality, vegetation, aquatic species, and terrestrial wildlife. These impacts would be limited to less than 2 percent of the total restored wetland acreage. Once in place, the tide control structures would require long-term management and operations to achieve the targeted restoration goals and protect adjacent landowners during storm surge events.

Over the long term, the controlled, regular influx of saline marine waters provided at the dike(s) would improve water quality and habitat for aquatic species, establish tidal channels for anadromous and catadromous fish passage, support re-establishment of native salt-tolerant wetland vegetation, and mobilize sediment to form a marsh plain. Terrestrial wildlife that now inhabit the restoration area would gradually be displaced over the several year adaptive management period to similar nearby environments. Should the NPS and HRRC choose to implement the preferred alternative, the largest practicable area would be restored to tidal marsh wetlands, with long-term tide gate operations and management.

4.12.2 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Under alternative A, the environmental conditions in the Herring River flood plain would continue – including the potential for episodes of poor water quality, spread of invasive plant species, land subsidence, and limited habitat for locally important fish and shellfish species. Impacts to these and other tidal salt marsh resources since construction of the Chequessett Neck Road Dike, over 100 years ago, are irretrievable and would continue into the future under current management. However, restoration is based on the premise that current conditions are not irreversible. By returning tidal influence to the flood plain, the processes that support a tidal salt marsh would gradually return, and transform the project area to conditions similar to that of the pre-dike estuary.

4.12.3 UNAVOIDABLE ADVERSE IMPACTS

Under any of the proposed restoration alternatives, construction activities and adaptive management actions would be accompanied by limited unavoidable adverse impacts. In addition to short-term disturbance of soils, vegetation, and wildlife; intermittent adverse impacts to water quality could result as the wetland soil chemistry changes from freshwater and upland to salt water; die-off of freshwater vegetation (including large trees) would occur and require management; and formation of tidal channels may need to be achieved by limited dredging and filling. Although these actions would support the long-term conversion of the project area to the desired salt marsh condition, they are accompanied by soil and vegetation disturbance, sediment impacts to nearby water quality, and noise. These impacts would be managed by BMPs and other appropriate resource protection measures.